MASTER OF SCIENCE IN LIFE SCIENCES

Master of Science HES-SO in Life Sciences
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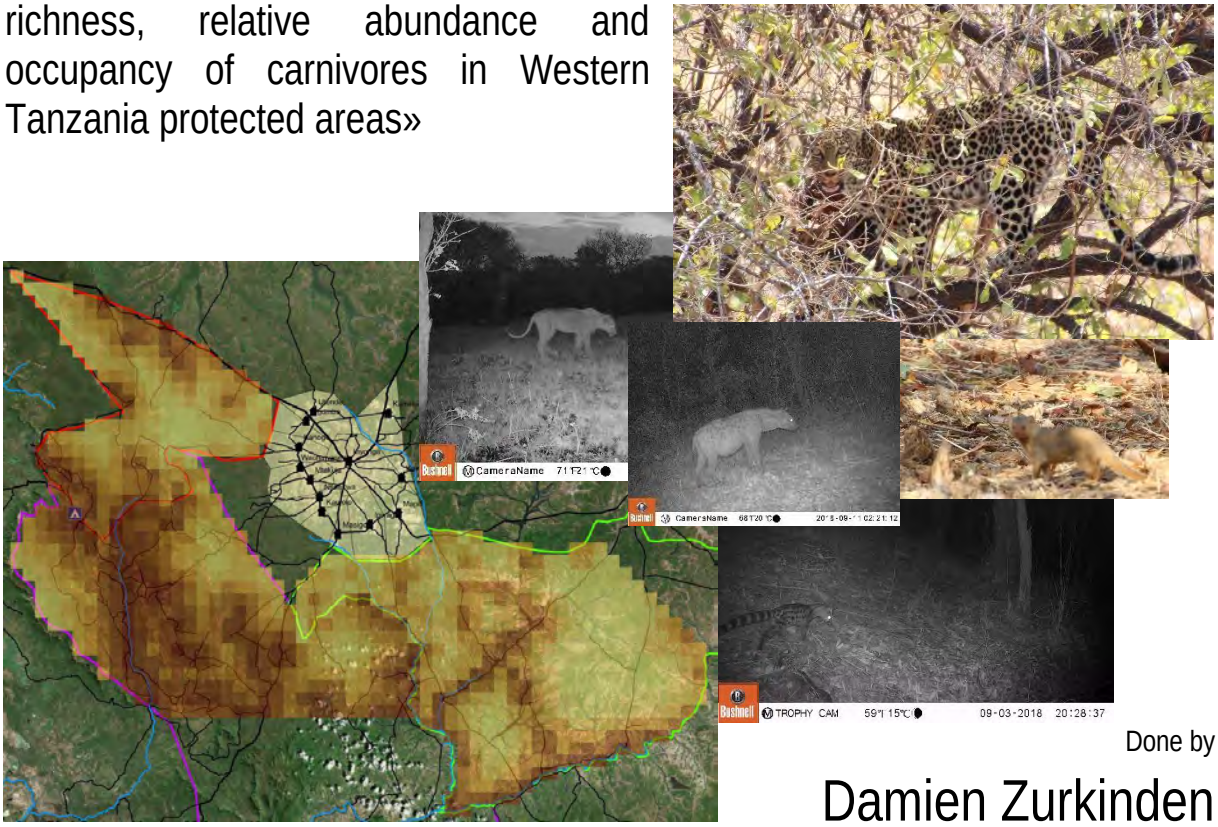
Master of Science HES-SO in Life Sciences

Orientation :
Natural Resource Management

«Using camera traps to investigate factors explaining variation in species richness, relative abundance and occupancy of carnivores in Western Tanzania protected areas»



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Declaration

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Foreword

«*Protected area management needs should be seen as primarily a human problem and not primarily a biological problem*»

Pritt 1988

All images whose source are not mentioned are personal or come from the camera traps taken during fieldwork, spanning a period from August to November 2018. The personal pictures were taken with a Canon EOS 600D, and those of the camera traps with the Trophy Cam HD model by Bushnell Corporation. Camera trap images can be recognized by the white band at the bottom of the picture, which shows the time, date and Bushnell logo.

The nomenclature of mammal species presented in this document are based on the Kingdon Field Guide to African Mammals, second edition (2015). Latin names of some species may therefore be slightly different compared to other references (articles, theses, ...), but they will be considered as same species during comparisons.

Acknowledgments

Many people and institutions have made this work possible. I would like to thank them for their help, their advice, their welcome, their support and their presence. Thanks especially to:

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Glossary

- Abiotic factors: a nonliving condition that influences or affects an ecosystem and the organisms in it (Ramade, 2009)
- Abundance: is the number of individuals per species (Berthet, 2005)
- Adaptive management: a framework and flexible decision-making process for ongoing knowledge acquisition, monitoring, and evaluation leading to continuous improvements in management planning and implementation of a project to achieve specified objectives (Water Code §85052)
- Anthropogenic variables: relating to, or resulting from the influence of human beings (Ramade, 2009)
- Biodiversity: biological diversity in an environment as indicated by numbers of different species of plants and animals (Campbell & Reece, 2007)
- Biomass: the amount of living matter (as in a unit area or volume of habitat) (Ramade, 2009)
- Biome: a major ecological community type (such as tropical rain forest, grassland, or desert) (Ramade, 2009)
- Biotic factors: relating to, or caused by living organisms (Ramade, 2009)
- Biotope: a region uniform in environmental conditions and in its populations of animals and plants for which it is the habitat (Ramade, 2009)
- Buffer zone: minimize the impacts of an adjacent land use. They protect the natural environment and help keep nearby ecological niches stable and functioning (Berthet, 2005)
- Camera trap days (sampling or survey effort): days during which camera traps have been functional (Rovero & Marshall, 2009). For example, 3 camera traps that work at the same time for 24h represent 3 camera trap days (or CT days)
- Camera trap: photographic camera in the form of a box that is fixed to a tree or another element and whose purpose is to photograph/film wild animals. The choice of photographic traps on the market is very wide and there are several types: with or without trigger, motion and/or heat detector, with flash or infrared, etc.) (O'Connell et al., 2011)
- Carnivore: an animal that feeds primarily or exclusively on animal matter (Campbell & Reece, 2007)
- Carrying capacity: the maximum population that an area will support without undergoing deterioration (Ramade, 2009)
- Cohort: represents an intermediate level between classes and orders (Ramade, 2009)
- Community: an interacting population of various species in a common location (Campbell & Reece, 2007)
- Community-based natural resources management: is a framework for advancing and combining community and conservation objectives (wwf.panda.org)
- Covariates: represent independent variables that have no direct interest as such, but on which depends another independent variable of interest (http://cognition.ups-tlse.fr)
- Detection probability: is the probability that an individual is captured at least once during a K capture occasion during a survey (Rovero & Zimmermann, 2016)
- Distribution: represent the natural geographic range of an organism (Ramade, 2009)
- Ecology: the totality or pattern of relations between organisms and their environment (Ramade, 2009)
- Ecosystem: the complex of a community of organisms and its environment functioning as an ecological unit (Ramade, 2009)
- Element: a major component of the evaluation Framework (see IUCN-WCPA Management Effectiveness Evaluation Framework) defined by the aspect of management that is being assessed. The elements relate to the steps in a strategic planning and management cycle. Performance within each element is assessed by reference to a number of defined criteria (Hockings et al., 2006)
- Environmental variables: relating to, or resulting from the influence of abiotic and biotic factors (Ramade, 2009)
- False negative: an animals can be missed at sites where they are present (Louvrier et al., 2018)
- False positive: due to species misidentification (Louvrier et al., 2018)

- Governance: The interactions among structures, processes and traditions that determine how power and responsibilities are exercised, how decisions are taken and how citizens or other stakeholders have their say (Hockings et al., 2006)
- Guild: a group of organisms that use the same ecological resource in a similar way (Ramade, 2009)
- Habitat: place and immediate environment, composed of biotic and abiotic factors, in which a species lives (Ramade, 2009)
- Herbivore: a plant-eating animal (Campbell & Reece, 2007)
- Home range: the area to which an animal usually confines its daily activities (Campbell & Reece, 2007)
- Imperfect detection: refers to the observation process occurring when detecting individuals or species during surveys; invariably, the detection will not be perfect and therefore a number of animals or species will go undetected; this bias is accounted for in modern statistical approaches, whereby both the observation and state (e.g. abundance, species richness, occupancy) processes are modelled (Rovero & Zimmermann, 2016)
- Independent capture event: an instance of capture of a target species by the camera trap, obtained by screening the original images acquired by a set interval of time between subsequent images; events are considered independent instance of capture as repeated images of an animal pausing in front of the camera traps are discarded (Rovero & Zimmermann, 2016)
- Index: dimension that is related to the current total number of animals (Sutherland, 1996)
- IUCN-WCPA Management Effectiveness Evaluation Framework: a system for designing protected area management effectiveness evaluations based around six elements: context, planning, inputs, processes, outputs and outcomes. It is not a methodology but is a guide to developing assessment systems (Hockings et al., 2006)
- Mammals: warm-blooded vertebrates that nourish their young with milk secreted by mammary glands and have the skin usually more or less covered with hair (Berthet, 2005)
- Management effectiveness: assessment of how well protected areas are being managed – primarily the extent to which management is protecting values and achieving goals and objectives. The term management effectiveness reflects three main 'themes' in protected area management: design issues relating to both individual sites and protected area systems; adequacy and appropriateness of management systems and processes; and delivery of protected area objectives including conservation of values (Hockings et al., 2006)
- Management: is the implementation of the human and material resources of an organization to achieve its objectives. Management consists of: setting objectives (strategic and operational); choosing the means to reach them; implementing these means (search for efficiency); monitoring implementation and results achieved; ensuring regulation from this control (Governance) (Bressy & Konkuyt, 2018)
- Monitoring: aims at inferring causes of ecosystem changes, by measuring ecosystem state variables in space and time (Yoccoz, 2012). Is composed of different surveys
- Naïve occupancy: is the proportion of cameras that have detected a given species, based on the total number of cameras. It gives an indication of the extent of occupation of a species in the reference area (Rovero & Zimmermann, 2016)
- Niche: the ecological role of an organism in a community especially in regard to food consumption (Ramade, 2009)
- Occupancy: represents the proportion of a site occupied by a species (MacKenzie et al., 2002). It is estimated through modeling approaches and accounts for imperfect detection (Rovero & Zimmermann, 2016)
- Paper park: a legally established protected area where experts believe current protection activities are insufficient to halt degradation (Dudley & Stolton, 1999)
- Population: group of individuals belonging to the same species, occupying the same biotope, and freely exchanging its gene pool (Ramade, 2009)
- Protected area: A clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values (Dudley, 2013)

- Relative abundance: refers to the evenness of distribution of individuals among species in a community (Berthet, 2005)
- Sampling occasion: in analytical framework such as occupamcy, this is the temporal interval in which the overall survey effort is parted to build matrices of repeated species detection at a given site. The discretization of effort in sampling occasions influences the estimation of detection probability (Rovero & Zimmermann, 2016)
- Species richness: The number of species within a given sample, community, or area (Millennium Ecosystem Assessment, 2005)
- Species: population or group of populations whose individuals are able to reproduce with each other in the wild and produce viable and fertile offspring (Campbell & Reece, 2007)
- Status: a protected area status is defined by its IUCN management category which should be based around the primary management objective(s) of the protected area and should apply to at least three-quarters of the protected area (Dudley, 2013)
- Survey: three-week period (21 days), during which camera traps are functional in the field

Abbreviations

ADAP	Association for the Development of Protected Areas
AIC	Akaike's Information Criterion
BKZ	Beekeeping Zone
CBD	Convention on Biological Diversity
CBNRM	Community Based Natural Resource Management
CBO	Community Based Organization
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CoP	Conference of Parties
COSTECH	Tanzania Commission for Science and Technology
CT	Camera Traps
DGO	District Game Officer
DHB	Diameter at Breast Height
DLNRO	District Land and Natural Resources Officer
DMCO	Documentation, Monitoring and Capitalization Officer
FR	Forest Reserve
GCA	Game Controlled Area
GIS	Geographical Information System
GPS	Global Positioning System
GR	Game Reserve
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
hepia	Haute Ecole du Paysage, d'Ingénierie et d'Architecture
HQ	Headquarter
IBA	Inyonga Beekeepers Association
IUCN	International Union for Conservation of Nature
KRCD	Katavi Rukwa Conservation and Development programme
ME	Management Effectiveness
METT	Management Effectiveness Tracking Tool
MIKE	Monitoring of Illegal Killing of Elephants
MNRT-FBD	Ministry of Natural Resources and Tourism – Forestry and Beekeeping Division
MoU	Memorandum of Understanding
NCA	Ngorongoro Conservation Area
NCAA	Ngorongoro Conservation Area Authority
NGO	Non-Governmental Organization
NP	National Park
NR	Natural Resources
NRM	Natural Resources Management
OA	Open Area
PA	Protected Area
PAME	Protected Area Management Effectiveness
PFM	Participatory Forest Management

PLUM	Planning of Land Use Management
PM	Project Manager
RAI	Relative Abundance Index
TANAPA	Tanzania National Parks
TAWA	Tanzania Wildlife Authority
TAWIRI	Tanzania Wildlife Research Institute
TBGS	Tanzanian Big Game Safari Ltd
TFS	Tanzania Forest Services
UTM	Universal Transverse Mercator
VGS	Village Game Scouts
VIF	Variance Inflation Factor
WCA	Wildlife Conservation Act
WCPA	World Commission on Protected Areas
WCS	Wildlife Conservation Society
WD	Wildlife Division
WMA	Wildlife Management Area
WWF	World Wide Fund for Nature

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Abstract

For more than a century, national parks have been the main strategy of biodiversity conservation. Nowadays, the present trend in wildlife conservation is to incorporate the support of local livelihoods to the protected area management. The initiative of the Association for the Development of Protected Area (ADAP) in supporting village-based beekeeping through the supported of Inyonga Beekeepers Association just do so. ADAP, in partnership with the University of Applied Sciences and Arts Western Switzerland, has set up, through its project "Community Resource Management in the district of Mlele" in Tanzania, a camera trap monitoring of medium- and large-mammals in Mlele beekeeping zone (Juget, 2008). The various surveys set in place have revealed a large cohort of carnivores (Fischer et al., 2013) even though the beekeeping zone has the lowest protection status (IUCN Category VI) and seem to confirm the hypothesis that protected areas with lower conservation status also help preserve a high diversity of carnivores. In order to test this hypothesis, the systematic sampling was extended to two adjacent protected areas under different management regimes and governance types. Rukwa game reserve and Rungwa forest reserve & game-controlled area. Accordingly, the objective of this study was to identify and correlate anthropogenic and environmental variables with species occurrence. However, in order to evaluate the management implemented in Mlele beekeeping zone in a comparative manner, camera traps are not sufficient. To help this process, Management Effectiveness Tracking Tool were used to evaluate the management of the three protected areas (Stolton et al., 2007) and allowed the estimation of the ability of the considered protected areas to conserve their values given a target (http://www.dfg.ca.gov).

In our study, 52 species of medium- to large-mammals – of which 17 are carnivores – were detected. Our results on species richness reveled that a stricter state protected area such as Rukwa game reserve holds a higher species richness than protected areas allowing multiple use natural resources use. However, our results on relative abundance index and naïve occupancy did not show a protected area being systematically less occupied. Besides, our results emphasize the importance of accounting for detection probability. Indeed, in our study, less detected species or species with larger home ranges lead to negative bias in relative abundance index ratio. Finally, our single season occupancy results demonstrated that variation in carnivore persistence seems not explained primarily by anthropogenic factors but by environmental ones. Indeed, contrary to our expectation, anthropogenic factors did not have consistent, negative effects on occurrence across the 17 carnivore species detected. However, our results on illegal activities are more nuanced as Rukwa game reserve and Mlele beekeeping zone present fewer signs of illegal activities than Rungwa forest reserve & game-controlled area, suggesting that little association exists between IUCN management categories and prevention of illegal activities. When assessing management effectiveness, Management Effectiveness Tracking Tool suggested that 1) guards are the most important factor for law enforcement strategy. Rukwa game reserve and Mlele beekeeping zone management effectiveness show that effective protection only occurs where manpower, patrols and financial resources are adequate with the size of the protected area to be controlled. 2) it is of paramount importance to develop a more integrative, trans-disciplinary monitoring approach to effectively adapt management, leading to continuous improvements in management planning and implementation of a project to achieve specified objectives. 3) awareness impact – on that it has given rise to a change in behavior – requires that landowners are empowered to manage the natural resources they depend on so that benefits outweigh the costs of the protected areas on their livelihoods.

In an attempt to examine arguments for collaborative approaches as they are likely to play a particularly important part in carnivore conservation, our results could not bring a clear answer to the debate that a 'top down command and control' approaches over a more collaborative one is the most effective way to conserve carnivores. However, results presented in this study show the importance and complementarity of lower IUCN management categories to effectively conserve mammal populations and especially those with large home range such as lions and African wild dogs. Indeed, a reliable assessment of carnivore population viability along this gradient of protected areas, and a better understanding of the nature of human impacts on these species, will require continued and detailed monitoring of species-specific occurrences. Overall, our study provides valuable information about the determinants of spatial occurrence of a complete cohort of carnivores in human-used protected areas and allowed the comparison of three protected areas. Indeed, this study demonstrated that a community-level approach provides a more comprehensive insight at a scale relevant to ecosystem-level management. Furthermore, our results highlight that Rukwa game reserve, Rungwa forest reserve & game-controlled area and Mlele beekeeping zone are still vital

areas supporting an entire cohort of carnivores and seems to serve as important buffer zones between Katavi national park and village lands. Thus, supporting the development of ADAP's new project along the Rungwa river Corridor as this area might be an important area for large carnivore conservation by reconnecting Katavi national park populations with those of Ruaha national park.

Key Words: camera trap, carnivore, detection probability, governance, management, occupancy, protected area, relative abundance, species richness, status, Tanzania, wildlife monitoring

1. Introduction

1.1. From Strict Protection to Sustainable Use of Natural Resources

Around the world – from Yellowstone to the Serengeti – protected areas (PA) and particularly the national parks (NP) concept have been, for nearly 150 years, considered a fundamental tool in the conservation of biodiversity. Today, over 15% of the planet is under some sort of protection (Figure 1). Even if these concepts spread quickly across the globe, the increase of PAs and the surface they cover is a very recent phenomenon (Figure 2). From a leisurely start in the 20th century, there is currently across the globe over 200000 PAs (Wuerthner, Crist & Butler, 2015). Nowadays, reference to PAs refers to the International Union for Conservation of Nature (IUCN) definition (www.iucn.org) which is:

"A clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values."

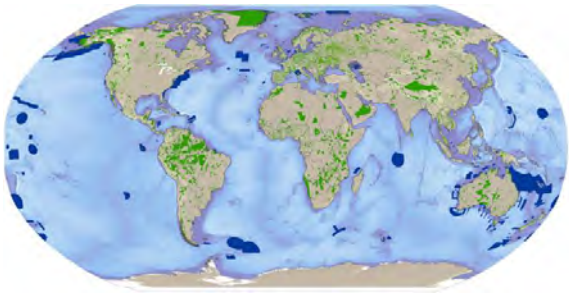

Figure 1: Protected area coverage (terrestrial PAs in green, marine PAs in blue)
Source: Protected Planet, 2018

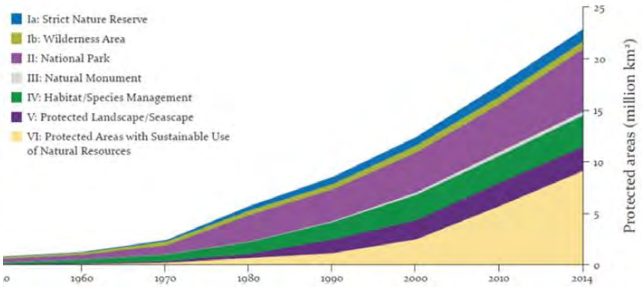

Figure 2: Evolution of PAs since 1950
Source: Protected Planet, 2018

In 1872, Yellowstone became the world's first NP in response to the ongoing over-exploitation characterizing the 19th century. The creation of Yellowstone NP set a new standard for land management, «where preservation of nature became the guiding philosophy». Since then, the Park reflects PAs evolution and challenges worldwide. One critic of the Yellowstone model suggest that it is yet another form of "imperialism" or "colonialism". (Wuerthner, Crist & Butler, 2015). Undeniably, the framing and purpose of conservation have shifted over the decades and especially the one based on the relationships between people and nature, with consequences for conservation sciences (Figure 3) (Mace, 2014) where trade-offs are now of outmost importance for conservationists. Indeed, the wider non-biological issues that surround making decisions about which species and geographic areas to prioritize for conservation must carefully be weighed in and conservationists must be explicit about the trade-offs they make every day in deciding what to save (Leader-Williams et al., 2010).

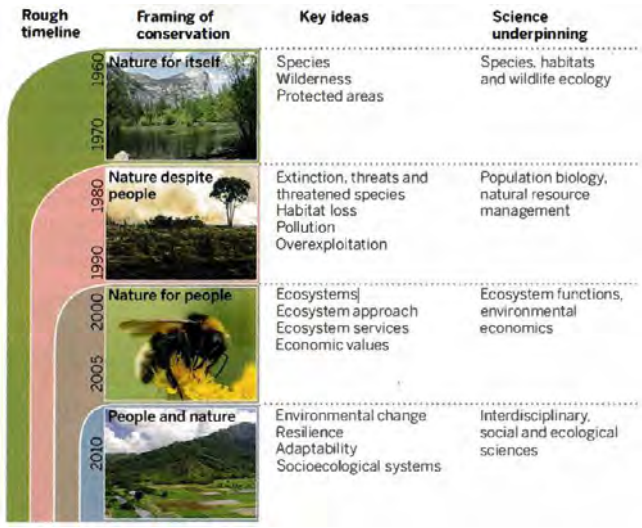

Figure 3: Changing views of nature and conservation. Over the past 50 years, the prevailing view of conservation has changed several times, resulting, for example, in a shift in emphasis from species to ecosystems. None of the framings has been eclipsed as new ones have emerged, resulting in multiple framings in use today
Source: Mace, 2014

One of the biggest trade-offs' conservationists face today are the social, economical, and political effects of conservation projects in PAs (West et al., 2006). Indeed, the creation of PAs to conserve biodiversity is inherently political and mostly done in the urban centers that control these areas. Thus, the implications of indigenous people rights, the combination of poverty reduction with conservation priorities and conservation-induced displacement are important political issues in contemporary international conservation policy (Adams, 2004; Brockington et al., 2006; Adams & Hutton, 2007). Conflicts over the management of natural resources (NR) are increasing and need to be managed to minimize negative impacts on biodiversity, human livelihoods, and human well-being. Conflict management is depending on the perceptions of the protagonists and therefore requires the parties to recognize problems as shared ones, and engage with clear goals, a transparent evidence base, and an awareness of trade-offs (Adams, 2003; Brockington, Duffy & Igoe, 2008; Redpath et al., 2013). The so called "fortress conservation" powerful myth is now opposed to the principle of local support[1] which opened a sharp debate about the human costs associated with coercive conservation. This awareness leads to the emergence of Community-Based Natural Resource Management (CBNRM) and aims at integrating development with conservation. As Mace (2014) exposed, this approach plays a leading role in conservation strategies nowadays and is the battle horse of the so called "social-conservationists" to return the stewardship of NR to local communities through participation, empowerment and decentralization (Brockington, 2002; Adams, 2004; Brockington, 2004; Dressler et al., 2010; Wuerthner, Crist & Butler, 2015).

1.2. Context

The Association for the Development of Protected Areas (ADAP), in partnership with the *Haute Ecole du Paysage, d'Ingénierie et d'Architecture* of Geneva (hepia)[2] , has set up, through its project "Community Resource Management in the district of Mlele" in Tanzania (www.adap.ch), a monitoring of medium- and large-mammals since 2008 (Juget, 2008) in the Beekeeping Zone (BKZ) of Mlele (Appendix I). This area represents a 850 km^2 portion of the Mlele Forest Reserve (FR) & Game Controlled Area (GCA) and is co-managed by local communities through a community-based organization, Inyonga Beekeepers Association (IBA) and Tanzania Forest Service (TFS).

Various research projects (Bachelor and Master) have demonstrated the significant species richness[3] of Mlele BKZ and its importance for the conservation of medium- and large-mammals (Juget, 2008; Mermod, 2012; Buffard, 2018). In fact, subsequent research has identified more than 50 species of mammals, highlighting the potential conservation value of PAs with low conservation status[4] (IUCN Management Categories IV-VI) (Hausser et al., 2017). The above-mentioned work revealed that the most represented groups were ungulates and carnivores (Appendix II), with 18 species for the latest. In addition, the BKZ hosts most of the rare species (www.iucnredlist.org) of large carnivores that are expected to be found in Tanzanian NPs, such as lions, *Panthera leo* (Linnaeus, 1758) (VU[5]), leopards, *Panthera pardus* (Linnaeus, 1758) (VU) or African wild dogs, *Lycaon pictus* (Temminck, 1820) (EN). The various monitoring set in place have thus revealed a large cohort of carnivores (Fischer et al., 2013; Zurkinden, 2017) even though the BKZ has the lowest protection status of IUCN (Management Category VI). (www.uicn.org).

Since camera traps (CT) appears to be the best method for detecting miombo species (see section 1.3.3), Hausser et al. (2017) setup a regular monitoring through systematic grids. Unfortunately, despite a high diversity of mammals in the PA, only recently, estimates taking into account imperfect detection could be produced. It is in this context that the study of carnivore populations, which represent a smaller number of species, is of interest. Furthermore, the quantitative data collected so far should allow the subsequent comparison between a PA with low protection

[1] PAs cannot survive without the support of their neighbors

[2] A University of Applied Sciences and Arts Western Switzerland

[3] Refers to the number of species in a given area

[4] See section 2.2.1.6 for more details

[5] With the IUCN Red List system, each species or subspecies can be categorized into one of the following nine categories: Extinct (EX), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD), Not Assessed (NE)

status and areas with stricter regulations. Indeed, the results presented in my Bachelor thesis (Zurkinden, 2017) seem to confirm that low status PAs contribute significantly to conserve carnivore diversity at landscape scale. Thus, my Master thesis will try to test this hypothesis. To do so, systematic sampling will be extended to two adjacent PAs, Rukwa Game Reserve (GR) and Rungwa River FR & GCA (Appendix I). Thus, with Mlele BKZ, these three PAs have different protection statuses, management regimes and governance types. Therefore, the comparison of these 3 PAs should allow the evaluation of the management of Mlele BKZ in a comparative manner.

Nevertheless, this study will take place in a larger context and will serve as baseline study – alongside another Master thesis (Daudet, 2019) – to a new project planned by ADAP titled "Community Forest Management of the Rungwa Corridor" in the Districts of Sikonge and Mlele (Figure 4). This project aims to improve the livelihoods of local communities living in the Katavi-Ruaha ecological corridor by giving them more rights over forests and by supporting the development of sustainable activities such as beekeeping. The project also aims to build the collaboration of all stakeholders to ensure the management and conservation of forests and NR for and by local communities and to help reduce conflict (www.adap.ch).

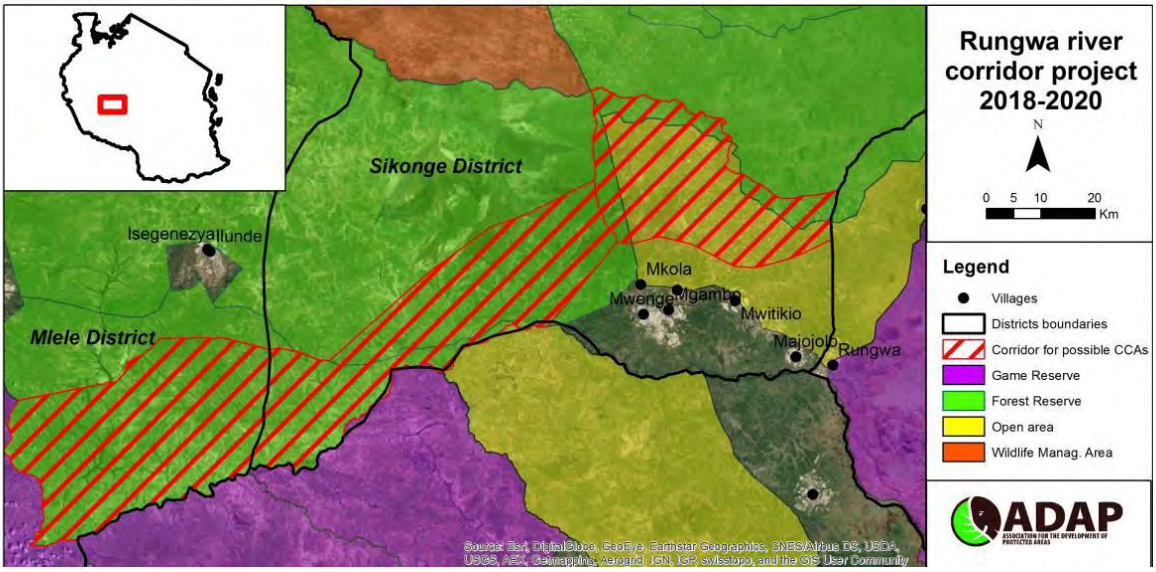

Figure 4: Presentation of the Rungwa corridor project developed by ADAP for which the present study will serve as base-line study

Source: ADAP, 2018

1.3. Statement of the Problem and Justification

The win–win discourse is in tune with the time and the conservation field in Africa is predominantly presented by key actors as such. Indeed, in Tanzania, an important part of conservation policies are presented as decentralized, involving community participation and serving poverty alleviation through benefit sharing. However, in practice, laws are associated with recentralization and economic marginalization (Benjaminsen & Svarstad, 2010). Indeed, NR benefits contributes to capital accumulation and is thus prized by more powerful actors (Benjaminsen & Bryceson, 2012). Thus, the term "green grabbing" is now used by some authors to demonstrate the trend observed in conservation practices that do not fit the win–win discourse. Indeed, conservation practices are more in line with the 'fortress conservation' that previously dominated conservation discourse (Benjaminsen & Svarstad, 2010) and express restrictions on local NR use. These restrictions are justified by degradation narratives, while financial benefits from tourism are drained away from local communities (Benjaminsen & Bryceson, 2012). However, this fortress approach might be counter-productive as it might produce more opposition to conservation (Benjaminsen & Svarstad, 2010).

1.3.1. Community-based conservation as alternative

In one of the most influential articles of is time, Hardin (1968) opened a major debate over the best property rights system for controlling overharvesting of shared NR. Hardin thought (based on the assumption that resource users of ''the commons'' are helpless to limit use patterns) that governments should impose public or private ownership on all NR. The debate continued as social scientists pointed out his confusion of open-access resources with closed-access shared or corporate resources. Unfortunately, decision makers do not take these strong critiques in consideration for the complex problems of resource governance and still recommend simple solutions. For example, «many analysts and conservation biologists assume that unless forests are put under government ownership and protection, deterioration will result. For these scientists, public ownership of forests, preferably as a designated park, is the only way to achieve sustained conservation over time» (Ostrom & Nagendra, 2006). Unfortunately, a growing body of literature suggest that many PAs are in fact ''paper parks[6]'' with no effective control of their boundaries. More so, government-controlled PAs have also generated considerable conflicts with local communities across the globe, even threatening in the long-term the sustainability of these programs (Ostrom & Nagendra, 2006). Nowadays, there is debate over the effectiveness of PAs and particularly in the matter of reducing deforestation and defaunation (Figure 5). This is even exacerbated when local people have rights to use the resources. Encouragingly, as it was discussed in *section 1.1*, CBNRM can help accomplish global environmental goals, suggesting some compatibility between conservation practices and the support for local livelihoods (Nelson & Chomitz, 2011). As such, the present trend in CBNRM is to focus attention on the development of economic alternatives in response to destructive environmental practices (e.g. slash and burn agriculture, poaching and charcoal production). The initiative of ADAP in supporting village-based beekeeping through the supported of IBA just do so (Hausser & Mpuya, 2004). Nowadays, in Tanzania, CBNRM of wildlife occurs more through the creation of Wildlife Management Areas[7] (WMA). Unfortunately, the ecological success or failure of WMA has not yet been quantified. Yet, Lee & Bond (2018) defined ecological success as significantly greater densities of wildlife and significantly lower densities of livestock in an area compared to another one.

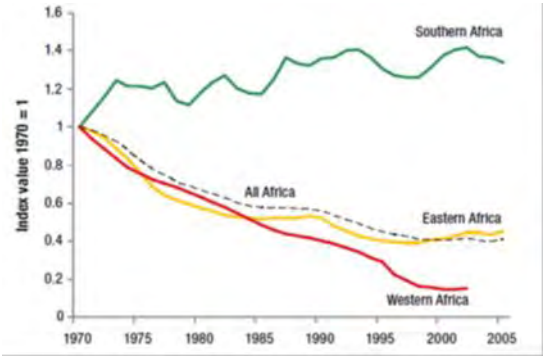

Figure 5: Decrease in large mammals' populations in African PAs.

Source: Craigie et al. 2010, Protected Area Report 2014

It is noteworthy to say that «PAs managers rely on reliable information to detect spatial and temporal trends of the species they intend to protect» (Schuette et al., 2018). Thus, underlying the importance of time series data that are crucial for population monitoring, to detect trends, and adapt management efforts (Schuette et al., 2018).

1.3.2. Mlele BKZ: presence of a complete guild of carnivore

In under-funded PAs, managers often prioritize ungulates and carnivores for monitoring given their socio-economic value and sensitivity to human disturbance (Schuette et al., 2018). As such, in the BKZ of Mlele, combined methods allowed the identification of 56 species of medium- and large-mammals. As the authors noted, this is a surprisingly high diversity for such area, outlining the potential conservation value of such PA and «call for better biodiversity monitoring throughout complexes of PAs of different statuses and management regimes» (Hausser et al., 2017). In addition, Fischer et al. (2013) demonstrated the presence of a complete cohort of carnivore, indicating the existence of a well-structured ecosystem where all niches are occupied. Besides, using carnivores as indicator of change is justified for several reasons (Sergio et al., 2008). Indeed, as human population increases, human-wildlife conflicts become more and more prevalent (e.g. livestock depredation, retaliatory killing) (Woodroffe et al., 2005; Kinnaird & O'brien, 2012). Moreover, the disappearance of carnivores, given their influence on different ecological processes (e.g. as prey population regulator), often has repercussions on the health of the entire ecosystem (Sergio

[6] A legally established PA where experts believe current protection activities are insufficient to halt degradation (Dudley & Stolton, 1999)

[7] These areas consist of land set apart for wildlife conservation that were designated by multiple villages who will share a portion of subsequent tourism revenues

et al., 2008). In order to better manage animal communities, it is therefore essential to better understand the vulnerability of carnivores. Their loss, in addition to ecological consequences, has dramatic socio-cultural implications – including the limitation of economic potential for a region through tourism – as well as conservation (Burton et al., 2011). Thus, effective conservation strategies should propose options for actions minimizing conflicts between local people and predators. The success of such strategies will depend primarily on their ability to reduce carnivore impacts on property and human lives to an "acceptable" level for them, without reducing carnivore populations (Michalski et al., 2006). Indeed, carnivores are particularly sensitive to human activities as their needs often conflict with the needs of local communities. In addition, local cultures, government policy and international exchanges influence the way humans look at carnivores, which in turn impacts them (Woodroffe, 2000). In addition, predation on livestock as well as, sometimes, on humans, makes coexistence with human societies conflictual (Woodroffe & Ginsberg, 1998). In East Africa, carnivores are viewed negatively because they are considered antagonistic to livestock, which are of great importance to pastoralists (e.g. Wasukuma & Masais) as a means of livelihood and as a source of income (Koziarski et al., 2016). Finally, Burton et al. (2011) demonstrated that variation in carnivore persistence was not explained by ecological or life-history traits such as body size or home range size, showing the importance to study carnivore response to anthropogenic factors.

1.3.3. Evaluate management implemented in Mlele in a comparative manner

Depending on environmental conditions and costs, assessing mammals species richness and abundance can use different methods (Silveira et al., 2003). Aerial censuses (Stoner et al., 2007; Caro, 2008), road transects (Caro et al., 1998) and walking transects (Waltert et al., 2009; Kiffner et al., 2009) were all used in the Katavi-Rukwa ecosystem and more recently, CT were also introduced to the region (Figure 6) (Moyer et al., 2006; Juget, 2008; Iida et al., 2012). Silveira et al. (2003) compared the efficiency of three different methods in detecting species richness and abundance of species. The authors found that track census was the most effective method for detecting species richness, followed by CT and that direct faunal counts was the less effective method of them all and concluded that, «despite the high initial costs for CT, this method is the most appropriate for mammal inventory in all environmental conditions, allowing a rapid assessment of wildlife conservation status».

In Mlele BKZ, different monitoring schemes were also tested (opportunistic observations, transects and CT) in order to evaluate which method was best suited for a long-term monitoring. Hausser et al. (2017) came to similar conclusions than Silveira et al. (2003) and finally opted for CT as this method is one of the most reliable and effective way to collect data on a large quantity of species, especially elusive mammals (O'Connell et al., 2011; Rovero & Zimmermann, 2016). As CT appears to be the best method to collect data and monitor wildlife trends within large-scale areas and over a long period of time, Hausser et al., (2017) setup a regular CT monitoring per systematic grids in the BKZ. For instance, the quantitative data collected so far should allow the subsequent comparison between a PA with low protection status and areas with stricter regulations. Furthermore, CT offer interesting perspectives in statistical treatments and higher performances than other methods if they are repeated using the same methodological protocols and within the same area (Hausser et al., 2017). If both preceding postulates can be met, then time series data will be helpful to detect population trends and adapt management measures according to fixed targets.

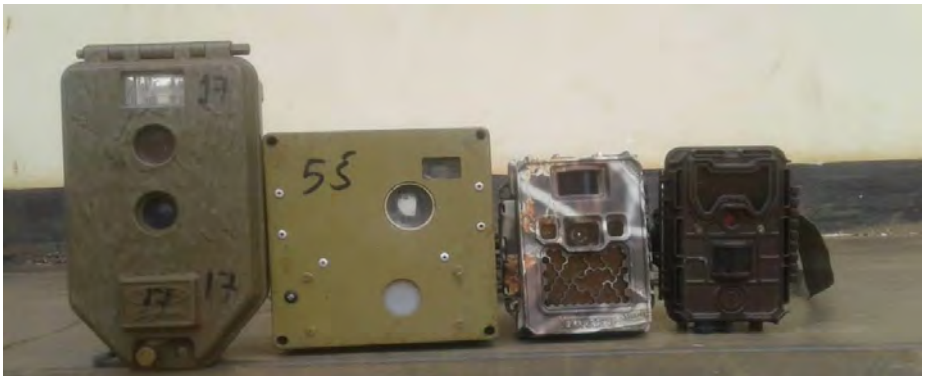

Figure 6: Evolution of CT used in the study area from 2008 up to now.

From left to right: Cuddeback, transformed digital camera, Reconyx & Bushnell

In order to evaluate the management implemented in Mlele in a comparative manner and to understand the strengths and weaknesses of those 3 PAs management and the threats they face, CT are not sufficient. Indeed, an adaptative management process «allows for taking action under uncertain conditions based on the best available science, closely monitoring and evaluating outcomes, and re-evaluating and adjusting decisions as more information is learned to achieve specified objectives» (http://www.dfg.ca.gov). To help this process, a number of assessment tools have been developed to assess management practices. The Management Effectiveness Tracking Tool (METT or Tracking Tool) is one of them and has been developed by the World Bank and WWF[8] International to help track and monitor progress in the achievement of PAs management effectiveness target. Thus, the METT aims to report progress on management effectiveness[9] (ME). It has been developed to improve the effectiveness of management in individual PAs by providing a quick overview of the progress but «because of the great differences between expectations, resources and needs around the world, the METT also has strict limitations in terms of allowing comparison between sites: the scoring system, if applied at all, will be most useful for tracking progress over time in one site or a closely related group of sites». Thus, the METT is really aimed at providing a quick overview of the management steps identified in the World Commission on Protected Areas (WCPA) Framework[10] (Stolton et al., 2007; Kiffner et al., 2009).

1.3.4. Study limitations

On the 4 months dedicated to fieldwork, 3 weeks had to be used for administrative purpose in order to allow us to enter the PA. In addition, some internal issues had to be addressed during the whole course of the fieldwork. In consequences, our planning had to be revised (Appendix III shows both planning for comparison) with consequences on the course of the project. Having data arriving in January instead of late November made us take the decision not to address time series data[11]. Furthermore, our study focused only on 1 CBNRM program and 2 control sites monitored over a relatively short time frame. As time series analyses could not be addressed, we suggest similar evaluation efforts be conducted over time to confirm our results and expand upon our findings. Moreover, as Lee & Bond (2018) noted, «most CBNRM programs are aimed at promoting conservation while maintaining or improving people's standards of living». As for them, our study did not assess impacts of the BKZ establishment on local human livelihoods. Moreover, this aspect of CBNRM should be formally quantified as the authors emphasized that «most CBNRM programs have only limited success at achieving both conservation and human development goals, and although linking conservation with development may be desirable, the simultaneous achievement of these 2 objectives may be impossible because of inherent contradictions».

Carnivore being particular (resource facilitation, trophic cascades, dependence on ecosystem productivity, sensitivity to dysfunctions, selection of heterogeneous sites and links to multiple ecosystem components) (Sergio et al., 2008), conclusions drawn here are not necessarily valid in the same time frame for other mammal species. For instance, some carnivores may be attracted by livestock for obvious reasons whereas ungulates will avoid areas with intensive livestock grazing for competition reasons (Butt & Turner, 2012; Böhm, Hutchings & White, 2009; Kissui, 2008; Voeten & Prins, 1999). Additionally, the keen use of roads that carnivores make off has been noted elsewhere (Zurkinden, 2017; Cusack et al., 2015; Burton et al., 2012; Larrucea et al., 2007; Henschel & Ray, 2003). Therefore, the use of elephant, *Loxodonta africana* (Blumenbach, 1797) as control species could be interesting and could contradict our results as this species represent a strong financial incentive to poachers, justifying greater risk-taking than other species (ivory trade). Another important aspect in carnivore conservation and management, is a) their relationship with other carnivores (competition) and b) resource availability (prey species) (Estes & Otte, 2012; Kingdon, 2013; Schuette et al., 2013). Those elements will be treated in the literature and will serve as reference for results interpretation but could not be assessed in the analyses has it was to much time consuming to correlate predation and competition with carnivore occurrence.

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[8] World Wide Fund (wwf.panda.org)

[9] Refers to the ratio between the means invested and the results

[10] Hockings, M, S Stolton, F Leverington, N Dudley and J Courrau (2006); Assessing Effectiveness – A Framework for Assessing Management Effectiveness of Protected Areas; 2nd Ed. IUCN, Switzerland.

[11] A set of observations on the values that a variable takes at different times (www.statisticssolutions.com)

Scale is also known to impact ecological patterns (Levin, 1992). This is why only the north part of Rukwa GR was monitored as the habitat is similar to Mlele BKZ and Rungwa FR & GCA and allows a better comparison. Thus, results cannot be extrapolated to the whole PA as the south part habitat of Rukwa GR are more closely related to Katavi NP. Here it has to be noted that a mistake occurred during fieldwork and made that the CT in R1 were placed on the old GPS (Global Positioning System) points instead of the new ones as it was planned (see Appendix IV and section 3.3.1. for more details). However, this aspect had no consequences on our results. In addition, changing the spatial resolution and/or the spatial extent of the background on the map used to extract covariates[12] could affect our results. Durant et al. (2010) give a good example on this: «on a country-wide scale species may appear to be attracted to rivers, however at a finer scale, species may move towards watersheds yet avoid the immediate vicinity of the river itself, which would be seen as avoidance». Indeed, the whole covariates analysis was performed at the km^2 scale, and it might well be that such spatial resolution is too low to correctly assess habitat-use patterns displayed by some species. Besides that, the 3 PAs varies greatly in size, degree of protection and consumptive use.

Concerning Illegal activities, their reliability may be diminished by associated uncertainty (Burton et al., 2012). For instance, our measures of illegal activity are dependent on the reliability of data generated in the field. We detected an ''observer effect'', where detection probabilities differed between the two field teams. Thus, it was decided only to take into consideration the illegal activities being ≤ 1 year old as this time frame was steadily reported by the two CT teams. Another inference was made in the type of illegal activities integrated in this analysis. Indeed, only the activities detected on the 3 PAs (timbering, poaching, grazing) were integrated. For instance, illegal fishing was only reported in Mlele BKZ whereas mining was only reported in Rukwa GR and thus were not integrated to our analyses. Also, because of the time constraints and the fact that data for Mlele were integrated from a Bachelor thesis (Buffard, 2018), distances from each point of interest to the closest illegal activity point (see section 3.4.1.) was calculated by PA and not on the whole sampling unit, which is not totally correct to produce occupancy analyses. Indeed, a detected illegal activity could be closer to a point of interest from the adjacent PA. Similarly, it would have been preferable to use the real GPS point of each CT station but for the same reasons, the planned CT position were used which can bring some minor biases on the analysis. Similarly, one legal activity was finally not taken into consideration; Trophy hunting. Indeed, this activity was not held on the visited PAs. In fact, only 1 hunting company was active in the south part of Rukwa GR (Malembeka, com. pers., 2018) and, thus, had no influence on our results.

Finally, in order to make valid comparisons between species, space and time in a CT study, it is necessary to assume that species detectability is constant between the aforementioned dimensions (Sollmann et al., 2013) (see section 3.2.1.) but essential to any occupancy model is the temporal pattern of detections at CT stations. Indeed the detection of a species is determined by the species population density and the speed and scale of the individual movement (Neilson et al., 2018). The authors harried that it is unclear how these factors affect the interpretation of occupancy estimates. The authors showed that occupancy models overestimated the proportion of an area occupied by a species when a low population density of animals moved quickly over large home ranges. Conversely, the proportion of an area occupied by a species was underestimated when the animals moved slowly in large or intermediately sized home ranges. The authors results emphasize that the interpretation of occupancy models depends on the underlying processes driving species detections. Additionally, two types of detection errors may occur in such CT study; false negatives[13] and false positives[14]. Indeed, some mongooses are hard to identify especially when the CT photographs are of poor quality, which could lead to species misidentification. Thus, there is a real need to take them both into account because if not, both can bias species estimates. False negative detections can be accounted for in models that deal with imperfect detection but in contrast, false positive have only rarely been accounted for in species occurrence models (Louvrier et al., 2018). The authors showed that, rather than to discard them, the addition of ambiguous detections increases the precision of the ecological parameters estimated and reveal additional occupied sites in areas where the species is likely expanding. Overall, the authors study shows that ambiguous data should be considered in any occupancy analysis accounting for

[12] A covariate is an independent variable that has no direct interest as such, but on which depends another independent variable of interest. Taking into account one or more covariates will make it possible to control a part of the variation of the variable of interest (http://cognition.ups-tlse.fr)

[13] animals can be missed at sites where they are present

[14] due to species misidentification

misidentification when studying the distribution of carnivores. Based on those conclusions, it was decided to incorporate ambiguous detections of unidentified genets, *Genetta sp.* which represent our false positive detection into both the miombo genet, *Genetta angolensis* (Bocage, 1882) and the large-spotted genet, *Genetta maculata* (Gray, 1830) data. Nevertheless, multi-species analysis lead to a great amount of uncertainty drawn by the considerable amount of species-level variation in occurrence patterns. Additionally, inference for rare species will always be limited by small sample which inevitably leads to less precise estimates of species with fewer detections (Burton et al., 2012). For example, the authors model identified few effects of measured landscape covariates for the rarest carnivores and, on the contrary, species with a greater number of detections had a better response to landscape factors, «highlighting the frequently complex relationships between landscape heterogeneity and carnivore ecology». This, again, underscores the importance of accounting for imperfect detection in carnivore occupancy models.

1.4. Research Questions and Hypothesis

1.4.1. Research question

Considering specifically medium- and large-mammal species in a gradient of PAs of different statuses, management regimes and governance types, which factors (topography, habitat, interspecific competition, resource availability (food and water), predation, roads, camps, villages, trophy hunting, protected areas, status, management, governance, poaching, timbering and grazing) explain most of species richness, relative abundance and occupancy at landscape scale (Figure 7)?

1.4.2. Hypothesis

According to literature, two types of factors are influencing these state variables (species richness, relative abundance & occupancy), the first relates to environmental variables (Banda et al. 2006; Kiffner et al., 2009; Waltert et al., 2009), the second to anthropogenic variables (Stoner et al., 2007; Caro, 2008 ; Waltert et al., 2009 ; Mgawe et al., 2012 ; Martin & Caro, 2013).

1.4.2.1 Hypothesis 1

In the context of the studied PAs, anthropogenic factors are believed to be the main explanatory factors of the observed levels of mammal species richness, relative abundance, and occupancy (Caro, 2008; Waltert et al., 2009).

1.4.2.1.1 Prediction

Environmental variables will have less influence than anthropogenic variables on mammals' descriptors.

1.4.2.1.2 Objective

1. To investigate this hypothesis, data regarding species richness, relative abundance and occupancy of species in each of the studied PAs, with similar survey methods and research effort, will be collected.
2. In view to assess their influence on results, data on environmental variables and anthropogenic variables will be extracted from ArcGIS[15] layers and then correlated to the observed descriptors of wildlife.

In addition, two sub-hypotheses regarding anthropogenic variables are formulated:

1.4.2.2 Hypothesis 2

Stricter level of protection reinforces local opposition which in turn, leads to negative impacts on wildlife (e.g. transgression of rules) (Hausser et al., 2009; Leroux et al. 2010; Nolte et al., 2013).

1.4.2.2.1 Prediction

[15] a Geographical Information System

A higher presence of illegal activities will be detected inside State governance PAs.

1.4.2.2.2 Objective

1. To confirm this hypothesis, characterize at theoretical (review of policies, laws, regulations) and practical level the level of protection of each studied PAs.
2. In view to assess their influence on results, collect data regarding illegal uses so as to be able to correlate it on observed descriptors of wildlife.

1.4.2.3 Hypothesis 3

ME at site level determine species richness, relative abundance and occupancy of mammals (Hockings et al., 2006; Leverington et al., 2010; Coad et al., 2015).

1.4.2.3.1 Prediction

A higher species richness, relative abundance, and occupancy of carnivores will be detected in the PAs with higher funds and resources compared to PAs with low funding (Mermod, 2016).

1.4.2.3.2 Objectif

1. To test this hypothesis, the ME of each studied PAs must be evaluated with a standardized methodology, which will support a ranking of the three studied areas in terms of ME, and then correlate this ranking to observed descriptors of wildlife.

Figure 7: Miombo ecosystem dominates the Western Tanzania landscape

2. Literature Review

An important task in wildlife management is to identify landscape-scale determinants of mammal distribution and abundance. At a landscape scale, the combined influence of environmental and anthropogenic variables may be particularly important in determining the distribution patterns of mammals (Redfern et al., 2003).

2.1. Environmental Variables

Environmental variables comprise different biotic and abiotic factors explaining reaction and behavior of individuals, population and communities in their respective biotopes (Ramade, 2009). Table 1 shows the classification of those factors.

Table 1: Classification of the environmental variables

adapted from Ramade (2009)

Abiotic factors	Climatic factors	Factors independent of the density	Biotic factors	Trophic factors	Factors dependent of the density
	Temperature			Resource availability	
	Illumination			Food	
	Hygrometry			Water	
	Pluviometry			Biotic factors	
	Other factors (wind, etc.)			Intraspecific interactions	
	Physicochemical factors			Interspecific interactions	
	Topography			Competition	
	Terrestrial biotopes			Predation	
	Aquatic biotopes			Parasitism	
				Other factors	

Looking at environmental variables that might affect distribution and abundance of mammals, and especially carnivores, one must pay attention to the following: topography, habitats, resource availability (food and water), predation and competition (Estes & Otte, 2012; Hunter & Barrett, 2012; Kingdon, 2015).

2.1.1. Topography

A few environmental variables are closely correlated with elevation. Although affected by local topography and weather, temperature, atmospheric pressure and relevant gases – such as oxygen and carbon dioxide – tend to decrease relatively uniformly with increasing elevation. Because most mountains have a conical form, land surface area also decreases relatively continuously with increasing elevation. Another well-known consequence of uplifting is that mountain tops tend to be more isolated than sites at lower altitude. For other variables, the relationship is not linear. For example, uplift and erosion reflect exposure of different strata and creates a heterogeneous topography of ridges, valleys, stream networks, and other features. This interacting influences of climate, topography and soil then determines plant distribution. In fact, precipitation and related ecologically relevant variables, such as soil moisture and evapotranspiration, typically concentrates at some intermediate elevation. This in turn determine a peak of mammal species richness at intermediate elevations. Although it is difficult to attribute the variation in the patterns of mammalian diversity to any single ecological variable, species richness appears to vary positively with precipitation, and probably with other variables such as evapotranspiration that index primary productivity, food resource availability and structural heterogeneity of vegetation. On the other hand, resources used directly by mammals, including not only food, but also elements of habitat structure used for foraging, nesting or avoiding predation also directly influence mammalian diversity (Brown, 2001).

2.1.2. Habitat

In western Tanzania woodlands are denoted as ‘‘miombo’’. In fact, this appellation refers to a highly variable mosaic of vegetation that ranges from open grassland to closed canopy forest communities. In Africa, the miombo biome (Figure 8) covers 2.7 million km^2 of land. It crosses the continent from Angola in the west through Zambia to Malawi and Mozambique in the east. Then it extends to the north from Tanzania and southern Democratic Republic of Congo and extend in the south to the northern provinces of South Africa (Banda et al., 2008). Classic miombo has a high diversity of trees that concentrates in the *Fabaceae* family with a dominance in *Brachystegia species*; *Julbernardia species* or *Isoberlinia species*. In the Katavi-Rukwa ecosystem however, Banda et al. (2008) found that woodlands in this region are atypical of the miombo biome with *Terminalia sericea* (Cambess.); *Combretum adenogonium* (Steud.) and *C. colinum* (Okafor.) as dominant tree species. The authors also found that the communities have a diffuse structure along the study area. Thus, the Katavi-Rukwa ecosystem is dominated by locally common trees, intermixed with a diverse assemblage of less common species.

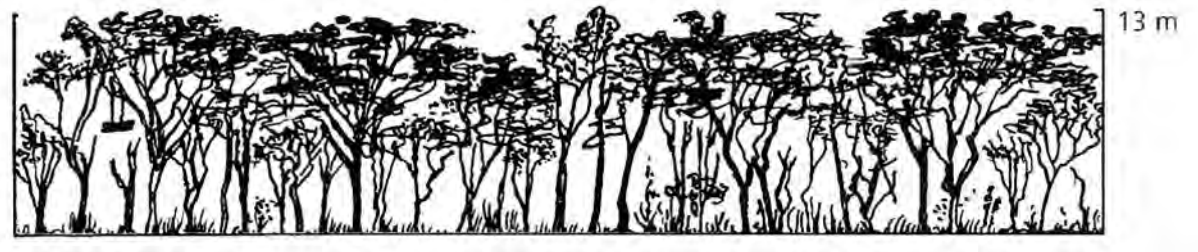


Figure 8: Miombo woodlands are typically dominated by Brachystegia and Terminalia spp.
Source: Kingdon (2015)

Rodgers (1996) showed that these nutrient-deficient landscapes support fewer mammal species, which generally lives at relatively low densities but that they could support high mammal densities when they are situated close to more suitable habitats (Waltert et al., 2009). As a result, large predators are scarce and the main large antelope in miombo, the sable antelope, *Hippotragus niger* (Harris, 1838) survives on a grazing strategy (Kingdon, 2015). Waltert et al. (2009) studied the differences in species-specific densities caused by the relative importance of vegetation cover and species-specific habitat preferences. Their study showed that density differences were moderately correlated with preferences for open habitats but that open habitat preference was found to explain 39.6% of the density differences between the two PAs they studied. Thus, suggesting that species distributions pattern mostly varied due to vegetation cover. As they quoted, «the main variable explaining density differences was found to be the different vegetation composition of the two areas and most species’ preferences for open habitats». Regarding carnivores, vegetation cover has, from a degree or another, relative importance for some species and especially cats. For example, leopards, as stalking predator, depend on dense vegetation cover and broken terrain to catch their prey (Hunter & Barrett, 2012; Kingdon, 2013).

2.1.3. Interspecific Competition

The general importance of interspecific competition as an ecological factor for carnivores is mostly lacking and is known only for some charismatic and vulnerable species. Caro & Stoner (2003) examined the potential of interspecific competition across carnivores in Africa. The authors results showed that carnivores in Africa share, on average, some of their geographic range and habitat with 26 other carnivore species and share food resources with 22 others. Thus, results suggest that competition could be prevalent. Moreover, some African carnivores may be vulnerable to predation by 15 other carnivore species although unlikely to be eaten. In addition, the meso-predator release hypothesis predicts that a reduced abundance of top-order carnivores results in an increase of smaller predators’ abundance due to a relaxation in interspecific competition and predation (Cupples et al., 2011). Thus, PAs where carnivores are more impacted by human activities than other areas, may be subject to meso-predator release (Vance-Chalcraft et al., 2007; Ritchie & Johnson, 2009). Accordingly, small- or meso-carnivores, which may have avoided certain habitat types due to competition, are less likely to be constrained, and hence might use a wider range of habitats than normally (Durant et al., 2010).

2.1.4. Resource availability (Food) and Predation

The focus will here be made on the importance of resource availability for carnivorous species. Table 2 shows the niche occupied by some African carnivores and summarizes the separation of species according to habitat and diet (Kingdon, 2015). In fact, few carnivores are strictly carnivorous, and most are, to some degree, omnivorous with the exception of cats and weasels. Additionally, carnivores usually select prey smaller than themselves (Estes & Otte, 2012).

Table 2: Carnivores are well distributed throughout the many ecosystems of Africa

Adapted from Kingdon (2015)

Habitat	Fruits	Sessile or cryptic invertebrates and eggs	Active invertebrates	Aquatic or semi-aquatic fauna	Reptiles and amphibia	Small mammals and birds	Medium-sized mammals	Large mammals	Carrion
Forest	Tree Civet				Tree Civet				
		Crossarchus cusimanses		Long-nosed & March Mongooses*					
		Black-legged Mongoose			Black-legged Mongoose				Tree Civet
		Servaline Genet			*Genetta* genets				
		Giant Genet		Aquatic genet					
Secondary growth		Savanna Mongoose				African Golden Cat			
		White-tailed Mongoose*			White-tailed Mongoose				
		Cape Genet*			Cape Genet				African Civet
		African Civet*			African Civet				
		Meller's Mongoose				African Stiped Weasel*			
Moist savannas and woodlands		Bushy-tailed Mongoose			Bushy-tailed Mongoose		Leopard		
		Ratel*			Ratel				Side-striped Jackal
		Side-striped Jackal*			Side-striped Jackal				
		Slender Mongoose*			Slender Mongoose				
						Serval			
Marshes and aquatic		Marsh Mongoose*			Marsh Mongoose				
		Congo Clawless Otter (forest swamps and rivers)							
		African Clawless Otter (swamps and rivers)							
		Spotted-necked Otter(rivers and lakes)							
Thicket, dry savannas and woodlands		*Helogale* dwarf mongooses*			*Helogale* dwarf mongooses				
		Hyaena hyaenas			Wildcat*				Hyaenas
		Bat-eared Fox			Bat-eared Fox				
		Common Genet			Common Genet				Black-backed Jackal
		Black-backed Jackal			Black-backed Jackal				
						Caracal			
(interzones)		Zorilla*			Zorilla				
		Aardwolf*					Wild Dog*		
Grasslands		*Mungos* mongooses*			*Mungos* mongooses		Spotted Hyaena		
		Ichneumon Mongoose*			Ichneumon Mongoose				
		Common Jackal			Common Jackal				Common Jackal
						Cheetah*			
					Lion		Lion		

* Species thus marked occupy a wider range of habitats than can be suggested in a simplified table.

Now let us have a closer look to some of the most charismatic and studied of the carnivores as those species are more likely to influence medium- to large- ungulates than smaller carnivores who prey preferentially on micro-mammals (such as hare and mice) and are thus of less conservation concerns. Hayward and various colleague did an extensive work on prey preferences and dietary overlap among lion, spotted hyaena, *Crocuta crocuta* (Erxleben, 1777), leopard, and African wild dog.

As lions are generally thought to prey on medium- to large-ungulates, Hayward & Kerley (2005) showed – throughout the distribution range of lions – that they preferentially prey upon species within a weight range of 190–550 kg, preferring prey weighing 350 kg. The authors also showed that lions significantly prefer Gemsbok, *Oryx gazella* (Linnaeus, 1758); buffalo, *Syncerus caffer* (Sparrman, 1779); wildebeest, *Connochaetes taurinus* (Burchell, 1823); giraffe, *Giraffa camelopardalis* (Linnaeus, 1758) and zebra, *Equus quagga* (Boddaert, 1785). Other prey species that are in the preferred weight range but are not significantly preferred – such as roan, *Hippotragus equinus* (Saint-Hilaire, 1803); sable and eland, *Tragelaphus oryx* (Pallas, 1766) – generally have sufficient anti-predator strategies. For instance, morphologically (e.g. sable horns), ecologically (e.g. roan and sable occurring at low density), or behaviorally (e.g. the large herd size and increased vigilance of eland). In general, species outside

the preferred weight range are avoided but warthog, *Phacochoerus africanus* (Gmelin, 1788) are yet taken in accordance with their availability. The authors quote that «this is probably due to their sympatry with lion, their relatively slow evasion speed and their lower level of vigilance».

In the past, spotted hyaenas were considered as strict scavengers but, nowadays, research revealed that they are also skillful predators. Hayward (2006) showed that spotted hyaenas do not preferentially prey on any species in contrast to the rest of Africa's large predator guild. However, results showed, surprisingly, that buffalo, giraffe and zebra are significantly avoided. In fact, spotted hyaena prefer preys weighing 56–182 kg, with an average of 102 kg. Actually, the dietary niche of the spotted hyaena overlap the one of lions. The two species having a 58.6% actual prey species overlap and a 68.8% preferred prey species overlap. Thus, Hayward highlighted the flexible and unselective nature of spotted hyaena predation, explaining the species' success throughout its range, despite a large degree of dietary overlap with lions.

The solitary hunting strategy of leopards and their catholic[16] diet suggest that leopard generally prey on medium-sized ungulates. Hayward et al. (2006) showed that leopards preferentially prey upon species within a weight range of 10–40 kg, with a preferred prey mass of 25 kg. The authors note that «leopards prefer prey within this body mass range, which occur in small herds, in dense habitat and afford the hunter minimal risk of injury during capture. Consequently, impala, *Aepyceros melampus* (Lichtenstein, 1812); bushbuck, *Tragelaphus scriptus* (Pallas, 1766) and common duiker, *Sylvicapra grimmia* (Linnaeus, 1758) are significantly preferred». Due to their catholic diet, species outside the preferred weight range are generally avoided, as are species that are restricted to open vegetation or that have sufficient features that reduce predation.

The study of Hayward et al. (2006) on African wild dogs showed a prey preference – which is abundant and less likely to cause injury when hunted – within a bimodal body mass range of 16–32 kg and 120–140 kg. «This bimodal range follows that of optimal wild dog pack sizes based on energetic costs and benefits». Thus, Greater kudu, *Tragelaphus strepsiceros* (Pallas, 1766); Thomson's gazelle, *Gazella thomsonii* (Günther, 1884); impala and bushbuck are significantly preferred. Moreover, Greater kudu and Thomson's gazelle are killed by wild dogs whenever they coexist.

Hayward & Kerley used reviews of the prey preferences of African wild dog; cheetah, *Acinonyx jubatus* (Schreber, 1775); leopard; lion and spotted hyaena to investigate the degree of dietary overlap and dietary niche breadth in their 2008 study. They found out that «wild dogs and cheetahs exhibited the greatest dietary overlap and smallest dietary niche breadth, while lions exhibited the least dietary overlap and, with leopards, had the broadest dietary niche breadth». Interestingly, they found relation between the increased extinction risk of wild dogs and cheetahs and their lower dietary niche breadth caused by their behavioral and morphological specializations. «Conversely, the large body mass and group hunting strategy of lions and the predatory flexibility of leopards and spotted hyaenas minimizes the effects of dietary overlap, assuring a more secure status», showing why cheetahs and African wild dogs are naturally less common in unmodified landscapes (Hayward & Kerley, 2008).

Another interesting article is Hayward et al. (2007) study on the carrying capacity of large African predators. Based on the observation that conservation managers had no idea of the carrying capacity of their PAs, the authors predict the carrying capacity by deriving the relationships between Africa's large predator guild population densities and their preferred prey (species and weight range). Accordingly, the authors found a highly significant linear relationships between the biomass of the preferred prey species of lion, leopard, spotted hyaena and African wild dog. Interestingly, this method, based on the abundance of carnivores preferred prey, can predict the carrying capacity of every predator that preys on large, readily surveyed wildlife. In fact, the ability to predict the carrying capacity of large predators is fundamental to their conservation. More so, Kiffner et al. (2009) showed that a lower prey abundance and possibly less access to surface water could contribute to an observed edge effect on the NP the authors studied (we will come back on the edge effect concept later).

2.1.5. Permanent Water

Water availability is highly seasonal, especially in the subtropics and in the dry corridor that runs from NE to SW Africa. Droughts are often followed by floods. Moreover, in shallow basins, such as in Rukwa, massive evaporation and empty feeder-streams lead to periodic drying up of lakes (Kingdon, 2015). Surface drinking-water is the single

[16] 'broad'

most limiting climatic factor for mammal's distribution. Evidence suggests that water availability is a crucial parameter in calculating the carrying capacity of a PA. Indeed, Western (1975) data showed that seasonal movements such as the wet season dispersal and dry season concentration of water-dependent species (obligate drinkers) – as opposed to the randomly distribution of water-independent species – can be related to the seasonality of rainfall and water availability. The author also demonstrated that «there appears to be a physiological barrier to a heavy utilization of the low water content grasses beyond reach of the water-dependent species, since most water-independent species select high water content browse in order to maintain a positive water balance». Interestingly, Western evidenced that water-independent communities are almost exclusively composed of browsers while most water-dependent species are grazers.

Previous studies suggest that water sources locations in the landscape impose a landscape-scale constraint on dry-season herbivore distributions. For example, a study in Amboseli, Kenya, found that during the dry season, 99% of herbivore biomass occurred within 15 km of surface water (Western, 1975). Hence, herbivores in African savanna ecosystems must meet their nutritional requirements within the constraints set by the location of water sources. If herbivore drinking requirements necessitate regular access to surface water, species' distributions relative to water sources should correspond to their water dependence. Specifically, herds of water-independent species should be distributed randomly with respect to distance to water, whereas herds of water-dependent species should occur close to water sources (Redfern et al., 2003).

Finally, two worrying trends in Africa are 1) the hijacking source-waters of rivers to irrigate agribusiness schemes and 2) the practice that pastoralists deny wild animals' access to waterholes. Consequently, these practices leave people and animals downstream finding their pastures and water drying out and precipitate die-offs over extensive areas (Kingdon, 2015). Several cases of the developing water crisis in semi-arid regions of Tanzania are described such as the case of the Great Ruaha River irrigation projects that are given national priorities. Other irrigation projects are driven by the local population to combat poverty. Manase, Gara & Wolanski (2010) paper describes the previously unreported case of irrigation in the upper Katuma River that flows into Lake Rukwa, «which lead to poverty increase, environmental degradation and a decrease in ecosystem services provision downstream».

2.2. Anthropogenic Variables

At a landscape scale, anthropogenic variables also act as constraints on mammal distributions, necessitating an evaluation of the influence of both environmental and anthropogenic variables (Redfern et al., 2003).

Anthropogenic variables represent all factors caused or produced by humans. Those factors can either influence positively (management factors such as law enforcement levels) or negatively (illegal hunting, grazing and habitat degradation and fragmentation) the distribution and abundance of species. The literature review presented hereafter shows' that some of those factors are either legal or illegal plus that they can be either influenced by managers' decisions and actions or not.

2.2.1. Legal Activities

2.2.1.1 Roads

Today, roads are present in almost all landscape and their negative impact on biotic integrity even lead to a new scientific discipline: road ecology (e.g. Van der Ree et al., 2015). Ibisch et al. (2016) results showed that about 80% of Earth's terrestrial surface remains roadless, but this area is fragmented into approximately 600,000 patches, more than half of which are less than 1 km^2 and only 7% of which are larger than 100 km^2. Trombulak & Frissell (2000) literature review showed that all kinds of roads have seven general effects: (1) mortality from road construction; (2) mortality from collision with vehicles; (3) modification of animal behavior; (4) alteration of the physical environment; (5) alteration of the chemical environment; (6) spread of exotics species and (7) increased used of areas by humans. Indeed, a higher density of roads also promotes increasing hunting, fishing and/or passive harassment of animals as the concerned area becomes easier to access. Of course, not all species and ecosystems are affected in the same way but, overall, the presence of roads is highly correlated with changes in species composition and population sizes.

Africa also faces the same challenges as the rapid proliferation of roads dramatically increase access to relatively unexploited regions. The pace and scale of road development and the profound environmental changes they bring,

makes it essential for land-use planning, capacity building, and environmental assessment (Laurance et al., 2017). The authors conclude that «it is no exaggeration to suggest that, unless carefully managed to ensure sustainability, the spate of planned and ongoing projects could irreparably diminish the forests and wildlife populations of Africa's most biologically diverse regions». Furthermore, Caro et al. (2014) pointed out that road constructions are now common through wilderness and PAs. Although the authors recognize that «infrastructure development is key to regional scale development, poverty alleviation and empowerment of rural poor who either depend upon or are driven to overexploit NR, […] they are concerned that PAs […] are becoming fragmented, degraded killing grounds for tropical charismatic fauna that governments in habitat countries do not always appreciate». On the other hand, success story emerge, as it was the case in Katavi NP, for example, where plans to upgrade a marram road connecting regional capitals has been stopped in favor of retaining the sanctity of the PA for general environmental and sociopolitical reasons (Caro, 2015). An interesting method used by Ibisch et al. (2016) consisted of applying a 1-kilometer buffer to all roads in order to present a map of roadless areas and extent of coverage by PAs (Figure 9). The authors conclude that international recognition and protection of roadless areas is urgently needed as global protection of ecologically valuable roadless areas is inadequate.

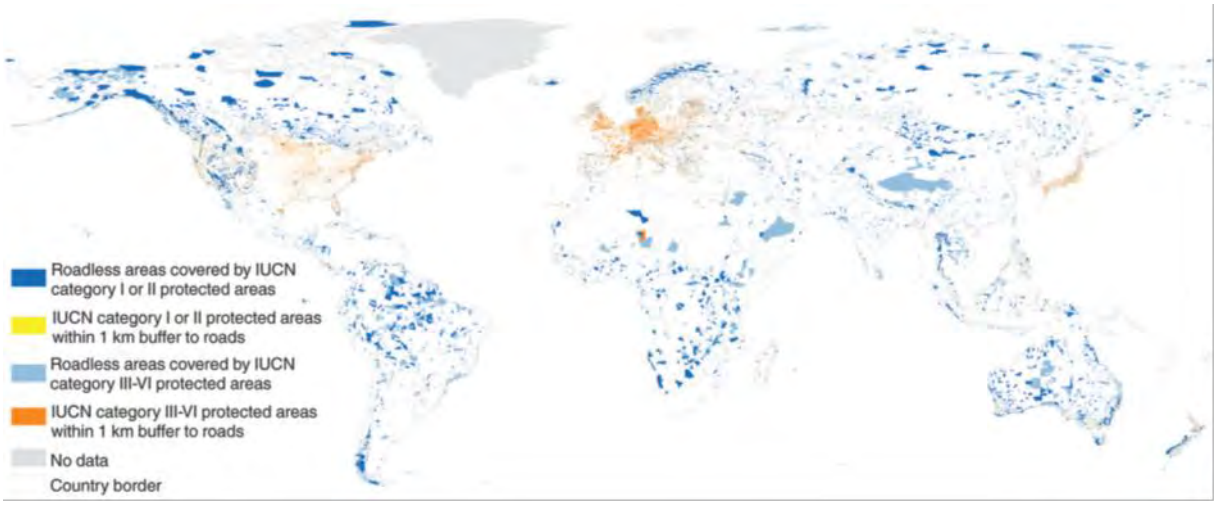


Figure 9: Global distribution of roadless areas in PAs, based on a 1-km buffer around roads

Source: Ibisch et al. (2016)

2.2.1.2 Camps

In Tanzania, beekeeping is widespread and it is estimated that more than 95% of beekeeping activities are concentrated in miombo woodlands where both honey hunters and traditional beekeepers acquire bee products from wild honeybee colonies and make hives out of trees in the wild (from the use of bark to log or box hive) (Ahmed, 2010). Thus, beekeepers are building light camps, systematically located close to water source, using rejected timber from timber exploitation. Definitely, a large number of temporary beekeepers' camps are present in the study area (Appendix V). Moreover, a study on the fluctuation of bee products production and its implication to livelihood in Mlele District (Ogejo & Lyimo, 2014) showed, that animals are quick to learn that they are somehow safer from poaching in the close vicinity of camps. Other camps in the studied PAs are tourist hunting camps and ranger camps (also see Appendix V). These camps have a significant size and therefore impact directly micro-habitat and species, but they are limited in space and time as hunting camps are dismantled at the end of each hunting seasons. Of course, human activity clearly represents a disturbance to species but the temporary nature of certain camps or the relative stability in location of others, contribute to limited negative impacts (Buffard, 2018).

2.2.1.3 Villages

As human population continues to growth, wildlife habitats are continuously converted for anthropogenic activities. As consequences, wildlife species decline or disappear (Mgawe et al., 2012; Masanja, 2014). Mgawe et al. (2012) studied factors affecting bushmeat consumption in the Katavi-Rukwa ecosystem of Tanzania. Their study revealed that more bushmeat was consumed in villages situated nearer to PAs. Interestingly, they also highlighted the fact that bushmeat consumption was more common in richer indigenous (Wakonongo) households than in poorer and that the opposite pattern took place in the immigrant (Wasukuma) households. Finally, the authors concluded that if bushmeat consumption is negatively associated with distance to PAs, then, the most effective way of ensuring

that conservation goals are met will be to focus attention on villages closest to PAs. Similarly, an analysis of forest cover change in Mlele District showed an increased forest degradation in favor of cultivated lands. Between 2002 and 2015, the deforestation growth was of 248%, whereas the population growth of Inyonga Division was “only” of 181% (Table 3).

Table 3: Evolution of the cultivated land and population between 2002 and 2015

Source: Mermod (2016)

Year	Inyonga Division		Inyonga		Illunde	
	Total cultivated land (km²)	Population*	Total cultivated land (km²)	Population*	Total cultivated land (km²)	Population*
2002	375	21,111	336	18,613	39	2,498
2015	929	38,137	762	34,049*	167	4,088
% of increase	248	181	227	183	428	164

*Based on the 2002 (URT, 2015) and the 2012 Census (URT, 2013) with a 3.2% annual growth rate for the District

Figure 10 shows how cultivated land extension is linked with village land boundaries and Land Use Plans and how these boundaries have already been exceeded by deforestation. Interestingly, it also shows that farmers preferred to extend cultivation into forests closer to villages (Mermod, 2016). Furthermore, Pettorelli et al. (2010) results suggested that habitat conversion to agriculture could have serious implications for carnivore distribution as 23 out of 35 carnivore species known to occur in Tanzania tend to avoid croplands. In 2014, a survey was conducted to estimate the future impacts of increasing human populations on wildlife populations densities. The results indicate that by 2050, many of the presently abundant types of wildlife species will begin to disappear as the number of people in contact with wildlife increases. The paper therefore suggests that «burgeoning human population around PAs must be curtailed to enhance both consumptive and non-consumptive forms of tourism in the future» (Masanja, 2014).

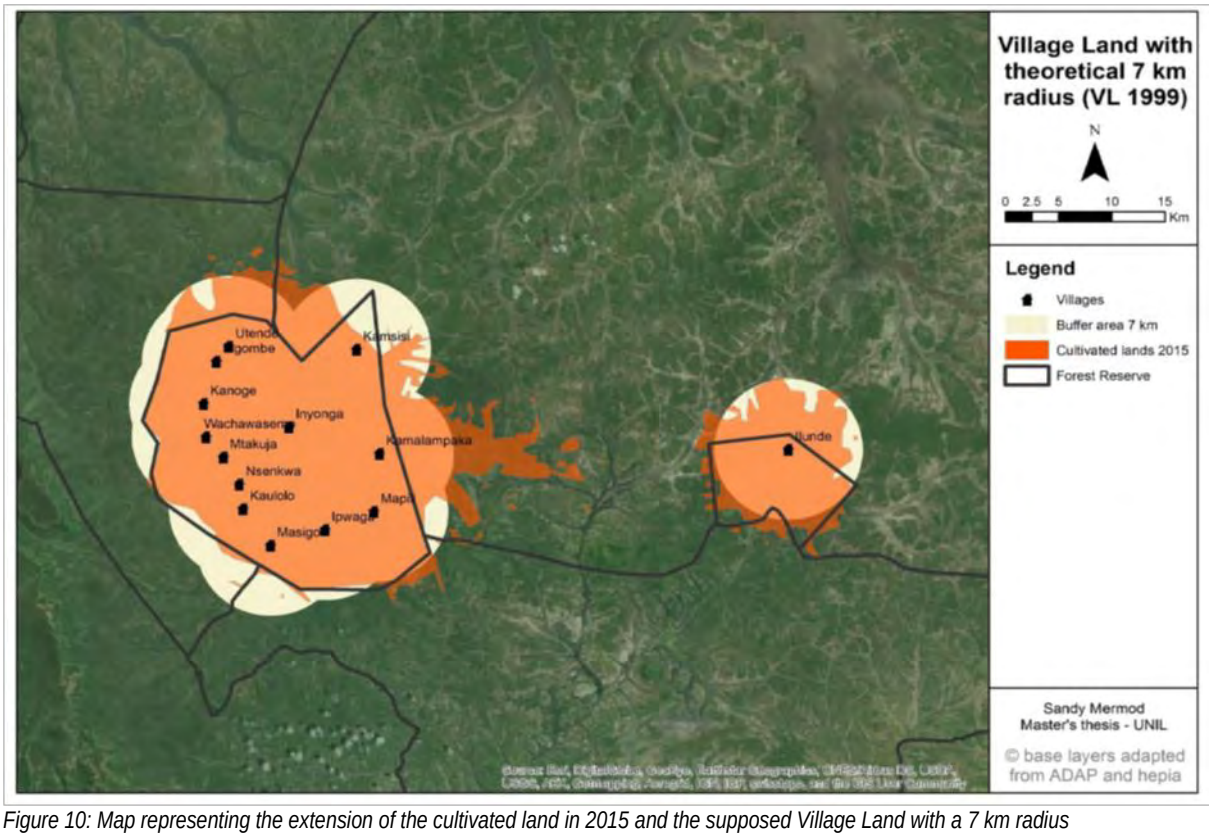


Figure 10: Map representing the extension of the cultivated land in 2015 and the supposed Village Land with a 7 km radius

Source: Mermod (2016)

2.2.1.4 Hunting

The legal – or so-called Trophy – hunting industry in Tanzania is run by the private sector. Nevertheless, it is the government that leases each hunting block to a private company and allocates species-specific annual quota per block. More so, it is argued – if undertaken sustainably – that trophy hunting of large, charismatic mammal species can have considerable conservation benefits (Brink et al., 2016).

Despite the lack of correlation between mammal density with habitat or hunting individually, Waltert et al. (2009) found that the combination of both factors has proven to explain for just less than 40% of the density's variance between the two areas they studied. The authors estimated legal off-take in Rukwa GR using hunting quotas taken from the management plan (TANAPA/WD, 2004). Thus, they calculated removed species-specific percentages of their assessed population and outlined the role of realistic hunting quotas. To better illustrate the later, I use Brink et al. (2016) study on lion trophy hunting in Tanzania as example. Tanzania is the main location for lion trophy hunting in Africa and still has a great proportion of the global population of free-ranging lions. The authors study focused on the Selous GR as it is the main trophy hunting destination in Tanzania. The authors used lion data collected from 1996 to 2008 to investigate how resource ownership patterns influence hunting revenue and off-take levels as there are concerns that current hunting levels are unsustainable. Intuitively, results showed that blocks with the highest lion hunting offtake were also those that experienced the steepest declines in trophy offtake but, interestingly, it was also found that this high hunting offtake and the resultant offtake decline tended to be in blocks under short-term tenure. In contrast, regarding the recommended sustainable offtake of 0.92 lions per 1000 km^2, lion hunting levels in blocks under long-term tenure matched it more closely. Conversely, annual financial returns were higher from blocks under short-term tenure, providing \$133 per km^2 of government revenue as compared to \$62 per km^2 from long-term tenure blocks.

2.2.1.5 Protected Areas

As we saw in the introduction, PAs are a center piece of conservation and wildlife can still be subject to considerable human influence even inside them. As Kiffner et al. (2013) quoted, «conservation theory suggests that many species should live at lower densities at the periphery of PAs compared with the core area». Plus, as we also saw it above, species are expected to have lower densities in areas close to human settlements compared with more remote areas. This type of edge effect can be termed as the core-periphery phenomenon. Thus, the protection of peripheral portions of PAs is of significant importance. This is why, buffer zones[17] are placed around PAs, as it is advocated by the United Nations Educational, Scientific and Cultural Organization's Man and the Biosphere Program (Batisse, 1986), and is formalized in the International Union for Conservation of Nature's PAs categories IV through VI (Hansen et al., 2011). Indeed, this role of buffer zone is vital for species having large home-range (Van der Weyde et al., 2018) and is generally concordant with the notion that habitat edges are beneficial to wildlife given the diversity of habitat in their proximity. However, when forest edge coincides with PAs border, distance to edge may also reflect disturbance-avoidance (Rovero et al., 2017) whereas, strongly protected NPs offers a safe environment for species most likely to come into conflict with people (Van der Weyde et al., 2018). Indeed, as Woodroffe already showed in 1998, border areas represent for carnivores population sinks as conflicts with people on reserve borders are most frequent. Species that range widely are thus, more likely to disappear first from an area as they are most exposed to threats on reserve borders—irrespective of population size. However, species that live in regions of rapid human population growth, like Inyonga, are at risk too. Cardillo et al. (2004) showed that species with the greatest discrepancy between current and predicted risk are the Viverridae (civets and genets) and stress that it is particularly worrying that most are currently rated as ''least concern'' on the Red List.

Kiffner et al. (2013) defined their edge categories derived as a distance of 5 or 10 km from Katavi NP boundary based on observations (people are occasionally seen at some distances inside the NP, gunshots are heard in proximity to a tourist camp that is 8 km from the boundary, and that findings from a foot survey carried out in the NP in 2004 suggest that most illegal activities occur within c. 5-10 km of the NP border). The authors found out that herbivore species occupancy was not significantly affected by being close to the edge of the NP or near human villages. Thus, they concluded that «assumed distributional differences between peripheral and core parts of PAs are not necessarily supported by empirical evidence, and that population declines within PAs do not inevitably

[17] an area of land that separates two other areas and that is designed to prevent fighting or harm (https://dictionary.cambridge.org)

proceed from boundaries inwards». On the contrary, evidence suggest that edge effects are manifested in spatial distribution of carnivore populations as border areas represent population sinks. Indeed, as we saw it in the introduction, conflict with people on PAs borders is the major cause of mortality in such populations. The species most likely to disappear from small PAs are those presenting large home-range and are therefore most exposed to threats on PAs borders (Woodroffe & Ginsberg, 1998).

2.2.1.6 Status

A PA status is, nowadays, defined by its IUCN management category. It should be based around the primary management objective(s) of the PA and should apply to at least three-quarters of the PA – the 75% rule. IUCN PAs definition (see *section 1.1*) is expanded by six management categories (one with a sub-division) (Dudley, 2013):

- Ia. Strict nature reserve: Strictly protected for biodiversity and also possibly geological/ geomorphological features, where human visitation, use and impacts are controlled and limited to ensure protection of the conservation values.
- Ib. Wilderness area: Usually large unmodified or slightly modified areas, retaining their natural character and influence, without permanent or significant human habitation, protected and managed to preserve their natural condition.
- II. National park: Large natural or near-natural areas protecting large-scale ecological processes with characteristic species and ecosystems, which also have environmentally and culturally compatible spiritual, scientific, educational, recreational and visitor opportunities.
- III. Natural monument or feature: Areas set aside to protect a specific natural monument, which can be a landform, sea mount, marine cavern, geological feature such as a cave, or a living feature such as an ancient grove.
- IV. Habitat/species management area: Areas to protect particular species or habitats, where management reflects this priority. Many will need regular, active interventions to meet the needs of particular species or habitats, but this is not a requirement of the category.
- V. Protected landscape or seascape: Where the interaction of people and nature over time has produced a distinct character with significant ecological, biological, cultural and scenic value: and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation and other values.
- VI. PAs with sustainable use of natural resources: Areas which conserve ecosystems, together with associated cultural values and traditional natural resource management systems. Generally large, mainly in a natural condition, with a proportion under sustainable natural resource management and where low-level non-industrial natural resource use compatible with nature conservation is seen as one of the main aims.

Nowadays, strictly PAs (IUCN categories I–III) are still seen as the best strategy for conserving biodiversity but it is recognized that they are limited in extent and exclude many species of key conservation importance. In contrast, multiple-use management areas (categories IV–VI) are often considered of little value to biodiversity conservation (Gardner et al., 2007). Therefore, it is interesting to compare the effectiveness of those different sorts of PAs in conserving mammalian fauna. In 1999, Caro compared large- and medium-sized mammal densities in three different sorts of partially PAs to mammal densities in Katavi NP. The author data showed that mammal diversity and mammal densities were relatively high in GCAs where temporary settlement, cattle grazing and tourist big game hunting was permitted. In the contrary, FRs[18] and Open Areas[19] (OA) presented low mammal diversity and densities. The author thus concluded that state-owned conservation areas permitting human activities within their borders compared to fully PAs such as Katavi NP cannot be relied upon as a means of conserving large- and middle-sized mammals in Africa compared to a strictly protected NP (Caro, 1999).

In 2007, two studies investigated the variation of species richness and density along a conservation gradient. Stoner et al. (2007) compared temporal changes in densities of large herbivores among heavily protected NPs and GRs, partially protected GCAs, and areas with little or no protection in Tanzania. The authors comparisons between two snapshots in time showed three consistent patterns across the country. First, data showed a significant decline in the densities of large herbivores in all protection categories. Second, more species fared well (increased

[18] permit limited hardwood extraction and resident hunting

[19] allow settlement, cattle grazing, firewood collection and beekeeping activities

significantly or showed no significant change) in NPs and GRs than in areas with partial or no protection. Third, significantly more species fared poorly (densities declined or were too low to detect a decline) than fared well in areas with partial or no protection. In contrast, Mtui et al. (2017) – based on the same data set than Caro (1999) and Stoner et al. (2007) – used aerial census data from 1991 to 2012 for the Tarangire, Ruaha – Rungwa and Katavi-Rukwa PAs for their assessment. The authors results contested Caro and Stoner findings and showed that population densities and range extend of three of six species or groupings of species dropped significantly each year across the three PAs they studied, both inside and outside. Similarly, Gardner et al. (2007) sampled small mammals, amphibians, birds, butterflies, and trees and found out that species richness did not decline along the four-step gradient they studied. Interestingly, the authors highlighted the fact that different management areas, occupying areas of largely similar habitat, hosted distinct communities of each taxa. Thus, showing that areas allowing varied resource extraction activities still possess vital and complementary conservation value although strictly PAs perform a unique and vital conservation service in East Africa by protecting large mammals. In complement, Kiffner and colleagues' studies on mammal response to human observers and a feeding guilds response along a conservation gradient is interesting in that sense. First, they assessed the response of eight species towards human observers in a landscape with variable anthropogenic hunting pressure. Four species «showed a gradual adjustment of responsiveness according to conservation status». Comprehensibly, there were most responsive in non-PAs than in fully PAs (0.02–0.29 times less responsive in fully vs. multiple-use areas). However, not all species adjusted their behavior according to conservation status (Kiffner et al., 2014). Second, they assessed large mammal species richness along a land-use gradient in the western part of the Tarangire–Manyara ecosystem[20] and rejoin Caro (1999) and Stoner et al. (2007) conclusions. But they also found that, except for top-order carnivores, all functional feeding guilds were still represented in pastoral and settled areas and they even showed that there was a trend that omnivores, mesopredators and top-order carnivores tended to occur at lower species richness in agricultural areas than in the pastoral and fully PAs. These results thus indicate that agricultural and settlement expansions are the main drivers of species richness loss in the Tarangire–Manyara ecosystem but that areas used for livestock keeping can maintain high wildlife species richness (Kiffner et al., 2015).

2.2.1.7 Management

Although PAs coverage increases, biodiversity experiences' a free-fall. This incapacity to protect wildlife results' in a renewed effort to improve PAs effectiveness (Coad et al., 2015) and the need for PAs effectiveness evaluation thereby echoes the one to evaluate and communicate the effectiveness of conservation strategies more generally (Leverington et al., 2010).

Assessing ME allows the estimation of the ability of a PA to conserve its values according to a predifined target, to evaluate the quality of the management plan, but also to assess its usefulness. Carried out regularly, the assessment of effectiveness enables the reorientation of management actions to find solutions to the identified problems. There are several tools that have been developed on the basis of the assessment method proposed by the WCPA which comprises six steps: Context; Planning; Inputs; Management process; Results; and Impacts. Assessment should always be a voluntary process led by or with the managers and combining all the stakeholders involved in the PA management. First, surveillance of the PA is a key aspect of effectiveness, as it allows the control of threats faced by the PA values. Indeed, good surveillance comes from relevant analysis and prioritization of threats. The surveillance strategy should be flexible and allow adaptation according to the evolution of threats and the PA values. Second, ecological monitoring is another side to effectiveness and gathers collection methods and data analyses that permit assessment of the PA values evolution. To support this, different methods – direct or indirect – of monitoring have been developed. The choice should be based on efficiency. Moreover, ecological monitoring should be carried out by the managers and should not simply be outsourced to external contractors. Third, it is of paramount importance to make sure everyone understands the PA priorities. To help this, various education and awareness programs were developed and facilitate the evolution of citizen perception towards a more realistic understanding of PA importance to their daily lives. «This approach is key to ground the conservation as a common cause». However, awareness impact – on that it has given rise to a change in behavior – is difficult to assess but this should remain an absolute priority (Hockings et al., 2006).

[20] However, Tarangire landscape is very different compared to Western Tanzania, the PAs are surrounded by agriculture and pastoralism and the human density is much higher (Hausser, pers.comm. 2019)

Leverington et al. (2010) compiled for the first time all information's from PAs ME assessments across the world in their article and draw some conclusions about strengths and weaknesses in management. Thus, PAs effectiveness can be considered at four different, complementary levels:

1. Coverage: evaluate the coverage of PAs systems and the extent to which biodiversity is represented within these systems.
2. Broadscale Outcomes: relationships between PAs and large-scale environmental impacts; provides' essential and objective information about conservation success at a broad level but have significant limitations (rely on a limited suite of indicators and may not detect other important changes, such as animal populations loss); more difficult to implement in non-forest environments such as grasslands or marine parks.
3. PAs Management Effectiveness Assessments[21] (PAME): methodologies to assess the effectiveness of PAs sites and systems; directed to one or more of four basic purposes (improve PAs management, increase accountability, communicate with the public, and assist in prioritization of resourcing); groups indicators according to six elements in the management cycle (context, planning, inputs, processes, outputs and outcomes).
4. Detailed Monitoring: consists of detailed monitoring and reporting on the conditions and trends of specific PAs values (e.g. animal populations, forest condition, cultural values and socioeconomic impacts). However, many monitoring and research projects on PAs are not incorporated into adaptive management and do not provide useful feedback loops into management.

The results the authors found is alarming, «PAs management leaves much to be desired». In their study sample, about 42% of PAs most recent assessment had major deficiencies (scoring less than 50% of the ideal), and 13% showed very inadequate management, making it unlikely that basic activities were undertaken. Thus, leaving the reportedly well managed PAs be the minority of the dataset.

- Establishment of PAs: such as PAs establishment indicators (gazettal, design, boundary marking, tenure resolution and adequacy of legislation), indicates' that the basics of PAs systems are in place. Nevertheless, the authors found that – except for the adequacy of legislation – the establishment of PAs is not closely linked with the development of adequate management systems.
- Inadequate resourcing: such as security of funding, adequate equipment and infrastructure to operate effectively, lack basic requirements. Indeed, continued or increased financial and logistical support for PAs is an important component of management effectiveness which is confirmed by the low scores for inputs and the strong correlation of these with overall increasing management capacity.
- Communication and community relations: such as communication, community involvement and programs of community benefit are generally inadequate but are strongly correlated with both effectiveness and good management outcomes.
- Resource management: such as management activities, law enforcement, and monitoring and research are strongly correlated with conservation values. As the authors quoted, this «suggests that if we wish to conserve the values of PAs, a focus is needed on specific activities to manage and monitor the values».
- Management planning and adaptive management: such as management planning, monitoring and research, and ME evaluation are strongly linked with PAs effectiveness. In fact, there is a real need to improve the application and use of planning, evaluation and management tools to deliver good and consistent management on the ground.
- Outcomes-values conservation: such as conserving PAs values and the well-being of their adjacent communities. Which for once, results indicate that many PAs are achieving success in management despite a lack in management processes and inputs.
- Improvement over time: PAs having time-series data where able to show improvements in management, with some scores increasing dramatically.

A positive aspect that the authors underline is the great variety of methodologies used to access PAs ME, meaning that «there is an emphasis on 'utilization-based' evaluation where indicators are designed to meet local needs and are likely to be used in adaptive management, rather than only in obligatory reporting». On the other hand, the authors harass the fact that «the area that appears to be most in need of further focus for assessment and reporting

[21] These methods relate to the framework for evaluating management effectiveness developed by the International Union for Conservation of Nature (IUCN) World Commission on PA IUCN-WCPA Framework (Hockings et al., 2006)

is that of measuring outcomes, both of biophysical and cultural conservation, and of impacts on local communities». The authors believe that effective PAs management is a worthwhile investment to tackle current and future threats to biodiversity and that it is an essential tool to improved management.

Another systematic review approach was applied by Geldmann et al. (2013) to investigate the evidence from peer reviewed and grey literature on the effectiveness of PAs. The authors focused their attention on two outcomes, habitat cover and species populations. Three conclusions emerged: (1) there is good evidence that PAs have conserved forest habitat; (2) evidence remains inconclusive that PAs have been effective at maintaining species populations and (3) causal connections between management inputs and conservation outcomes in PAs are rarely evaluated in the literature.

2.2.1.8 Governance

The IUCN and the Convention on Biological Diversity (CBD) roughly recognize 4 PAs governance types. Each type having sub-categories to it (Borrini et al., 2013):

- State governance: This refers to cases where decisions are made by governments. The state generally owns the territory and can choose to consult other parties involved in managing PAs, but at the end, it is always the state who makes the decision and takes responsibility for it. 5 sub-categories are recognized: 1) Governance by federal or national government; 2) Governance by State or regional government; 3) Governance by municipal government; 4) Governance delegated to an NGO and 5) Governance delegated to a private company.
- Shared governance: Decision-making involves several actors that each hold part of the responsibility in the final decision. This sharing of decision-making can go as far as a full delegation of the PA management by the state or a third-party. But in most cases, the state is reluctant to delegate its authority, even when it is unable to meet the set targets. 3 sub-categories are recognized: 1) Collaborative governance; 2) joint governance and 3) Transboundary protected areas.
- Private governance: Territories that are controlled or owned by an individual, a Non-governmental organizations (NGO), or a company, for profit or not. In this case, the management authority of the PA and its resources belong to the owner, who sets the management targets, develops the management plan, and remains in charge of the decisions. It must, however, respect the legislation in force. This is quite a rare form of governance in Africa, but it is developing. 4 sub-categories are recognized: 1) Protected areas owned by private companies; 2) Protected areas established through conservation easements; 3) Protected areas owned by non-profit NGOs and 4) Protected areas established as tourism businesses.
- Community governance: Management responsibility is granted to local inhabitants under different institutionalized forms or by formal or informal customary regulation. In this case, the territory is under the control of local communities, responsible for meeting the targets, even if the PA is not recognized by a legal instrument. By allowing local stakeholders to be the users and guardians of their own resources, the hope is to generate a more effective support for conservation of the PA. 2 sub-categories are recognized: 1) territories and areas conserved by indigenous peoples and 2) territories and areas conserved by local communities.

A good introduction to governance as factor influencing species conservation is to focus on predators because of the particular challenges they pose for government trustees, trust managers, and society. Indeed, many democratic governments recognize a duty to conserve environmental resources, including wild animals, as a public trust for current and future generations. But history showed that in North America and most of Europe, numerous mammalian carnivores' population were eradicated in the 20th century. Then in the 1970s, environmental movements and strict legal protections encouraged predator recoveries across the U.S.A. and Europe. Nowadays, predator subpopulations management are again in the hands of subnational jurisdictions instead of central governments. Showing that, without conservation informed by public trust, predator populations will face repeated cycles of eradication and recovery (Treves et al., 2017). Treves et al. (2017) case study on Gray wolves, *Canis lupus* (Linnaeus, 1758) is of particular interest. Indeed, in the face of interest group hostility, detailed information and abundant policy debates across regions have exposed four important challenges for preserving predators and points out that «environmental assets demand sophisticated, careful accounting by disinterested trustees who can both understand the multidisciplinary scientific measurements of relative costs and benefits among competing uses, and justly balance the needs of all beneficiaries including future generations». Thus, in the context of changing governance on NR, it is necessary to have a critical view of the relationship between conservation success and

local support. One trend, as we saw in Introduction, is the increased devolution of control of NR away from states to communities and local organizations (Agrawal et al. 2008).

Across sub-Saharan Africa, NR remain central to rural people's livelihoods. In contrast, the commercial uses of NR often remain highly centralized, conditioned by government policies of the colonial and post-colonial eras (Roe et al., 2009). Therefore, PAs in tropical countries are managed under different governance regimes but a common distinction between governance regimes is that of strictly PAs that discourage consumptive resource use or even physical access and that of sustainable use areas that allow controlled resource extraction, land use change, and in many instances human settlements (Nolte et al., 2013). In fact, resource use is not much an outcome of governance but rather of conservation status as management objectives prescribe it. Undeniably, inclusive forms of governance were allowed by conservation stakeholders to be developed only in low status PAs, which are mostly extractive ones. The conservation community seems reluctant to accept these forms of governance in stricter PAs, even if – in principle – it should be possible (Hausser, pers.comm. 2019). Moreover, in South Africa, Thondhlana et al. (2015) findings show that though collaborative governance has a practical appeal, it is hampered by lack of participation in decision-making, information dissemination, transparency, trust and accountability, power relations, divergent interests and unequal access to NR. The findings also draw attention to the issues of heterogeneity, even within indigenous communities assumed to be homogenous by local conservation authorities as reflected in land settlement agreements in co-managed PAs. The authors argue that collaborative governance arrangements need to reflect and be understood within the broader background of complex local realities. Thus, when developing and designing conservation projects, «there is a strong need to consider the implications of local people's power to undermine conservation, to ensure it is equitable and fair, and to move towards solutions which are beneficial to both the environment and the local people» (Holmes, 2013). In order to document the context of community-based conservation in Tanzania, WMA are particularly telling as they are being discursively associated with participatory and decentralized approaches to Natural Resources Management (NRM). Indeed, their policies have the ambition to promote the empowerment of communities to decide over rules that govern access to land and resources. On the other hand, Bluwstein et al. (2016) findings suggest that «WMA foster very limited ownership, participation and collective action at the community level», because «WMA governance follows an austere logic of centralized control over key resources». Thus, suggesting that «it is difficult to argue that WMA are community-owned conservation initiatives until a genuinely devolved and more flexible conservation model is implemented to give space for popular participation in rule-making». Indeed, in most part of East Africa CBNRM is interpreted by government authorities, donor agencies and NGOs as a benefit-sharing system between PAs and adjacent communities. In these contexts, communities do not see their empowerment strengthened as authorized officials of local resources but intervene mainly as passive beneficiaries of controlled profits. In all cases, CBNRM involves a co-management measure between the central authorities, local government authorities and local communities that share rights and responsibilities across various institutional arrangements (Roe et al., 2009).

PAs are the core unit of biodiversity conservation but can only fulfil their role when properly managed. In many cases, this will require a reduction in human impact to allow natural processes to occur without artificial disturbance. Law enforcement is the best way to prevent further biodiversity erosion and is necessary to achieve proper management of PAs as a common good (Gibson et al. 2005). The most promising form of law enforcement is prevention, which in most cases means patrols within and around PAs that can be performed to a certain extent by local people. Indeed, Holmern et al. (2007) show that involving local people can improve the management of PAs. In western Serengeti VGS were able to arrest significant numbers of illegal hunters in their patrol areas. Overall, cooperation with district level law enforcement units is probably essential for improving the performance of the VGS. However, we cannot ask local people to understand how important conservation is when they suffer from immediate disadvantages obeying conservation laws. It is this conflict that makes law enforcement so controversial. It is important, however, since mankind depends so heavily on nature, natural processes, and hence on PAs. Until decision makers at all levels understand the economic benefits of conservation and deliberately make funds available for it, we need to actively defend PAs and their intrinsic natural wealth and will most likely have to continue to do so afterwards. Thus, limited financial resources should be used for law enforcement (Fischer, 2008). This holds especially true since law enforcement seems to be a more successful conservation tool than development aid (Hilborn et al. 2006). Undeniably, Hilborn, et al. (2006) results in Serengeti showed that a precipitous decline in enforcement in 1977 resulted in a large increase in poaching and decline of many species. Conversely, expanded budgets and antipoaching patrols since the mid-1980s have greatly reduced poaching and allowed populations of buffalo, elephants, and rhinoceros to rebuild. Moreover, Nolte et al. (2017) suggests, in the context of their study area, that national governments are more likely than subnational governments in agricultural frontiers to adopt

restrictive forest conservation policies, due to differences in political constituencies and capacity. The authors findings suggest that subnational governments can make important contributions to reducing large-scale deforestation in agricultural frontier.

In 2006, evaluations of the success of different conservation strategies were still in their infancy but Brooks et al. (2006) show that permitted use of NR, market access, and greater community involvement in the conservation project were all important factors for successful outcomes. Without better monitoring schemes in place it is still difficult to provide a systematic evaluation of how different strategies are best suited to different conservation challenges (Brooks et al., 2006). This evolution in views and directions is reflected by Kalumanga et al. (2018) paper that shows' that «in many tropical developing countries such as Tanzania, modern forest management has been characterized by a top-down state-centric governance». But the growth of participatory management forms, with multiple stakeholders is leading to a «plethora of changes to laws and organizational structures and more complex interplay between international interests and local decision making». Participatory management is generally thought to be more sustainable in terms of both local livelihoods and environmental outcomes. Initially and ideally, the Participatory Forest Management (PFM) aimed at a simple partnership between state institutions and local communities in forest management and «engagement of NGO and other non-state actors was not part of the PFM equation at the beginning». Nowadays, these kinds of initiatives are stimulating multi-stakeholder engagement and more collaborative processes in the forest sector resulting into a more complex partnership of state and non-state actors. «Cross-scale institutional linkages (at different levels) for technical, institutional as well as financial support have become common among the actors in the forest sector». «The extent to which multi-stakeholder engagement and participatory processes in forest governance and management result in more equitable and sustainable livelihoods and environmental outcomes is still not known in Tanzania, among many other tropical developing countries» (Kalumanga et al., 2018).

Whichever actor is in charge of governing a PA, governance relies on the notion of responsibility. Indeed, too few African PA decision-makers give accounts for the decisions they make and the way they are made (see section 1.1). As a result, management results in the field are weakened. Thus, evolving towards a better governance of the conservation sector is of paramount importance and requires more responsibility and transparency from the actors involved (Borrini et al., 2013).

2.2.2. Illegal Activities

2.2.2.1 Poaching

Human exploitation can have severe conservation implications for wildlife populations and illegal hunting – more commonly known as poaching – is one of serious concern for wildlife management. Indeed, the escalating rates of illegal hunting and trade in wildlife increasingly raised concerns of conservation organizations. But to better understand in which context poaching come from, one must replace motivations for illegal wildlife hunting within the context of the complex history of how wildlife laws in Africa were initially designed and enforced and to indicate how hunting practices by specific communities were criminalized (Duffy, 2016).

Duffy (2016) literature review showed a trend that distinguish between subsistence and commercial hunting. The former typically targets small game (e.g., antelope) and is hunted with simple technology (e.g., traps and snares) to meet food needs. This kind of hunting is supposed to have a minimal impact on wildlife populations (Mackenzie 1988; Bodmer & Lozano 2001; Adams et al., 2004; Adams 2009; Lowassa et al. 2012; Fischer et al. 2013; Twinamatsiko et al. 2014; Harrison et al. 2015). By contrast, commercial hunting is composed of organized groups that use more advanced technologies (e.g., firearms and geographic positioning systems) and target commercially valuable species, such as rhinoceroses, *Diceros bicornis* (Linnaeus, 1758) and/or *Ceratotherium simum* (Burchell, 1817), elephants, orangutans, *Pongo sp*. (Linnaeus, 1760) and tigers, *Panthera tigris* (Linnaeus, 1758) (Ellis 1994; Ellis & Reeve 1995; Leakey 2001; Duffy 2014; Nellemann et al. 2014; Harrison et al. 2015). However, this distinction is not always clear because meat can be hunted to supplement both diets and income (Mackenzie et al. 2011; Vega et al. 2013). Furthermore, illegal hunting for subsistence can become commercial as shows Duffy (2016) example: «subsistence hunting can transform into commercial hunting in response to the arrival of logging companies in remote forests, where a workforce has to be fed or transport links give easier access to urban markets» (Nellemann et al. 2014; Harrison et al. 2015). The authors also showed that previous studies conclude that people hunt illegally because they are financially poor or lack alternative livelihood strategies. Of course, illegal hunting is closely associated with economic factors but Mgawe et al. (2012) pointed out that it could vary according

to urbanization and economic strata. Furthermore, the authors show that in Wakanongo society, bushmeat consumption was more common in richer households than in poorer. On the other hand, the Wasukuma had the opposite pattern.

Setsaas et al. (2007) used impala as a model species to investigate if density, demography and behavior can be used as indicators of human exploitation inside and outside a strictly PA. The authors result suggest that density, demography and behavior can be used as indicators of human exploitation, but that this probably varies according to local hunting pressure. Indeed, the present harvest levels by poachers in their study area are most likely the cause of the observed differences in-between PAs. In 2008, Caro (2008) used two measures of poaching (household surveys and informal discussions about commercial trade) to investigate the decline of large mammals in the Katavi-Rukwa ecosystem and revealed little impact on herbivore populations. Nonetheless, interviewees revealed that poaching is of sufficient magnitude to impact large prey species and especially those favored by poachers, namely buffalo; giraffe; hippopotamus, *Hippopotamus amphibius* (Linnaeus, 1758); zebra; bushpig, *Potamochoerus larvatus* (Cuvier, 1822); warthog and perhaps eland. The author thus, concluded that poaching is a promising candidate for larger herbivores population declines and calculations showed that warthog – which face a steep decline in Katavi-Rukwa – are most likely impacted by both predation (lion, leopard and hyaena) and poaching. Again, Waltert et al. (2009) is informative on the subject and recorded all illegal human activities during their foot survey. For all sightings, they recorded GPS location. This included human tracks, sightings of poachers and hunting camps, illegal tree felling and gunshots. Finally, the authors inter-specific comparison showed that density differences were moderately correlated with estimates of combined legal and illegal off-take but not when these were taken separately and that several species were overexploited by illegal (elephant; giraffe; buffalo; bushpig; warthog) or combined off-take (hippopotamus; eland; waterbuck, *Kobus ellipsiprymnus* (Ogilbyi, 1833)), thus emphasizing the need for a more efficient anti-poaching control, especially in GRs.

At a broader scale, it is generally admitted that patrols, arrestations and fines in association with a greater attention on social and economic factors could have a chance to reduce poaching in Africa (Mgawe et al., 2012).

2.2.2.2 Timbering

Miombo woodland covers much of central and southern vegetation of the African continent. This relatively intact biome, thanks to low human population density, still constitutes one of the few great wildness areas on the continent. Despite this, «a number of hardwood species are heavily exploited commercially within the miombo nations of Angola, the Democratic Republic of Congo, Malawi, Mozambique, Tanzania, Zambia and Zimbabwe. Hardwoods are also harvested for export to Europe, Japan, and the Middle East» (Caro et al., 2005). One of the principal hardwoods exploited in those regions is *Pterocarpus angolensis* (DC) and is used in construction, for furniture or medicinal purpose (Caro et al., 2005). In Tanzania however, *P. angolensis* wood is mostly used for furniture, veneer, carving and general-purpose timber (Monela et al., 1993) but logging practices seems unsustainable as a large quantity of trees are removed from western, central and southern portions of the country (Caro et al., 2005).

Figure 11: Saw pit presenting hand saw boards illegally harvested in one of the PA

FRs covers approximately 67,740 km^2 of forest in Tanzania and it is a parastatal institution, the Tanzania Forest Service (TFS) that manages' FRs since 2012. TFS main activities concerns promoting selective timber harvest, controlling illegal firewood collection and charcoal extraction. As many administrations in the country, the organization is underfunded which results in poor management effectiveness. As consequences, Caro & Davenport (2016) revealed that most forests have become heavily degraded within the last two decades (Hall et al. 2009) resulting in creeping defaunation (Rovero et al. 2014).

In Rukwa Region, results showed that adult *P. angolensis*, given its slow growth rate, were removed very rapidly. At present however, trees are harvested by hand, cutting trunks with hand saws, then rolling them to saw pits and hand sawing them into boards (Figure 11). However, as it cannot be predicted when economic extinction will occur within this system, there is a serious concern about the long-term viability of the current harvest, although the population is heading toward economic extinction rapidly (Schwartz et al., 2002). To verify this assumption, Caro et al. (2005) sampled 300 adult *P. angolensis* in six different types of PAs: Katavi NP where no tree cutting has

been allowed since 1912; in Katavi National Park Extension (EXT) where limited selective logging of trees was permitted in the wet season; in Lwafi District GR where cutting is forbidden but is starting to occur illegally; in Mlele GCA where cutting is sanctioned in the wet season; in Msanginia FR where cutting is permitted year round under license; and in Usevya OA where logging occurs throughout the year for local consumption. The authors found that outside the well protected areas (Katavi NP & EXT), most large trees were removed. In fact, results are very relevant: 61.3% of the observed tree trunks were cut in the FR and operators in the GR, GCA, FR and OA always set priority to the larger trees, resulting in few large ones remaining. In Tanzania, the legal size of tree that can be cut is 60 cm Diameter at Breast Height (DBH) or more but, results showed that the average DBH of standing trees, particularly in the GR and FR, is far less than this. Thus, indicating that operators are breaking the law by cutting trees smaller than the legal-size limit. Schwartz et al. (2002) found that the modal DBH for live *P. angolensis* in the FR was 25 cm and that the modal size of cut trees was 30 cm DBH, half the legal limit. Thus, in Rukwa Region, *P. angolensis* is under heavy cutting pressure, bringing to the conclusion that «the prognosis for sustainable exploitation of *P. angolensis* looks bleak» (Caro et al., 2005). Accordingly, Caro et al. (2005) supported the hypothesis that fully PAs such as NPs are often assumed to be the best way to conserve plant diversity and maintain intact forest composition and structure. To evaluate this assertion, Banda et al. (2006) sampled – similarly as Caro et al. (2005) – trees in four different levels of protection: a NP, a GCA, a FR, and an OA. Results showed that species richness in the FR and GCA was significantly higher than in the other areas. Their measures of forest structure and composition showed that fully protected NPs did not «necessarily conserve the greatest diversity of tree species or unique species». Joining the hypothesis that the best strategies to conserve species in Africa is a suite of different types of protection. An interesting meta-analysis of 20 studies of deforestation in and around PAs, based on remote sensing, suggested that 32 out of 36 PAs had a faster deforestation outside the boundaries than within (ranging from 0.1% to 14% faster). Moreover, this finding suggests firmer evidence that public PAs may have some degree of effectiveness (Naughton-Treves et al., 2005).

In a more general context, forest cover in Tanzania continues to decline at a rate of 1.16%/year. For miombo woodlands, estimates indicate that in average 1000 ha are being lost every day (FAO 2010). In response to this report documenting revenue deficits, large-scale corruption, unsustainable rates of harvesting and loss of biodiversity, the Tanzania Forest Working Group recommended community participation in forest management through outreach and advocacy to reduce illegal logging (Persha & Blomley, 2009). «These community-based forest management schemes, mostly confined to miombo woodland, involve establishment of FRs on village land and joint forest management ventures, where local communities co-manage forests with authorities of local or national forests». However, local officials are often tempted by a flourishing international timber trade and often allow local communities to convert village land to agriculture lands through illegal cutting. In summary, the forestry sector is in poor shape as it lacks funding and transparency (Caro & Davenport, 2016).

2.2.2.3 Grazing

Livestock and wildlife co-existence can be problematic. Especially when considering large carnivores who often enter in conflicts with herder through livestock depredation (Kissui, 2008). However, livestock and wildlife co-existence can cause other challenges as disease transmission (Böhm, Hutchings & White, 2009) and competition for resources (Voeten & Prins, 1999; Butt & Turner, 2012). However, this matter hinders a more political challenge. A good example comes from Jonathan Kingdon (2015): «[Tanzania] status as one of the most important conservation regions of the world depends upon formal protection for viable and representative samples of every one of these habitats (this a primary target for all national conservation programmes). One of these unique areas is its only 'Somali-arid' sample, a small reserve called Mkomazi. Livestock interests continue trying to wrest this area away from the nation's conservation estate, so far without success. Here a small cabal of cattle-men, with huge herds that they hope to enlarge, threaten a vital asset – the range and depth of Tanzania's biological wealth. They seek to invade a viable ecosystem and impoverish one of the world's most fortunate nations. This is a struggle being played out all over Africa with ever-increasing severity». Indeed, more and more PAs are threatened by population growth as even the PAs themselves may encourage growth by providing economic benefits that attract migrants, threatening as consequences the capacity of such areas for biodiversity conservation (Bamford et al., 2014). Bamford et al. (2014) studied a community-governed WMA bordering the Selous GR in Tanzania and found out that population growth appeared to be unrelated to their studied PAs but instead by the readily available land as the increasing proportion of immigrants cited it as their reason for moving. But more interestingly, the authors data revealed that the presence of cattle, *Bos taurus* (Linnaeus, 1758) was associated with fewer signs of large grazing mammals and elephants, which is of particular concern given the increase in immigration by pastoralists

(Figure 12). More so, agriculture was associated with fewer signs of elephant and buffalo but more signs of other ungulates. As the authors quote, «the negative influence of both pastoralism and agriculture on elephant distribution may be because farmers regard elephants as problem animals and chase them away from their land».

Figure 12: Livestock can be detected at large distances from village lands as proves this picture taken by one of the CT during field survey

As we saw it already, land-use change is one of the major drivers of biodiversity loss in the world. Kiffner et al. (2015) assessed large mammal species richness along a land-use gradient (NP, uninhabited pastoral area and settled pastoral- and farmland) in the western part of the Tarangire–Manyara ecosystem, Tanzania. The authors results showed a trend that omnivores, mesopredators and top-order carnivores tended to occur at lower species richness in agricultural areas than in the pastoral and fully PA. The authors thus assumed that areas used for livestock keeping can maintain high wildlife species richness whereas agricultural and settlement expansions are the main drivers of species richness loss in the Tarangire–Manyara ecosystem.

3. Material and Methods

3.1. Study Area

The three PAs this study aimed at comparing lies in the Rift Valley and is part of the Katavi-Rukwa ecosystem, Western Tanzania. This ecosystem consists of large floodplains, Rungwa river, Rukwa Lake and a hilly landscape south of Rukwa GR. In addition, granitic escarpments rise to form plateaus north of Rukwa GR and Mlele BKZ. The altitude therefore varies greatly between the plains, located at about 800 m above sea level, and the plateaus at the top of the escarpments, at about 1600 m (Mermod, 2012). Two seasons punctuate this ecosystem, the rainy season, from November to April (600-1200 mm), and the dry season, from May to October (Banda et al., 2008). A map of the topography and hydrography can be found in Appendix VI.

The study area is mainly composed of four main classes of vegetation, namely, flooded plains, mixed scrub, open forest and miombo. Another characteristic vegetation of the region is formed by the important gallery forests bordering main rivers (Figure14)(Mermod, 2012). A map of the vegetation can be found in Appendix VII.

This region is quite isolated with low population density (12.3 inhab./km²) and limited infrastructure (Hausser et al., 2009). In addition, the region encompasses a considerable number of PAs of three different IUCN management categories: II, IV and VI. Katavi NP being the only one having a IUCN II category in the study area (Figure 13) (Stampfli, 2016).

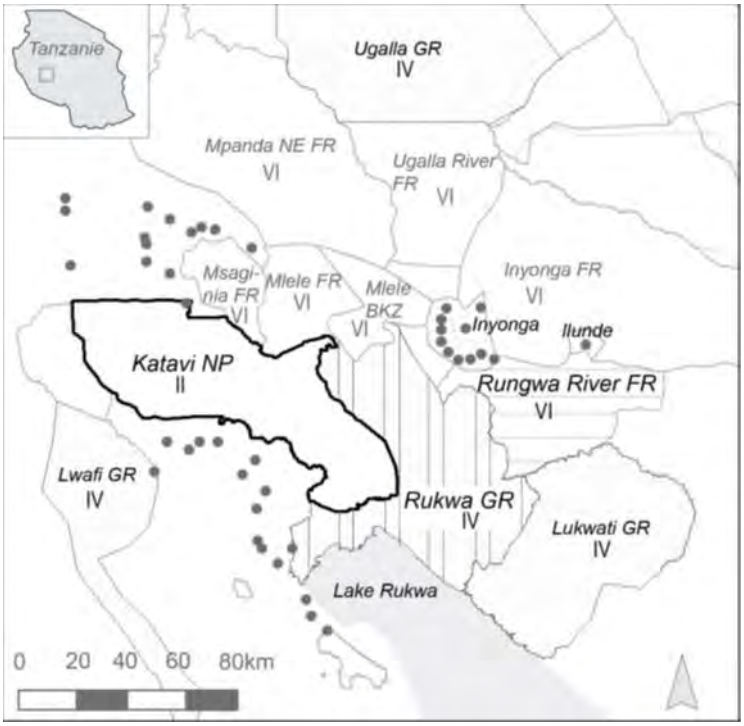


Figure 13: The study area comprises a NP (IUCN category II), a good portion of GRs (IUCN category IV) and numerous FRs (IUCN category VI). Note the presence of the Mlele BKZ (IUCN category VI). The black dots represent villages

Source: Stampfli, 2016

The main infrastructures present in the study area (Appendix IV) are important but unpaved roads, some secondary roads and a significant number of tracks. In addition, the Tabora – Ipole – Inyonga – Mpanda main road is upgrading to a tarmac road and is still in construction. The study area is also scattered with trails and beekeeper camps. Finally, the BKZ hosts the headquarter (HQ) of Rukwa GR, where the Tanzania Wildlife Authority (TAWA) employee lives. Also note the presence of an airstrip. ADAP has a camp for tourists southwest of the BKZ (Mermod, 2012).

Figure 14: Lush riverine forest are important landscape features used by many animals for displacement in the Miombo ecosystem and seasonaly flood large open plaines called Mbuga that punctuate Miombo forests

3.1.1. Studied Protected Areas

The United Republic of Tanzania has set aside 38.15% of its terrestrial area and 3.02% of its marine area, totaling 839 PAs with 14 different national designations (Table 4) (UNEP-WCMC, 2018).

Table 4: Tanzania PAs are encompassed in 14 different national designations

Adapted from UNEP-WCMC (2018)

Categories	Count
Marine Reserve	2
Nature Reserve	6
National Park	17
Marine Park	2
Forest Reserve	695
Game Reserve	19
Conservation Area	4
Wildlife Management Area	14
Locally Managed Marine Area	1
Game Controlled Area	20
Sanctuary and Closed Forest Reserve	1
Collaborative Fishery Management Area	1
Open Area	24
Forest Plantation	23

3.1.1.1 Governance

92.25% of these PAs have federal or national ministry or agency governance type which are governed by different organizations (Table 5) (UNEP-WCMC, 2018).

Table 5: Organizations governing areas and territories for conservation in Tanzania[22]

Organization	Role/Mandate
Tanzania National Parks (TANAPA)	Parastatal organization responsible for the management of NPs
Ngorongoro Conservation Area Authority (NCAA)	Parastatal organization responsible for the management of Ngorongoro Conservation Area (NCA)
Tanzania Wildlife Authority (TAWA)	Responsible for the management of GRs, GCAs and all wildlife outside PAs boundaries and Wetlands
Wildlife Division (WD)	The Wildlife Division facilitates the establishment of WMAs, creates awareness and disseminates information about wildlife management to the village communities in their village lands and wildlife policy
Communities	Manage Community Forests and FRs through PFM – co-management with government; manage WMA
Village council	Manage Village Land Forest Reserves (VLFR) and Beach Management Units (BMU)
District council	Manage District Forest Reserves and Coastal Fisheries Management Areas (CFMA)
Tanzania Forest Service (TFS)	Executive Agency with the mandate for the management of national forest reserves (natural and plantations), bee reserves and forest and bee resources on general lands
Private Organizations/ individuals	Some private organizations or individuals run estates managed for conservation benefits, e.g. Grumeti Reserve
Marine Conservation Unit (ZNZ) (Department of Fisheries Development)	Coordinates the management of all marine conservation areas in Zanzibar and promotes coordination with other forms of marine managed areas (MMAs) such as privately managed sanctuaries
Department of Forests and Non-Renewable Resources Zanzibar (DFNR)	Manages and conserves 7 parks and reserves in Zanzibar, mostly forest and including mangrove forests
Marine Parks and Reserves Unit (MPRU)	Semi-autonomous governing body responsible for the formulation of policies, management and administration of Marine Protected Areas (MPA) in Tanzania. Currently, there are three (3) marine parks and fifteen (15) marine reserves operating under MPRU

At the policy level, wildlife resources are seen in Tanzania as a unique natural heritage that is of great importance nationally and globally. Indeed, Tanzania first president, Mr. Julius K. Nyerere (1962 -1985) highlighted in his 'Arusha Manifesto' (1961) the heritage dimension of wildlife for the country. This vision is still relevant and inspires Tanzanian conservation policies nowadays. Those policies are backup by Acts that represent the laws in force. The Acts are then translated into Regulations for their applications. Finally, General management plans indicates the procedure to implement Regulations at site level.

[22] adapted from IUCN, JRC and AWF, East African Community State of Protected Areas Report, unpublished draft 2017

3.1.1.1.1 Review of Policies and Strategies

This sub-section presents four of the most important policies and strategies that are related to the studied PAs.

1. National Environmental Policy (1998):

The Environment Policy of 1998 (URT, 1998*a*) states that wildlife resources shall be protected with participation of local communities. Thus, financial benefits should accrue to local communities. An important aspect of the policy is that it calls for an equitable and sustainable use of the resources.

2. Wildlife Policy (2007):

The Wildlife Policy of 2007 (URT, 2007) aims at involving a broader section of the society in wildlife conservation particularly the rural communities and the private sector. The role of the public sector will be to stimulate and guide the local communities and the private sector by administering, regulating and promoting the management of the wildlife resource.

3. Forest Policy (1998):

The main objective of the Forest Policy of 1998 (URT, 1998*b*) is to enhance the sustainable development of Tanzania by the contribution of the forest sector as well as the conservation and management of its NR for present and future generations. Thus, the Forest Policy encourages participatory forest management based on the current thinking of joint management of resources between communities and the government and seeks the integration of biodiversity values in forest management.

4. Beekeeping Policy (1998):

The Beekeeping Policy of 1998 (URT, 1998*c*) aims at enhancing sustainable contribution of the sector for socioeconomic development and environmental conservation. It covers both stinging and non-stinging (stingless) honeybees regardless of ownership or administration, including feral (wild) and domesticated (kept in hives) colonies and all other bees which are nonparasitic and collect nectar and or pollen for their food.

3.1.1.1.2 Review of Laws and Guidelines

This sub-section presents five of the most important laws and guidelines that are related to the studied PAs.

1. Wildlife Conservation Act (2009):

The Wildlife Conservation Act (WCA) of 2009 (URT, 2009) serves as the primary governing legislation for wildlife resources management in Tanzania and the allocation of existing rights and authority. Wildlife resources being controlled by the central government, three layers of authority must be respected: the President, the Minister of the Ministry of Natural Resources and Tourism (MNRT), and the Director of Wildlife. «The President is given the power to appoint the Director of Wildlife (S.3) the power to establish Game Reserves (s.5); the power to modify any restrictions in GRs and GCAs, and the power to declare any category of persons unfit for the grant of a game license (S. 22)» (IRA, 2007).

Game Reserves

GRs are the foremost category of PAs under the WCA and only the President may establish this category of PAs by using his powers under section 5 of the Act as seen above. Concerning entry rights into a GR, only people having the express permission of the Director of Wildlife are authorized by the WCA to enter the reserve. «The only people that are allowed to enter the GR without such permission are those who are ordinarily resident within the reserve, or persons travelling in a highway passing through the reserve». Section 8 restrict, without the express permission of the Director of Wildlife, the entry of a GR for anyone to be in possession of a firearm or bow and arrows. «Section 9 restricts setting of fires, felling, cutting, burning, injuring, or removing any standing tree shrubs, sapling, seedling or any part thereof without the express permission of the Director of Wildlife». Resident people within a GR are allowed to fell trees for their personal purposes, dependents and domestic employees, of building dwellings. «This permission is, however, not in prejudice of any written law restricting the felling of trees in any FRs or other areas». Again, without the written permission of the Director of Wildlife, nobody is allowed to hunt, capture, kill, wound or molest any animal in a GR. The same is true for anyone to dig, lay or construct any pitfall, net, trap, snare or other device of whatsoever capable of killing and capturing or wounding any animal. Section 11 of the

WCA even «prohibits the carrying of weapon that may be used to hunt, kill, wound or capture any animals». At least, grazing of livestock is also prohibited in GRs without the written permission of the Director of Wildlife (IRA, 2007).

Game Controlled Areas

GCAs are less restrictive than GRs but, as in GRs, the hunting, killing, wounding, molesting and capturing of an animal is forbidden unless the written permission of the Director of Wildlife. It is also «prohibited to dig, lay, or construct any pitfall, net, trap, snare, or other device capable of killing, wounding and capturing an animal without the express permission of the Director of Wildlife». These are the only restrictions in GCAs. For instance, unlike in GRs, the entry of people is not restricted, neither is the grazing of livestock, cultivation or any kind of human settlement (IRA, 2007).

2. Wildlife Conservation (Tourist Hunting) Regulations (2000):

Under section 84 of the WCA the MNRT promulgated in 2000 the Wildlife Conservation (Tourist Hunting) Regulations (URT, 2000). The regulations provide to tourist hunting companies procedures for the allocation of hunting blocks and gives conditions while performing hunting activities. Indeed, it imposes fines but also the possible license cancellation of a hunting block for any company or person that conducts contrary activities to it (IRA, 2007).

3. Land Act (1999) and Village Land Act (1999):

Wildlife being dependent on the habitats they live on, it justifies the strong linkage between land and wildlife legislation. Thus, the Land Act No. 4 of 1999 (URT, 1999*a*) and Village Land Act No. 5 of 1999 (URT, 1999*b*) established three categories of land: general land, reserved land and village land. «The Village Land Act deals with the management of the latter category of land while the Land Act deals primarily with the management of reserved land and general land in line with the sectoral pieces of legislation that the reserved lands are established under». Logically, most of the areas established for wildlife management fall under the category of reserved lands. For instance, GRs, FRs and GCAs all qualify as reserved lands and the restrictions and conditions prescribed by that Act apply but certain reserved lands, including most GCAs, are mainly found within village lands. Thus, the use of the land in those areas will have to be in conformity with the restrictions imposed by the Wildlife Conservation Act of 1974. Nonetheless, except for wildlife resources, This Act do not take away the rights of the villagers and the Village Councils to utilize lands and resources found within the reserve (IRA, 2007).

4. Forest Act (2002):

The Forest Act No. 14 of 2002 authorize the Minister to declare any area of forest to be a National FRs. In this case, a forest management plan should be prepared. In addition, a «joint management agreement for the management of a forest may be made between the Director and any person or organization in the public or private sector providing for the management within the vicinity of that National FR, community groups or other groups of persons living adjacent to and deriving the whole or apart of their livelihood from that National FRs» (URT, 2002*a*).

Forest Reserves

There is three type of National FRs (hereafter FRs). The first is known as Production FRs and is used principally for purposes of sustainable production of timber and other forest products. The second is Protection FRs which represent an area used principally for the purposes of protection of water sheds, soil conservation and the protection of wild plants. The third type are Nature FRs which aimed at protecting nature and scenic areas of national or international significance and to maintain and enhance biodiversity and genetic resources in an undisturbed, dynamic and evolutionary state. On and after the coming into force of a declared FRs, no person, other than an existing rightsholder which has been granted a concession or a license or a permit in accordance with the provisions of this Act, has the right to enter the reserve. Thus, it is forbidden to performs any act which is prohibited by section 26 of this Act or which is prohibited by a forest management or other agreement; obstructs any existing road, path or water course; covers any tree stump with brushwood or earth or by any other means whatsoever conceals, destroys, or removes such tree stump or any part thereof; damages, defaces, alters, shifts, removes, or in any way whatsoever interferes with any beacon, fence or other boundary mark or notice, or notice board, shall be guilty of an offence against this Act. At least, grazing of livestock is also prohibited in FRs (URT, 2002*a*).

5. Beekeeping Act (2002):

The Beekeeping Act No. 15 of 2002 was established «to make provisions for the orderly conduct of beekeeping, for the improvement of the products of beekeeping and for the prevention and eradication of diseases and pests amongst bees». The Director of Beekeeping has the power, by order, to prohibit the keeping of bees or the establishment of an apiary if it represents any kind of public nuisance or a danger to public health or public safety or for any other reasons (URT, 2002*b*).

Beekeeping zone

The Director of Beekeeping may, on his own motion or on behalf, establish a BKZ within a FR, a local authority forest reserve or general land. More so, the Director of Beekeeping may delegate any powers conferred on him to any local authority nearby FRs. In the case of local authority forest reserve, local authorities have the right to establish a beekeeping zone within it. Any person, group of persons or organization may apply in the prescribed form to the Director of Beekeeping to keep bees within a BKZ. The Director of Beekeeping shall always give preference to persons living in proximity to a BKZ when determining whether to approve or not an application to keep bees within the BKZ (URT, 2002*b*).

3.1.1.2 Management

Four entities are responsible of the management of the 3 PAs studied in this paper (Table 6), three of which are most relevant.

Table 6: Overview of the studied PAs, their statuses, governance types and management regimes
Source: present study

	Rukwa Game Reserve (4323 km2)	*Rungwa River Forest Reserve & Game Controlled Area (2480 km2)*	Mlele Beekeeping Zone *(850 km2)*
Status	IUCN Category IV Game Reserve	IUCN Category VI Forest Reserve & Game Controlled Area	IUCN Category VI Forest Reserve & Game Controlled Area & Beekeeping Zone
Governance	Central Government: MNRT - TAWA	Central Government: MNRT - TFS+TAWA Local Government: Mlele District	Central Government: MNRT - IBA+TFS Local Government: Mlele District+Village Councils
Management	TAWA	TFS + TAWA + District	IBA + TFS + District

1. Tanzania Wildlife Management Authority

TAWA under the MNRT is an autonomous public institution that was established in 2014. It is responsible of biodiversity conservation and the sustainable management of wildlife resource outside NPs and NCA which still are under TANAPA and NCAA management respectively. This involves managing GRs, GCAs and OAs for a total area of 169,553 km^2 (79% of the total size of PAs in the country). TAWA is mandated to implement the Wildlife Conservation Act No. 5 of 2009 and subsequent regulations to ensure that wildlife resources available outside NPs and NCA are properly conserved. Thus, TAWA strives to reinforce law enforcement by conducting antipoaching patrols and conduct inspection of trophy at entry and exit points to prohibit poaching and illegal wildlife trafficking and outflow of trophies outside the country. TAWA also endeavors to mitigate human-wildlife conflicts and supervise hunting activities conducted in different hunting blocks. Other activities include liaison with other law enforcement agencies investigation and prosecution of wildlife related cases such as inspecting permits at zoos and farms (www.tawa.og.tz).

2. Tanzania Forest Services

TFS is a semi-autonomous government Executive Agency founded in 1998 and administered through The Forest Act No. 14 of 2002 and Beekeeping Act No. 15 of 2002 which provides legal framework for the management of forests and bee resources. Thus, TFS – in accordance to policies and regulations – will «develop and manage forest and bee resources sustainably in collaboration with stakeholders in order to deliver sufficient and quality goods and services to meet local and international socio-economic and environmental needs». In order to asses this vision, TFS is in charge of establishing and managing national natural forest and bee reserves, national forest plantations and apiaries and forest and bee resources in general land. To achieve this mission, a Strategic Plan was developed and represent the first FR management plan of Tanzania. Thus, TFS attempts to enforce forest and beekeeping legislation, provides forest and beekeeping extension services in areas of TFS jurisdiction and monitor and evaluate TFS activities. Other activities include developing TFS human resources, collecting forestry and beekeeping revenue, safeguarding TFS assets and marketing of forest and bee products and services (www.tfs.go.tz).

3. Inyonga Beekeepers Association

IBA was duly registered under Non-Governmental Organization Act of 2002 with Registration No. OONGO/1226 on 18th October 2007 and has signed in 2010 a Memorandum of Understanding (MoU) with the MNRT – Forestry and Beekeeping Division (MNRT-FBD) for ten years. IBA received a mandate from MNRT-FBD to carry out beekeeping activities for development and sustainable use of forest plants in the BKZ of Mlele as income generator to local beekeepers. IBA is thus responsible for the management and sustainable utilization of genetic resources – in cooperation with FBD – of the BKZ in accordance to the Beekeeping Act No. 15 of 2002 and the Beekeeping Regulation of 2005. IBA main task is to abolish unregulated exploitation of trees, especially rare and overexploited species but also protect, conserve and develop forest bio-genetic resources and ensure sustainable existence of honeybees by maintaining and effectively applying appropriate beekeeping techniques and methods, make this zone a source of bee breeding materials, a source of package colonies for both stinging and stingless honeybees, enhance conservation of biodiversity of honeybees and production of bee products. Thus, IBA should improve the quality and quantity of honey, beeswax and other bee products and ensure sustainable supply of the same. Other activities include the plantation of indigenous tree species with beekeeping values, perform regulated eco-tourism and provide services as demonstration center for beekeeping activities (MoU, 2010).

3.2. Material and Methods

3.2.1. Camera Traps

Evaluating the abundance and distribution of carnivore community is a vital goal in defining long-term conservation programs (Kauffman et al., 2007). CT are an ideal tool to do so because they work day and night for several weeks, allowing the detection of rare and cryptic species such as carnivores, which they provide evidence of presence by images, all for a relatively low total cost (the purchase of CT is expensive, but field work and time are saved). They also have the advantage of giving quick results, require a modest research effort, are easily set up (even by Village Game Scouts (VGS), who have only a low level of education (Hausser, com. pers., 2017)) and is a non-intrusive method for wildlife, causing minimal disturbance (Rovero et al., 2010; O'Connell et al., 2011; Ancrenaz et al., 2012; Rovero & Zimmermann, 2016).

CT can be used to study the size, composition and dynamics of animal communities. Thus, the data can be used to determine species richness, to calculate a relative abundance index (RAI) or to determine occupation of a territory. In addition, CT study also reports covariates data from the site where the camera was placed. These covariates should be selected based on their influence on species detectability, occupancy or any other parameter of interest (O'Connell et al., 2011). Indeed, most environmental monitoring attempts to understand the effects of management interventions or covariates on a given population. Monitoring methods allow an assessment of the population concerned or, at a minimum, generate an index related to species abundance via their probability of detection. Thus, CT are particularly suited to study large home range mammals that cannot be fully sampled or cryptic and elusive species, such as carnivores (O'Connell et al., 2011).

3.2.1.1 Sampling design

Fieldwork involved systematic monitoring in Rukwa GR and Rungwa FR & GCA (Appendix VIII). A sampling unit consist of a 10 x 10 km grid, formed by 2X2 km cells, designed by Claude Fischer in 2010, for the systematic monitoring of Mlele BKZ. This sampling design is not adapted to the home range of all species but allows to maximize their capture. A systematic sampling was performed by placing CT (Bushnell Trophy Cam HD model) at their intersection (36 camera/grid). This sampling design leads to the fact that every intersection has a chance to be visited. Subsequently, the location of the traps is not influenced by the characteristics of the environment. The location of the camera will be made on the closest tree to the intersection point– at a high of approximately 30-100 cm, within 100 m and presenting obvious signs of passing animals (tracks and signs) identified through Stuart & Stuart (2000) field guide (Figure 16). Two grids (72 CT in total) will be sampled at a time for a total of 21 CT Days (Mermod, 2012). An example of field protocol can be found in Appendix IX as well as setup guidance in Appendix X.

Furthermore, the 10 x 10 km grid will be used to asses' illegal activities in the study area. Indeed, based on Waltert et al. (2009), illegal activities (e.g. timbering, poaching, grazing) will be recorded by means of GPS along 10 km transects running along the horizontal lines of each visited grids.

3.2.1.2 Species Richness

Species richness is the number of species present in a sample, ecological community, ecosystem, landscape, region, or any defined spatial unit (Millennium Ecosystem Assessment, 2005). It is a simple and straightforward metric. With regard to surveys, one need only record the presence or absence of species within the sample, community, or ecosystem. Besides being easy to measure, species richness is also favored due to its ease of interpretation. It is simply a count of species represented in a sample (checklist of species) (O'Connell et al., 2011). Moreover, species richness can be used to assess the completeness of a survey by plotting a species accumulation curve (Figure 15) as it is set to count the species richness as CT days increase. This sampling curve rises relatively rapidly at first, then much more slowly in later samples as increasingly rare taxa are added. This has important practical implications, as researchers can use this curve to judge when sampling is adequate and adjust the study design and duration accordingly. When the species accumulation curve reaches the asymptote, we can be quite confident that the species community has been sampled exhaustively (Rovero & Zimmermann, 2016). However, species richness is too simplistic. It ignores information about the relative abundances of species. Indeed, two samples could have the same richness but differ in abundance (Ancrenaz et al., 2012).

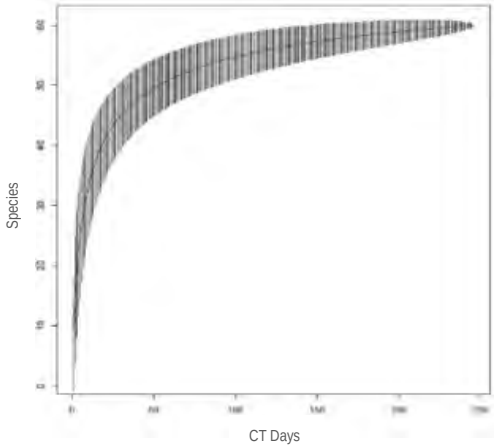


Figure 15: Usual representation of a randomized species accumulation curve (solid line) and its confidence interval

Source: Hausser & Fischer (2017) unpublished data

3.2.1.3 Relative Abundance

Species diversity is determined not only by the number of species within a biological community (i.e. species richness) but also by the relative abundance of individuals in that community. Relative abundance refers to the evenness of distribution of individuals among species in a community (Ancrenaz et al., 2012). For example, each community may contain 2 species and 200 individuals, but in one community all species are equally common (e.g. 100 individuals of each species), while in the second community one species significantly outnumbers the other one.

For species that cannot be individually identified on the basis of photographs, index are often used to draw analogies of differences in abundance over time, space and species (Sollmann et al., 2013). Thus, the raw data from long-term monitoring allows us to produce RAI[23] per camera given if an interval between consecutive images

[23] is calculated as the ratio of events per unit of effort (Rovero & Zimmermann, 2016).

is used to separate out independent events[24] from repeated images of the same event (typically 30min). This descriptor is useful for initial evaluation of data from CT monitoring (Rovero & Zimmermann, 2016). The fundamental problem with this descriptors is that in order to make valid comparisons between species, space and time, it is necessary to assume that species detectability is constant between the aforementioned dimensions (Sollmann et al., 2013). The authors were able to demonstrate that RAI do not take into account variations and imperfect detection and join Ancrenaz et al. (2012) on that RAI should not be used as a measure of abundance, but rather as a tool to evaluate the detection probability of different species in the study area.

3.2.1.4 Occupancy Analysis

Another basic descriptor of species presence is the naïve (or observed) occupancy that is simply the proportion of cameras that have detected a given species, based on the total number of cameras and gives an indication of the extent of occupation of a species in the reference area (Rovero & Zimmermann, 2016). As this simplistic presence-absence data may – as for RAI – be biased by detection error, naïve occupancy should only be seen as an information on where a species is more or less likely to be detected rather than an estimate of true occupancy.

True occupancy is defined as the proportion of a site occupied by a species (MacKenzie et al., 2002). Thus, the occupancy estimate is particularly suitable for species that cannot be identified individually, which makes it possible to determine the distribution and spatial use of a species while taking into account imperfect detection (Ancrenaz et al., 2012). In addition, this method allows the inclusion of covariates, making it a robust statistical model (Rovero et al., 2010).

Occupancy is based on repeated monitoring of presence/absence at different sites and allows the estimation and correction of imperfect detections. Indeed, the detection of a species clearly indicates that this species is present, but its non-detection does not necessarily imply that it is absent (Rovero & Zimmermann, 2016). Thus, single-season model with homogeneous detection probability was used in this study. This model was developed by MacKenzie et al. (2002) and involves randomly setting CT in the reference area several times. Information on detection – non-detection is collected during each sample, which is done in a short time to ensure a closed system to changes (emigration/immigration) (Rovero & Zimmermann, 2016). This model requires that 1) sites and detections are independent, 2) species are not confounded, and 3) probabilities of occupancy and detectability are constant across sites or can be modeled using covariates (O'Connell et al., 2011).

3.2.2. Management Effectiveness

In order to evaluate the management implemented in Mlele in a comparative manner and to understand the strengths and weaknesses of those 3 PA management and the threats they face, the extent of the PAs only are not sufficient. Indeed, geographic location and spatial extent provides only a unidimensional indicator of political commitment to biodiversity conservation and are not sufficient in determining if global biodiversity targets are met. Thus, ME is of paramount importance in this regard (Chape et al., 2005).

ME evaluation is defined as «the assessment of how well PA are being managed – primarily the extent to which management is protecting values and achieving goals and objectives» (Hockings et al., 2006). ME thus, reflects three main 'themes' in PAs management:

- design issues relating to both individual sites and PAs systems (e.g. PA size, PA boundary);
- adequacy and appropriateness of management systems and processes;
- delivery of PA objectives including conservation of values.

To maximize the potential of PAs, and to improve management processes, we need to understand the strengths and weaknesses of their management and the threats that they face. The WCPA provides an overarching framework (Table 7) – based on the idea that PAs management follows a process with six distinct stages, or elements – for assessing ME of both PAs and PAs systems. Thus, managers and researchers can use this framework as guidance and help harmonize assessment around the world. To help this, different evaluation 'tools' – based on this framework – can be used to conduct evaluations at different scales and depths (Stolton et al., 2007).

[24] events are considered independent instance of capture as repeated images of an animal pausing in front of the camera traps are discarded (Rovero & Zimmermann, 2016).

Table 7: Summary of the WCPA Framework

Source: Stolton et al., 2007

Elements of evaluation	Explanation	Criteria that are assessed	Focus of evaluation
Context	Where are we now? Assessment of importance, threats and policy environment	- Significance - Threats - Vulnerability - National context - Partners	Status
Planning	Where do we want to be? Assessment of protected area design and planning	- Protected area legislation and policy - Protected area system design - Reserve design - Management planning	Appropriateness
Inputs	What do we need? Assessment of resources needed to carry out management	- Resourcing of agency - Resourcing of site	Resources
Processes	How do we go about it? Assessment of the way in which management is conducted	- Suitability of management processes	Efficiency and appropriateness
Outputs	What were the results? Assessment of the implementation of management programmes and actions; delivery of products and services	- Results of management actions - Services and products	Effectiveness
Outcomes	What did we achieve? Assessment of the outcomes and the extent to which they achieved objectives	- Impacts: effects of management in relation to objectives	Efficiency and appropriateness

3.2.2.1 Management Effectiveness Tracking Tool

The METT has been designed to be a simple and rapid site assessment system which help monitor progress towards improving ME. Indeed, this tool is aimed at providing a quick overview of the management steps identified in the WCPA Framework (Stolton et al., 2007). The following guidance on process – developed by Stolton et al., 2007 – should assist in making an assessment of ME as rigorous, reliable and useful as possible.

The METT is constructed around a set of questions contained in two main sections: Datasheets and Assessment Form (see below). Both sections can be found in Appendix XI. The METT will be used to asses management

implemented in Rukwa GR and will be filled in by the Project Manager (PM) and other relevant site staff like the PM Assistant, Patrol Officer, Site MIKE[25] Officer, Weapon & Ammunition Responsible and Driver & Mechanic.

1. Datasheets: the data sheet comprises two separate sections:

    Data sheet 1: records details of the assessment and some basic information about the GR and records as well information on international designations.

    Data sheet 2: provides a generic list of threats which the site can face.

2. Assessment Form: the assessment is structured around 30 questions presented in table format which includes 3 columns for recording details of the assessment.

- Questions and scores: the assessment is made by assigning a simple score ranging between 0 (poor) to 3 (excellent). A series of four alternative answers are provided against each question to help assessors to make judgements as to the level of score given. In addition, there are supplementary questions which elaborate on key themes in the previous questions and provide additional information and points.
- Comment/explanation: a box next to each question allows for qualitative judgements to be explained in more detail. This could range from local staff knowledge, a reference document, monitoring results or external studies and assessments.
- Next Steps: for each question respondents are also asked to identify any intended actions that will improve management performance.

3.3. Analyses

3.3.1. Sites covariates

On ArcGIS (ESRI, 2017), the layer containing the CT sites had to be converted into UTM (Universal Transverse Mercator) to match other layers geographical projections. This has been done by: right-click on the CT sites layer, click data, choose Export data, save the new set into UTM. Then, distances to explanatory factors (Water, Roads, Camps, Villages, other PAs) to CT sites have been extracted one by one through ArcGIS ArcToolbox, Spatial Analyst Tools, Proximate function. After having created additional layers on ArcGIS to transpose data gathered during fieldwork (timbering, poaching, grazing), the same procedure was applied.

Altitude of each CT site has been extracted using the ArcGIS ArcToolbox, Spatial Analyst Tools, Values extraction to points. This created a new layer (automatically in UTM projection).

In order to extract the landscape cover at CT site location, right-click on the new UTM CT sites layer, then click on Juncture and relations, Join. This allows to join data points to a layer based on a mutual spatial location. Then, choose Join_Output as a new layer, select Point-Point as a classification of entities, and set the result to be stored in a new set of layers.

Results have been consequently added to the ArcGIS attributary

of the CT sites layer and have been exported to .csv Excel file. This has been done by using the ArcGIS ArcToolbox, Conversion tools, by selecting Table to Excel function. The results, then, had to be ordered into rows and columns so that they could be suitable for further analysis on R. Information on Management (METT results), Statuses (VI/VI) and Governance regimes (1; 2; 3) were added manually at the end for each PAs.

3.3.2. Lepus software 4.2

Lepus (Huber, 2018) was developed in collaboration with hepia and aims at facilitating the seizure of raw data related to CT monitoring. It allows independent events to be detected automatically. Results can then be extracted and used for several purposes, such as creating GIS layers for distribution, exporting species richness or RAI. It

[25] Represent the Monitoring the Illegal Killing of Elephants (MIKE) programme that was established by the Conference of the Parties (CoP) in collaboration with the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) on its 10th Meeting (Harare, 1997)

also allows the extractions of statistics pertaining to the set of captured data, such as research effort or graphs representing the number of individual events in a simple and user-friendly manner.

3.3.3. R script

After the adding of the 2018 data collected in Mlele by another student to Rukwa and Rungwa data, CT raw data were extracted from Lepus in a .cvs format. Then, an R script was developed on RStudio (RStudio Team, 2017) to link the CT tables with the Factors table extracted from ArcGIS. The R script was then extended to allow the extraction of species accumulation curves, naïve occupancy and an extended occupancy analysis. The complete R script can be found on Appendix XII. See section 4.3. for more details.

3.3.4. Management Effectiveness Tracking Tool

On 22 November 2018 METT questionnaires were passed to a selection of Rukwa GR staff: the PM and his Assistant which is also the Site MIKE Officer, a Patrol Officer, the Weapon & Ammunition Responsible and a Driver & Mechanic. Additional questions were also asked to the PM followed by an open discussion with him and a TANAPA Instructor.

Each METT questionnaires were passed individually and then regrouped into one assessment (each question score was calculated as the mean of the 5 results provided and comments/explanations were regrouped/added) – which can be found in Appendix XIII – in order to calculate the final score of Rukwa GR. In order to evaluate the management implemented in Mlele beekeeping zone in a comparative manner, METT score will be calculated as a percentage of each of the six elements of the WCPA Framework. The maximum score of the 30 questions and supplementary questions is 99. However, question 23 was discarded as it was not relevant to the particular PAs and was redundant with question 24. Thus, a final total of the score from completing the Assessment Form can be calculated as a percentage of 96. This total score is then correlate to the observed descriptors of wildlife through our occupancy analysis.

Finally, Mlele BKZ and Rungwa FR & GCA METT (Appendix XIII) final score provided by Daudet (2019) will be integrated to the CT analysis. Similarly, to Rukwa METT, Mlele and Rungwa METT score will be calculated as a percentage of each of the six elements of the WCPA Framework to allow the evaluation of the management implemented in Mlele in a comparative manner. However, there are clear limitations in this regard. Indeed, METT relay – being qualitative assessment – on the judgement and honesty of the evaluators. Thus, usefulness being also closely connected to how well the assessment is carried out, Stolton & Dudley (2016) suggests that a good METT process is way better if the assessment is evidence-based and a diverse group of stakeholders have inputs into the results. Moreover, the score approach has limitations himself. Specifically, although all six elements of the WCPA Framework are represented in the METT, most of the questions relate to planning, inputs and process resulting in an unbalance between the 6 elements when comparing the results as a percentage of the WCPA Framework. Thus, detailed comparison of individual indicators between different sites are not recommended and METT assessment are better at addressing changes over time at a single site. However, it should be recalled that the evaluation of ME is recognized as a vital component of responsive, pro-active PA management (Hockings et al., 2006). Thus, based on thousands of assessments of PAME, the global conservation community conclude that «PAME data, while designed as a tool for local adaptive management, may also help to provide insights into the impact of PA management interventions from the local-to-global scale» (Coad et al., 2015). Furthermore, the Royal Government of Bhutan developed a custom-made tool for assessing management effectiveness: the Bhutan Management Effectiveness Tracking Tool Plus (Bhutan METT +) and used it during the 2014–2016 period. This tool was implemented in 10 PAs and 1 botanical garden and provides a good example of how to develop a baseline against which to measure the effectiveness of PAs over time and assess the impact of conservation inputs (Lham et al., 2018).

Figure 16: Installation of a CT in the field. First, configure the CT. Second, set-up the CT on the chosen tree. Third, trigger the CT ("test" mode) to verify CT functioning properly

4. Results

4.1. Species Richness

CT survey was conducted for 189 days, from 27 Mai 2018 to 10 December 2018, in the study area. 311 sampling units were sampled and worked for 8128 CT days. Figure 17 expresses the research effort for Rukwa GR, Rungwa FR & GCA and Mlele BKZ. In the study area, 13271 independent events of 52 species (Figure 18) were detected out of 313757 pictures. Figure 18 also show that the research effort was sufficient for the time-interval considered. Appendix XIV gives the details of the CT parameters and Appendix IV shows the final emplacement of CT in the study area (maps & GPS positioning).

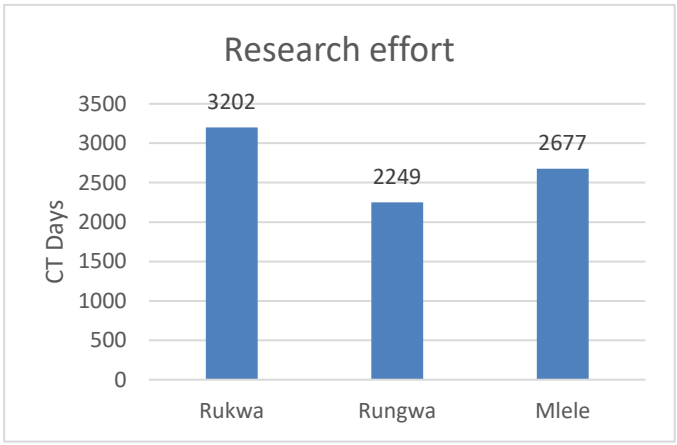


Figure 17: Comparison of the research effort for the 3 studied PAs

Source: Lepus

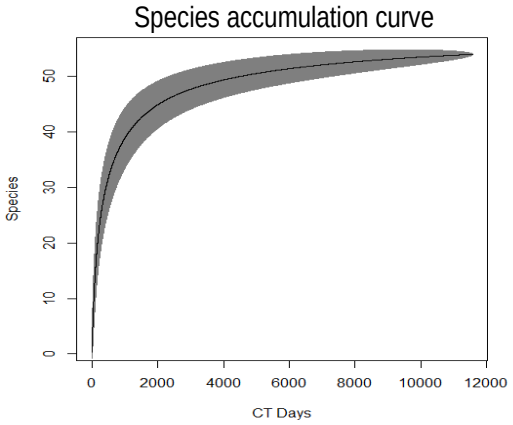


Figure 18: Randomized species accumulation curve (solid line) and confidence interval for the study area (3 PAs)

Source: RStudio

Considering each PAs species accumulation curves separately (Figure 19), Rukwa GR did not attend a plateau yet despite having the highest research effort (4 grids were sampled) and highest species capture (46). Rungwa FR & GCA on the other hand shows the steepest accumulation curve and seemed to approach its plateau (presenting 40 species) while it had the lowest research effort (only 2 grids were sampled). Finally, Mlele BKZ shows also a steep accumulation curve but has not yet attained its plateau as only 35 species are displayed for a research effort of 2677 CT Days (3 grids were sampled).

A complete list of species detected during the 2018 CT survey is also available in Appendix XIV and is declined per grids and then regrouped per PAs and finally at the study area level. Figure 20 shows a selection of pictures provided by the CT during fieldwork. However, considering specifically carnivore species (Figure 21), Table 8 shows, based on the predictive list presented in Appendix II, the species detected during the survey.

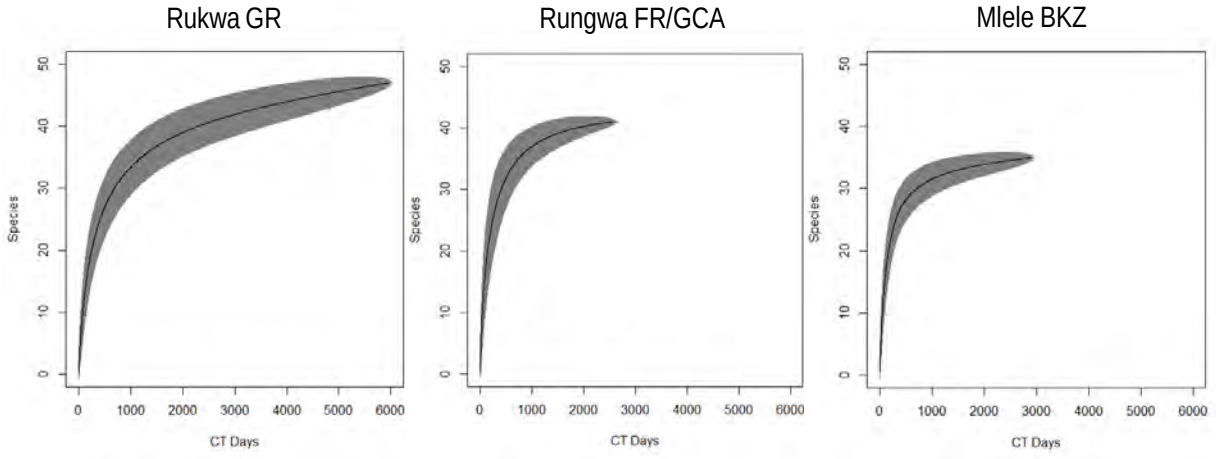


Figure 19: Species accumulation curves for Rukwa GR, Rungwa FR/GCA & Mlele BKZ and the resulting samplings completeness

Source: RStudio

Table 8: Checklist of carnivores detected in the study area during the 2018 CT survey
Source: Present study

Common name	Scientific name	Rukwa GR	Rungwa FR/GCA	Mlele BKZ
Side-striped jackal	*Canis adustus*	X		
Black-backed jackal	*Canis mesolemas*			
African wild dog	*Lycaon pictus*	X	X	
Caracal	*Felis caracal*			
Serval	*Leptailurus serval*	X	X	
Wildcat	*Felis sylvestris*		X	
Leopard	*Panthera pardus*	X	X	X
Lion	*Panthera leo*	X	X	
Marsh mongoose	*Atilax paludinosus*	X		
Bushy-tailed mongoose	*Bdeogale crassicauda*	X	X	X
Banded mongoose	*Mungos mungo*	X	X	X
Dwarf mongoose	*Helogale parvula*	X		
Ichneumon mongoose	*Herpestes ichneumon*			
Slender mongoose	*Herpestes sanguineus*			
White-tailed mongoose	*Ichneumia albicauda*	X	X	X
Meller's mongoose	*Rhynchogale melleri*	X		X
Spotted hyaena	*Crocuta crocuta*	X	X	X
Aardwolf	*Proteles cristatus*			
Honey badger	*Mellivora capensis*	X	X	X
Zorilla	*Ictonyx striatus*			
Tree Civet	*Nandinia binotata*			
African civet	*Civettictis civetta*	X	X	X
Miombo genet	*Genetta angolensis*	X	X	X
Common genet	*Genetta genetta*			
Large-spotted genet	*Genetta maculata*	X	X	X
Servaline genet	*Genetta servalina*			
Total		16	13	10

Based on this list, 16 carnivores were detected in Rukwa GR, 13 in Rungwa FR & GCA and 10 in Mlele BKZ and follow the same trend as the result presented above. For the whole area this represent 17 carnivore species detected out of the 18 known to occur in the region (Hausser et al., 2017; Fischer et al., 2013) suggesting that a good proportion of the cohort was captured. By this simple assessment, species like the bushy-tailed mongoose, banded mongoose, white-tailed mongoose, spotted hyaena, honey badger, African civet, miombo genet and large-spotted genet have been detected in the 3 PAs. In contrast, the side-striped jackal, wildcat, marsh mongoose and dwarf mongoose were only detected in 1 PA. Finally, three species are interesting to highlight for their presence on the IUCN Red List, the leopard which was detected in the 3 PAs, the lion and the African wild dog which were detected in Rukwa GR and Rungwa FR & GCA.

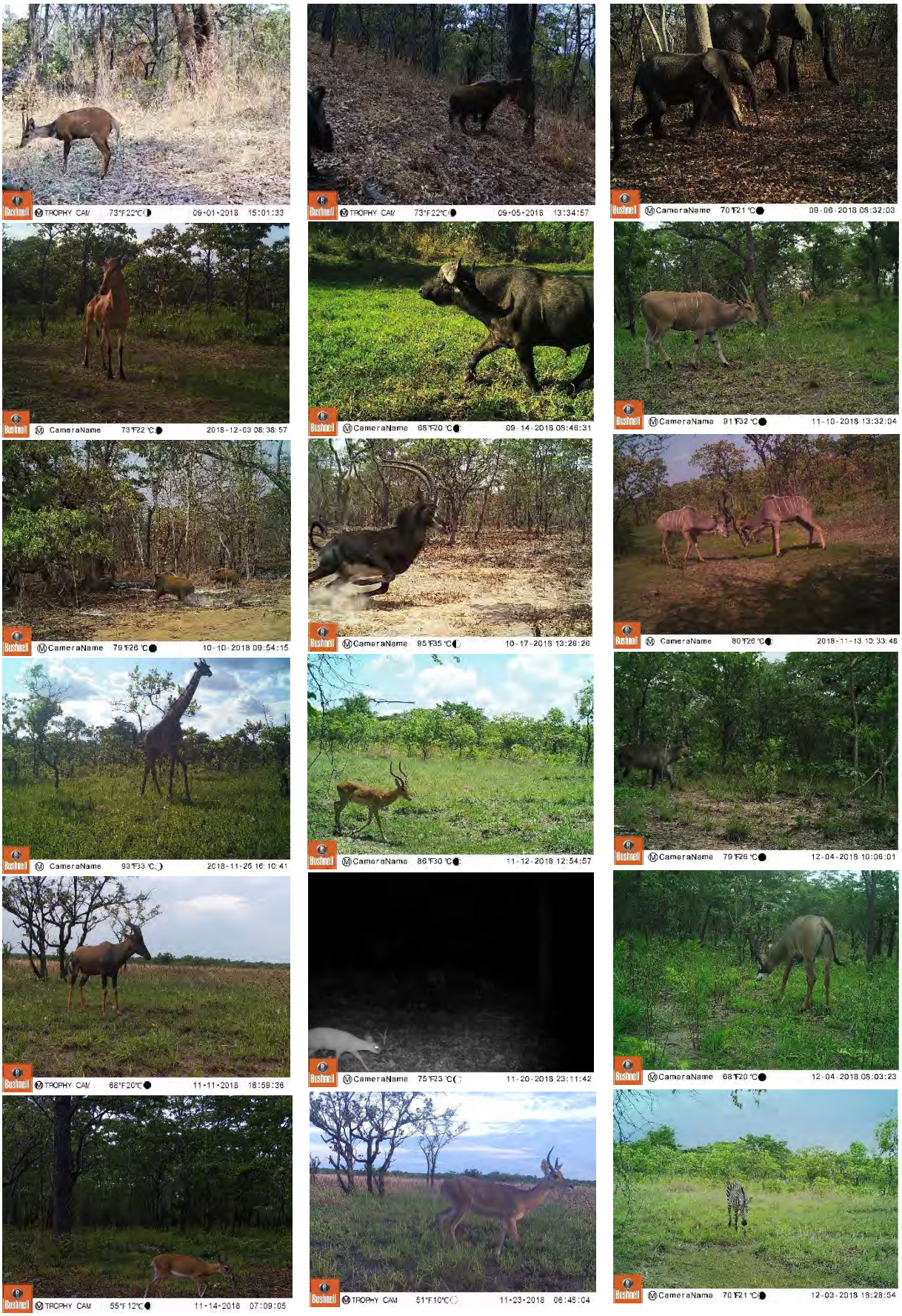


Figure 20: Selection of non-carnivore mammals detected during the 2018 survey in Rukwa GR and Rungwa FR/GCA

4.2. Raw descriptors

The full inventory results presented hereafter (Table 9) provide a description of the variation among species in terms of RAI and naïve occupancy (the 2 indices should be broadly concordant). Additionally, independent events – or event counts – were used to draw distribution maps for each focal species and can be found in Appendix XV.

Species like the side-striped jackal, the African wildcat, the dwarf mongoose and Mellers' mongoose do not present enough data to make any inference on their distribution. The march mongoose do not present enough data either but its detection was always made in Mbugas in the close vicinity of water as this species is one of the most specialized mongoose (Kingdon, 2013). The white-tailed mongoose seems to favor lower altitude and a more open habitat (Ramesh & Downs, 2015; Kingdon, 2013). Its detection was also mostly made in the proximity of tracks & roads. The banded mongoose seem to be evenly distributed across the study area as this species is highly dependent on termite months (Stuart & Stuart, 2000; Estes & Otte, 2012; Kingdon, 2013). The bushy-tailed mongoose seems to occur mainly on the escarpment. The same pattern seems to occur for the miombo genet as this species seems to be more present at higher altitude. On the contrary, the large-spotted genet seems to favor lower altitude and a more open habitat as was confirmed by previous work (Buffard, 2018; Hausser et al., unpublished data). The African civet seem distributed in the vicinity of permanent rivers in the escarpment region. The honey badger seems also more present at higher altitude. Hyaenas are evenly distributed across the study area. The serval seems to favor open grassland (Ramesh & Downs, 2015; Kingdon, 2013). Leopards seem to be evenly distributed across the study area even if it seems to avoid the vicinity of the villages. This species is also known to make frequent use of riverine forest in the area (Hausser et al., unpublished data). Lions and African wild dogs were either detected in difficult terrain in Rukwa GR probably to avoid human encounter or close to Rungwa river. However, proximity to water might translate predator-prey relationship. Indeed, during dry season, ungulates are mostly found in the vicinity of water and thus, attracts predators (Estes & Otte, 2012; Stuart & Stuart, 2000).

*Table 9: Presentation of the full inventory results of the camera trapped carnivores**

Source: Lepus & RStudio

		Rukwa			Mlele			Rungwa		
Common name	Scientific name	Event counts	RAI	Naïve occupancy	Event counts	RAI	Naïve occupancy	Event counts	RAI	Naïve occupancy
Marsh mongoose	*Atilax paludinosus*	5	0.238	0.021	0	0.000	0.000	0	0.000	0.000
Bushy-tailed mongoose	*Bdeogale crassicauda*	91	0.219	0.236	108	0.260	0.352	4	0.010	0.208
Side-striped jackal	*Canis adustus*	2	0.400	0.014	0	0.000	0.000	0	0.000	0.000
African civet	*Civettictis civetta*	28	0.217	0.090	22	0.171	0.120	5	0.039	0.069
Spotted hyaenas	*Crocuta crocuta*	10	0.078	0.056	11	0.085	0.056	13	0.101	0.097
Wildcat	*Felis silvestris*	0	0.000	0.000	0	0.000	0.000	2	0.400	0.014
Miombo genet	*Genetta angolensis*	52	0.123	0.285	140	0.332	0.444	19	0.045	0.375
Large-spotted genet	*Genetta maculata*	23	0.209	0.236	5	0.046	0.176	24	0.218	0.417
Dwarf mongoose	*Helogale parvula*	1	0.167	0.007	0	0.000	0.000	0	0.000	0.000
White-tailed mongoose	*Ichneumia albicauda*	2	0.050	0.014	1	0.025	0.009	16	0.400	0.264
Serval	*Leptailurus serval*	1	0.029	0.007	0	0.000	0.000	15	0.441	0.167
African wild dog	*Lycaon pictus*	1	0.077	0.007	0	0.000	0.000	4	0.308	0.042
Honey badger	*Mellivora capensis*	7	0.090	0.049	22	0.282	0.176	8	0.103	0.097
Banded mongoose	*Mungos mungo*	14	0.197	0.063	6	0.085	0.056	15	0.211	0.250
Lion	*Panthera leo*	4	0.364	0.021	0	0.000	0.000	2	0.182	0.028
Leopard	*Panthera pardus*	8	0.094	0.049	8	0.094	0.049	4	0.047	0.097
Meller's mongoose	*Rhynchogale melleri*	2	0.118	0.014	1	0.059	0.008	0	0.000	0.000

*As a reminder, the length of the surveys is not equal. Thus, comparisons need to be made carefully

Raw descriptors such as RAI and naïve occupancy (Figure 22) do not account for imperfect and variable detection (Sollmann et al., 2013). Indeed, in our study, the less detected species led to bias in RAI ratios (e.g. side-striped jackal and marsh mongoose in Rukwa or serval and African wildcat in Rungwa). Another bias comes from species with larger home ranges like the lion in Rukwa or the African wild dog in Rungwa who also inflate RAI (0.364 & 0.308 respectively). However, naïve occupancy seems more concordant with independent events and thus, seems more reliable as measure of detection probability as it seems less biased.

In Rukwa GR, the species having the highest detection probability were the bushy-tailed mongoose and the Miombo genet closely followed by the large-spotted genet and African civet. Banded mongoose, hyaena, honey badger and leopard were relatively easily detected. Less detected species were the marsh mongoose, lion, side-striped jackal, white-tailed mongoose, Meller's mongoose, dwarf mongoose, serval and African wild dog.
In Rungwa FR & GCA, the large-spotted genet was the most detected species followed by the Miombo genet. The white-tailed and banded mongoose also presented good detection probabilities. The serval, bushy-tailed mongoose, hyaena and honey badger were relatively easily detected. Less detected species were the African civet, the African wild dog, the leopard, the lion and the African wildcat.
In Mlele BKZ, the most detected species was the Miombo genet followed by the bushy-tailed mongoose. The African civet, honey badger and hyaena were relatively easily detected. Less detected species were the leopard, banded mongoose and large-spotted genet. Occasionally detected species were the white-tailed and Meller's mongooses.

Figure 21: Example of carnivores detected in the study area by the CT. From left to right, top to bottom: honey badger; bushy-tailed mongoose; African civet; African wildcat; serval; lion; leopard; African wild dog; marsh mongoose; hyena; large-spotted genet; side-striped jackal

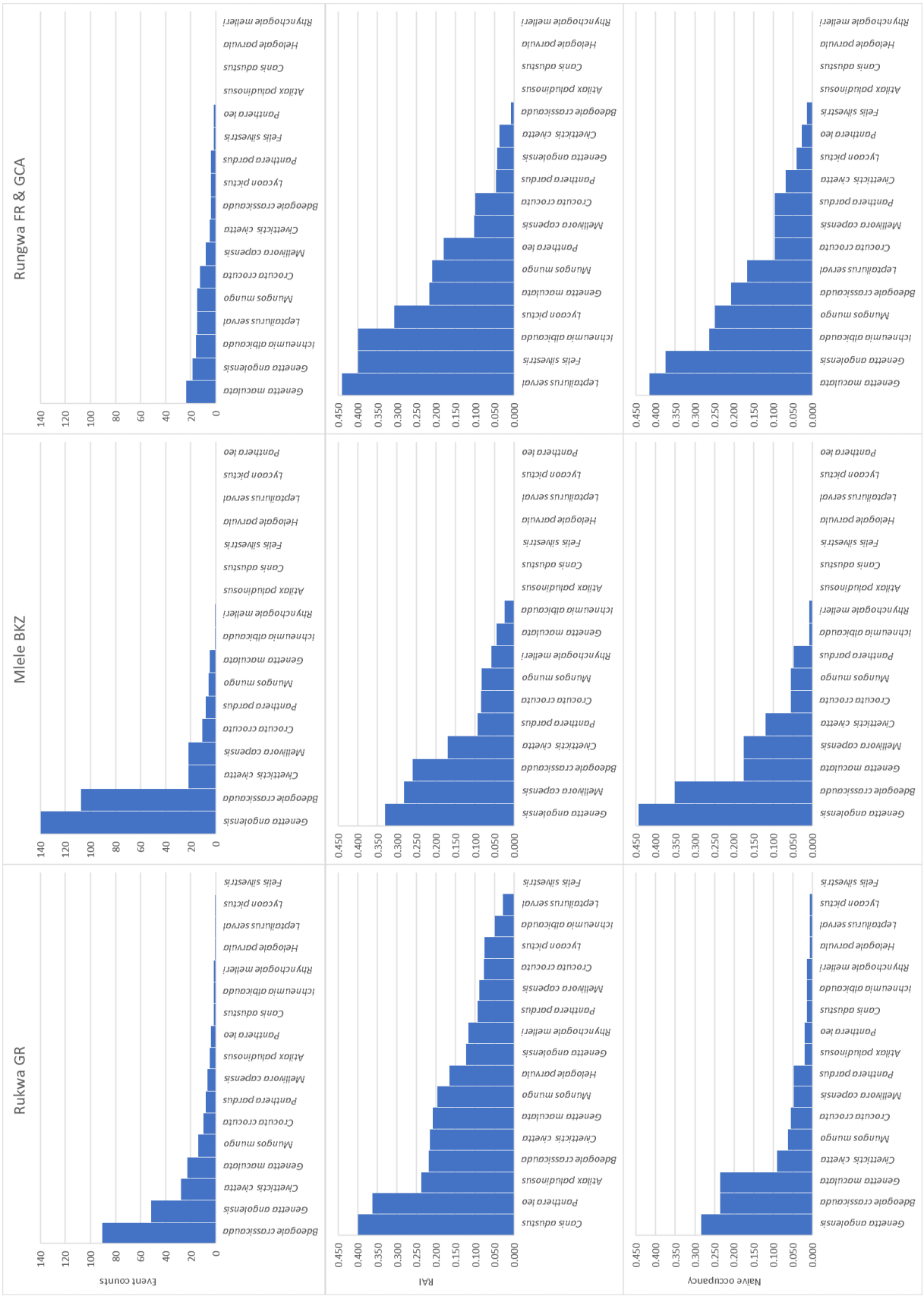


Figure 22: Description of the variation among species in terms of independent events, RAI and naïve occupancy

Source: Lepus & RStudio

4.3. Occupancy

Before starting occupancy analyses, the length of the sampling occasion needs to be defined. We defined that each survey occasion lasted 1 day and thus, 21 survey occasions were created. This matrix allowed to enter a 1 to indicate the detection of a species during a specific day and a 0 to indicate the non-detection of the species another day. In order to have the same sampling effort per site for the analysis, cameras lasting less than 10 days were omitted as well as pictures taken after 21 days.

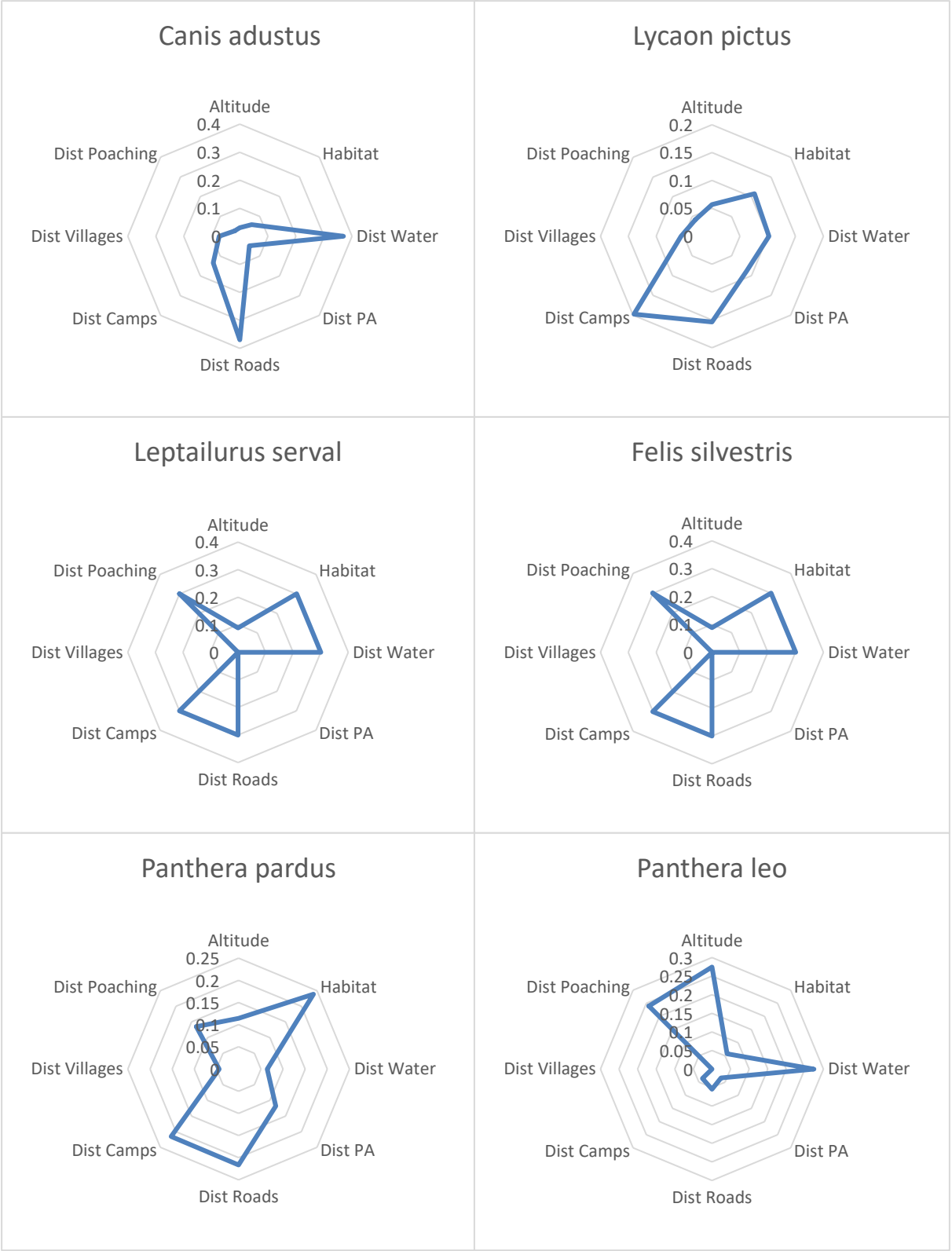
13 covariates were identified (see section 2.) and are either environmental or anthropogenic and are detailed in Table 10. Continuous covariates were transformed using a square-root transformation in order to reduce the influence of extreme values and approach normality. Also, all continuous variables were standardized based on the recommendations of Friske & Chandler (2012). Through logistic regression models, multicollinearity between covariates were tested using Variance Inflation Factor (VIF) (see Appendix XVI for results). Unfortunately, high collinearity (VIF superior to 10) was found between *Governance*, *Status* & *Management*. Thus, only *Management* was retained as it was linked to the METT analyses and thus was better suited to represent a real effect. Besides, two other factors had to be withdrawn, *Timbering* & *Grazing* that were related to the distance of villages (*D_Villages*). Thus, at each camera site 9 covariates were retained finally.

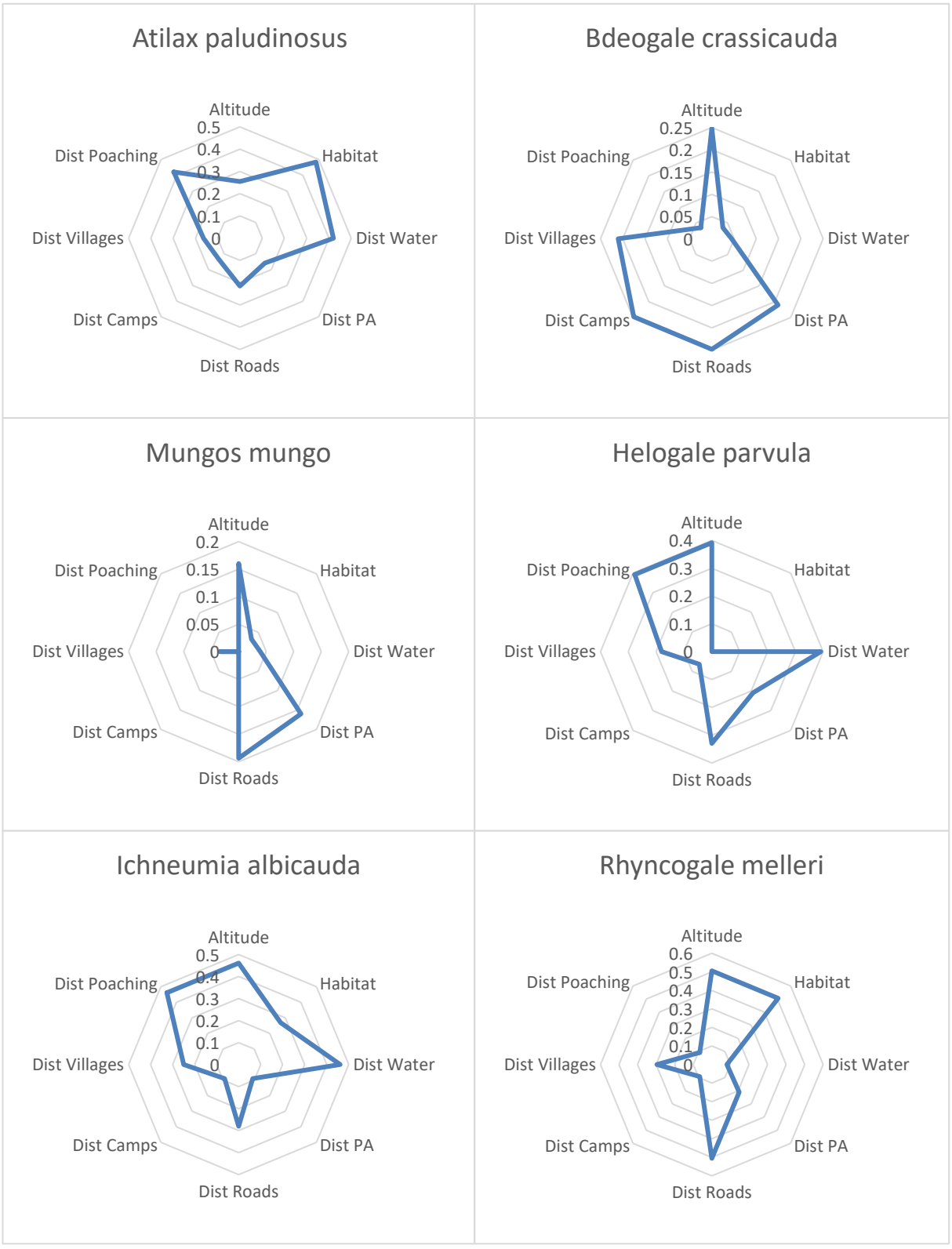
Table 10: Presentation of the retained covariates identified in section 2. and the metrics used for analyses. The covariates are grouped by environmental and anthropogenic factors with a separation between legal and illegal activities for the latest. In bold are the covariates finally retained (after multiple collinearity was tested) for the analyses

Source: Present study

Covariates				*Metrics*
Environmental factors	Topography	Altitude		[m alt]
	Habitat type	Riverine Forests		1
		Closed Miombo		2
		Miombo		3
		Open Miombo		4
		Mbuga		5
	Distance to permanent water			[m]
Anthropogenic factors	Legal	Distance to roads		[m]
		Distance to camps		[m]
		Distance to villages		[m]
		Distance to PAs (Katavi NP & Lukwati GR)		[m]
		Status	IUCN IV	4
			IUCN VI	6
		Governance	Tanzanian Government	1
			Tanzanian Government + Local Government	2
			Tanzanian Government + Local Government + Local community	3
		Management	METT	[METT Results]
	Illegal	Distance to poaching		[m]
		Distance to timbering		[m]
		Grazing		[RAI cattle]

In order to estimate the occurrence of carnivores inside the different PAs, single season occupancy analysis was used for each species using the package "unmarked" in R. Unlike raw descriptors, occupancy analysis has the advantage of taking into account the imperfect detection probability, therefore, occupancy models are fitted in order to estimate 2 parameters: detection probability (p) and occupancy (ψ) (MacKenzie et al., 2006). First, environmental and anthropogenic factors influencing occupancy were identified. For each species, the selection of covariates was made comparing all possible model combinations with the 8 occupancy covariates identified before integrating effect of *Management* to the model in order to asses specifically its influence on species occurrence. The comparison was based on Akaike's Information Criterion (AIC). Accordingly, only well supported models with $\Delta AIC < 2$ were considered (Rovero & Zimmermann, 2016). Then, for each species the relative importance of each covariate was estimated by summing the AICweight ($\sum \mathrm{AICw}$) in which that covariate appears across supported models (Figure 23). Covariates were only integrated to the final model if $\sum \mathrm{AICw} > 0.05$. This allowed to reduce the number of predictors and reduce the risks of overfitting. The selection of the best model per species using AIC allowed to reduce the number of covariates to be used in the final models. Altitude and roads seem to influence most species, followed by the habitat, presence of water and the distance from Katavi NP and Lukwati GR. Factors having less influence seems to be poaching, the presence of temporary camps and the nearby villages. The number of covariates retained varied across species and went from 3 to 8 out of the 8 possible initial covariates. This first results seem to tend toward the fact that environmental variables are more influencing than anthropogenic one. *Management* was then added to these models to evaluate its importance on the occupancy of species once the other covariates were controlled.


Canis adustus
Altitude
Habitat
Dist Water
Dist PA
Dist Roads
Dist Camps
Dist Villages
Dist Poaching
0.4
0.3
0.2
0.1
0
Lycaon pictus
Altitude
Habitat
Dist Water
Dist PA
Dist Roads
Dist Camps
Dist Villages
Dist Poaching
0.2
0.15
0.1
0.05
0
Leptailurus serval
Altitude
Habitat
Dist Water
Dist PA
Dist Roads
Dist Camps
Dist Villages
Dist Poaching
0.4
0.3
0.2
0.1
0
Felis silvestris
Altitude
Habitat
Dist Water
Dist PA
Dist Roads
Dist Camps
Dist Villages
Dist Poaching
0.4
0.3
0.2
0.1
0
Panthera pardus
Altitude
Habitat
Dist Water
Dist PA
Dist Roads
Dist Camps
Dist Villages
Dist Poaching
0.25
0.2
0.15
0.1
0.05
0
Panthera leo
Altitude
Habitat
Dist Water
Dist PA
Dist Roads
Dist Camps
Dist Villages
Dist Poaching
0.3
0.25
0.2
0.15
0.1
0.05
0


Atilax paludinosus
Altitude
Habitat
Dist Water
Dist PA
Dist Roads
Dist Camps
Dist Villages
Dist Poaching
0.5
0.4
0.3
0.2
0.1
0
Bdeogale crassicauda
Altitude
Habitat
Dist Water
Dist PA
Dist Roads
Dist Camps
Dist Villages
Dist Poaching
0.25
0.2
0.15
0.1
0.05
0
Mungos mungo
Altitude
Habitat
Dist Water
Dist PA
Dist Roads
Dist Camps
Dist Villages
Dist Poaching
0.2
0.15
0.1
0.05
0
Helogale parvula
Altitude
Habitat
Dist Water
Dist PA
Dist Roads
Dist Camps
Dist Villages
Dist Poaching
0.4
0.3
0.2
0.1
0
Ichneumia albicauda
Altitude
Habitat
Dist Water
Dist PA
Dist Roads
Dist Camps
Dist Villages
Dist Poaching
0.5
0.4
0.3
0.2
0.1
0
Rhyncogale melleri
Altitude
Habitat
Dist Water
Dist PA
Dist Roads
Dist Camps
Dist Villages
Dist Poaching
0.6
0.5
0.4
0.3
0.2
0.1
0

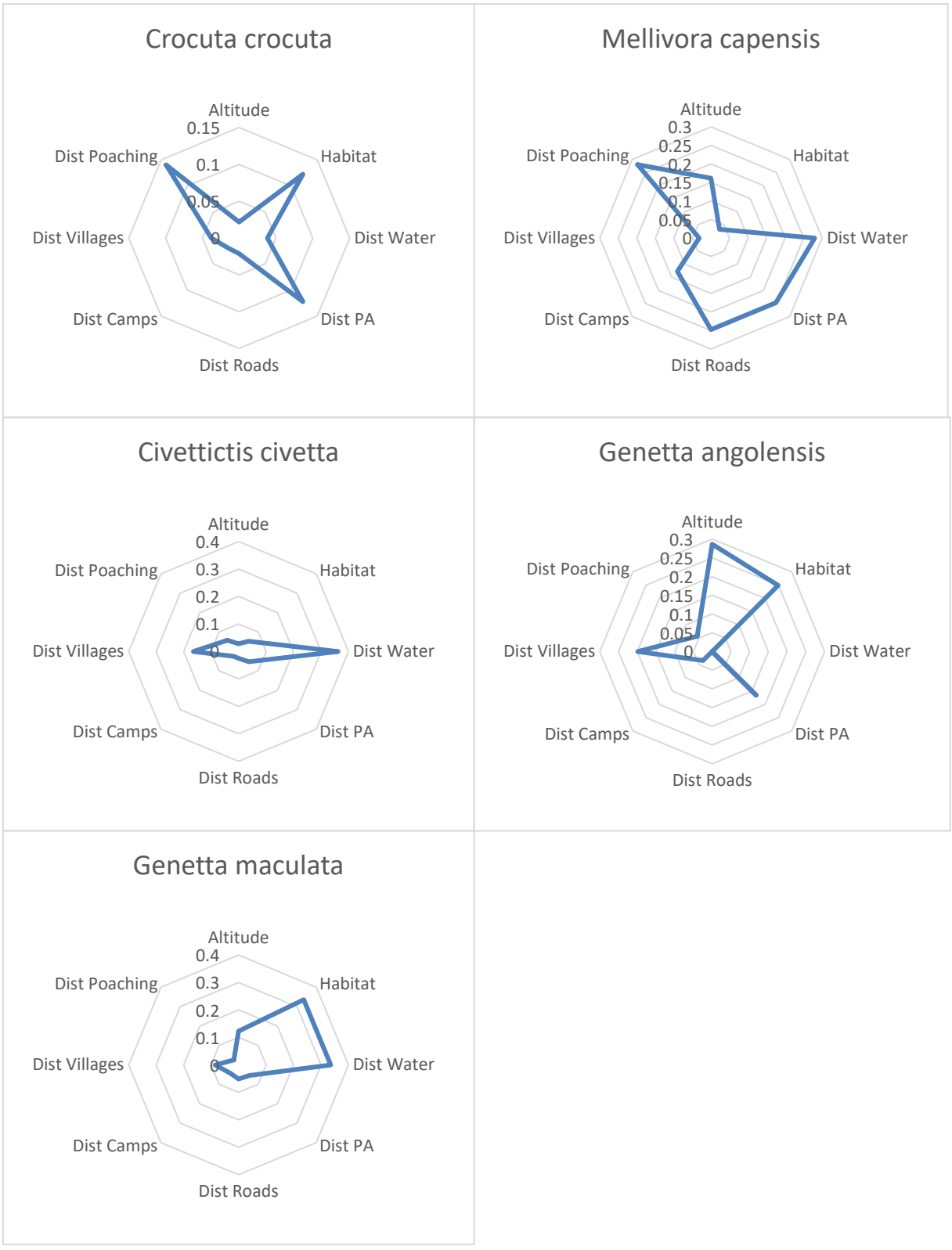


Figure 23: Graphical representation of the influence of the 8 retained covariates over the 17 carnivores detected during the survey. Only covariates having ΣAICw > 0.05 were retained in the final model

Source: Present study

Figure 23 results shows that the dog family seems more influenced by anthropogenic factors, where roads seem to influence both, the side-striped jackal and the African wild dog, strongly. The cat family is primarily influenced by environmental factors such as habitat and water. However, each of the cat species that were detected (African wild dog, serval, leopard and lion), were also influenced by the presence of roads. The mongoose species are all and primarily influenced by environmental variables and the presence of roads. Most are also influenced by poaching. Contrary to the other species, the spotted hyaena seems to be principally influenced by poaching but also shows a close relationship to habitat. The honey badger seems to be principally influenced by water and poaching, followed by roads. The viverrids (the African civet, miombo genet and large-spotted genet) are all primarily influenced by environmental factors and anthropogenic factors such as roads or poaching seem to have less influence. However, these first results do not allow to say in which direction (positive or negative) covariates influences species occurrence and, thus, the analyses need to be pushed further.

Among the 17 carnivores identified, only 4 of them presented enough observations to model occupancy. The species retained were the bushy-tailed mongoose, the African civet, the miombo genet and the large-spotted genet. The tables summarizing the selected models per specie and the corresponding covariate estimates can be seen in Table 11. Corresponding occupancy maps for each species can be found in Appendix XVII. Negative estimates for distances should be interpreted as an expected higher occupancy when getting closer to the object (e.g. water, road, village, etc.). For altitude, negative estimates indicate that occupancy is higher when the altitude is low. For habitat, the different habitat categories were classified form the denser to more open habitat. Thus, estimates should be interpreted according to the reference category that is *Miombo*. For example, a positive estimate would mean that occupancy is higher there than in *Miombo*. Thus, occupancy estimates allow to appreciate for the identified covariates whether it influences positively or negatively the occurrence of a species in the study area.

Table 11: Estimates and standard errors (in parentheses) for the selected best models for the 4 species presenting enough observations. For Management, Mlele BKZ is the reference category. For Habitat, Miombo is the reference category

Source: RStudio

Parameter	Covariate	Bdeogale Crassicauda	Civettictis civetta	Genetta angolensis	Genetta maculata
	Intercept	-0.623 (0.249)	-3.237 (1.228)	-1.306 (-1.306)	-3.057 (1.021)
	Altitude	0.506 (0.248)		0.984 (0.984)	-0.027 (0.262)
	Habitat		0.222 (0.353)	0.378 (0.223)	0.576 (0.302)
	Dist Water		-1.029 (0.322)		0.236 (0.209)
	Dist PAs	0.377 (0.245)	0.319 (0.365)	0.691 (0.268)	0.501 (0.348)
ψ	Dist Roads	0.351 (0.179)			0.100 (0.176)
	Dist Camps	-0.477 (0.182)			
	Dist Villages	0.517 (0.179)	0.620 (0.427)	0.583 (0.26)	0.481 (0.3)
	Dist Poaching		0.088 (0.379)	0.607 (0.24)	
	Rukwa	-0.649 (0.351)	0.981 (0.63)	-1.449 (0.412)	0.604 (0.506)
	Rungwa	-0.478 (0.559)	-0.329 (0.859)	1.282 (0.62)	0.929 (0.666)
$\hat{p}$		-2.38 (0.102)	-3.09 (0.254)	-2.35 (0.0839)	-2.91 (0.14)

The bushy-tailed mongoose seems to occur more at higher altitude and when more distant from roads and villages. On the other hand, bushy-tailed mongoose seems to be attracted to temporary camps. The African civet seems to occur more in denser habitat and tend to favor proximity to water. However, results seem to indicate that this species tend to avoid human activities. For the Miombo genet, as expected, this species seems to inhabit higher altitudes and favor denser habitat. In addition, as for the civet, Miombo genet seem to avoid human activities. Finally, large-spotted genet negative estimates of altitude indicate that this specie occur at lower altitudes that the other species. Surprisingly, the large-spotted genet seems to prefer denser vegetation and doesn't seem to be dependent on water proximity. This specie too seems to avoid human contact as show the positive estimates for the distance to roads and villages. Lastly, the 4 considered species are influenced positively by the presence of

other PAs (Katavi NP and Lukwati GR). Thus, occupancy increases with distances from these two PAs which is questioning.

The adding of *Management* after controlling for relevant anthropogenic and environmental factors allowed to measure the effect of this covariate in the occupancy of the detected carnivores. The results for the 4 species having enough observation are summarized in Figure 24. In general, Management seems to influence small carnivores. However, for those species, there is no defined patterns showing a PA being systematically less occupied.

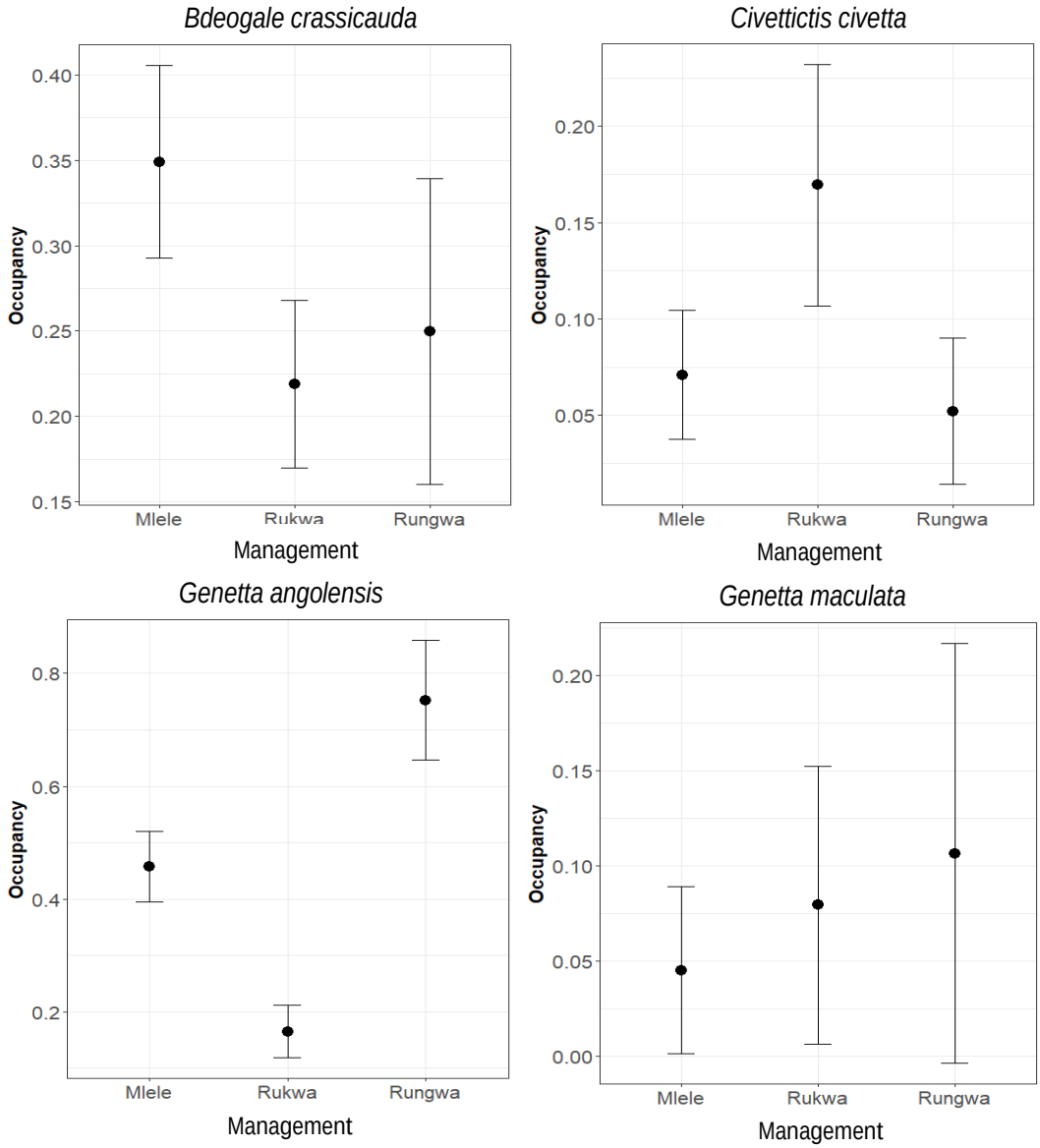


Figure 24: Graph of predicted occupancy according to PA management and prediction standard error (whiskers)

Source: RStudio

Finally, in order to compare true occupancy results with the naïve occupancy[26] results of the 4 species presenting enough data (Table 12), we first standardized the research effort of the naïve occupancy the same way as for occupancy analyses to make valid comparisons. Thus, cameras lasting less than 10 days were omitted as well as pictures taken after 21 days. This comparison allows us to determine the relationship between true occupancy and naïve occupancy in order to draw inference on the species presenting not enough data for occupancy. Thus, obliging us to use raw descriptors even if not accounting for imperfect detection. Figure 25 allows us to determine that both descriptors are more or less concordant even if naïve occupancy seems to underestimate species occurrence.

Table 12: Presentation of the hierarchical model results and standard errors (in parentheses) and the naïve model results

Source: RStudio

	Bdeogale crassicauda		*Civettictis civetta*		*Genetta angolensis*		*Genetta maculata*	
	True occupancy	Naïve occupancy	True occupancy	Naïve occupancy	True occupancy	Naïve occupancy	True occupancy	Naïve occupancy
Rukwa	0.219 (0.049)	0.219	0.169 (0.062)	0.217	0.165 (0.046)	0.123	0.079 (0.071)	0.209
Mlele	0.349 (0.056)	0.26	0.071 (0.033)	0.17	0.457 (0.063)	0.332	0.045 (0.065)	0.045
Rungwa	0.249 (0.089)	0.01	0.052 (0.038)	0.039	0.752 (0.106)	0.045	0.106 (0.126)	0.218

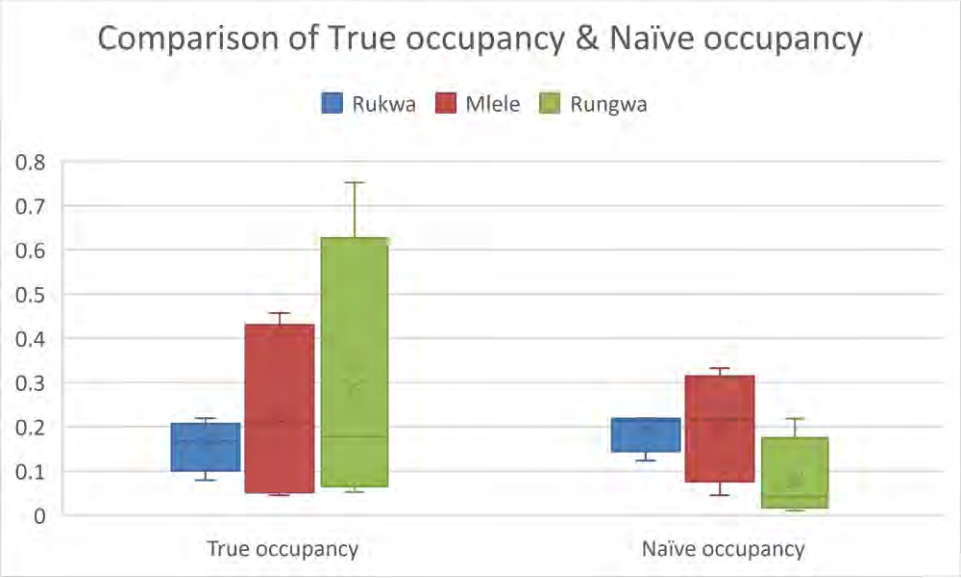


Figure 25: Comparison of true and naïve occupancy to determine the relationship between the two descriptors in order to draw inference on the species presenting not enough data for occupancy

[26] Figure 22 shows that naïve occupancy was better suited than RAI to interpret detection probability

4.4. Management Effectiveness

As stated in section 3.2.2., PAs geographical location and spatial extent are not sufficient in determining if global biodiversity targets are met. Thus, ME is of paramount importance in this regard (Chape et al., 2005) and help assess if management is protecting values and achieving goals and objectives (Hockings et al., 2006). To help this, METT were used to evaluate the strengths and weaknesses of the 3 studied PAs management and the threats that they face. As mentioned in section 3.4.2. METT for Rungwa FR & GCA and Mlele BKZ are based on Daudet (2019) and, thus, subsequent results presented hereafter. METT was designed to be a simple and rapid site assessment system which helps monitor progress towards improving ME (Stolton et al., 2007). METT scores were thus calculated as a percentage of each of the six elements of the WCPA Framework (Figure 26) to allow the evaluation of the management implemented in Mlele in a comparative manner.

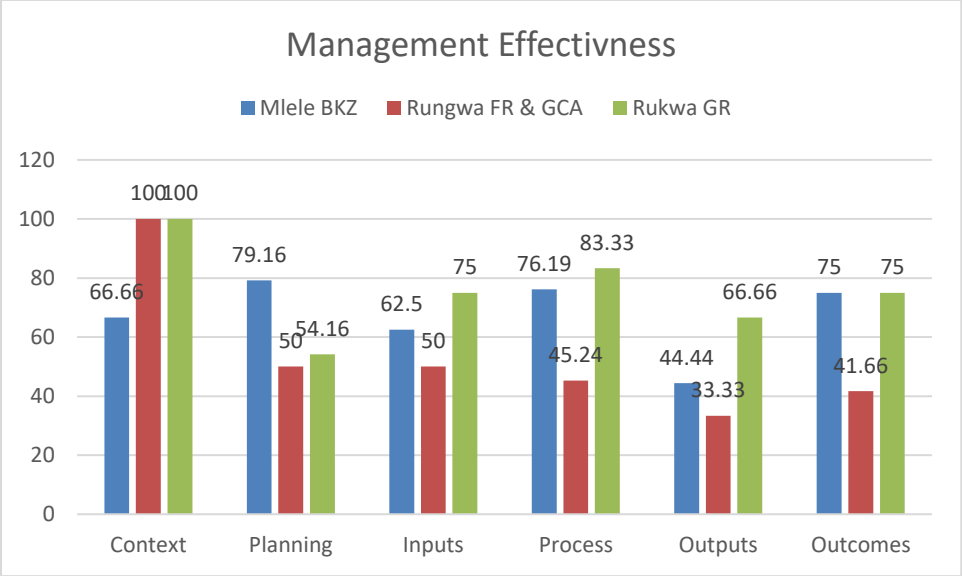


Figure 26: Out of the total score per reserve obtained (which was correlated with the wildlife descriptors), METT scores were calculated as a percentage of each of the six elements of the WCPA Framework for a better comparison

Source: Present study

With a total of 72 points Mlele BKZ ME is very close to Rukwa GR (73) and far better than Rungwa FR & GCA (45). The major difference between Mlele BKZ and Rukwa GR can be explained by the context of Mlele BKZ. Indeed, Mlele BKZ is still awaiting is gazettement and thus loosed substantial points. However, as this aspect should soon be granted, Mlele BKZ will have a ME score equal to Rukwa GR. Thus, it appears that it is the proper management of a PA that allows the conservation of medium- to large-mammals and less its IUCN management category and joins Mermod (2012) conclusions. Indeed, Mlele BKZ and Rungwa FR & GCA have equal IUCN management categories. However, Mlele BKZ present a score equal to Rukwa GR a stricter state PA.

4.4.1. Context

4.4.1.1 Rukwa GR

Rukwa GR was nationally gazetted in 1995. In 2015, in the study area, TAWA – a parastatal institution under MNRT – took over WD the management of the 4194 km^2 area. TAWA being under the control of the state, has the duty to follow Policies, Act, and subsequent Regulations (see section 3.1.1.1). All decisions are made in Dar Es Salaam at the MNRT and then transferred to the GRs HQ in Selous before being sent to Rukwa GR (Habibu, pers.comm. 2018).

In Rukwa GR no threats seriously degrading values were revealed. However, METT results indicated that medium threats such as droughts and Lake Rukwa shoreline erosion are having some negative impact on wildlife. Finally, Livestock grazing, mining, logging and habitat alteration are present but not seriously impacting values.

As Mermod (2012) quoted based on Igoe & Brockington (2007) analysis, Tanzania GRs are IUCN management category IV but are managed as IUCN management category II as they prohibit establishment of populations. In practice, IUCN management category IV PAs are rarely large enough to protect an entire ecosystem (Dudley, 2013) but Rukwa GR is part of Katavi-Rukwa Ecosystem – 1 of 6 Tanzanian ecosystems of importance for elephant. It is also a habitat for the endemic puku, *Kobus vardonii* (Livingstone, 1857) and shelters the largest crocodile, *Crocodylus niloticus* (Laurenti, 1768) population in Tanzania (Mrina, pers.comm. 2018). On the other hand, GRs could not be placed in IUCN management category II because the latter generally does not allow the use of resources except for subsistence or light recreation purposes (see section 2.2.1.6).

4.4.1.2 Rungwa River FR & GCA

Rungwa River FR & GCA, a IUCN management category VI PA, was nationally gazetted in 1954 and the 2480 km^2 area is managed by TFS Inyonga in collaboration with the Mlele District, represented by District Land and Natural Resources Officer (DLNRO) and District Forest Manager. Thus, Managers are from two different institutions: the local government, that is, Mlele district, and TFS, a parastatal institution of Tanzanian central government. TFS is fairly new in the landscape as it is only present in Mlele District since 2015. As Mermod (2016) pointed out, these two institutions have overlapping authorities and there is a conflict between the decentralization laws (see section 3.1.1.1) and the creation of TFS.

As Rungwa FR has also the status of GCA, the WD is involved in the management of these area through the District Game Officer (DGO) and the regional unit. However, they manage only the wildlife resources and all related activities. Normally, TAWA should have taken over WD wildlife management since 2015 but it is not yet in place. Within GCAs, another stakeholder is involved, directly or not, with regard to the management of Rungwa: Hunting Companies, which have antipoaching and road maintenance tasks. However, Rungwa GCA Hunting block is allocated to Game Frontiers of Tanzania Ltd. but has not reopened since 2014. Thus, no antipoaching and surveillance activities from Hunting compagnies occurs in the PA, creating a free access zone (Stampfli, 2016).

In Rungwa FR & GCA, housing and settlement, crop cultivation, illegal hunting and logging were revealed as serious threats degrading the PA values. Medium threats such as livestock grazing and roads development are having some negative impact on the values. Finally, mining and quarrying, gathering terrestrial plants or plant products (non-timber) and fishing are present but not seriously impacting values.

4.4.1.3 Mlele BKZ

Mlele BKZ, also a IUCN management category VI PA, is a 850 km^2 demarcated area within Mlele FR & GCA. Its management rights were officially granted in 2011 to IBA which is still supported by ADAP (Mermod, 2012). The area has thus a complicated legal framework as it is both under the statuses of FRs and GCAs (see above) in addition to the BKZ status. Thus, the legal basis of Mlele BKZ is bound to the statuses of FRs and GCAs and cannot contradict the national laws (see section 3.1.1.1).

In Mlele BKZ no threats seriously degrading values were revealed. However, METT results indicated that medium threats such as logging and loss of cultural links (traditional knowledge) are having some negative impacts. Finally, illegal hunting, mining and fishing are present but not seriously impacting values.

The central government devolved exclusive management rights to IBA through the MoU and thus, the management plan involves only IBA as operational manager and describe the roles of the District and Villages Councils to control and assist the association. Thus, the District duties is to provide technical support or information to IBA concerning planning and operational management but also to participate in the antipoaching patrols and law enforcement activities. However, the District has other priorities and thus only provides few supports to IBA (Didier, 2014). Moreover, since the MoU was signed between MNRT-FBD and IBA before TFS establishment, TFS does not recognize it (Halfani, pers.comm. 2018) and want simply to «apply their slogan “Forest is Wealth” literally» (Mermod, 2016). Indeed, this forest is a national production FR, which means it is allowed to harvest timber within the area as long as a license has been delivered (MNRT, 2003). Nonetheless, as the status of the BKZ makes it the only part of Mlele FR & GCA where timbering is prohibited for conservation purposes, TFS is losing substantial benefits to it and try by all mean to discredit IBA (Halfani, pers.comm. 2018).

Consequently, local managers face the complex structure of Tanzania NRM. Indeed, the United Republic of Tanzania is composed of many administrative levels, different sectors and different institutions (parastatal, central government, civil servant, elected leaders, political parties, etc.). Moreover, the procedures are complicated and

take time due to a lack of governmental institutions efficacity. Management of Mlele District PAs is even more complicated because of the double status they have. Thus, involving different sectors with, sometimes, contradictory legal framework (Hausser et al., 2009; Mermod, 2016). Thus, the power the central government retains over NR despite a theorically decentralized legal framework call into question the benefits local community management could generate (Mermod, 2012).

4.4.2. Planning

4.4.2.1 Rukwa GR

In Rukwa GR, regulations for controlling inappropriate land use and activities exist, especially under the form of the Wildlife Conservation Act No5 of 2009 (also see section 3.1.1.1) and provide an excellent basis for management. Indeed, in 2002, a management plan was completed for the Katavi-Rukwa Ecosystem (Appendix XVIII) and both PAs share common goals on protecting species and habitats. In contrast to Katavi NP, Rukwa GR has the particular objective to regulate and evaluate Trophy hunting in order to ensure sustainable quotas, high standards and ethical values. In fact, there is a General Management Plan that was designed by the WD with the support of a Zimbabwean expert, Ian Games, for Rukwa GR in 2004. Unfortunately, it is only being partially implemented because it was not formally validated (Hausser, pers.comm. 2019). However, an Action Plan defines specific objectives accordingly to constraints such as funding's and other problems which is a good sign for Rukwa effective management. Yet, as the Action Plan could not be provided by Rukwa GR PM, there is a needs to show, as Stampfli (2016) pointed-out, some evidence that these goals are really being put into practice. Indeed, activity reports exist and are sent to Selous GRs HQ (Mrina & Habibu, pers.comm. 2018). Unfortunately, these reports could not be collected either. The planning process also allows adequate opportunity for key stakeholders to influence the action plan. Especially through the implementation of a workshop during the action plan creation. Now, opportunities to involve local communities in the decision process are represented by meetings with villagers during visits in the surrounding villages and teaching in local schools. A follow up of benefits (security, education, job creation, etc.) is also set in place. The Action Plan is weekly backed up in a Regular Work Plan were the following activities are implemented: routine patrols (antipoaching activities & surveillance), response team (investigations), protection of wildlife, supervision of hunting companies, sending people to court, ecological monitoring (aerial sensing). On the contrary, there is only some ad hoc monitoring and evaluation, but no overall strategy and/or regular data collection. For instance, with the example provided by the PM who explained that illegal activities are decreasing. Indeed, evaluation comes from different sources of information and are not properly monitored but comes from a mere observation. Undeniably, this affirmation comes from the count of the animal around (aerial survey, patrols), the illegal infrastructures, timbering and poaching signs encountered during patrols and the fact that 95% of cattle grazing has vanished from the PA (it only occurs at the boundary as Sukumas are entering the GR only from time to time as they are living nearby) (Mrina, pers.comm. 2018). However, as it is not a demonstrated trend but only guessed or assumed and, as mentioned, there is no systematic monitoring, this affirmation might be particularly true for area where hunting is not active anymore as the management is focusing its limited means on area in exploitation.

4.4.2.2 Rungwa FR & GCA

Rungwa FR & GCA as primarily a Tanzanian governmental forest is deemed to implement the National Forest Policy (1998), the Forest Act No14 of 2002, and the National Forest Program which provides a comprehensive framework for management (also see section 3.1.1.1). Other laws and strategies are involved in the management of this PA as Policies, Acts and Regulations relating to the management of wildlife or beekeeping also applies to the PA thanks to it double status (Wildlife Policy of 2007, Wildlife Conservation Act of 2009, Wildlife Conservation Regulation, Beekeeping Act of 2002 & Beekeeping Regulation). These documents are backup in the 2017 Rungwa River FR Management Plan which present the objective for the management of the FR. However, this Management Plan does not present specific objectives for this PA but instead, overarching objectives of the Policy, Act and Regulation mentioned above for all FRs & GCAs in the country. Moreover, as TFS has only been established since 2015 in Inyonga, the Management Plan is gradually implemented in the area. Thus, this document is declined in an annual Operation Plan and then, according to managers and employees, a Work Plan is established each week and all fixed objectives are achieved. Unfortunately, it was not possible to verify those sayings because the Work Plan was not accessible. Moreover, it is doubtful that those Plans are effectively implemented (see section 4.4.6.2). Thus, on paper, TFS main actions are aimed at reducing illegal activities inside the FR and sustainably manage

the forest. In order to implement those objectives, TFS main activities should be anti-deforestation patrols, establishment of checkpoints, management of activities inside the FR through issuance of permits and licenses in partnership with the District, leadership of the Harvesting Committee and some externals services as the training of villagers over management of forests or the sustainable practice of beekeeping. Concerning the GCA part, the WD base its actions on a yearly developed Action Plan. Here too, no specific goals are set for the PA and no regular Work Plan exist. Furthermore, only joint patrols are organized in collaboration with TFS and TAWA to implement law enforcement activities (antipoaching activities). The major inadequacies in the PA design is the size of the area (2480 km^2) versus men power. Even if this range is adequate to maintain ecosystem functions, the sheer size of the area means it is difficult to achieve objectives and implement actions considering actual budget allocation and means.

4.4.2.3 Mlele BKZ

IBA Managers base their actions for Mlele BKZ through the Management Plan of 2007 which was revised in 2014/2015 and send to TFS and MNRT in 2016. The new Management Plan is currently under revision and awaits validation from MNRT and TFS (see section 4.4.1.3 to understand the context). Thus, regulation for controlling inappropriate land use and activities in the BKZ are based on the objectives from the above-mentioned Management Plan and provide an excellent basis for management but are only partially implemented. Indeed, the following actions are regularly undertaken in or for the BKZ: 1) Patrols which are organized for 2 weeks a month, 2) Trainings delivered to VGS for antipoaching and surveillance activities and for staff members, 3) Training for sustainable forest management and sustainable practice of beekeeping, 4) Biodiversity monitoring through CT for wildlife each year and vegetation through transects from time to time. However, 5) Collection of fees and fines cannot be fully implemented as benefit sharing between TFS and IBA are not clear yet and in discussion for the validation of the new Management Plan. Hopefully, achievement of the other objectives within the BKZ are helped by the appropriate design of the PA. Indeed, according to Hausser, pers.comm. (2018) its 850 km^2 are enough to maintain a good portion of its ecosystem and is appropriate for species and habitat conservation. The PA size also allows beekeeping to be practiced sustainably and, in addition, the staff employed to protect the PA (20+ VGS[27]) are in line with the size of the PA (Hausser, pers.comm. 2018). Furthermore, the planning process allows key stakeholders to influence the Management Plan as IBA Central Committee is composed of 12 representatives – 1 for each village – which allows villagers and beekeepers to be represented during the organized meetings (1 every 3 months). Moreover, results of monitoring, research and evaluation are routinely incorporated into planning and information on the critical habitats, species, ecological processes and cultural value of the BKZ is sufficient for most key areas of planning and decision making. Then, a regular Work Plan is drawn up from the Management Plan as management staff meets every week to make feedbacks over previous implemented activities and to discuss current issues to decide which activities should be implemented. Unfortunately, planned activities are not always dependent of their own jurisdiction and may depend over other stakeholders, which can delay implementation of actions. Finally, ADAP initiated a Land Use Management Plan (PLUM) in order to take into account, the long term needs of the PA for adjacent land and water use planning. The PLUM was mainly designed to limit the uncontrolled encroachment of agriculture into GRs and FRs. The PLUM was completed (a 6-step process that lasted 10 years), and the Detailed Village Management Plan for the 12 villages was formally approved. It is as a result of this process – reached at the end of the previous phase (2016) – that ADAP disengaged from it and forwarded the file to the District of Mlele. Thus, the District is now responsible for its implementation. However, in recent years, the process has been undermined by the massive internal migration of Wasukuma that now involve updating the PLUM, but this is no longer the responsibility of ADAP.

4.4.3. Inputs

4.4.3.1 Rukwa GR

Rukwa GR staff have acceptable capacity/resources to enforce the PA legislation and regulations, but some deficiencies remain as described hereafter. First, Rukwa GR HQ is not in the GR but inside Mlele BKZ (Appendix II). Mlele HQ was planned to welcome Katavi NP and Rukwa GR staff, explaining the large number of buildings which are an additional charge (Stampfli, 2016). This emplacement is not practical at all as it is remote (fuel, food

[27] there are about 20 operational VGS, others have given up (especially women following the arrival of children) and some VGS have been fired for professional misconduct

availability, etc.) and no mobile network or internet are available (Mermod, 2012). Therefore, as Mermod (2016) already mentioned, the administrative staff has to go to the nearest town to work and communicate, spending a huge amount of fuel and monopolizing a car, which is an important handicap for management. Second, Rukwa GR is managed locally by a PM and his assistant. According to Mrina & Habibu, pers.comm. (2018) human resources are inadequate for critical management activities. The main reason being that the PA size is too big for the number of employees. Indeed, there is 39 permanent staff members where only 20-25 rangers do on ground patrols. This represent 1 ranger for ~188,7 km^2 in Rukwa GR (Mrina, pers.comm. 2018) which by rule[28] should be 1/25 km^2 (Stampfli, 2016). Rangers are placed by the government and are responsible for antipoaching activities and Trophy hunting supervision. They also deal with bushfire management (Mermod, 2012). Thankfully, staff are qualified and receive active training on a regular basis from TANAPA instructors. This includes paramilitary activities, antipoaching & corruption activities, cartography (GPS, maps, compass), leadership insights, physical fitness training, tracking skills, weapon utilization & care, knowledge of relevant laws & patriotism talks (Mewama, pers.comm. 2018). Thus, staff training and skills are aligned with the management needs of the PA. Other staff members represent storekeeper, housekeeper, secretaries, mechanics and drivers. Third, the available budget is said acceptable by the PM but could be further improved to fully achieve effective management[29]. The financial resources come from two major sources: 1) the central government (TAWA HQ) and 2) external donors (like WCS[30], which make substantial contribution to fuel, food & equipment). The major source of income provided by TAWA HQ is secured, but without the help of international NGO the management of the GR wouldn't be sustainable. Even so, financial resources are insufficient, especially with regard to road maintenance (Mrina, pers.comm. 2018). Equipment and facilities are at disposal, but still some gaps that constrain management exist. At the HQ, they have 4 patrol vehicles, of which 2 are out of order and 2 vehicles for administrative tasks. Therefore, only two vehicles are used for surveillance which is by far not sufficient to patrol a 4194 km^2 area. Indeed, in order to implement all planned actions, 6 vehicles for patrol will be needed, 2 vehicles for administrative purpose and 1 vehicle for community-conservation. In addition, 2 boats are available at Lake Rukwa to control the lake shores encompassed in the GR boundaries. In order to implement law enforcement activities and self-protection, GPS, radios, tents and several semi-automatic weapons are at disposal – some of which are old and in bad condition (Mrina & Habibu, pers.comm. 2018). In addition, Rukwa GR PM showed an interest in CT and drone surveillance. Indeed, the central government is looking forward to implementing new technologies for the surveillance of its PAs. Now, considering access to the GR, budget is insufficient for road maintenance. Thus, roads are in poor conditions and difficult to pass, thereby making some area inaccessible during rainy season (Mrina, pers.comm. 2018). Finally, TAWA HQ in Mlele BKZ is composed of 81 buildings of which only 36 are inhabited. Those 45 remaining houses are used to host TANAPA instructors when training occurs or by occasional visitors (Mewama, pers.comm. 2018). The rest of the time these buildings are empty.

4.4.3.2 Rungwa FR & GCA

For Rungwa FR & GCA, there are major gaps in TFS and WD staff capacity and resources to enforce legislation and regulation. Indeed, TFS is only represented by 9 officers (7 Forest Officer & 2 Beekeeping Officer) whereas, the WD is only represented by 3 Wildlife Officer. Now, considering staff training and skills, the Forest, Wildlife and Beekeeping Officer have expertise in NRM as the majority of them hold a Bachelor degree in NRM. However, the situation could be improved as most of them come from Arusha region and thus are unfamiliar with the Katavi/Rukwa region. Fortunately enough, 1 training a year is organized at Tabora HQ – even if not sufficient as the managers themselves recon. Now considering TFS budget – around 459329000 TSH per month supplemented by fees from permits delivery, royalties and fines perceived during arrests – is by far not sufficient to manage 5 FRs which represent more than 2000000 ha. Thus, the strategy is to prioritize the most degraded areas that are Rungwa FR and Inyonga FR. For example, Rungwa FR has at disposal 2000000 TSH per month whereas the budget required for Rungwa FR according to the management plan for 2017/2018 is of 351108 TSH per month. Moreover, from the overall budget, only 41% was used in 2018 questioning budget allocation and revenue management.

[28] Defined in: James, A.N., Green, M.J.B., Paine, J.R., 1999. A Global Review of Protected Area Budgets and Staffing. WCMC – World Conservation Press, Cambridge, UK, 46.

[29] However, this affirmation could not be checked as budget document could not be provided for security reasons.

[30] The WCS or Wildlife Conservation Society, is an American non-governmental organization whose objective is the preservation of nature in the world and particularly in Africa (www.wcs.org)

Ordinarily, revenues are distributed accordingly, 95% of revenue goes directly to the TFS and 5% is redistributed to the District Council. Within the 95%, 60% goes directly to the central government and 40% can be directly reinvested by TFS Inyonga. Thus, providing a reasonably secure core budget (70% of the annual budget comes from revenue collection and Tanzanian Found Forest). In contrast, WD only received 11000000 TSH from the District Council for the 2017/2018 period and is variable from one year to another. Fortunately, WD can rely on Hunting block allocations where – at the end of each hunting season – 25% of Trophy hunting profit goes to the District Council of which 40% goes directly to the DLNR department, which allows the management of GCA. In general, as Stampfli (2016) pointed-out, «one of the main problems seems to come from the allocation of funds and not the amount available». Indeed, TFS, the District and WD have to send a portion of their revenue from NR exploitation to the central government in Dar es Salaam. This proportion varies from one NR to the other but for example, 75% of wildlife taxes goes to the central government. That is why Benjaminsen et al. (2013) mention a kind of resistance to decentralization. Considering the available budget of these 2 institutions, patrols are the main measures put in place to enforce laws. For the considered 2017/2018 period, only 84 days of patrols were conducted by TFS in the District FRs only representing 17 days of patrols for the 2480 km^2 area considered. The same logic applies to the GCA, where 15 days of patrols are planned by the Action Plan, but since no vehicle is at their disposal, it is very doubtful that they manage to put in place these patrols. They certainly depend more on the joint patrols organized with TFS to patrol the FRs and GCAs as these areas mainly overlap and sometimes call other organizations to supplement their staff during major interventions. These are usually Officers from the DLNRO, TAWA rangers and VGS from IBA. Finally, considering equipment and facilities, these are mostly inadequate for most management needs. Indeed, TFS has at disposal 1 office, 6 computers, 1 GPS, 1 vehicle, 1 motorcycle and at least 1 weapon, while, WD only means available are 1 tent and 1 weapon for patrols. Additionally, 1 GPS has been offered to one of the Officers. As for Rukwa GR, roads are a main challenge. Most tracks are not maintained or even abandoned (as it is normally the duty of hunting companies) and thus difficult to pass during rainy season, making access difficult to entire areas. Moreover, new tracks are created each year for logging. Thus, the number of roads in the PA are not known and no up-to-date maps are currently available making it difficult to managers to know on which tracks to focus during patrols. Overall, insufficient budget and a lack of staff and means does not currently allow TFS and the WD to conduct appropriate law enforcement activities. Indeed, essential means such as vehicles and GPS are significant gaps that strongly limit the implementation of effective management since they are essential tools for the establishment of patrols.

4.4.3.3 MIele BKZ

IBA staff members have good capacity and resources to enforce the BKZ legislations and regulations. Indeed, the NGO is functioning according to a complex structure organization chart (Appendix XIX). As mentioned earlier, the 20+ VGS patrolling the area are enough to protect the BKZ but their work couldn't be possible without the dedicated management team behind them that is ADAP Project Supervisor, IBA Manager, IBA Accountant, IBA Cashier, IBA Documentation Monitoring Capitalization Officer (DMCO), IBA Drivers and IBA VGS Manager. The later making the link between IBA management team and VGS. The management team only implement decisions taken within IBA Central Committee[31] which is represented by a Chairperson, a Vice-Chairperson, a Secretary and 12 Village Representatives. This decision-making group is also the link between the government, villages and the association members for informations and knowledge transmissions (Didier, 2014). Staff members also benefit from regular trainings to enhance their skills to adequately fits the management needs. Thus, the management team benefit from a 3 weeks training session per year corresponding to their work situation. Regrettably, those acquired skill do not stay in the association as staff turnover are frequent. Thus, accumulated training are not as beneficial as it could be and thus, some low qualified employee requires frequent support. In addition to the management team, training sessions are also followed by VGS. Training are dispensed from TANAPA, TAWA, WD and/or the District (lawyers) and consist more or less of the same training as followed by Rukwa GR rangers. Training such as firearm handling, poaching signs recognition and behavior to adopt when encountering offenders are worth mentioning (Didier, 2014). In addition, the VGS CT team received an active training on CT functioning and deployment from Claude Fischer, Yves Hausser and Sandy Mermod[32]. This training includes GPS handling, field protocol filling and animal tracking skills. The training paid off as some VGS are now able to realize these monitoring activities by

[31] The Central Committee is the highest decision board composed of members elected from subcommittees' members to represent the 12 villages of Inyonga Division (Didier, 2014).

[32] ADAP members

themselves. Now considering available funds, the available budget is acceptable but could be further improved to fully achieve effective management. Indeed, IBA has sufficient budget to maintain roads, train beekeepers and build infrastructures like a camp or beacons for boundary – but one should keep in mind that IBA is still financially supported by ADAP and, for the moment, it could not cover the management costs with their current revenues without its support (Mermod, 2016). Thus, improvements could be made concerning the beekeeping activity, particularly the construction of modern beehives (the construction of 40 beehives amount 1600000 TSH) and the purchase of the entire annual honey production that could attract "big" buyers who will provide IBA a secure core budget. However, this is not the case and IBA budget reduces gradually each year as ADAP support comes to an end by the end of May 2019 (MoU, 2016). Fees are collected but make no real contribution to the budget as entry fees are not fully applied. Indeed, only 9 permits for beekeeping were paid in 2018 but 45 beekeepers went to practice beekeeping in the BKZ according to the beekeeping monitoring. This situation is mainly related to the conflict of interest between the three organizations that are entitled to issue permits (TFS, the District and IBA). Regrettably, IBA has less and less power over this situation as TFS does not recognize their rights. Additionally, membership fees for IBA are almost never paid by members and beekeepers participate only very little financially to the association even if benefiting from trainings dispensed by IBA. Consequently, IBA is currently not financially self-sufficient, which could impact the sustainability of the project in future years. Finally, considering equipment facilities, there is still some gaps that constrain management. Indeed, IBA owns an office with adequate furniture and is equipped with computers (5x) and one printer. Additionally, one room is dedicated to store and sell honey. Thus, the room is equipped with harvesting and manufacturing equipment. Finally, IBA possess 2 cars – 1 for patrols and 1 for administrative purpose, 1 motorbike, 1 weapon for the 20+ VGS, ~100 CT and associated furniture, 6 GPS and 3 tents.

4.4.4. Processes

4.4.4.1 Rukwa GR

Assessment of the way in which management is conducted starts with appropriately demarcated PA boundaries which is demarcated on paper by the authority as well as on the ground demarcation elements. Those boundaries are known by local residents through TAWA educational missions which raise awareness toward local communities. Additionally, Rukwa GR access and resource use are controlled during routine patrol as well as by permanent advanced control posts (e.g. Lake Rukwa, Kaololo & Kavu beach) (Habibu, pers.comm. 2018). As exposed above, budget management is adequate but could be improved. For instance, Mrina, pers.comm. (2018) revealed that there is a problem in the system. Indeed, Hunting companies present in Rukwa GR have to pay their fees to TAWA HQ in Selous which then distribute the profits evenly between all GRs in Tanzania. Thus, there is no return of investment from them to Rukwa GR directly. Regrettably, no in-depth information could be gathered in regard to budget amount and distribution. Thus, the following are based on Stampfli (2016) findings and even if it was for the WD management of Rukwa GR, it is certainly still true for TAWA management. Budget management is the task of the PM, but employee salaries are distributed directly by the government and are thus not supported in the on-site budget allocation. 60% of the budget goes for antipoaching activities and 40% for administrative and social expenses. On this 40%, 60% covers fuel costs and food expenses for patrols. The remaining 40% are less explicit but could covers costs like above mentioned trip of administrative staff to the nearest town and the cost of infrastructure maintenance. As shown, staff training and skills are aligned with the PA management needs and there is basic maintenance of equipment and facilities (presence of mechanics and a garage) but some major problems can't be solved at the HQ in Mlele (e.g. 2 vehicles cannot be fixed with local means and should be send to Mpanda for in depth reparation). Requirements for active management of critical habitats, species, ecological processes and, cultural values are being substantially or fully implemented. Indeed, there is a comprehensive, integrated programme of survey and research work, which is relevant to management needs:

1. Ecological Monitoring

As Mermod (2012) noted, ecological monitoring should be carried out within the PA and a program was implemented in the late 90s by the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), the German technical agency for cooperation through the Katavi Rukwa conservation and development (KRCD) project with joint protocols between Katavi NP and Rukwa GR (Hausser et al., 2009). But since the project ended, even nowadays, no NR inventory was implemented. In fact, only TAWIRI aerial censuses provide data on mammal presence (Habibu, pers.comm. 2018). Nonetheless, as mentioned in section 1.3.3., their relevance is poor. During a free discussion, Rukwa GR PM revealed that the government foresees to provide CT to the GR in order to

implement a systematic monitoring of the PA (Mrina, pers.comm. 2018). Yet, this tool seems to be primely planned for surveillance and antipoaching activities.

2. Patrols

According to Mrina, pers.comm. (2018), two patrols are in place. 1) a routine patrol which runs daily (after 30 days, a new team of 6 to 7 rangers arrives and replaces the onsite team), focusing on antipoaching and surveillance activities, but are focusing on Lake Rukwa shores and 2) a response team which is quickly deployed on site depending on relevant information received. Patrols are randomly unleashed to make it less predictable to offenders. Ordinarily, a part of the rangers duty during patrols is to walk about 20 km a day but, as Mermod (2016) discovered, the new generation of rangers does not like to walk nor to sleep in the bush. This affirmation could be verified during field work as an assigned ranger hardly made it through the 10 km walk of first day, even staying in the car for the rest of the assignment. Besides, rangers also take note of encountered animals and illegal activities occurring in the GR. Again, this information was verified during the fieldwork. Moreover, Rukwa GR, alongside Katavi NP, is officially in the MIKE program, having the duty to pick up encountered elephant geographical location with GPS points (Habibu, pers.comm. 2018). During rainy season, no more than 50-60 km a day can be accomplished because of road condition. Furthermore, for obvious reasons, patrols are primarily implemented by car (Stampfli, 2016). It is also during this time of the year that rangers use the boats to patrolled Lake Rukwa (Mrina, pers.comm. 2018). Unfortunately, duration of those sporadic patrols are not known as well as the patrol effort[33] but, when poachers are caught, they are transferred to the nearest police station where they are then brought before the court of the corresponding division (Halfani, pers.comm. 2018). Finally, TAWA joins forces with Katavi NP, Mlele BKZ, the District and/or Hunting companies to implement law enforcement in the neighboring areas (Mjengi, pers.comm. 2018).

3. Trophy Hunting Companies

There are 4 activities allowed in Rukwa GR: Trophy hunting, Beekeeping, Scientific Research and access to Spiritual places. Trophy hunting being the main legal activity of Rukwa GR. Thus, there is good co-operation between managers and tourism operators to enhance visitor experiences and maintain the PA values even if the tour operators per se are not taking part in the management as it is the Hunting companies' duty. For this, the PA is divided into three hunting blocks: Mlele south, Rungwa River and Lake Rukwa (Figure 27) which are respectively allocated to Robin Hurt Safari Ltd., Game Frontiers of Tanzania Ltd. and Green Leaf Ltd. (Appendix XX). All 3 companies have returned their blocs and Tanzanian Big Game Safari Ltd. (TBGS) took over Lake Rukwa bloc. As mentioned earlier, after the two main incomes (donors & government), game fees are the main income of Rukwa GR. Fees are collected and make a substantial contribution to the protected area and its environs (Mrina & Habibu, pers.comm. 2018). Then, hunting quotas are decided on the basis of TAWIRI aerial

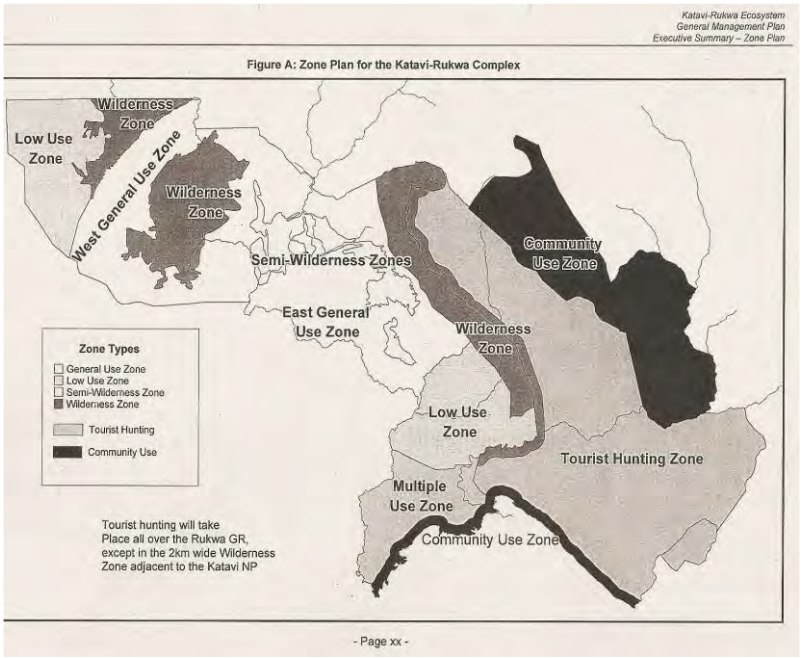


Figure 27: Three Hunting blocks (Mlele south, Rungwa River and Lake Rukwa) are divided in the Tourist Hunting Zone. Those are allocated to Robin Hurt Safari Ltd., Game Frontiers of Tanzania Ltd. and Green Leaf Ltd.

Source: MNRT, TANAPA, 2002

[33] The patrol effort is defined as the expected total amount of time spent during a patrol (Xu et al., 2019)

census and Hunting company's activity reports. To better understand how quotas are calculated, Mr. Mjengi gave us an example: «in 2016 a first census is made were no hunting is allowed. 120 buffalo were counted. In 2017 a second census is conducted. Again, no hunting is allowed and this time 180 buffalo were totaled. Thus, as the buffalo population is increasing, quotas are defined in accordance with the species birthrate in question and harvesting is permitted the next year» (Mjengi, pers.comm. 2018). However, this example does not enable to understand how the hunting quotas are calculated. Moreover, an increase of 60 individuals is somewhat lacking credibility and does not correspond to the natural growth rate of the species. In addition, it is only mature males that can be harvested (Habibu, pers.comm., 2018). However, and since this year hunting quotas could not be obtained for this area, Stampfli (2016) observation are telling. Stampfli (2016) observed that for the year 2015, some species having a hunting quota were even not present in the studied area. For those two reasons, the basis on which quotas are defined seems ambiguous. Thus, it seems difficult for Rukwa GR to ensure sustainable quotas. Showing a lack of monitoring on this particular aspect were financial resources and means are insufficient. Finally, Hunting companies have the duty to financially contribute to antipoaching actions but because there is a lack of control on the duties of the hunting companies, these have varying implication to the antipoaching activities and infrastructures maintenance. However, Hunting companies do not have to count the species they encounter. Again, the fact that there is only one company in operation is quite disturbing. Even if TBGS does what is needed on Lake Rukwa block, the abandonment of the other two blocks implies that neither tracks opening nor antipoaching activities are performed on the north part of the GR.

4. Education and Awareness Programme

There is an appropriate and fully implemented education and awareness programme where TAWA goes to school to raise awareness of what they do and visit around villages to involve local communities for combating illegal activities and avoid people/wildlife conflict. Moreover, there is some co-operation between the PA managers and neighboring management bodies (WD, TFS, IBA) were joint patrols are organized from time to time as explained more in details above. Another contribution comes from the Trophy hunting companies, were 25% of Trophy hunting revenues goes to the District council to support local communities. Those communities have also some input into discussions relating the GR management but no direct role in management as decisions are taken at the governmental level with the strategic plan. Then it is back up by the action plan at the GR level were local communities are involved in the decision process. Finally, when decisions are agreed, local communities leave the management to TAWA. Thus, open communication and trust is maintained between local communities and other stakeholders and the PA managers. Two complementary aspect should be developped in the future to further enhance this aspect: 1) a community development programmes to enhance community welfare, while conserving the PA resources and 2) compensation scheme to actively support local communities from damages caused by wildlife. Finally, by doing antipoaching patrols and thanks to the rangers paramilitary training, TAWA also protects people living nearby the GR, offers job opportunities (as ranger or in the Tourism hunting industry), permit beekeepers to harvest in the GR[34] and help avoid human/wildlife conflict (Mrina, pers.comm. 2018).

4.4.4.2 Rungwa FR & GCA

Rungwa FR & GCA boundary are "known" by the management authorities but is not fully known by local communities. No map of the different FRs & GCAs in TFS and WD office was available. For instance, GIS layers of Rungwa FR & GCA indicate that the PA size is about 2480 km^2 although the Management Plan mention an area of 4028 km^2. This information is, thus, not clear and all interviewee had a different opinion on the issue. Moreover, no GPS points of the different boundary markers (5 signboards et 10 beacons) exist and everything seems to be in Tabora HQ but, being unreachable, it is difficult to assess the situation. Even employee admit that it is sometimes difficult for them to know where the boundary between the village and the FR is. Considering local communities, villagers where informed by the authorities about the implementation of the different national FRs, however some doubts and uncertainties remains over the real boundary for the above-mentioned reasons. On the other hand, this awareness program was not reedited upon arrival of newcomers, such as Sukumas. Budget management is adequate but could be improved for the FR part whereas it is not adequate for the GCA part. Indeed, budget

[34] Ugalla GR and Rukwa GR were two Tanzanian pilot project allowing beekeeping in an area normally prohibiting it in order to give back some rights to local communities over an area they had access before its gazettement (Hausser, pers.comm. 2018).

management is done internally by the TFS District Manager and WD District Game Manager respectively but, despite a budget management strategy, it is not always enough to carry out all planned activities. Thus, priorities are set on important elements such as FRs & GCAs invasion by cattle herding and implementation of patrols. Additionally, PM complains about the insufficient budget allocated and justify through it the current management that is still not very efficient. Considering equipment and facilities that are by far insufficient, it is at least well maintained. Moreover, equipment and facilities are listed in an inventory present in the annual reports. At least, survey – organized mainly in co-operation between managers and neighboring official, which are relevant to management needs – are implemented but are only partially effective in controlling access to the PA and NR use.

1. Ecological Monitoring

A vegetation monitoring was conducted in 2016 for the implementation of the 2017 Management Plan of FRs and is the only serious monitoring carry out in the PA so far. Normally, NR inventory are the building blocks for a proper Management Plan and should thus limit the pressure on NR through regulation of access and sustainable harvesting (Mermod, 2016). Accordingly, for Rungwa FR & GCA, employee lack data to carry out proper management as too little information is at their disposal to take informed decisions.

2. Patrols

As being also a GCA, Hunting blocks inside the PA are allocated to Hunting companies and, as Hunting companies are, in Tanzania, mandatory to organize antipoaching patrols Rungwa FR & GCA should be fully protected. However, as mentioned in section 4.4.1.2, Rungwa GCA Hunting block is allocated to Game Frontiers of Tanzania Ltd. but has not reopened since 2014. Thus, no antipoaching and surveillance activities from Hunting compagnies occurs in the PA, creating a free access zone where no instance actively monitors wildlife (Stampfli, 2016). In reaction to this situation and according to Rungwa FR & GCA managers, 15 days of patrols per month should be implemented in each FRs & GCAs. Unfortunately, the lack of means and staff implies that only 17 days of patrols are executed per year for a single FR or that a focus is made on one or two PAs only. Additionally, road access are not fully known by Officers which implies that, most of the time patrols are focusing on villages to find information and arrest offenders. Also, these patrols are never set on foot and only vehicle patrols are conducted, questioning it usefulness. Finally, a Check Point System is set in place to control access to the PA. This system seems to work since many arrests have been made. For instance, 116 licenses have been inspected and 84 vehicles have been thoroughly checked in 2018.

3. Logging, Trophy Hunting Companies & Beekeeping

A system of permits and licenses is in place to control legal activities carryout in FRs & GCAs. However, a lack of "on the-ground" control occurs. No proper management of NR are in place. For example, as FR are PAs where logging is allowed, TFS Officers should proceed to a distribution of blocks to be exploited but instead, logging companies have "free access" to the PA and are even not constraint on DHB to be exploited. Normally, the process should be as follow: 1) Villages bordering the FR should agree on the logging companies allowed to exploit the resource and 2) the District Harvesting Committee (composed of TFS, Mlele District and village representatives) define the number of trees allowed to exploit. However, as Mermod (2016) showed, TFS 2014-2019 timber harvesting plans are fairly basic documents and are based on partial inventories and other secondary data. Appendix XXI presents the allowable harvest from these harvesting plans and shows that the allowable harvest per year for Rungwa FR & GCA is 151932 m^3. Now, considering the GCA part, licenses are usually issued to Trophy hunters, when a Hunting block is allocated to a Hunting company but, as Trophy hunting – according to District Game Manager – is not allowed since 2016 in Rungwa GCA, no hunting licenses were delivered and thus, no fees could be perceived by the WD. In reality, as the Hunting company ceased the exploitation of the Hunting block in 2015 and formally returned the block to the MNRT in 2016, it is normal that no permit delivery occurs. Nevertheless, usually, quotas are established by the WD in Dar es Salaam and – as for Rukwa GR – it seems that quotas are issued without accurate information regarding existing wildlife populations and without taking hunting results of previous years into account even if the DGO explained it the way around through an example. Indeed, hunting quota do not change over the years and – as Stampfli (2016) discovered – some species having hunting quota are even not found inside the PA. Finally, as for Rukwa GR, Mermod (2016) noted that the WD staff and some Hunting compagnies antipoaching units harvest some medium-sized mammals to fulfil their "needs", which are qualified as excessive by some hunters. Of course, this activity is not regulated and occurs with impunity. Finally, local hunting – which was banned from 2015 to 2018 – is now allowed and local people can apply again for a permit to the WD.

However, prices are too expensive in comparison to local revenue and thus, forces local hunters to hunt illegally. Unfortunately, no documents of game price were available, but the District Game Manager knows them by heart…However, informations on hunting fees are accessible on TAWA as well on hunting companies websites (http://www.tawa.go.tz). As Rungwa has the double status of FR & GCA, attention should be paid to which authority issued the permit. Indeed, as Mermod (2016) rightly mentioned, «the authorities which issue the permits are not necessarily the ones which plan the activities.» Indeed, for forest and wildlife resources, quotas are defined by central institutions (TFS and TAWA) as this NR generate high revenues. Conversely, honey is managed by the District level as this practice is considered a "side" activity. Thus, no quotas are defined for beekeeping and since a permit can be valid for 5 beekeepers, it is not possible to know the exact number of beekeepers exploiting the PA (Mermod, 2016). Controversy, since TFS took over the management of the FR, beekeepers need to apply for permits to TFS office but, as prices are exorbitant, they prefer to request it directly to the District which propose a much more affordable price. Thus, TFS has no mean to control the number of permits delivered and without a proper patrol system, few permits are checked. This aspect should, however, be answered with the introduction of a new registration system of beekeeper camps even if a Beekeeping Officer admits that it is not possible to check them all (Appendix V shows a non-up-to-date map collected by ADAP between 2004 and 2006 were a great number of beekeepers' camps are represented).

4. Education and Awareness Programme

Through the same procedure as mentioned for Rukwa GR, Local communities have some input into discussions relating to management through committee but not direct role in management. Moreover, there is a limited ad hoc education and awareness program through trainings for beekeepers and sustainable management of forest resources. Beekeeping Officers mentioned a 6 time a year training but interestingly, villagers did not notice that this training had taken place, raising doubts on its real implementation... Regarding the GCA, awareness programs are conducted in the neighboring villages and mainly focus its effort on the clarification of benefits sharing system set in place between the Hunting companies, the District and the villages in order as villagers perceive the benefits, they receive by conserving the forest and fauna.

4.4.4.3 Mlele BKZ

The boundary of Mlele BKZ is known by the local authority and neighboring residents and is appropriately demarcated by beacons. Information boards were also added in 2017 (Figure 28) so that users are aware in which kind of area they are entering and know the local authority in charge of the PA. Of course, beacons and panels are maintained or replaced if there are degraded and for each element, GPS position were taken and saved on a map. Those maps are available in the Village Executive Office and local communities are aware of the borders and knows exactly where to find them. In order to facilitate their identifications, VGS – during field patrols – ensure that beacons are well demarcated and visible. As was presented in section 4.4.3.3, budget management is adequate but could be improved as currently it is done by ADAP in Switzerland which then transfer it to IBA which is then in charge of applying it. However, nowadays, budget management from IBA management team seems efficient and to be guaranteed. Considering equipment and facilities, basic maintenance is carryout and an inventory of IBA property is held where furniture's are checked once a year. In general, material is in good condition but storage could be improved especially for battery used in CT. Indeed, batteries are stored in bulk inside boxes which affects their longevity (Zimmermann, pers.comm. 2016). Indeed, to avoid battery being discharged or even worse, taking fire, the anode and cathode should never touch. Implying a separate storage as proposed by Buffard (2018). Additionally, the two cars are old and need frequent maintenance. Fortunately, cars maintenance are rapidly fixed and does not hinder management activities to be carryout.

Figure 28: Information boards were placed at the principal entry points of Mlele BKZ to inform users about local authority in charge of the PA

Many of the requirements for active management of critical habitats, species, ecological processes and cultural values are implemented in the BKZ and the area is locally recognized as the best managed PA in the District.

Indeed, VGS are responsible for the management activities implementation as they work under the management team. Thanks to their practical knowledge of the management VGS implement regular antipoaching patrols, ensure the ecological monitoring of the BKZ and maintain borders, roads and infrastructures in good state (Didier, 2014). Thus, protection systems are largely or wholly effective in controlling access and resource use.

1. Ecological Monitoring

There is a comprehensive, integrated program of survey and research work, which is relevant to management needs. Indeed, monitoring and evaluation system are well implemented and used in adaptive management. For example, Wildlife monitoring is in place since 2008 and is carryout once every year, Vegetation monitoring were performed in 2004, 2013 and 2017, Beekeeping monitoring is conducted on a yearly basis since 2016 and a Village survey was conducted in 2002. In addition, Patrols report & Annual report are completed. Finally, this integrated program of survey and research work was supported by eighteen or so Bachelor and Master thesis and scientific publications and provide information for the management of the BKZ (www.adap.ch).

2. Patrols

VGS are villagers who have been delegated the right to enforce laws and patrol Mlele BKZ. VGS main task is to control and fight illegal activities. Therefore, they are actively trained to conduct antipoaching patrols and surveillance activities, identify and heckled illegally exploited forest products and non-forestry products such as beekeeping. Currently 20+ VGS are trained and available. Patrols are, in the MBKZ, the main measures to check and ensure that laws are respected. In the BKZ, 14 days of patrols divided in two sessions of 7 days are organized every month. For information, a 7-day patrol costs approximately 900000 TSH. To patrol, the entire surface of the BKZ is tempted to be covered and some areas are visited according to information obtained on illegal activities. Thus, a vehicle is available to bring the VGS to the planned destination and is then completed by a 10 km on foot patrol per day. Additionally, some opportunistic controls are carryout during trips outside the BKZ (Mermod, 2016). However, the implementation of tracers inside GPS brought to light that VGS seem to be reluctant to walk and that patrols were mainly made by car. As consequence, only 37,5% of the area has been covered by patrols, and mainly near roads (Appendix XXII) (Buffard, 2018). Buffard (2018) also constated that patrols are not randomized in terms of timeframe, making it predictable for offender to know when a patrol is set free. This constraint shows the importance of foot patrols as this practice increases the chances of arrest and/or property seizure of related illegal activities. This is why the planning of both means is crucial to limit the presence of illegal activity inside Mlele BKZ. Additionally, 2 permanent guards are placed at Mlele camp for surveillance purpose. Furthermore, regular contact between managing institutions and, from time to time, co-operation to conduct joint patrols are organized between TFS, WD or TAWA upon information received. However, Tanzania Big Game Safari Ltd. does not take part in joint patrols inside the PA but lead antipoaching, even in the rainy season, activities. However, TBGS focus their activities on the parts of the block not covered by the VGS. Overall, with regards to the resources available (1 car and 1 firearm), VGS are competent and effective in the field. Laws are well enforced, users know the rules and most play the game. For those, who don't and are caught, they are brought to the police and usually the next day are presented in front of Mlele District court in Inyonga.

3. Logging, Trophy Hunting Companies & Beekeeping

All legal activities allowed inside the BKZ are subject to permit delivery in order to facilitate their control. However, this process is complicated by the fact that, as mentioned above, 3 institutions have now the capacity to issue permits for beekeeping activities in the District. Consequently, confusion occurs and maybe detrimental to the management of the BKZ (see above). Even worse, permits to enter the BKZ are sometime delivered by neighboring District while no right allows them to do that. Nevertheless, the problem has been exposed the concerned parties in order to clarify the situation but IBA is still awaiting results up to now.

4. Education and Awareness Programme

There is an appropriate and fully implemented education and awareness programs which provides local communities appropriate training. First, training related to income generating activities are implemented. The main target groups are beekeepers, but women's groups are also regularly involved. Generally, courses are offered once a year and consist mainly of modern beekeeping practice training, but also sustainable management of forest product training, No timber Forest Product training and batik training. Second, training to raise community awareness on the BKZ management are implemented. Indeed, information on IBA activities inside the BKZ are

regularly provided by IBA, through IBA Village Representative or directly by missions set-out by the management team, to local communities. Those communities are also directly contributing to the improvement of the BKZ management through the election of IBA Village Representative and the representation of villager voices during meetings held every 3 months at IBA office. As a result, villagers put their trust in the association and regularly expose their ideas and problems to managers and try to find affordable solutions for both parties. This process is helped by the fact that most staff members are from Inyonga or neighboring villages. Additionally, when a serious problem occurs, IBA Central Committee reacts quickly and tries to find acceptable solutions.

4.4.5. Outputs

4.4.5.1 Rukwa GR

As a regular work plan exists for Rukwa GR, many activities mentioned above are implemented. But, even with TAWA effort to implement education and awareness programme, conflicts between local population and conservation agents remains as the latter main strategy is a coercive one (Table 13).

Table 13: Conflicts typology

Adapted from Hausser et al. (2009)

Type of conflict	Involved parties	Type of areas	Manifestation of conflict	Drivers of conflicts
Boundaries conflict	Communities vs. PA management/law enforcement by TAWA, TFS, WD, IBA	GR, FR, GCA	Boundaries of PA not accepted, encroachment into PA, poaching and illegal harvesting of NR	Historical claims of communities on land and resource use rights. Sense of ownership of areas, argument of legitimacy, land converted to PA is perceived as lost for communities
Access	Communities vs. PA management	GR, FR, GCA	Illegal access to PA	Historical claims of communities on land and resources use rights, sense of ownership of areas, spiritual practices
User rights/use by conflicting parties	Communities vs. PA management	GR, FR, GCA	Contestration of the rights of local communities to practice beekeeping in PA	Historical claims, double status of FR/GCA: GCA overlaps in the western Tanzania with FR and village land. This is creating room for conflict among users about user rights
Regulation of illegal use	Communities vs. PA management	GR, FR, GCA, village land	Almost all the local hunting is qualified as "poaching" since the gazettment of most of the land as PA and thus repressed	Economies of local livelihoods still dependent on natural resource (nutrition and revenue). There is a strong demand for bushmeat in local markets, and ivory is still illegally collected and traded. There are not enough resources to conduct efficient law enforcement
Land use and mangement conflict on village land (tenure insecurity)	Different useres within the community	Village land	Conflict between different users, encroachement (e.g. of cattle into farmland), lack of sense of ownership leads to lack of responsibility	No previous village land demarcation, no land title in villages for the communities. No ‘‘forum’’ for villagers to plan the use of their land in participatory way
Benefit generation	Communities vs. PA management	All type of land	Lack of benefit legally accruded by communities from natural resource management	No incentive to conserve wildlife and habitats on village land as the current framework don’t allow local landholders to accrue revenue from wildlife management. Outreach action not effective or not effectively distributed. The only ways to generate benefits for local communities are through illegal use of resources or land conversion to agriculture
Human/wildlife conflict	Wildlife vs. Crops, livestock and communities	Village land	Crop destruction by herbivores, livestock losses by predators and human injuries and deaths by wildlife	Proximity with wildlife, absence of organized systems to protect crops from animal raiding. Low level of protection of livestock and human beings from predators. No mitigation/compensation schemes to damages

In Rukwa GR, 130 to 150 people are arrested each year (all categories combined). The number of arrests amounted 122 people in 2017. Of these arrested, 70% are poachers and the remaining 30% are arrested for illegal logging and pastoralism. The offenders are either farmers from Inyonga and neighboring villages or another District. 90% of those offenders go to court. TAWA follows the cases in order to make appeal if necessary. Even if cattle grazing has experienced a 95% decrease in the area and is cantoned to Rukwa GR borders it is still a major problem for the PA. Indeed, the growing population of Sukuma – a migrant agro-pastoralists tribe – who leaved the central part of Tanzania due to drought and overexploited pastures and water availability (Hausser et al., 2009) still exerts an increasing encroachment pressure. Indeed, cattle grazing was usually a problem only during dry season but

nowadays, in order to avoid their own crops browsing, Sukumas also enter the GR during rainy season (Mrina, pers.comm. 2018). Table 14 shows activities allowed inside the studied PAs. This table highlights the fact that most extractive activities undertaken by local communities become illegal through law. Wildlife hunting is totally prohibited and timber and beekeeping harvesting subject to permit system. This situation is not improved by the fact that available land for NR extraction only represent a 640 km^2 of village land surrounded by 13'050 km^2 of PAs (Hausser et al., 2009). As the authors cited, «enhanced conflict resolution capacity involving private stakeholders, conservation agents and local communities, as well as improved collaboration between projects, helped to solve part of the conflicts. This was the case with the negotiation of rights of access for beekeepers to Rukwa GR». It has to be noted that the beekeeping activity is reserved to the northern part of the Kasege community area (Habibu, pers.comm., 2018). In the same extent, with community-conservation engagement, people are more aware, they become informant on the critical habitats, species, ecological processes and cultural values of the PA. Thus, supporting conservation effort (Mrina, pers.comm. 2018).

Table 14: Legal activities encountered in the studied PAs

Adapted from Mermod (2012) & Stampfli (2016)

Activity	Rukwa GR	Mlele BKZ	Rungwa FR/GCA
Trophy hunting (permit mandatory)	✓	✓	✓
Local hunting (permit mandatory)	×	×	✓
Fishing (permit mandatory)	✓	×	✓
Beekeeping (permit mandatory)	✓	✓	✓
Mining (permit mandatory)	×	×	✓
Registered temporary camps	✓	✓	✓
Fruits, larvae, mushrooms & roots harvesting (permit mandatory)	×	✓	✓
Scientific research (permit mandatory)	✓	✓	✓
Cultural activities (permit mandatory)	✓	✓	✓
Timbering (permit mandatory)	×	×	✓
Rejected timber harvesting (permit mandatory)	×	✓	✓
Tourism	✓	✓	×
Settlement	×	×	×
Agriculture	×	×	×
Cattle grazing	×	×	×

Considering hunting quotas, even if their definition is controversial, hunting quotas are usually respected as it can be observed in Appendix XXIII for the hunting period 2014/2015 and 2015/2016 (Stampfli, 2016). Trophy hunting most popular species in Rukwa GR are: buffalo, hartebeest, leopard, roan and sable antelope (Habibu, pers.comm., 2018). Besides, some species like the hippopotamus, giraffe, leopard, lion and puku benefit from IUCN Red List Status (Appendix I). For lion, hunting quota seems, for some years, quite high (Stampfli, 2016). Especially as the specie seems rare in the area. Indeed, this aspect was already revealed above and shows that Trophy hunting is not practiced sustainably. Now comes the question of the patrols distribution, the north part of the GR seems to be a "free access" because few patrols are carried out in this sector (only the response team patrols this area depending on received information) and as it was observed during fieldwork, most tracks are abandoned. Even so, only few illegal activities signs were discovered (Appendix XXIV) in the bush and very few pictures were taken by the CT (Figure 29). Unfortunately, the absence of 2 Hunting companies does not improve the situation as Mlele South block is unoccupied. Indeed, the presence of a Hunting company would help limit illegal activities in the PA. Another anecdote comes from the fact that rangers them self, harvest some mammals. Of course, no quotas are defined but this practice only occurs for self-subsistence and only common species are harvested (Rukwa GR ranger, pers.comm. 2018). Anyway, legally this practice is ambiguous. Finally, as only 1 hunting block out of 3 is

operating, facilities on the 2 non-operating blocks need reparation as they are not suitable to welcome customers. Thus, visitor facilities and services are adequate for current levels of visitation (6-12 tourist/season) but should be improved, especially if photographic tourism will be implemented as it is planned in a near future (Mrina, pers.comm. 2018).

Figure 29: CT data also help access illegal activities inside the PA even if few pictures were collected

4.4.5.2 Rungwa FR & GCA

Regarding Rungwa FR & GCA, 6 main activities are allowed inside the PA: Trophy hunting, timbering, fishing, beekeeping, scientific research and access to spiritual places (Table 13). However, as mentioned above, Trophy hunting has not been practiced since 2014. The reason being that the Hunting company in charge at that time was not accepted by local communities and faced some retaliations (Hausser, pers.comm. 2018). However, quotas seemed to be delivered anyway and effective harvesting for the 2013-2016 period in Rungwa GCA were provided. That is, 13 buffalos, 2 crocodiles, 2 duikers, 5 elands, 3 greater kudus, 18 hartebeests, 3 lions, 8 reedbucks, 6 roan antelopes, 9 sable antelopes, 11 topi, 5 warthogs & 5 waterbucks. Now, with regard to timbering, 2018 presents a ban over random harvesting and sales of forest products in all FRs as measure seeking to increase the central government revenue collections (https://allafrica.com, 19.02.2018). Therefore, more illegal timbering activities were encountered during fieldwork (Appendix XXIV) and showed that some logging companies have no scruple to exploit the forest even if a ban is in force. However, as comparing information, 16 licenses were issued for Rungwa River in 2015 and out of the above-mentioned 151932 m^3 allowable harvest per year, 650 m^3 of Mninga (*Pterocarpus angolensis*), 585 m^3 of Mkora (*Afzelia quanzensis*) and 65 m^3 of white padouk (*Pterocarpus tinctorious*) were harvested in the PA (Stampfli, 2016). Even if quotas of all NR are not based on scientific data, permits and licenses are issued. Thus, managers should ensure law enforcement by controlling and sanctioning users if necessary. Yet, some stakeholders deplore that illegal users caught by TFS are simply warned or have some minor penalties while they should receive stronger sanctions (Mermod, 2016). Now, with regards to wildlife resources, between 10 to 20 poachers are arrested each year in Mlele District and each time a poacher is arrested, a file is opened at the police office and lawyers of the District follow the case (Stampfli, 2016). Finally, as Mermod (2016) already exposed, the last factor influencing management of Rungwa FR & GCA is the growing human population of the District and the resulting pressure over NR, which would be difficult to contain even with a stronger management. The pressure over NR is mainly due to the economic conjuncture that in grips the whole country and pushes people to use NR for their livelihoods or to earn money. The international market also plays a significant role in NR extraction, especially for the timber, tobacco and more recently minerals. Lastly, activities such as grazing, or farming occur in FRs only because of the scarcity of land in the village land and its mismanagement as explained in section 4.4.5.1. Thus, raising the question «that not enough land was left for village land in the 50s and is now causing problems in the Inyonga Division» (Mermod, 2016). In general, there is a poor opinion of land use management in Tanzania and the situation is not improved by the fact that 1) District Land Use Officers have to be financially supported by projects to achieve their assigned tasks and 2) there is a lack of intersectoral coordination (Mermod, 2016).

4.4.5.3 Mlele BKZ

At first, and what Buffard (2018) qualified as the major problem, the legitimacy of IBA's management over Mlele BKZ has been challenged by TFS since it took over the responsibilities of MNRT-FDB in 2010. Indeed, TFS refuses to recognize IBA's management's rights over the area and sees IBA as a rival instead of a partner. Thus, this situation led to a serious worsening of relationships between the two parties and resulted in the non-signature of

the new MoU between MNRT-FBD, TFS and IBA so far. As such, «IBA is denied the right of collecting fines from offenders practicing illegal activities within the BKZ. While this item was collecting lots of funds until recently (Halfani, pers.comm. 2018), it is reduced to zero since 2010». However, this situation can not represent a sustainable source of income since ideally there should no longer be illegal activities if management is effective (Hausser, pers.comm. 2019). Another already mentioned bias is TFS and the District directly emitting permits to Beekeepers for the BKZ, cutting down IBA subsequent revenues. Now, considering timber products, an arrangement had been reached in the past years between TFS and IBA to allow the later to collect rejected timber products for free, or at a very low price in order to construct modern beehives. Despite this, no wood was allowed to be collected and beehives are still expensive to produce and almost unaffordable for beekeepers (~80'000 TSH). Furthermore, TBGS exploitation of a hunting block within the BKZ should allow a retrocession of funds to IBA as 25% of TBGS total fees are reassigned to the District. «Considering then an imbalanced situation of the costs of conservation (material, training, fuel, VGS salary, …) at the expense of IBA and the profits for the benefits of WD and TBGS, this leads to a market distortion, depriving IBA of a serious source of income. Despite recent several attempts to improve this situation (Hausser, pers.comm., 2018), no agreement has been set up». At least, local communities «seems to be aware on what IBA is conducting in Mlele BKZ since information has been spread for years now» and appreciate beekeeping trainings as they reckon that the quality of honey has considerably improved over the past years. However, TFS problem stalled IBA scheme of benefit redistribution to local populations and stands the risk of a deleterious situation. Indeed, as IBA has not reached its sustainability yet and has no benefits to redistribute – as it has been impossible to set up the honey taxation system which would have represented a sustainable source of income (Hausser, pers.comm. 2019) – local communities, deprived of right to gather products in the PA and receiving poor or no benefits from it, may overcome the prohibition and practice illegal activities such as poaching, mining or illegal logging (Buffard, 2018).

4.4.6. Outcomes

4.4.6.1 Rukwa GR

To assess the outcomes and the extent to which they achieved objectives, one should first look at TAWA Mission and Vision. TAWA «see conservation as one of the key processes sustaining life and with potential to effectively contribute to socio-economic development through creation of employment, availing recreational environment and providing a genetic resource bank for potential multiple uses and benefits for future generations». Thus, TAWA «aspires to see that wildlife resources in its PAs are effectively protected and are thriving» (www.tawa.go.tz). Indeed, by effectively implementing law enforcement and curb illegal off take of wildlife resources, TAWA protects and conserve wildlife in an administered area that is designated as a GR. It thus effectively administers protection and utilization of wildlife in a preserved area being part of the Katavi-Rukwa ecosystem which is a major ecosystem for the conservation of an entire mammal community of which some are on the Red List of Threatened Species (Appendix II). By implementing government commitment to National, Regional and International obligations in relation to the development of the wildlife sector, TAWA ensures – to the extent of the financial resources and means provided – the systematic management of financial, human and NR for the conservation of wildlife. As seen above, TAWA join forces with other institutions to unsure wildlife is secure and mitigates human/wildlife conflict in the villages surrounding the GR. TAWA also ensures an equitable distribution of cost and economic benefits to local communities in order to sensitize, educate and communicate the values of wildlife resources and ensure a participatory approach to wildlife management during the decision process to villagers and other stakeholders. Finally, it also improves wildlife resource base investment in collaboration with Hunting companies and local communities (e.g. through beekeeping). However, some aspect of ME are not optimally implemented. Indeed, TAWA issue permits for wildlife resources utilization but, as we saw, hunting quotas – even if not in the hands to Rukwa GR management – are not sustainably defined and they cannot address all land use conflicts (e.g. cattle grazing) affecting wildlife by they own. Undeniably, this particular aspect is closely related to another constraining factor, corruption. Currently, Tanzania is in the grip of a high level of national corruption as it is ranked 99th out of 180 on the corruption perception index (Transparency International, 2018). The country's governance is riddled by patronage practices that occur at all governmental levels (Benjaminsen et al., 2013; Nelson et al., 2007). For instance, in 2017, Rukwa GR PM was arrested and arraigned with immediate effect. He was accused to allegedly allow poachers and business people to collect timber and logs illegally in the GR. The PM and his fellow TAWA officials even stamp the logs to show that they were authentic forest products harvested legally while it was not true (https://allafrica.com, 03.02.2018). Governance in the hunting companies is not better either. As Mermod (2016)

noted, « [governance] is not transparent at all and in the grip of extensive corruption, especially in regards to the leases of hunting blocks which are allocated to friends of politicians or former politicians (Benjaminsen et al., 2013; Nelson & Blomley, 2010).» As such, some biodiversity, ecological and cultural values are being partially degraded but, thanks to a complete reform – undertaken by the central government – over Rukwa GR management, goals on protecting species and habitats have been maintained. Thus, it seems that the most important values have not been significantly impacted even if a lack of monitoring is recognized. More so, the particular objective of GRs to regulate and evaluate Trophy hunting in order to ensure sustainable quotas is not fulfilled.

4.4.6.2 Rungwa FR & GCA

The Mission of TFS is "To sustainably manage the National forest and bee resources in order to contribute to the social, economic, ecological and cultural needs of present and future generations". Thus, TFS should be "A center of excellence in the conservation and sustainable supply of quality forest and bee products and services in Tanzania" (www.tfs.go.tz). However, one of the main objectives fixed by the central government implies an enhanced sustainable supply of quality forest and bee products but loggers admitted that forest management is not sustainable and that the target hardwood species mentioned above are almost inexistent because of unregulated harvest. Those sayings are also confirmed by local communities who see the forest increasingly being deforested by the Sukumas because no restriction so far prevented it. Undeniably, TFS objective to enhance good governance and gender balance is by far not achieved as FRs & GCAs are poorly managed by government managers and legal operational rules are not enforced. Indeed, controls in the field are very weak and users are not treated with equity with permit/license issuance disconnected from a role to achieve sustainability, having only economic and power purposes, which maintain patronage relationships. Furthermore, there are conflicts among the managers and between the managers and the users which sometimes result in violent interactions[35]. «Managers focus on less damaging practices such as bark hives or firewood collection instead of big threats like encroachment or logging» and confirms what Mermod (2016) rightly pointed out. In addition to a lack of collaboration and communication between central and local bodies, there are intersectoral conflicts between the local managers that Hausser et al. (2009) already observed in the region 10 years ago. The recent establishment of the Mlele District and the TFS complicate the situation further. Conversely, regarding NR, the majority of governmental Managers and Officers, think that Rungwa FR & GCA is not in such bad conditions compared to Inyonga FR and only areas near villages are in poor conditions (3% of Rungwa FR & GCA is deforested) and is mainly due to agricultural encroachment. Only the District Game Manager mentioned an average situation in regard to wildlife since financial resources, means and manpower are not enough to protect the resource. Now regarding the last and strange objective of TFS – as it should not be their focus – to support and reduce HIV/AIDS infections, local communities never mentioned such actions and only perceive some economic benefits from TFS revenue through the above-mentioned sharing system where 5% of TFS revenue is redistributed to the District Council who then redistribute these sharing's to the communities. In addition, when hunting blocks are allocated, local communities also perceive some benefit from it. Indeed, 25% of Trophy hunting profit goes to the District Council of which, 40% goes to the department and the extra 60% are redistributed to local communities. However, TFS policy is to employ people from outside the region to prevent cronyism and other conflicts and thus, preventing job opportunities to local communities to enhance their livelihood.

4.4.6.3 Mlele BKZ

After more than 15 years, the main results are that local beekeepers have successfully established a community-based organization, IBA, which is recognized by all local and regional stakeholders in the NR sector – even if some friction exist – and established a 850 km^2 BKZ in part of the Mlele FR & GCA. Management rights were granted to IBA (in partnership with the villages and Mlele District) following an agreement with MNRT-FBD which brought the BKZ under effective management and prevent encroachment thus, stabilizing the BKZ boundaries (Figure 30). Therefore, Mlele BKZ has relatively well-preserved forest habitats compared to adjacent reserves and the national average and is also recognized as the largest community-managed beekeeping area in Tanzania. IBA objective to encourage sustainable multiple uses of the forest enabled to protect and maintain the quality forest for apiary products through multiple trainings. For instance, over the past years, more than 3000 beekeepers have been

[35] During fieldwork, a team of VGS employed for the new project of ADAP in the Rungwa corridor (see section 1.3.) was attacked by Sukumas supported by TFS employee and the project car was confiscated by TFS Officers for one month (Halfani, pers.comm. 2018)

trained in modern beekeeping and hundreds of women gathered in economic groups registered within the District received training in various fields (production of printed fabrics, soap production, production of fruit juice, jams and wines wild fruits). Accordingly, trainings allowed to generate increasing income. For example, honey production passed from 7 tons in 2002 to 120 tons in 2014 and honey price consequently multiplied by 10 thanks to a better honey quality. Indeed, honey production for Mlele BKZ alone is about 40 tons per year. But results do not stop at the local community level as the better management also enhanced conservation in the BKZ. Indeed, various survey and research work highlighted the important biodiversity of the PA, both in terms of flora and fauna. Thus, 124 or so tree species were identified and 56 species of medium- to large-mammals are present in the BKZ, indicating a high species richness – where all niches are occupied – for a low IUCN management category whose resources are exploited (www.adap.ch).

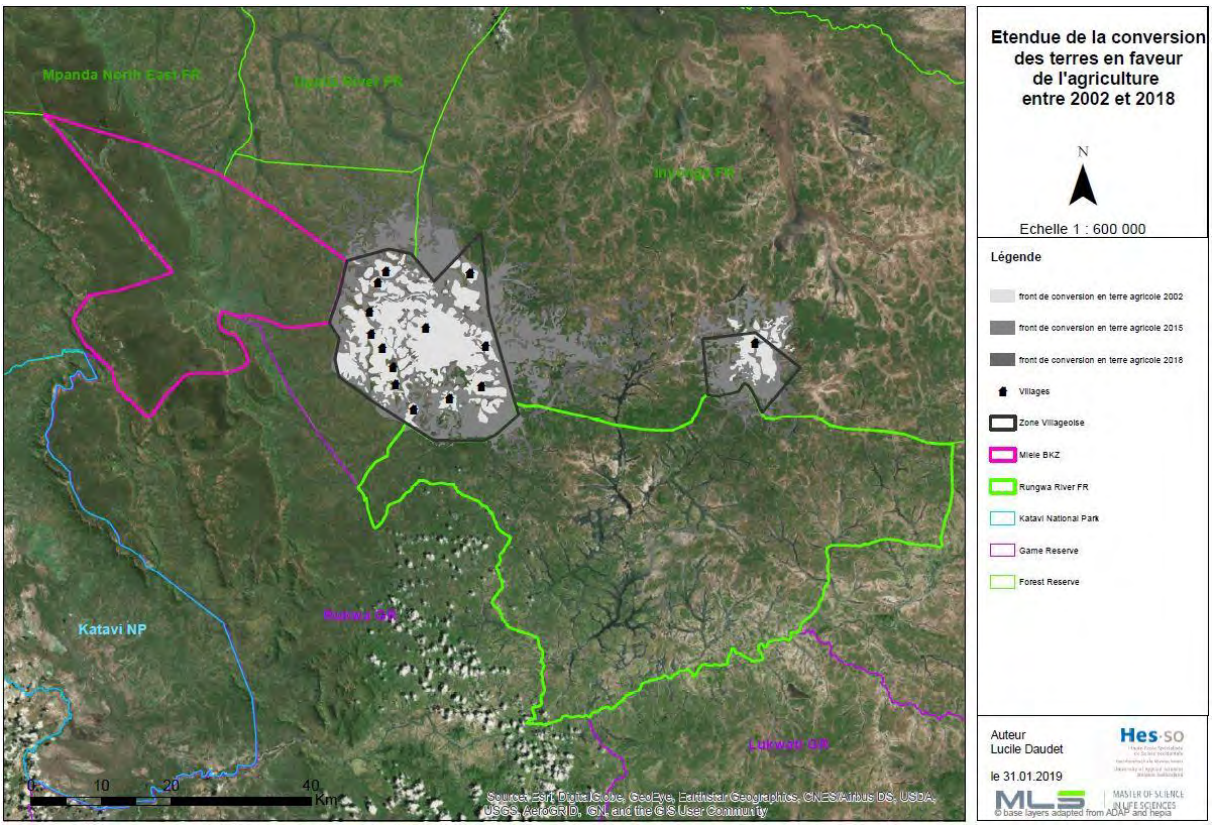


Figure 30: Mlele BKZ effective management can be appraised through cartographic modeling. It shows that the border of the BKZ is the only one truly respected. Thus, showing the effective law enforcement activities conducted within its borders. Which in turns ensures the preservation of the PA values

5. Discussion

5.1. Species Richness

In our study, 52 species of medium- to large-mammals were detected out of which 17 were carnivores. In Rukwa GR, 16 carnivores were detected out of the 46 mammals detected. In Rungwa FR & GCA, 13 carnivores were detected out of the 40 mammals detected. In Mlele BKZ, 10 carnivores were detected out of the 35 mammals detected. The higher research effort in Rukwa GR (3202) might explain this situation whereas the lower research effort in Rungwa FR & GCA (2249) compared to Mlele BKZ (2677) indicate that another factor influences species detectability. This might be due to the more open habitat of Rungwa FR & GCA and thus, offers a better detectability of species by the CT. The lower altitude of the PA or the presence of permanent water through Rungwa river that might attract more species are also possible explaining factors. Of course, a combination of factors is most probably explaining this situation. However, Mlele BKZ did not fully revealed its potential and this may come from the 850 km^2 PA size in comparison to Rukwa GR and Rungwa FR & GCA (4323 & 2480 km^2 respectively). Even if 32 species are detected on average in this PA, the total potential of the BKZ is of 56 mammals of which 18 are carnivores. Moreover, lions & African wild dogs – which were not detected by our camera in this PA – are known to occur in this part of the study area as direct observations are made from time to time and reported in the VGS reports. This initial evaluation of our data suggests that Rukwa GR, based on its accumulation curve, has a higher species richness than the other PAs studied and might justify its higher IUCN status.

Species richness in the study area seem to concord with early studies held in the Katavi-Rukwa ecosystem which shows that strictly PAs (NPs & GRs) were more effective than multiuse areas (GCAs & FRs) in preserving large-body size mammals in a snapshot of time (Caro et al., 1998; Caro, 1999) or between two snapshot of time (Stoner et al. 2007). In contrast, other studies found that species richness did not decline along PAs status gradient (Gardner et al., 2007; Mtui et al., 2017). Additionally, not all species adjusted their behavior according to conservation status (Kiffner et al., 2014).

In summary, our study reveled that a stricter state PA such as Rukwa GR holds a higher species richness than a state PA allowing multiple use NR use such as Rungwa FR & GCA which holds a higher species richness that a CBNRM PA such as Mlele BKZ. However, existing literature shows discordant results as discussed above. Moreover, a simple count of species such as species richness is too simplistic and ignores information about the relative abundances of species (O'Connell et al., 2011; Ancrenaz et al., 2012) or the extent of occupation of species in the reference area (Rovero & Zimmermann, 2016). Thus, further analyses are required to evaluate the evenness of distribution of individuals among species in the carnivore cohort and the extent of occupation of a species in the study area.

5.2. Raw descriptors

When focusing our analyses on carnivores, our results on trapping rates (RAI) showed that in Rukwa GR, the species having the highest detection probability were the bushy-tailed mongoose and the Miombo genet closely followed by the large-spotted genet and African civet. Banded mongoose, hyaena, honey badger and leopard were relatively easily detected. Less detected species were the marsh mongoose, lion, side-striped jackal, white-tailed mongoose, Meller's mongoose, dwarf mongoose, serval and African wild dog. In Rungwa FR & GCA, the large-spotted genet was the most detected species followed by the Miombo genet. The white-tailed and banded mongoose also presented good detection probabilities. The serval, bushy-tailed mongoose, hyaena and honey badger were relatively easily detected. Less detected species were the African civet, the African wild dog, the leopard, the lion and the African wildcat. In Mlele BKZ, the most detected species was the Miombo genet followed by the bushy-tailed mongoose. The African civet, honey badger and hyaena were relatively easily detected. Less detected species were the leopard, banded mongoose and large-spotted genet. Occasionally detected species were the white-tailed and Meller's mongooses.

Naïve occupancy results show that species in Rungwa FR & GCA had a better trapping rate than in the two other PAs despite seemingly fewer independent capture events. This might well be explained by the more open habitat found in this part of the study area. However, raw descriptors results are mixed as differences in management regimes are difficult to detect as Stoner et al. (2007) noticed. This might come – at least for Rukwa GR and Mlele

BKZ – from the relative similar onsite enforcement strategy and relatively similar restrictions on NR. Indeed, recent illegal activities encountered during fieldwork were quite low in those two PAs. Interestingly, most poaching signs or poachers' pictures taken by CT where found in Rukwa GR, questioning if the GR status does not attract this kind of activity as the area is known to hold a high mammal population diversity. Indeed, a high elephant population occurs inside the PA and was confirmed by a higher number of independent pictures (20 in Rukwa GR vs. 3 in Rungwa FR & GCA) taken during Rukwa CT survey and countless indirect signs encountered during fieldwork. CT survey was also relevant for species like civet or leopard greater occurrence on the western part of the study area, where poaching signs were lower (see map on Appendix XV). Another important data comes from the detection of African wild dogs and lions, the later being more detected in Rukwa GR whereas African wild dog were more detected in Rungwa FR & GCA. Yet, a bias might come from Rukwa GR higher research effort as it is shown by the only detection of the dwarf mongoose in the study area or higher naïve occupancy results for lions in Rungwa FR & GCA.

Our results also highlighted the fact that less detected species or species with larger home ranges lead to positive bias in RAI ratio. Those results are concordant with literature which shows that differences in detection between species led to positive bias in RAI toward species with larger home ranges (Sollman et al., 2013). However, the authors demonstrated contrary to our results that it was the more detectable species that led to positive bias in RAI ratios. This might be confirmed for the Miombo genet and bushy-tailed mongoose results in Mlele BKZ. Literature shows that a plethora of factors might bias raw descriptors that do not take into account variations and imperfect detection. Sollman et al. (2013) also demonstrated that species specific responses to different types of CT setup biased RAI ratios, and that changes in detection over time blurred true population trends. Other studies showed the influence of the seasons, animal size and vegetation type on detection probability (Bukombe et al., 2016).

In summary, our raw descriptors results do not show a species being more represented or having a greater naïve occupation of territory in one of our studied PAs. However, when looking at top-order carnivores like lions, leopards and African wild dog, distribution maps (Appendix XV) seems to present a clear demarcation between RW1 grid closer to human settlements and presenting more signs of illegal activities than RW4 grid. This result seems to show an effect of the relative quality of the surrounding landscape on the persistence of this species and follow results of Baeza & Estades (2010) who showed that «under high environmental variability, when the PA had a high habitat quality, the highest population persistence was not attained when the exterior was also of high quality, but when the surroundings had an intermediate quality». Rungwa FR & GCA was also the only PA studied presenting signs of cattle grazing (RW1_01; RW1_07; RW1_13; RW1_21; RW1_27) and joins Msuha et al. (2012) that areas used for livestock keeping can maintain high wildlife species richness – for instance, Rungwa FR & GCA was the only PA were African wildcat was detected (which is consistent with Stampfli (2016) results) and presented a higher detection of both African wild dog and serval than the other PAs. Moreover, our results emphasize the importance of accounting for detection probability. Thus, understanding sources of variation in detection probability and how they can be managed is a key part of monitoring (Campbell & Graham, 2016). A better approach than making untested or unstated assumptions is to explicitly account for imperfect detection when making inference about animal communities (O'Connell et al., 2011). Thus, occupancy analysis based on presence/absence at different sites for species such as carnivores that are widespread and occur at low densities allows the estimation and correction of imperfect detections (Rovero & Zimmermann, 2016).

5.3. Occupancy

Our results on the AICw retained in our final single season occupancy model per species permitted to quantify each covariates importance for each species. Most species were influenced by 1) altitude & roads, 2) habitat, water & other PAs, 3) poaching, 4) camps and finally 5) villages. Obviously, the number of covariates retained, and their importance varied across species.

5.3.1. Environmental Variables

Our results show that altitude was the most significant factor having an influence on species occurrence. It was an important factor for the small carnivore guild (all mongooses & genet sp.) and important in honey badger and lion distribution. The bushy-tailed mongoose and the miombo genet are more present at higher altitude as suggest their distribution map and occupancy results (Appendix XV) whereas, the large-spotted genet seems to favor lower

altitude as was confirmed by previous work (Buffard, 2018; Hausser et al., unpublished data) and revealed in Appendix XV species map and occupancy results. The significant relationships that emerged broadly indicate that elevation is a significant predictor, for most species and joins Rovero et al. (2017) conclusion. The author also emitted the hypothesis that the results were likely an indication of «preference for interior portion of the forest, and, in turn, of disturbance-avoidance». This might well be the case in our study, especially in regard to lion data who tend to be detected in difficult terrains (Rukwa GR) or well inside the studied PAs (Rukwa GR & Rungwa FR & GCA) (see corresponding map in Appendix XV).

A second significant environmental factor detected by our study was the distance to permanent water. A good portion of the focal species (marsh mongoose, dwarf mongoose, white-tailed mongoose, African civet, honey badger, large-spotted genet, African wildcat, serval, side-stripped jackal, lion and African wild dog) were related to water distance. For instance, occupancy results on African civet was positively associated with permanent water whereas, large-spotted genet seemed to avoid this factor. Those two results show the discordance found in literature related to positive or negative association with water. Indeed, Ramesh & Downs (2015) found that all species they studied were attracted to rivers while, Pettorelli et al. (2010) results demonstrated avoidance by most species. A more recent study found – quite similarly to this one – that permanent water was positively associated with their wildlife descriptor but that the magnitude and direction of this effect varied across species. However, one must keep in mind that the focal group of the present study are carnivores and that the study was mostly carryout during dry season. Thus, proximity to water might translate predator-prey relationship. Indeed, during dry season, ungulates are mostly found in the vicinity of water and thus, attracts predators (Estes & Otte, 2012; Stuart & Stuart, 2000). A good example might come from our African wild dog or lion AICw results as, if occupancy analyses could be finalized, it would probably have join Mkonyi et al. (2018) results who found that lions were strongly associated with permanent water as close proximity to water increases encounter rates with water-dependent herbivores. Indeed, Buffard (2018) results in Mlele BKZ demonstrated that buffalo – lions main prey in the Katavi-Rukwa ecosystem – were positively correlated with water presence.

With similar significance to water proximity in our study, habitat type is an important factor to consider for all cat species, except lions, and genet species. Our AICw results also demonstrated that the African civet, spotted hyaena and African wild dog also pay attention to their habitat. The present study occupancy analysis demonstrated that the African civet and the two genets were mostly found in denser vegetation and seems to confirm Waltert et al. (2009) suggestion that the thicker miombo vegetation constitutes a more suitable habitat for those species. This might also be confirmed for leopard and hyaena in our study area who are known to use dry river bed to patrol their territory (Araldi, pers.comm. 2012) and leopard frequent use of riverine forest in the area (Hausser et al., unpublished data). Indeed, Burton et al. (2012) study on vegetation biomass variation influence on carnivore occurrence is interesting as the authors identified a key community-level effect of riverine corridors. Indeed, several of their species showed either positive or negative associations with riverine forest but had no association with other habitat type. Ramesh & Downs (2015) confirmed that spotted hyenas selected areas with dense vegetation and near seasonal streams. Finally and as suggest our distribution maps, marsh mongooses being one of the most specialized mongoose and commonly found in the vicinity of water favors like Mellers' mongoose wetlands while the white-tailed mongoose prefers open grassland like serval and African wild cats which is concordant with what was already known (Ramesh & Downs, 2015; Kingdon, 2013). Those records are also concordant with Pettorelli et al. (2010) findings which suggest that small cats and mongooses appear less tolerant than genets or larger carnivores.

In summary and contrary to expectations, variation in carnivore persistence seems not explained primarily by anthropogenic factors but by environmental ones, which seem more influencing on carnivore occurrence predictability. This is confirmed by general carnivore ecology who demonstrated that prey availability and a diverse habitat are imperative conditions for this order to thrive (Ramade, 2009). Thus, refuting our first hypothesis. However, our analysis demonstrated some evidence of differences in habitat selectivity between different species, which, where information was available, supported what was known about these species. However, as Durant et al. (2010) pointed out, «carnivores are a relatively generalist taxon and their ecological niche might be less habitat specific than other taxa». Thus, raising the question about the choice of carnivores as our focal species. Moreover, it is also possible that the 5 class of habitat type used in our occupancy analysis was insufficient to detect clear habitat specializations in the carnivore assemblage examined here. As Van der Weyde et al. (2018) recommend, we suggest to include fine scale habitat measures as it has been shown to influence detection probabilities for some species even in relatively homogenous habitats.

5.3.2. Human Disturbance

In the context of the studied PAs, anthropogenic factors were believed to be the main explanatory factors of the observed levels of species richness, relative abundance, and occupancy. The 4 species analyzed more in details seemed to avoid human activities, except the bushy-tailed mongoose who seemed attracted to temporary camps where it might find some food leftover provided by beekeepers. Contrary to expectations, those species tend to occur more when distant from roads. Previous work (Zurkinden, 2017) showed that there were no significant difference between systematic and on roads sampling for small carnivores (the bushy-tailed mongoose, and both genets) inside Mlele BKZ, while it became clear for larger species such as the African civet, the hyaena and the leopard who made frequent use of tracks and roads. However, this factor is the most constant factor with altitude to influence the occurrence of our focal species in the study area. Thus, presence of roads may influence negatively the occurrence of small carnivores but seems to be more favorable for medium- to large-carnivores and especially the cat family which concords with Cusack et al. (2015) observations.

Two indicators were used to show potential edge effect on the studied carnivore cohort – distance to villages and distance to Katavi NP and Lukwati GR boarders – in an attempt to qualify lower IUCN management category PAs as buffer zone for strongly protected NPs and GRs. Unfortunately, the few results obtained by this study does not allow to show an edge effect from the villages distance except from the Bushy-tailed mongoose who showed a clear avoidance to this parameter which reveals, as showed Rovero et al. (2017) study, a general trend of negative impact of human disturbance for this species. However, distance to the other PAs seem to be a factor to take into account for 13 carnivores of our focal species. However, occupancy analyses showed that it had no influence for the bushy-tailed mongoose, the two genets and the African civet. This might well be explained by the relatively small home range of those species (Estes & Otte, 2012). Interestingly, results (AICw results show that distance to villages is not an influencing factor for hyaena, leopard, lion and African wild dog as well as distance to other PAs for lion) seem to tend toward the fact that large carnivores are not influenced by this factor which contradict findings of Van der Weyde et al. (2018) and Kiffner et al. (2009) on lion which have been increasingly found being restricted to NPs, likely as part of an avoidance strategy of pastoralist areas due to increasing conflict and subsequent retaliation killing (see section 2.2.2.3). However, results of Mhlanga et al. (2018), Van der Weyde et al. (2018) and Balme et al. (2010) show that our results for leopards and hyaenas are consistent with their findings. Indeed, those species are likely to inhabit areas outside NPs and do not avoid non-PAs, finding substantial resources in the vicinity of villages despite an increased risk of mortality (Zurkinden, 2017) which may function as an ecological trap (Balme et al., 2010) or not (Msuha et al., 2012). Another, not mutually exclusive, hypothesis formulated by Kiffner et al. (2015) might be that distance to source populations (Katavi NP & Lukwati GR) may play an important role for the persistence of lion and African wild dog in the studied area for instance. Indeed, the spatial proximity may allow this species to be sustained by the respective larger populations found in the more strictly PAs.

Unfortunately, Trophy hunting could not be investigated as a factor explaining variation in wildlife descriptors, but it seems that, from previous studies, the presence of tourist hunters has little positive or negative impact on species even if it benefits wildlife indirectly by providing revenue to the wildlife sector through governmental support to GRs and GCAs (Caro et al., 1998).

In summary and contrary to our expectation, anthropogenic factors did not have consistent, negative effects on occurrence across the 17 carnivore species detected. Thus, confirming our conclusion on environmental variables and thus, refuting our first hypothesis. However, one bias might come from the index chosen to model increasing disturbance at the PAs edge and the role of the studied PAs as buffer zone. Indeed, distances to the village's boundaries were made on the basis of GIS extraction which are not exactly consistent with the real influence of the villages presented in Figure 30 of section 4.4.6.3 except for Mlele BKZ boundary. This is concordant with what Burton et al. (2012) noticed, «an index as seemingly simple as distance to the park edge is subject to some uncertainty associated with inconsistent boundary demarcation, and its reliability as a proxy for human disturbance is affected by spatial variation in population density and land use.»

5.3.3. Illegal Activities

In our study area, illegal activities were quiet low in Rukwa GR and Mlele BKZ compared to Rungwa FR & GCA. Rukwa GR presented mainly signs of poaching activities (poachers camps & structures to dry meat) as well as some signs of mining activities (pits). Rungwa FR & GCA presented a high number of illegal timbering activities including debarking for traditional beehives manufacturing. This PA also presented a high number of cattle grazing

whether it was detected during fieldwork or by our CT. In this PA too, poaching signs were revealed (Appendix XXIV). Finally, in Mlele BKZ several trees presenting debarking signs were also revealed but only one illegally logged tree was found. Finally, some poaching activities (three mammal's traps) were also encountered during fieldwork (Buffard, 2018).

Contrary to expectation, carnivore occurrence had various association with measured poaching signs. Indeed, 12 species out of the 17 detected during the survey seemed to be affected (positively or negatively) by poachers but only 5 of them showed a high probability of effect. This effect was negative for the African civet and Miombo genet as shows the positive estimates of occupancy results. This situation seems also corroborated for other species by studding their distribution map (Appendix XV). Indeed, lions seem to avoid patches presenting a high density of illegal activities. Conversely, the higher detection probability of African wild dog in Rungwa FR & GCA, for example, suggest that hunting pressure and human disturbance may not only decrease the probability of carnivore occurrence and make them more wary and thus more difficult to detect. Thus, results presented here on hunting pressure joins Burton et al. (2012) results who showed that hunting pressure did not have consistent, negative effects on occurrence across the carnivore species the authors detected. However, retaliatory killing of large carnivores as a response to livestock predation happen in the region and is particularly true for lions, hyaena and leopard (Zurkinden, 2017). This may of course reduce large carnivore density and lead to the phenomenon of mesopredators release[36] (Schuette et al., 2013). This might well be the case in Mlele BKZ were large carnivores seem to occur less often than in the two other PAs and thus, present a higher detection probability of medium-sized carnivores such as the African civet in this PA. Another influence might come from the indirect hunting of ungulates which might reduce carnivore prey – resulting in an increase of human–carnivore conflict through livestock depredation. Indeed, Soofi et al. (2018) found that illegal hunting of ungulates was the most influential depredation predictor as an increase in the intensity of illegal hunting of ungulates can intensify livestock depredation by carnivores. However, those results seem differing from the results of Waltert et al. (2009) who were more interested in the low number of carnivores despite an abundant prey base.

Considering illegal timbering no analyses could be conducted as this factor, alongside cattle grazing, had a high collinearity with the distance to villages and had thus, to be withdrawn from the analyses. However, literature suggest that vegetation cover is an important factor for carnivores (see section 5.1.) thus, selective timbering – as practiced in the study area – might not influence carnivore occurrence as it does not alter vegetation covers. Despite the often postulated negative effects of livestock on wildlife populations, Kiffner et al. (2015) showed that mesopredators and top-order carnivores conservation appears to be compatible with livestock keeping and joins Msuha et al. (2012) on that areas were grazing occur holds a significant proportion of mammal communities and thus, show that biodiversity conservation can be achieved outside strictly PAs. However, recent studies suggested that human-related activities such as increased livestock presence and human settlements may displace wild ungulates and indirectly exert a stronger influence on prey availability for carnivores (Abade et al., 2018; Rovero et al., 2018; Strampelli et al., 2018). Moreover, large carnivores can still be threatened directly by livestock, as «overstocking can trigger human–carnivore conflicts and hamper the conservation of large carnivores» (Rovero et al., 2018). Woodroffe et al. (2005) suggest that sustainable coexistence between carnivore and people can be achieved through livestock husbandry that include appropriate herding practices (Woodroffe et al., 2007), predator proof fences (Kissui, 2008), and vaccination of livestock (Osofsky, 2005). Indeed, those effective measures – which none is present within the study area – effectively deters predators from acquiring stock-killing behavior.

In summary, results presented here contradict the prediction that a higher presence of cattle grazing, and other illegal activities will be detected inside State governance PAs. Results also showed – in the snap shot of this study – that poaching did not have consistent, negative effects on the occurrence and distribution of our carnivore cohort. Indeed, results are more nuanced as Rukwa GR (IUCN management category IV) present fewer signs of illegal activities than Rungwa FR & GCA (IUCN management category IV), both being State governance PAs whereas, Mlele BKZ, a co-managed PA (IUCN management category IV) also presented fewer signs of illegal activities. This situation thus, shows the complementarity between IUCN management categories and shows that a stricter approach such as in the GR shows similar results as a more collaborative approach such as in the BKZ. Thus, the answer to our second hypothesis is more nuanced as PAs status by itself cannot explain this situation and thus, management activities implemented inside each PAs seems to be a better explaining factor. This conclusions are

[36] probably because smaller carnivores are no longer limited by competition with or predated by larger carnivores

also consistent with Caro et al. (1998) predictions that law enforced by teams of disciplined rangers or VGS are effective in protecting PAs values.

5.4. Management

As management activities implemented inside each PAs seems to be a better explaining factor on our species occurrence, the adding of *Management* after controlling for relevant anthropogenic and environmental factors allowed to measure the effect of this covariate in the occupancy of the detected carnivores. The results for the 4 species presenting enough observation (bushy-tailed mongoose, Miombo genet, large-spotted genet and African civet) showed that management seems to influence small carnivores. However, for those species, there is no defined patterns showing a PA being systematically less occupied, which joins Msuha et al. (2012) conclusions. This might be partly explained by Caro (2001) findings that small mammals (potential small carnivores' prey) species richness and abundance were greater outside than inside a NP during dry season. However, the selected carnivores presenting enough data in our study do not represent good "response" species to measure the effects of management activities. Indeed, species of high conservation value such as top-order carnivores would have been more appropriate according to Sergio et al. (2008) analyses.

In our study, occupancy results on management effect where not relevant. Consequently, management effectiveness has been evaluated for the three PAs studied through METT questionnaires in order to evaluate the management of the BKZ in a comparative manner. As a reminder the total METT score obtained for each PAs was 73pts for Rukwa GR; 45pts for Rungwa FR & GCA and 72pts for Mlele BKZ were 16, 13 and 10 carnivores were detected respectively with leopards being detected in each PAs (8 independent events in Rukwa, 4 independent events in Rungwa and 8 independent events in Mlele) and lion and African wild dogs being detected in Rukwa GR (4 independent events of lions and 1 independent event of African wild dogs) and Rungwa FR & GCA (2 independent events of lions and 4 independent events of African wild dogs).

Important to notice that METT assessment relies heavily on a self-evaluation, necessarily complacent (see section 3.3.4.) and shows an unbalance between the 6 elements of the WCPA Framework. Therefore, detailed comparison of individual indicators between different sites are not recommended (Hockings et al., 2006) but still provide some insights into the impact of PAs management interventions from the local-to-global scale (Coad et al., 2015).

5.4.1. Context

The context of the two state governed PAs of our study obtained a similar and full score of 100% whereas Mlele BKZ our co-managed by local communities PA only obtained 66.66%. This situation is mainly explained by the fact that Mlele BKZ has not yet been officially gazzeted compared to the other PAs. Otherwise, management authority, partners and other national context such as IUCN management categories are well identified within each PAs. Indeed, each PAs establishment is significant in protecting/managing its values (fauna, flora, ecological functioning, …) and each PAs faces similar threats (timbering, grazing, poaching, mining, …). Yet, Rungwa FR & GCA is vulnerable in that sense that the PA can be characterized as an open access area whereas Mlele BKZ faces a challenge about is legitimacy as manager over the area.

According to Leverington et al. (2010) those PAs establishment indicators (gazettal, design, boundary marking, tenure resolution and adequacy of legislation), indicates' only that the basics of PAs systems are in place. Indeed, according to our results on PAs vulnerability, the establishment of a PA is not sufficient in determining management effectiveness as this measure only provides a unidimensional indicator of political commitment to NR protection as Chape et al. (2005) highlighted. Indeed, addressing governance and capacity deficits – including law enforcement, technical skills, and funding – are key to effective PAs management (Caro & Davenport, 2016). Studies found that two main actions are thought to influence conservation outcomes: law enforcement and community outreach (Chape et al., 2005; Msuha et al., 2012; Caro & Davenport, 2016; Chen et al., 2018).

5.4.2. Planning

In our study, Mlele BKZ present the highest score in the assessment of the PAs design and planning (79.16% vs. 54.16% for Rukwa GR and 50% for Rungwa FR & GCA). If the three PAs studied are well supported by national legislation and policies it is not the case for the PA design, management planning and system design. Indeed,

Rukwa GR and Rungwa FR & GCA faces challenges content the size of the PA they are supposed to patrol and the number of staff and means at disposal. Mlele BKZ on the contrary has aligned staff and means to properly manage the 850 km^2 area. In addition, if Rukwa GR and Mlele BKZ have well demarcated boundaries (planned and on the ground) this is not the case for the FR & GCA. Concerning management planning, Mlele BKZ is by far better than the other two PAs. Indeed, Mlele BKZ management plan is specifically adapted to the PA they intend to protect and follows a structured process to implement daily actions. On the contrary, Rukwa GR managers partially implement a specific Management Plan designed for the PA as it was not formally validated. Rungwa FR & GCA managers (TFS and WD) simply apply general objectives from the strategic plan of all FRs & GCAs to the PA they are supposed to manage. According to constrains, Rukwa GR and Mlele BKZ present a well implemented system design were patrols (anti-poaching activities and surveillance), training (for staff and local communities), monitoring (Rukwa GR only use results of TAWIRI aerial census whereas Mlele BKZ implement wildlife monitoring through CT and vegetation monitoring through transects) and permit & licenses issuance (Rukwa GR: mainly for Trophy hunting; Mlele BKZ: mainly for beekeeping) are delivered. In contrast, Rungwa FR & GCA mainly focus their attention on permit & licenses issuance and some controls.

Mlele BKZ management planning, monitoring and researches are a good example of how a PA can ensure adaptive management, which is strongly linked with PAs effectiveness as Leverington et al. (2010) demonstrated. Indeed, the sheer number and spatial extent of PAs can be further enhanced toward ME through biodiversity monitoring in order to provide a basis for management adaptability (Chape et al., 2005) as biodiversity monitoring is critical to assess the effectiveness of management activities and policy change (Pettorelli et al., 2010). Furthermore, Rukwa GR and especially Rungwa FR & GCA show the need to improve the application and use of planning, evaluation and management tools to deliver good and consistent management on the ground which is consistent with Leverington et al. (2010) findings.

5.4.3. Inputs

Concerning our results on resources of agencies and sites, Rukwa GR (75%) is better suited to carryout management activities, followed by Mlele BKZ (62.5%) and Rungwa FR & GCA (50%). Indeed, Rukwa GR benefits as major source of income from the financial support of the central government (TAWA HQ) as well as some support from external donors such as the WCS. Similarly, Rungwa FR & GCA major source of income is secure (government – TFS central agency). However, governmental incomes are not sufficient in regard to the PA size and allocation of funds are doubtful putting at risk the sustainable management of Rungwa FR & GCA. Concerning Mlele BKZ, IBA is still financially supported by ADAP and, for the moment without its support, could not cover the management costs with their current revenues. Concerning allocation of means, Rukwa GR and Mlele BKZ have sufficient resources whereas Rungwa FR & GCA lack equipment to properly manage the area. Concerning allocation of staff members Rungwa FR & GCA faces the same situation as for its equipment. Rukwa GR eider is not allocated enough personal to patrol the entire PA. Only Mlele BKZ has enough personal to patrol the entire PA.

Except Mlele BKZ, the other two PAs and especially Rungwa FR & GCA face inadequate resourcing and lack basic requirements for proper management, which is confirmed by their low scores for inputs. TFS should focuses most of its effort on controlling and promoting selective and sustainable timber harvesting, yet the institution is chronically underfunded, has low human capacity and means, budgets and objectives are poorly prioritized and conflicts between managers impacts effective management. Consequently, as Hall et al. (2009) already demonstrated, FRs became heavily degraded (3% of deforestation in Rungwa FR & GCA) and resulted in creeping defaunation (Rovero et al. 2015). These findings are concordant with literature which highlighted that continued or increased financial and logistical support for PAs is an important component of management effectiveness with strong correlation with overall increasing management capacity (Leverington et al. 2010). However, this last point could not be confirmed in Rungwa FR & GCA as this PA presented a relative similar species richness with the other two PAs considered. Having even species specific to this area with, for instance, impalas and waterbuck detected in the vicinity of Rungwa river.

5.4.4. Processes

Our assessment of management processes suitability showed that Rukwa GR (83.33%) and Mlele BKZ (76.19%) management is appropriate and efficient whereas Rukwa FR & GCA (45.24%) faces some challenges. Indeed, Rukwa GR management is organized around 30 days routine patrols focusing on Lake Rukwa and a response

team depending on relevant information received. A good co-operation between managers and Trophy hunting companies exist. However, of the three hunting blocks existing (Mlele south; Rungwa River; Lake Rukwa), only TBGS took over Lake Rukwa bloc exploitation. Moreover, discussions revealed that Hunting quotas are not sustainable. An ecological monitoring is not really in place for this PA but TAWIRI aerial censuses are regularly carryout in the region and results are transmitted to the GR HQ in Selous. TAWA management seem thus, to be effective as wildlife monitoring results seem to concur with METT assessment. Following the same basis, TAWA personnel implement education and awareness programmes in neighboring school. Moreover, when a hunting block is exploited, 25% of Trophy hunting revenues goes to the District council to support local communities. Mlele BKZ management is organized around 14 days of patrols divided into two sessions of 7 days organized every month. The vehicle patrols are normally completed by a 10 km on foot patrol per day and opportunistic controls outside the BKZ are made when ever possible. Furthermore, ADAP setup for IBA a complete ecological monitoring allowing adaptative management. Wildlife monitoring is in place since 2008 and is carryout once every year and vegetation monitoring were performed in 2004, 2013 and 2017. Beekeeping monitoring is conducted on a yearly basis since 2016. Village survey was conducted in 2002 and numerous research work (Bachelor and Master thesis & scientific publications) are conducted in the PA. All legal activities allowed inside the BKZ are subject to permit delivery in order to facilitate their control. However, 3 institutions (the District, TFS and IBA) have now the capacity to issue permits for beekeeping activities in the District. Even worse, permits to enter the BKZ are sometime delivered by neighboring District while no right allows them to do so. There is an appropriate and fully implemented education and awareness programs which provides local communities appropriate trainings whether it is related to income generating activities or to raise community awareness on the BKZ management. Those communities are also directly contributing to the improvement of the BKZ management through the election of IBA Village Representative and the representation of villager voices during meetings held every three months at IBA office. Rungwa FR & GCA management is centered around 17 days of patrols per year for a single FR or a focus is made on one or two PAs only (normally, 15 days of patrols per month should be carryout in each FRs & GCAs). As WD has no vehicle available, staff members join from time to time TFS patrols. Moreover, no proper distribution of logging blocks is made by TFS and no antipoaching and surveillance activities from Hunting compagnies occurs in the PA as Game Frontiers of Tanzania Ltd. has not reopened its hunting block since 2014 thus, creating an open access zone. As for Rukwa GR, WD benefits from TAWIRI aerial censuses but does not implement any proper monitoring. TFS indicated a vegetation monitoring realized for its Management Plan but contradicting information gathered indicated a partial inventory in 2007. TFS mentioned a limited ad hoc education and awareness program through trainings for beekeepers and sustainable management of forest resources but beekeepers denied it. For the WD part, their activities toward local communities' mainly focus on the clarification of benefits sharing system set in place between the Hunting companies, the District and the villages.

Management activities, law enforcement, monitoring and research are strongly correlated with conservation values and our results, according to literature, indicate that a focus is needed on specific activities to manage and monitor the values to be conserved. Another strongly correlated aspect with both effectiveness and good management outcomes are communication and community relations (Leverington et al. 2010). Now considering hunting quotas, both, TAWA and WD could implement a transparent monitoring system that would allow «rapid assessment of sustainable offtake of every species in each hunting block» (Caro & Davenport, 2016). Indeed, as WD not only issue limited hunting permits to Tanzanian resident but also to tourist hunter through allocation of hunting blocks inside GCAs (Caro et al., 1998), «hunting-company certification based on ecological and social criteria agreed on between the hunting companies, local villages, and independent accredited certifiers could be explored» (Caro & Davenport, 2016) and could open up hunting blocks for wildlife monitoring hunting to draw hunting quotas based on science, something that now can only be assessed indirectly, and additionally reduce poaching activity (Caro & Davenport, 2016). However, as the authors mentioned, the private hunting sector that use GRs and GCAs feels unconcerned over these maters because of short concession time frames and institutional reluctance over independent wildlife monitoring, limited accountability and lack of knowledge of wildlife population trends. Additionally, the superposition of status in Rungwa FR & GCA provides some confusions as it provides legal loopholes that shows contradiction between legislations or lack of clarity in the law (Mermod, 2016). Indeed, GCAs allow settlement, cattle grazing and timber extraction whereas, FRs only allows the latter. Therefore, the double status of this PA ensures better preservation than a single GCA status. However, the Hunting blocks abandonment that occurs in the region is alarming. The reason being the difficulty to achieve quotas of the species that represent the leading call products for tourist hunters. This are the lion, the leopard, the buffalo and to a lesser extent the elephant (http://robinhurt.com/; http://tanzaniabiggame.com/). According to Hausser pers.comm. (2019), in three

years on Rukwa North, Robin Hurt Safari Ltd. failed to achieve the lion quota even not taking a single individual. This species seems to have greatly decreased following years of excessive harvesting (Caro, 2008; Kiffner et al., 2009; Packer et al., 2011). It is interesting to note that this block abandonment and the resulting cessation of hunting could allow some lion population recovery. Indeed, in 2012 no lion was captured in Rukwa CT grids (off-grid, capture of 2 young males), neither in 2014 and 2015, while in 2018, lions were caught in the north of Rukwa GR (R3_06; R3_25; R3_28).

5.4.5. Outputs

Our assessment of the implementation of management programmes and actions showed that Rukwa GR better delivered products and services (66.66%) than Mlele BKZ (44.44%) and Rungwa FR & GCA (33.33%). Indeed, Rukwa GR effective management prevent encroachment but the absence of two Hunting companies and an unfair patrols distribution results in the North part of the PA to become a close free access zone. Moreover, one of TAWA main objective is to sustainably manage wildlife population. However, even if Hunting quotas are respected, they are not sustainably defined (yet, this aspect is not in Rukwa GR hands). Mlele BKZ is locally recognized as the best managed PA in the District. Its effective management prevent encroachment and permit to maintain a well-preserved habitat with 124 or so tree species sheltering 56 species of medium- to large-mammals. Results of IBA actions do not only stops at the ecological level but also successfully integrated development with conservation. On the other hand, Rungwa FR & GCA management capability is challenged by an ever-growing human population facing economic conjuncture and scarcity of Village land. Thus, resulting in an increased pressure over NR. As for Rukwa GR, NR quotas (forest & wildlife) are not sustainable and the country economic conjuncture and international market incentive encourage mismanagement (Milledge et al., 2007). The absence of Trophy hunting company does not help this situation either. In response to a MNRT report (Milledge et al., 2007), the Tanzania Forest Working Group recommended community participation in forest management by documenting revenue deficits, large-scale corruption, unsustainable rates of harvesting and loss of biodiversity in order to reduce illegal logging (Persha & Blomley 2009).

5.4.6. Outcomes

When looking at the effects of management in relation to objectives, our results showed that Rukwa GR and Mlele BKZ presented decent results (75% both). Rukwa GR effectively implement law enforcement activities which curb illegal offtake of wildlife resources. By ensuring a participatory approach to wildlife management during the decision process and equitably distribute cost and economic benefits to local communities, TAWA sensitize, educate and communicate values of wildlife to local communities. However, Hunting quotas are not sustainably defined and there is a recognized lack of monitoring. On the contrary, Mlele BKZ present a well implemented monitoring system which highlighted the important biodiversity (124 tree species & 56 species of medium- to large-mammals) of the area and allow an adaptative management of it. The successful establishment of a community-based organization (IBA) and the establishment of the BKZ prevent encroachment and stabilized the PA boundaries thanks to a sustainable multiple use of the forest resources which generate increasing incomes. Besides, species on the Red List, such as lions or African wild dogs are also known to occur in the BKZ as regular observations are noted in the VGS reports. Furthermore, regular indirect signs of elephant were discovered in the vicinity of ADAP camp in the BKZ, having an elephant passing through the camp at night. Those track and signs are encouraging signs of the effective protection of the BKZ alongside deforestation prevention and seems to show the promise of animal knowing that they are in safety inside the BKZ. Indeed, mechanisms involved could be that certain species are adapting their spatial distribution according to encroachment (agriculture & settlement) outside the BKZ and effective implementation of protective antipoaching patrols inside the PA. It is also possible that this shift in distribution results from the better quality of habitat such as increased cover because of effective protection of the ecosystem (Lee & Bond, 2018). Indeed, the present study demonstrate that the BKZ establishment and management has positive outcomes both in term of local community and biodiversity outreach and joins Andrade & Rhodes (2012) that local community participation in the PA decision-making process seem to be related to the level of compliance with PA polices. In addition, as no cattle grazing was detected inside the BKZ (Buffard, 2018) and based on Lee & Bond (2018) definition of ecological success (see section 1.3.1.), Mlele BKZ apparent positive ecological effects seem to provide evidence that CBNRM likely compliments the conservation value of stricter PAs (see section 2.2.1.5). However, despite the apparent positive ecological outcome detected, results presented here do not imply that current efforts are sufficient to sustain Mlele BKZ success in the longer term as IBA did not reached

yet its sustainability and mainly depends on ADAP funding's which comes to an end this year (Buffard, 2018). On the contrary, Rungwa FR & GCA efficiency is insufficient at achieving targets and its appropriateness is dough full (41.66%). Indeed, legal operational rules are not enforced, and permits & licenses issuance are disconnected from sustainability. Thus, forest management is not sustainable, and the target hardwood species are almost inexistent. Moreover, the forest is increasingly invaded by Sukumas and their livestock's. Surprisingly, a still diverse community of wildlife occurs in the PA. Last but not least, there is concurrent conflicts among managers & between managers and users.

In summary, assessing ME allows the estimation of the ability of a PA to conserve its values given a target, to evaluate the quality of the management plan, but also to assess its usefulness. METT difference in favor to Rukwa GR and Mlele BKZ might be largely explained by 1) the surveillance set in place by these two PAs as literatures puts it as a key aspect of effectiveness (Hockings et al., 2006). Indeed, it allows the control of threats faced by the PA values. Mlele BKZ especially demonstrated that good surveillance comes from relevant analysis and prioritization of threats. 2) Monitoring is another side to effectiveness and gathers collection methods and data analyses that permit assessment of the PA values evolution. As for Mlele BKZ, the choice should be based on efficiency. Moreover, monitoring should be carried out by the managers and not simply be provided by external institutions such as in Rukwa GR and Rungwa FR & GCA. 3) According to literature, it is of paramount importance to make sure everyone understands PAs priorities (Hockings et al., 2006). However, awareness impact – on that it has given rise to a change in behavior – is difficult to implement and hard to assess. Rungwa FR & GCA, by not taking into account this aspect and according to the number of illegal activities found in the PA shows that awareness should remain an absolute priority. Indeed, Rungwa FR & GCA capacity shortfalls in funding, governance, transparency, staff, means and education program at the village level hinders their management capability. However, this PA surprisingly seem to held a good portion of wildlife present in the study area, contradicting Stoner et al. (2007) conclusions. Thus, challenging the idea that enforcement is only effective when spending is high which joins Caro et al. (1998) conclusions.

Our results suggest that complementarity of shared governance and top-down regulation between the studied PAs help preserve the carnivore cohort in the Katavi-Rukwa ecosystem and join Redpath et al. (2017) and Davis et al. (2018) conclusions. Besides, the resilience of mammalian species (Weaver et al., 1996) and the confirmed presence of endangered species such as lions or African wild dogs in each of our studied PAs (according to direct and indirect signs in Mlele BKZ) might hinder the impact on wildlife (particularly in terms of livestock invasion) as hunting cessation during the 3 years preceding our study might have had a positive effect on large carnivore numbers. Indeed, Mtui et al. (2012) results in the Katavi-Rukwa and Ruaha-Rungwa ecosystems highlighted contractions in distribution and reductions in abundance. Therefore, if the trend in Rungwa FR & GCA is confirmed, it is conceivable that it is a question of time before the carnivores studied will finish to disappear. Indicating that our third hypothesis is probably confirmed. Indeed, in the light of those predictions, our results tend in favor of our prediction that a higher proportion of species present are detected in the PAs with higher funds (Rukwa GR and Mlele BKZ) and resources compared to PAs with low funding (Rungwa FR & GCA).

5.5. Notes on the method

All along the discussion, some bias on the method were revealed, questioning the adequacy of the method to the aims pursued. First is the choice of carnivores as our focal species. Indeed, carnivores are a relatively generalist taxon (Durant et al., 2010) questioning their ability to reveal complex interactions with the selected environmental and anthropogenic factors. Second, carnivores being cryptic animals only few species (bushy-tailed mongoose, Miombo genet, large-spotted genet, African civet) presented enough data to model occupancy even when using CT. This constraint should have been identified in the Material and Methods section. In fact, the relevance of conducting occupancy estimates for species with little conservation value is of poor relevance as they do not represent a major conservation issue and do not represent good response species for measuring the effect of management actions. Indeed and in the view of the limited possibilities to estimate occupancy for species with high conservation value, the interannual comparison for some of them (e.g. lion in Rukwa GR) would have been more interesting than the occupancy of small carnivores, which do not represent a major issue in terms of management or conservation. We thus recommend, given the low detection probabilities of certain species – especially for naturally rare species, on a single CT session – to take into account data from other types of observations, direct

and indirect reported in the VGS reports. Further work is thus needed to model the carnivore cohort occupancy in the study area. Furthermore, time series data are required to draw reliable estimates on management outcomes. Third, bias might come from the site covariates modeling. One bias might come from the index chosen to model increasing disturbance at the park edge. Indeed, distances to the village's boundaries were made on the basis of GIS extraction which are not exactly consistent with the real influence of the villages. Moreover, it is also possible that the 5 class of habitat type used in our occupancy analysis was insufficient to detect clear habitat specializations in the carnivore assemblage examined. As Van der Weyde et al. (2018) recommend, we suggest to include fine scale habitat measures as it has been shown to influence detection probabilities for some species even in relatively homogenous habitats. Fourth, as Zielinski et al. (2015) exposed, «season affects many characteristics of populations and, as a result, the interpretations of surveys conducted at different seasons». As our study was conducted in the dry season, inferences are limited for understanding long-term dynamics and may not be as applicable during the wet season. For example, lions follow buffalo in their search of water and hence are less common during dry season in the study area (Hausser, com. pers., 2017). Undeniably, as fieldwork was conducted during dry season, some difference occurred from the start to the end of the monitoring. Indeed, the survey conducted in Mlele BKZ was held at the beginning of dry season and some areas were still difficult to access du to late rainfall. The survey in Rukwa GR was performed in the middle of dry season and proved no major difficulties in term of weather conditions. Whereas, Rungwa FR & GCA survey, held at the end of dry season/beginning of wet season had to be abridge because of rainfall and accessibility. This has two main constrains on the comparison between PAs and results interpretation has to be taken carefully. 1) It has as consequences that the sampling effort is not the same between PAs. Indeed, 3 grids were surveyed in Mlele BKZ, 4 in Rukwa GR and only 2 in Rungwa FR & GCA. 2) As it was mentioned above, seasonal changes are likely to impact on prey biomass and consequently carnivore distribution (Van der Weyde et al., 2018). Fifth METT assessment relies heavily on a self-evaluation, necessarily complacent and shows an unbalance between the 6 elements of the WCPA Framework. Thus, detailed comparison of individual indicators between different sites are not recommended (Hockings et al., 2006). Here too, time series data would be relevant as they enable a better assessment of effectiveness which shows an improvement in management over time (Leverington et al. 2010).

6. Conclusion

We conducted a study to investigate factors explaining variation of species richness, relative abundance and occupancy of carnivores in three PAs in Western Tanzania. Our statistical model has been developed to integrate a large numbers of CT data to investigate regional patterns in the distribution and composition of an entire carnivore cohort in relation to environmental and anthropogenic variables in a gradient of different protection statuses, management regimes and governance types PAs.

In view to assess their influence on our results, data on environmental factors and anthropogenic factors were correlated to the observed descriptors of wildlife, permitting to pinpoint those variables having the strongest impacts. Results presented in this study showed, contrary to expectation, that the carnivore cohort showed no considerable species richness, relative abundance or occupancy differences between the differently managed PAs studied and infirm – at least for carnivores – Caro (1999), Stoner et al. (2007) and Waltert et al. (2009) conclusions and joins Mtui et al. (2012) conclusions. Moreover, our results joined Cardillo et al. (2004) results that carnivore occurrence is predicted more strongly by environmental variables than exposure to anthropogenic ones but also showed that in an human-influenced landscapes, ignoring anthropogenic factors will result in misrepresentation of some species occurrence and may lead to inappropriate management as Behr et al. (2017) suggested. However, in our study area, the influence of those variables was species-specific, likely due to the differences in ecology and behavior of our focal species which seems to determine how well populations are able to withstand exposure to threatening processes. Indeed, the resilience of mammalian species and the confirmed presence of endangered species such as lions or African wild dogs in each of our studied PAs might hinder the impact on wildlife (particularly in terms of livestock invasion) as hunting cessation during the 3 years preceding our study might have had a positive effect on large carnivore numbers. Indeed, Mtui et al. (2012) results in the Katavi-Rukwa and Ruaha-Rungwa ecosystems highlighted contractions in distribution and reductions in abundance. This situation would probably be confirmed by Schuette et al. (2013) results who showed that fragmented habitats (3% of Rungwa FR & GCA was deforested) and reduced resource availability (hunting plus livestock competition) will undeniably elevate rates of human-carnivore conflict and consequently end with the disappearance of large carnivores first.

In an attempt to examine arguments for collaborative approaches as they are likely to play a particularly important part in carnivore conservation, our results could not bring an answer to the debate (Redpath et al., 2017) that a 'top down command and control' approaches (Rukwa GR and Rungwa FR & GCA) over a more collaborative approaches (Mlele BKZ) is the most effective way to conserve large carnivores. Thus, further research is required to reduce uncertainty and examine the effectiveness of alternative approaches to carnivore conservation in different contexts. Results presented in this study are by no mean an attempt to disqualify stricter PAs but rather show the importance and complementarity of lower IUCN management categories PAs to effectively conserve mammal populations and especially those with large home range such as lions and African wild dogs. The government is aware of this and promotes establishment of buffer zones around NPs and corridors under the 2009 Wildlife Act. Accordingly, this study revealed the similar and high species richness of this 3 PAs and support the development of ADAP new project along the Rungwa Corridor as this area might be an important area for large carnivore – alongside other species, like the African elephant – by connecting Katavi NP populations with Ruaha NP populations, ensuring some genetic exchanges between adjacent populations (meta-population approach). Thus, this corridor appears to be an extremely important area for carnivore conservation given the dramatic decline of these species – for instance lions have disappeared from over 80% of their range and African wild dogs from over 90% of theirs (www.ruahacarnivoreproject.com).

In assessing ME along a gradient of PAs of different statuses, management regimes and governance types of the carnivore cohort, our study suggested that little association exists between IUCN management categories and conservation effectiveness. Indeed, our METT analyses suggested that 1) guards are the most important factor for law enforcement strategy in a PA. Surprisingly, State PAs (especially Rungwa FR & GCA) are allocated only small sums of money by the government, reducing the ability of rangers (GRs) and especially Forest and Wildlife Officers (FRs & GCAs) to conduct patrols over large areas. Rukwa GR and Mlele BKZ ME show that effective protection only occurs where manpower, patrols and financial resources are adequate with the size of the PA to be controlled and joins Caro et al. (1998) conclusions. 2) it is of paramount importance to develop a more integrative, trans-disciplinary monitoring approach to effectively adapt management, leading to continuous improvements in management planning and implementation of a project to achieve specified objectives. Our results thus, joined Bennett et al. (2017) conclusions who showed that increasing evidence confirm that simply providing monitoring results to managers such as in Rukwa GR and Rungwa FR & GCA is not sufficient. 3) awareness impact – on that

it has given rise to a change in behavior – requires that landowners are empowered to manage the NR they depend on so that benefits outweigh the costs of the PAs on their livelihoods. This approach seems conclusive for Mlele BKZ but could be improved by a national conservation strategy considering landscape-level approaches to land-use planning that aim at providing landowners encouragements as few village lands were left after the creation of the different PAs in the region. Indeed, lack of rights to manage and utilize NR and uncertain land tenure reduced local communities' potential benefits from the situation. Possible encouragements easily implemented in Mlele District could be based on Kinnaird & O'brien (2012) propositions to improve PAs access to ecotourism benefits, resolve human-wildlife conflicts, allow direct benefits to management body directly through NR harvesting and expanding opportunities for grazing leases. Another opportunity comes from ADAP incentives forging agreements to maintain wildlife habitat and corridors as in Mlele BKZ or through their new project along the Rungwa river.

Even if our study permitted to answer our research question, it is important to note the uncertainty reflected in our results, which ultimately represent a fairly coarse and preliminary assessment for the Katavi-Ruaha corridor. Several species were rarely detected in our survey, limiting inference on their occupancy and suggesting that they could be perilously close to local extinction – even if results ultimately proved that rare and endangered species such as lions and African wild dogs are still present in the study area. Additionally, even among the more frequently detected species, the long-term viability of their populations has not yet been appraised. Indeed, a reliable assessment of carnivore population viability along this gradient of PAs, and a better understanding of the nature of human impacts on these species, will require continued and detailed monitoring of species-specific occurrences. Though further work is needed, our approach provides a valuable framework for the assessment of wildlife communities subject to anthropogenic impact and confirmed that CT data are well-suited for such analyses (as the limiting factor seems more to be the focal species). Indeed, our results – provided enough data – resulted in robust estimation of occurrence and detection probabilities but as data collection is exactly the challenge – especially for naturally rare species such as apex predators – it also stresses the need to use data collected by other methods.

In summary, our results indicate that legal protection, backed up by on ground protection and the ability of managers to reconcile biodiversity conservation goals with social and economic issues which promotes greater compliance of local communities with PAs conservation strategies (Andrade & Rhodes, 2012) has an important role to play in maintaining carnivore species in Tanzania. Overall, our study provides valuable information about the determinants of spatial occurrence of a complete cohort of carnivores in human-used PAs and allowed the comparison of three PAs to evaluate the management done in Mlele beekeeping zone in a comparative manner. Indeed, this study demonstrated that a community-level approach provides a more comprehensive insight at a scale relevant to ecosystem-level management. Furthermore, our results highlight that Rukwa GR, Rungwa FR & GCA and Mlele BKZ are still vital areas supporting an entire cohort of carnivores and seems to serve as important buffer zones between Katavi NP and village lands even if our occupancy analysis could not support this assertion. An important issue recognized by Stampfli (2016) is the increasing encroachment of Rungwa FR & GCA by livestock species. Indeed, poor management of livestock is common, and livestock is often allowed to wander far from villages (Van der Weyde et al., 2018). In this study, livestock was detected at large distances from villages, and this will increase their vulnerability to predation and might exacerbate conflict and not only threaten carnivores, but the value of the PA. As suggested Van der Weyde et al. (2018), conflict levels and overgrazing issues should be regularly assessed. This is exactly what ADAP tries to implement in its new project on the Rungwa river corridor by implementing an integrated management of pastoralism in Kululu village reserve (www.adap.ch). Additionally, the presence of flagship species like lions and African wild dog but more probably sable antelope (Figure 31) could be used to attract tourists in the area. Local communities could then take advantage of this situation through campsites, crafts and other adventure activities (Conservation International, 2010). This situation also shows that large carnivores can also be useful for promoting the protection and management of large areas such as investigated Sergio et al. (2008). This in turns ensure the conservation of other species through the preservation of their habitat such as the African viverrid species that are particularly likely to become threatened, even though most are currently considered relatively safe (Cardillo et al., 2004). To conclude, regular monitoring of NR is still encouraged as long-term sustainability of habitat and biodiversity is vital for both local communities and wildlife populations and that maintaining the stability of the ecosystem might be more cost-effective in the long term than post decline attempts to reduce harms. Thus, time series data will assist managers to target vulnerable species – particularly in the light of accelerating environmental change and anthropogenic impacts (Pettorelli et al., 2010). Indeed, «finding effective ways of conserving large carnivores is widely recognized as a priority in conservation. However, there is disagreement about the most effective way to do this, with some favoring top-down 'command and control' approaches and others favoring collaboration» (Redpath et al., 2017). In addition, in an extensive review in the

African Journal of Ecology special section – Camera trapping in Africa – demonstrated that CT are now firmly established as one of the most useful tools in all biomes and ecosystems to conduct wildlife monitoring (Cusack et al., 2018) but CT are interesting in a fairly new context, as images of people can be used to inform conservation practice. Indeed, Rukwa GR PM interest demonstrated that CT are a key tool in conservation surveillance. Sandbrook et al. (2018) showed that human bycatch had a positive impact in law enforcement strategy. However, the authors warn «that these findings reveal a breach of commitment to do no harm and could undermine conservation success if they exacerbate conflict».

Figure 31: The main large antelope in the Miombo woodlands is the Sable Antelope, Hippotragus niger

Yverdon-les-bains, Mai 9th, 2019.

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7. References

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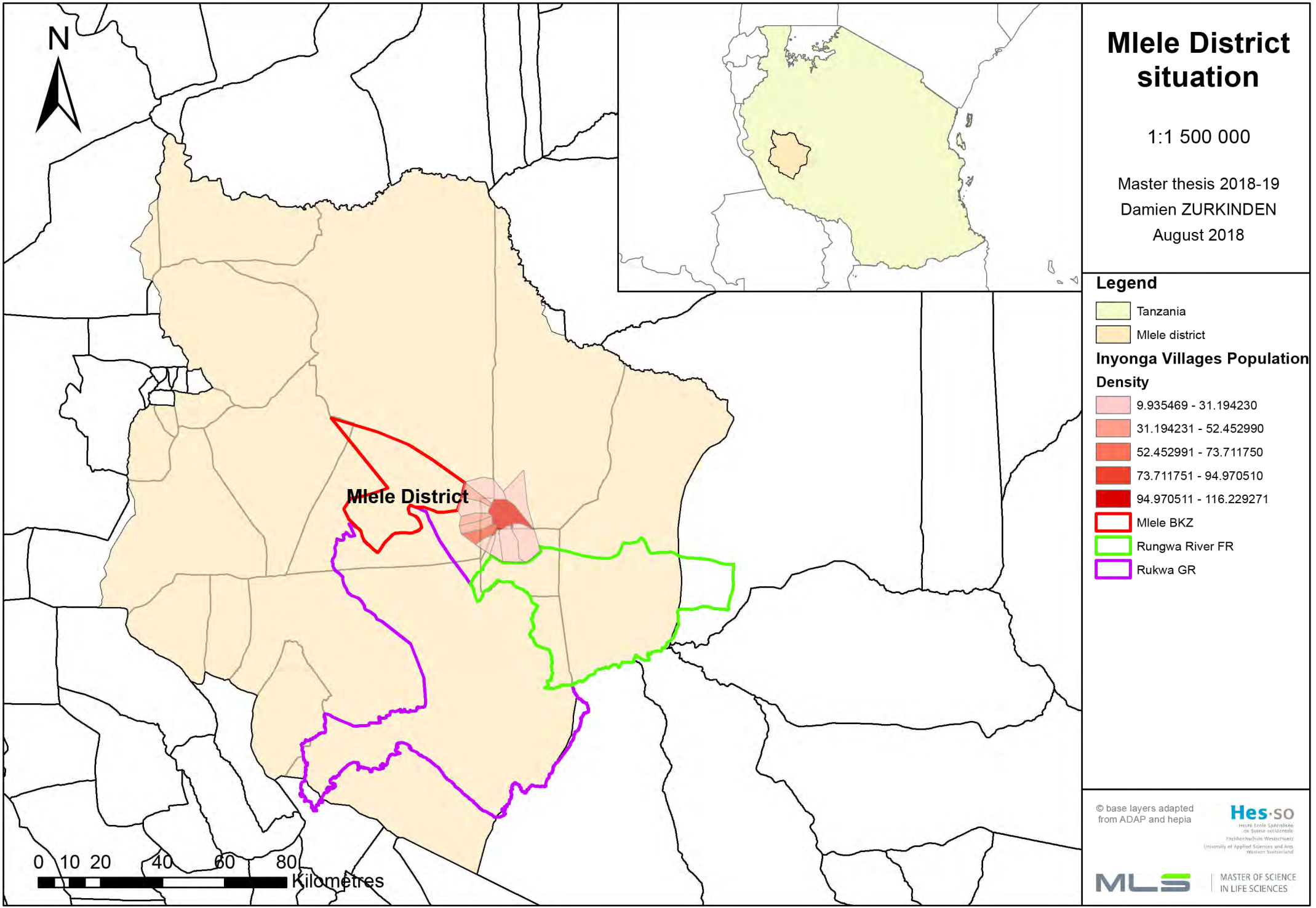
8. Appendices

Appendix I: Study Area Situation Maps

Source: ESRI, 201



Mlele District situation

1:1 500 000

Master thesis 2018-19
Damien ZURKINDEN
August 2018

Legend

- Tanzania
- Mlele district

Inyonga Villages Population Density

- 9.935469 - 31.194230
- 31.194231 - 52.452990
- 52.452991 - 73.711750
- 73.711751 - 94.970510
- 94.970511 - 116.229271
- Mlele BKZ
- Rungwa River FR
- Rukwa GR

Hes·so
Haute Ecole Spécialisée de Suisse occidentale
Fachhochschule Westschweiz
University of Applied Sciences and Arts Western Switzerland
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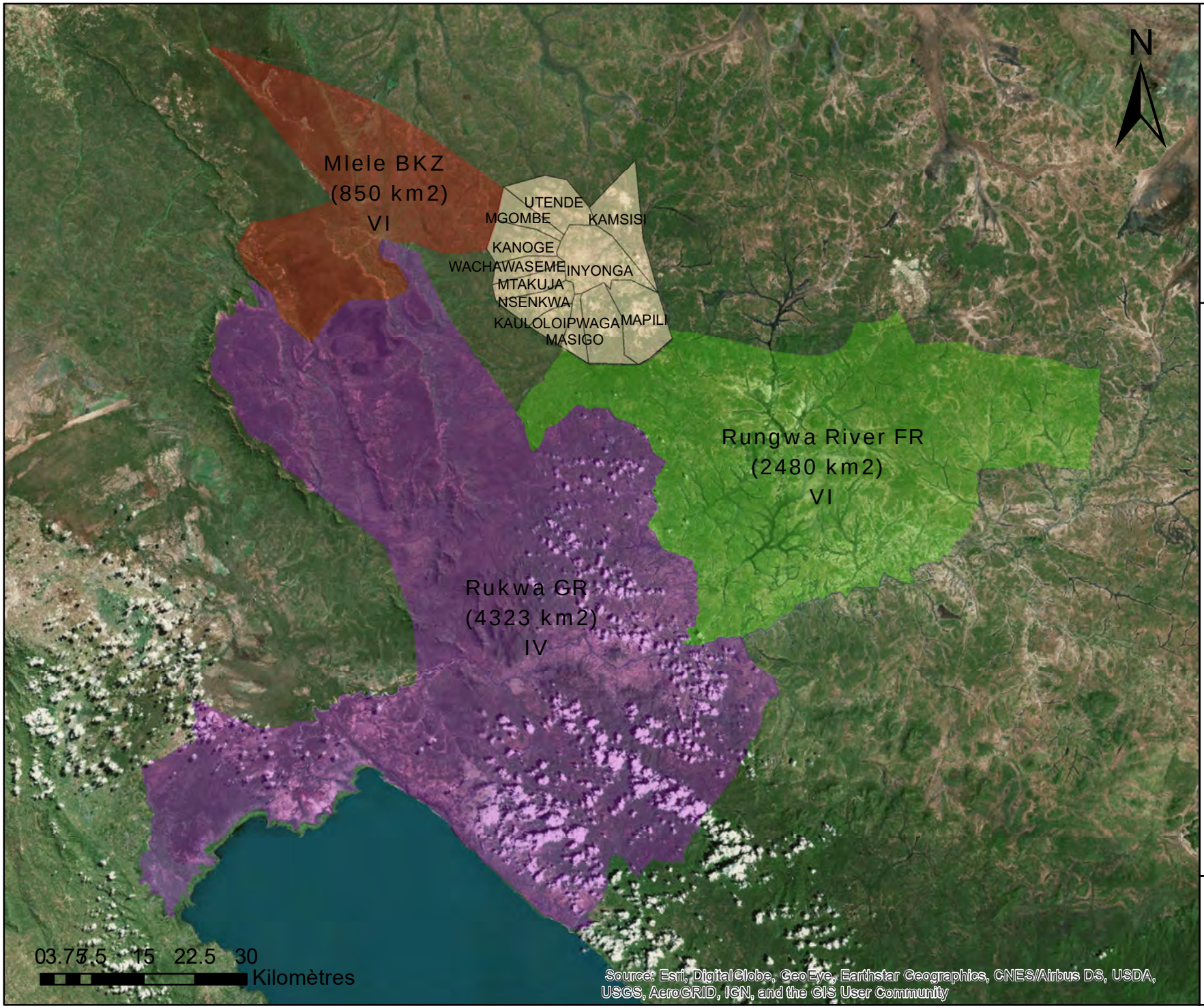

Study area

1:750 000

Master thesis 2018-19
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August 2018

Legend

- Mlele BKZ
- Rungwa River FR
- Rukwa GR

Hes·so

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Appendix II: Predictive List (based on literature) of Mammals Present in the Katavi-Rukwa Ecosystem

Adapted from Mermod, 2012

N°	Ordre	Famille	Nom français	Nom anglais	Nom swahili	Nom latin	Red Liste*
1	Proboscidea	Elephantidae	Eléphant d'Afrique	African elephant	Tembo	*Loxodonta africana*	*VU*
2	Proboscidea	Hyracoidae	Daman des steppes	Bush hyrax	Pimbi	*Heterohyrax brucei*	*LC*
3	Proboscidea	Hyracoidae	Daman des arbres	Tree hyrax	Pimbi mti / Perere	*Dendrohyrax arboreus*	*LC*
4	Proboscidea	Orycteropodidae	Oryctérope	Aardwark	Muhanga	*Orycteropus afer*	*LC*
5	Artiodactyla	Bovidae	Impala	Impala	Swala pala	*Aepyceros melampus*	*LC*
6	Artiodactyla	Bovidae	Budale de Lichtenstein	Lichtenstein's hartebeest	Kongoni	*Alcelaphus lichtensteinii*	*LC*
7	Artiodactyla	Bovidae	Damalisque	Topi	Nyamera	*Damaliscus lunatus*	*VU*
8	Artiodactyla	Bovidae	Antilope rouanne	Roan antelope	Korongo	*Hippotragus equinus*	*LC*
9	Artiodactyla	Bovidae	Hippotrague noir	Sable antelope	Palahala	*Hippotragus niger*	*LC*
10	Artiodactyla	Bovidae	Cobe defassa	Defassa waterbuck	Kuro	*Kobus ellipsiprymnus*	*LC*
11	Artiodactyla	Bovidae	Puku	Puku	Sheshe	*Kobus vardoni*	*NT*
12	Artiodactyla	Bovidae	Dik-dik de Kirk	Kirk's dik dik	Digidigi	*Madoqua kirkii*	*LC*
13	Artiodactyla	Bovidae	Oréotrague	Klipspringer	Mbuzi mawe	*Oreotragus oreotragus*	*LC*
14	Artiodactyla	Bovidae	Ourébi	Oribi	Taya	*Ourebia ourebi*	*LC*
15	Artiodactyla	Bovidae	Raphicère de Sharpe	Sharpe's grysbok	Dondoro	*Raphicerus sharpei*	*LC*
16	Artiodactyla	Bovidae	Cobe des roseaux	Southern reedbuck	Tohe ndope	*Redunca arundinum*	*LC*
17	Artiodactyla	Bovidae	Redunca	Bohor reedbuck	Tohe	*Redunca redunca*	*LC*
18	Artiodactyla	Bovidae	Buffle d'Afrique	African buffalo	Nyati	*Syncerus caffer*	*LC*
19	Artiodactyla	Bovidae	Céphalophe bleu	Blue duiker	Ndimba / Paa chesi	*Philantombamonti cola*	*LC*
20	Artiodactyla	Bovidae	Céphalophe couronné	Common duiker	Nsha / Nsya	*Sylvicapra grimmia*	*LC*
21	Artiodactyla	Bovidae	Eland du Cap	Common eland	Pofu	*Tragelaphus oryx*	*LC*

22	Artiodactyla	Bovidae	Guib harnaché	Bushbuck	Pongo / Mbawala	*Tragelaphus scriptus*	*LC*
23	Artiodactyla	Bovidae	Grand koudou	Greater kudu	Tandala mkubwa	*Tragelaphus stepsiceros*	*LC*
24	Artiodactyla	Giraffidae	Girafe	Giraffe	Twiga	*Giraffa camelopardalis*	*VU*
25	Artiodactyla	Hippopotamidae	Hippopotame	Hippopotamus	Kiboko	*Hippopotamus amphibius*	*VU*
26	Artiodactyla	Suidae	Phacochère commun	Warthog	Ngiri	*Phacocherus africanus*	*LC*
27	Artiodactyla	Suidae	Potamochère	Bushpig	Nguruwe pori / Mwitu	*Potamochoerus larvatus*	*LC*
28	Carnivora	Canidae	Chacal à flancs rayés	Side-striped jackal	Bweha miraba	*Canis adustus*	*LC*
29	Carnivora	Canidae	Chacal à chabraque	Black backed jackal	Bweha mgongo mweusi	*Canis mesolemas*	*LC*
30	Carnivora	Canidae	Lycaon	Wild dog	Mbwa mwitu	*Lycaon pictus*	*EN*
31	Carnivora	Felidae	Caracal	Caracal	Simbamangu	*Felis caracal*	*LC*
32	Carnivora	Felidae	Serval	Serval	Mondo	*Leptailurus serval*	*LC*
33	Carnivora	Felidae	Chat sauvage	Wild cat	Kimburu / Pakapori	*Felis sylvestris*	*LC*
34	Carnivora	Felidae	Léopard	Leopard	Chui	*Panthera pardus*	*VU*
35	Carnivora	Felidae	Lion	Lion	Simba	*Panthera leo*	*VU*
36	Carnivora	Herpestidae	Mangouste des marais	Marsh mongoose	Nguchiro maji	*Atilax paludinosis*	*LC*
37	Carnivora	Herpestidae	Mangouste à queue touffue	Bushy tailed mongoose	Nguchiro kijivu	*Bdeogale crassicaudata*	*LC*
38	Carnivora	Herpestidae	Mangue rayée	Banded mongoose	Nguchiro miraba	*Mungos mungo*	*LC*
39	Carnivora	Herpestidae	Mangouste naine du Sud	Dwarf mongoose	Nguchiro mfupi / Kitafe	*Helogale parvula*	*LC*
40	Carnivora	Herpestidae	Mangouste ichneumon	Egyptian mongoose	Nguchiro mkubwa	*Herpestes ichneumon*	*LC*
41	Carnivora	Herpestidae	Mangouste rouge	Slender mongoose	Nguchiro (mwembamba) / Kicheche	*Herpestes sanguinea*	*LC*
42	Carnivora	Herpestidae	Mangouste à queue blanche	White tailed mongoose	Nguchiro (mkiamweupe)	*Ichneumia albicauda*	*LC*
43	Carnivora	Herpestidae	Mangouste de Meller	Meller's mongoose	Nguchiro	*Rynchogale melleri*	*LC*
44	Carnivora	Hyaenidae	Hyène tachetée	Spotted hyena	Fisi	*Crocuta crocuta*	*LC*

45	Carnivora	Hyaenidae	Protèle	Aardwolf	Fisi Mdogo	*Proteles cristatus*	*LC*
46	Carnivora	Mustelidae	Ratel	Honey badger	Nyegere	*Mellivora capensis*	*LC*
47	Carnivora	Mustelidae	Zorille commune	Zorilla (striped polecat)	Kicheche	*Ictonyx striatus*	*LC*
48	Carnivora	Nandinidae	Nandinie	African palm civet	Fungo	*Nandinia binotata*	*LC*
49	Carnivora	Viverridae	Civette d'Afrique	African civet	Ngawa / Paka wa zabidi	*Civettictis civetta*	*LC*
50	Carnivora	Viverridae	Genette d'Angola	Miombo genet	Kanu / Kamsimba	*Genetta angolensis*	*LC*
51	Carnivora	Viverridae	Genette d'Europe	Common genet	Kamsimba	*Genetta genetta*	*LC*
52	Carnivora	Viverridae	Genette pardine	Large spotted genet	Kanu / Kamsimba / mavalevale	*Genetta maculata*	*LC*
53	Carnivora	Viverridae	Genette servaline	Servaline genet	Kanu	*Genetta servalina*	*LC*
54	Lagomorpha	Leporidae	Lièvre des rochers	Scrub hare	Sungura	*Lepus victoriae*	*LC*
55	Insectivora	Erinaceidae	Hérisson africain	White-bellied hedgehog	Kalunguyeye	*Atelerix albiventris*	*LC*
56	Perissodactyla	Equidae	Zèbre des plaines	Plain zebra	Punda milia	*Equus q. boehmi*	*NT*
57	Primates	Cercopithecinae	Cercopithèque diadème	Mitis monkey	Karasinga / Kima	*Cercopithecus mitis*	*LC*
58	Primates	Cercopithecinae	Vervet bleu	Vervet monkey	Tumbili	*Chlorocebus pygerythrus*	*LC*
59	Primates	Cercopithecinae	Cynocéphale	Yellow baboon	Nyani njano	*Papio cynocephalus*	*LC*
60	Primates	Galagonidae	Galago moholi	Southern lesser Galago	Komba mdogo	*Galago moholi*	*LC*
61	Primates	Galagonidae	Galago à queu touffue	Large-eared Greater Galogo	Komba makubwa	*Otolemur crassicaudatus*	*LC*
62	Rodentia	Hystricidae	Porc-épic à crête	African Porcupine	Nungunungu	*Hystrix africaeaustralis*	*LC*
63	Rodentia	Pedetidae	Lièvre sauteur	Spring hare	Kamendegere	*Pedetes surdaster*	*LC*
64	Pholidota	Manidae	Pangolin terrestre du Cap	Ground pangolin	Kakakuon (waaridhini)	*Smutia temminckii*	*VU*

*LC = least concern, NT = nearly threatened, VU = vulnerable, EN = endangered (IUCN, 2017)

Appendix III: Plannings

Planned planning

AUGUST	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
THESE						Arriving Dar es Salam	COSTECH Permit				Arriving Inyonga									CT Pose (2 Grids)											
Info	Organize Interviews																														

SEPTEMBER	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
THESE										CT Depose (2 Grids)							Battery Charging				CT Pose (2 Grids)									
Info			Organize Interviews																											

OCTOBER	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
THESE												CT Depose (2 Grids)							Battery Charging				CT Pose (2 Grids)								
Info	Organize Interviews																														

NOVEMBER	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
THESE													CT Depose (2 Grids)							Battery Charging				CT Pose (2 Grids)					
Info					Organize Interviews																							Departing			

DECEMBER	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
THESE															CT Depose (2 Grids)																
Info																															

Effective planning

AUGUST	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
THESE						Arriving Dar es Salam		COSTECH Permit				Arriving Inyonga																			
Info																															

SEPTEMBER	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
THESE	CT Pose (2 Grids)																		CT Depose (2 Grids)								Battery Charging			
Info										Interviews																					

OCTOBER	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
THESE	CT Pose (2 Grids)																				CT Depose (2 Grids)								Battery Charging		
Info									Interviews																						

NOVEMBER	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
THESE		CT Pose (2 Grids)																				CT Depose (2 Grids)								
Info												Interviews																Departing			

DECEMBER	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
THESE	Battery Charging							CT Pose (2 Grids)																CT Depose (2 Grids)							
Info																															

Appendix IV: Camera Traps GPS Positioning and Maps

Rukwa					Rungwa				
	Projected		Real			Projected		Real	
numero	coord_x	coord_y	coord_x	coord_y	numero	coord_x	coord_y	coord_x	coord_y
R1_01	31.61027736	-6.794925178	31.6107	-6.7957	RW1_01	32.18914726	-6.922872014	32.1887	-6.9232
R1_02	31.62837185	-6.794976755	31.6287	-6.7953	RW1_02	32.20725009	-6.922902529	32.1887	-6.9232
R1_03	31.64646649	-6.795027657	31.6469	-6.7952	RW1_03	32.225353	-6.922932355	32.224	-6.9229
R1_04	31.66456127	-6.795077883	31.66520	-6.7945	RW1_04	32.243456	-6.922961493	32.2443	-6.9231
R1_05	31.68265618	-6.795127435	31.6827	-6.795	RW1_05	32.26155907	-6.922989944	32.2621	-6.9233
R1_06	31.70075122	-6.795176311	31.6999	-6.79520	RW1_06	32.27966221	-6.923017703	32.2799	-6.9232
R1_07	31.61022535	-6.813011897	31.61	-6.81300	RW1_07	32.18911634	-6.940962169	32.1895	-6.9398
R1_08	31.62832052	-6.813063614	31.6282	-6.8127	RW1_08	32.20721986	-6.940992767	32.207	-6.9405
R1_09	31.64641584	-6.813114653	31.6469	-6.8129	RW1_09	32.22532346	-6.941022672	32.2251	-6.9415
R1_10	31.66451129	-6.813165014	31.6645	-6.81310	RW1_10	32.24342714	-6.941051887	32.2434	-6.9413
R1_11	31.68260687	-6.813214699	31.6826	-6.8134	RW1_11	32.2615309	-6.941080413	32.2615	-6.9411
R1_12	31.7007026	-6.813263706	31.7004	-6.8129	RW1_12	32.27963474	-6.941108245	32.2799	-6.9416
R1_13	31.6101732	-6.831098604	31.6108	-6.8304	RW1_13	32.18908533	-6.959052314	32.1891	-6.9593
R1_14	31.62826905	-6.831150459	31.6284	-6.8314	RW1_14	32.20718955	-6.95908299	32.2069	-6.9591
R1_15	31.64636504	-6.831201635	31.6466	-6.8308	RW1_15	32.22529384	-6.959112974	32.2259	-6.9589
R1_16	31.66446117	-6.831252132	31.6642	-6.8306	RW1_16	32.24339822	-6.959142268	32.2431	-6.9592
R1_17	31.68255744	-6.831301949	31.6823	-6.831	RW1_17	32.26150267	-6.959170867	32.2615	-6.9591
R1_18	31.70065384	-6.831351087	31.7008	-6.8309	RW1_18	32.27960719	-6.959198773	32.2795	-6.9591
R1_19	31.61012091	-6.849185297	31.6099	-6.849	RW1_19	32.18905424	-6.977142442	32.1891	-6.9771
R1_20	31.62821744	-6.84923729	31.6281	-6.8486	RW1_20	32.20715915	-6.977173201	32.2079	-6.9774
R1_21	31.64631411	-6.849288603	31.6463	-6.8492	RW1_21	32.22526414	-6.977203263	32.2254	-6.9774
R1_22	31.66441092	-6.849339234	31.6646	-6.8496	RW1_22	32.24336921	-6.977232632	32.2435	-6.9772
R1_23	31.68250787	-6.849389185	31.6825	-6.8496	RW1_23	32.26147435	-6.977261307	32.2614	-6.9773
R1_24	31.70060495	-6.849438454	31.7001	-6.8491	RW1_24	32.27957957	-6.977289286	32.2796	-6.9773
R1_25	31.61006847	-6.867271975	31.61030	-6.8676	RW1_25	32.18902307	-6.995232558	32.1888	-6.9952
R1_26	31.62816569	-6.867324107	31.6285	-6.8669	RW1_26	32.20712867	-6.995263396	32.2075	-6.996
R1_27	31.64626304	-6.867375556	31.6471	-6.86680	RW1_27	32.22523436	-6.995293537	32.2251	-6.9954
R1_28	31.66436054	-6.867426323	31.6655	-6.86760	RW1_28	32.24334012	-6.995322985	32.2434	-6.9951
R1_29	31.68245817	-6.867476406	31.6823	-6.8671	RW1_29	32.26144597	-6.995351734	32.2614	-6.9954
R1_30	31.70055593	-6.867525808	31.7022	-6.8677	RW1_30	32.27955188	-6.995379786	32.2797	-6.9956
R1_31	31.6100159	-6.88535864	31.6099	-6.8856	RW1_31	32.18899182	-7.01332266	32.1888	-7.0134
R1_32	31.6281138	-6.88541091	31.62800	-6.8854	RW1_32	32.20709812	-7.013353577	32.2076	-7.0133
R1_33	31.64621184	-6.885462497	31.6459	-6.88540	RW1_33	32.2252045	-7.013383801	32.2252	-7.0137
R1_34	31.66431001	-6.885513398	31.6642	-6.8856	RW1_34	32.24331096	-7.013413322	32.2439	-7.0137
R1_35	31.68240833	-6.885563614	31.68230	-6.8852	RW1_35	32.2614175	-7.013442147	32.2612	-7.0132
R1_36	31.70050677	-6.885613146	31.7001	-6.8854	RW1_36	32.27952412	-7.013470272	32.2792	-7.0132
R2_01	31.71875037	-6.831399546	31.7198	-6.8312	RW2_01	32.3162916	-6.869007633		
R2_02	31.73684704	-6.831447326	31.7369	-6.8313	RW2_02	32.33439291	-6.869033111		
R2_03	31.75494383	-6.831494427	31.755	-6.83160	RW2_03	32.35249429	-6.869057904		
R2_04	31.77304075	-6.831540848	31.7736	-6.8305	RW2_04	32.37059573	-6.869082017		
R2_05	31.79113779	-6.83158659	31.7908	-6.83180	RW2_05	32.38869724	-6.869105443		
R2_06	31.80923496	-6.831631653	31.8091	-6.8314	RW2_06	32.40679881	-6.869128188		
R2_07	31.71870216	-6.849487043	31.7188	-6.8496	RW2_07	32.31626573	-6.887098358		
R2_08	31.73679951	-6.84953495	31.7374	-6.8492	RW2_08	32.33436772	-6.887123903		

R2_09	31.75489698	-6.849582176	31.7553	-6.8483	RW2_09	32.35246979	-6.887148762		
R2_10	31.77299458	-6.849628723	31.7728	-84948.0	RW2_10	32.37057191	-6.887172939		
R2_11	31.7910923	-6.849674586	31.791	-6.8496	RW2_11	32.3886741	-6.887196428		
R2_12	31.80919015	-6.84971977	31.8091	-6.8496	RW2_12	32.40677636	-6.887219232		
R2_13	31.71865382	-6.867574526	31.7188	-6.8685	RW2_13	32.31623979	-6.90518907		
R2_14	31.73675185	-6.867622561	31.73710	-6.868	RW2_14	32.33434247	-6.905214681		
R2_15	31.75485001	-6.867669913	31.7544	-6.8682	RW2_15	32.35244522	-6.905239609		
R2_16	31.77294829	-6.867716583	31.7732	-6.8682	RW2_16	32.37054804	-6.905263848		
R2_17	31.79104669	-6.86776257	31.7907	-6.8678	RW2_17	32.38865091	-6.905287401		
R2_18	31.80914522	-6.867807873	31.80960	-6.8678	RW2_18	32.40675385	-6.905310264		
R2_19	31.71860535	-6.885661994	31.7185	-6.8859	RW2_19	32.31621378	-6.923279765		
R2_20	31.73670406	-6.885710157	31.7372	-6.8855	RW2_20	32.33431715	-6.923305447		
R2_21	31.7548029	-6.885757636	31.75480	-6.88580	RW2_21	32.35242059	-6.92333044		
R2_22	31.77290187	-6.88580443	31.7744	-6.8861	RW2_22	32.37052409	-6.923354744		
R2_23	31.79100096	-6.885850538	31.7906	-6.8857	RW2_23	32.38862766	-6.923378359		
R2_24	31.80910017	-6.885895963	31.8096	-6.8856	RW2_24	32.40673128	-6.923401284		
R2_25	31.71855675	-6.903749449	31.7186	-6.90410	RW2_25	32.3161877	-6.941370449		
R2_26	31.73665615	-6.903797739	31.73670	-6.9042	RW2_26	32.33429176	-6.941396198		
R2_27	31.75475567	-6.903845344	31.7549	-6.9039	RW2_27	32.35239589	-6.941421257		
R2_28	31.77285533	-6.903892262	31.7728	-6.9031	RW2_28	32.37050008	-6.941445625		
R2_29	31.7909551	-6.903938492	31.7911	-6.9044	RW2_29	32.38860434	-6.941469301		
R2_30	31.809055	-6.903984038	31.80890	-6.90420	RW2_30	32.40670866	-6.941492288		
R2_31	31.71850802	-6.92183689	31.7191	-6.9228	RW2_31	32.31616156	-6.959461118		
R2_32	31.73660811	-6.921885308	31.7363	-6.922	RW2_32	32.33426631	-6.959486935		
R2_33	31.75470832	-6.921933039	31.7541	-6.9234	RW2_33	32.35237113	-6.959512061		
R2_34	31.77280866	-6.92198008	31.7728	-6.9221	RW2_34	32.37047601	-6.959536491		
R2_35	31.79090912	-6.922026433	31.7909	-6.92170	RW2_35	32.38858096	-6.959560231		
R2_36	31.80900971	-6.922072098	31.80910	-6.9219	RW2_36	32.40668597	-6.959583276		
R3_01	31.77276187	-6.940067885	31.7735	-6.9401	RW3_01	32.42444662	-6.99560815		
R3_02	31.79086302	-6.94011436	31.7904	-6.9402	RW3_02	32.44255314	-6.995629947		
R3_03	31.8089643	-6.940160146	31.809	-6.9402	RW3_03	32.4606597	-6.995651046		
R3_04	31.8270657	-6.940205241	31.8262	-6.9391	RW3_04	32.47876633	-6.995671451		
R3_05	31.84516722	-6.940249646	31.8452	-6.9397	RW3_05	32.496873	-6.995691161		
R3_06	31.86326885	-6.94029336	31.8621	-6.94	RW3_06	32.51497973	-6.99571017		
R3_07	31.77271495	-6.958155675	31.7727	-6.9582	RW3_07	32.42442443	-7.013699155		
R3_08	31.7908168	-6.958202273	31.7919	-6.9588	RW3_08	32.44253164	-7.013721009		
R3_09	31.80891876	-6.958248179	31.8086	-6.9572	RW3_09	32.46063891	-7.013742165		
R3_10	31.82702085	-6.958293393	31.8269	-6.9582	RW3_10	32.47874623	-7.013762622		
R3_11	31.84512307	-6.958337915	31.8449	-6.9586	RW3_11	32.4968536	-7.013782381		
R3_12	31.86322539	-6.958381745	31.8632	-6.9587	RW3_12	32.51496103	-7.013801443		
R3_13	31.77266791	-6.976243452	31.7725	-6.976	RW3_13	32.42440218	-7.031790145		
R3_14	31.79077045	-6.976290171	31.791	-6.9762	RW3_14	32.44251009	-7.031812058		
R3_15	31.80887311	-6.976336198	31.8089	-6.9764	RW3_15	32.46061805	-7.031833268		
R3_16	31.82697589	-6.976381531	31.8274	-6.9763	RW3_16	32.47872607	-7.031853778		
R3_17	31.8450788	-6.97642617	31.8452	-6.9764	RW3_17	32.49683415	-7.03187359		
R3_18	31.86318182	-6.976470114	31.8624	-6.9767	RW3_18	32.51494227	-7.031892701		
R3_19	31.77262074	-6.994331214	31.7728	-6.9939	RW3_19	32.42437987	-7.049881124		
R3_20	31.79072397	-6.994378056	31.7901	-6.9942	RW3_20	32.44248848	-7.049903091		
R3_21	31.80882733	-6.994424203	31.8084	-6.9948	RW3_21	32.46059714	-7.049924356		

R3_22	31.82693081	-6.994469654	31.8269	-6.9948	RW3_22	32.47870587	-7.049944923		
R3_23	31.84503441	-6.994514409	31.8454	-6.9946	RW3_23	32.49681465	-7.049964784		
R3_24	31.86313813	-6.99455847	31.8626	-6.9945	RW3_24	32.51492347	-7.049983945		
R3_25	31.77257344	-7.012418961	31.773	-7.0126	RW3_25	32.4243575	-7.067972088		
R3_26	31.79067738	-7.012465926	31.7905	-7.0137	RW3_26	32.44246681	-7.067994112		
R3_27	31.80878143	-7.012512193	31.8084	-7.0127	RW3_27	32.46057618	-7.068015433		
R3_28	31.82688561	-7.012557764	31.826	-7.0124	RW3_28	32.47868561	-7.068036051		
R3_29	31.84498991	-7.012602636	31.8453	-7.0128	RW3_29	32.49679509	-7.068055965		
R3_30	31.86309432	-7.012646811	31.8629	-7.0133	RW3_30	32.51490462	-7.068075174		
R3_31	31.77252603	-7.030506695	31.7718	-7.0305	RW3_31	32.42433507	-7.086063037		
R3_32	31.79063066	-7.030553782	31.7903	-7.0301	RW3_32	32.44244509	-7.086085119		
R3_33	31.80873541	-7.03060017	31.8087	-7.0307	RW3_33	32.46055517	-7.086106495		
R3_34	31.82684029	-7.030645859	31.8286	-7.032	RW3_34	32.4786653	-7.086127167		
R3_35	31.84494528	-7.030690848	31.8452	-7.0303	RW3_35	32.49677548	-7.086147132		
R3_36	31.8630504	-7.030735138	31.8631	-7.0311	RW3_36	32.51488638	-7.086166421		
R4_01	32.00800989	-6.97679546	32.0081	-6.9767	RW4_01	32.26130499	-7.085803873	32.2614	-7.0857
R4_02	32.02611389	-6.976833159	32.0268	-6.9771	RW4_02	32.27941443	-7.0858322	32.2794	-7.0861
R4_03	32.04421799	-6.976870164	32.0429	-6.9773	RW4_03	32.29752395	-7.085859822	32.298	-7.0861
R4_04	32.06232218	-6.976906474	32.0618	-6.9772	RW4_04	32.31563354	-7.085886736	32.3156	-7.0859
R4_05	32.08042647	-6.976942091	32.0807	-6.9765	RW4_05	32.3337432	-7.085912949	32.3333	-7.0857
R4_06	32.09853086	-6.976977013	32.1003	-6.9764	RW4_06	32.35185293	-7.085938454	32.3515	-7.0859
R4_07	32.00797176	-6.99488467	32.0077	-6.9949	RW4_07	32.26127624	-7.103894225	32.2611	-7.1035
R4_08	32.02607646	-6.994922468	32.0257	-6.9945	RW4_08	32.27938639	-7.103922625	32.2792	-7.1039
R4_09	32.04418125	-6.994959569	32.0443	-6.9949	RW4_09	32.29749662	-7.103950317	32.2973	-7.1034
R4_10	32.06228614	-6.994995976	32.0627	-6.995	RW4_10	32.31560692	-7.103977303	32.3165	-7.1036
R4_11	32.08039113	-6.995031685	32.0803	-6.9947	RW4_11	32.33371729	-7.104003581	32.3343	-7.1034
R4_12	32.09849621	-6.995066699	32.0989	-6.9953	RW4_12	32.35182772	-7.104029152	32.3507	-7.1051
R4_13	32.00793353	-7.012973866	32.0079	-7.0132	RW4_13	32.26124742	-7.121984562	32.2615	-7.1222
R4_14	32.02603893	-7.013011763	32.0262	-7.0131	RW4_14	32.27935828	-7.122013036	32.2804	-7.1219
R4_15	32.04414442	-7.01304896	32.0446	-7.0131	RW4_15	32.29746922	-7.122040798	32.2975	-7.1226
R4_16	32.06225	-7.013085462	32.0619	-7.0133	RW4_16	32.31558022	-7.122067853	32.3157	-7.1221
R4_17	32.08035569	-7.013121265	32.0813	-7.0135	RW4_17	32.3336913	-7.122094201	32.3329	-7.122
R4_18	32.09846147	-7.01315637	32.099	-7.013	RW4_18	32.35180244	-7.122119836	32.3517	-7.1224
R4_19	32.0078952	-7.031063048	32.0082	-7.0309	RW4_19	32.26121852	-7.140074886	32.2615	-7.1406
R4_20	32.0260013	-7.031101043	32.0261	-7.0308	RW4_20	32.27933009	-7.140103431	32.2795	-7.1403
R4_21	32.04410749	-7.031138339	32.0442	-7.0309	RW4_21	32.29744174	-7.140131265	32.2975	-7.1398
R4_22	32.06221377	-7.031174935	32.0625	-7.0313	RW4_22	32.31555346	-7.14015839	32.3155	-7.1403
R4_23	32.08032016	-7.031210832	32.0807	-7.0314	RW4_23	32.33366524	-7.140184805	32.3337	-7.1403
R4_24	32.09842663	-7.031246028	32.0969	-7.0305	RW4_24	32.3517771	-7.140210508	32.3515	-7.1403
R4_25	32.00785677	-7.049152216	32.0078	-7.0488	RW4_25	32.26118955	-7.158165196	32.2611	-7.158
R4_26	32.02596357	-7.04919031	32.0258	-7.0496	RW4_26	32.27930183	-7.158193812	32.2794	-7.1585
R4_27	32.04407046	-7.049227703	32.0445	-7.0494	RW4_27	32.29741419	-7.158221721	32.2971	-7.1582
R4_28	32.06217745	-7.049264394	32.0621	-7.0621	RW4_28	32.31552662	-7.158248914	32.3149	-7.1586
R4_29	32.08028453	-7.049300383	32.0803	-7.0488	RW4_29	32.33363912	-7.158275394	32.3334	-7.1587
R4_30	32.09839171	-7.049335671	32.0974	-7.0492	RW4_30	32.35175169	-7.158301163	32.3516	-7.1585
R4_31	32.00781824	-7.067241371	32.0081	-7.0667	RW4_31	32.2611605	-7.176255491	32.2611	-7.1765
R4_32	32.02592574	-7.067279562	32.0247	-7.0666	RW4_32	32.2792735	-7.176284181	32.2793	-7.1763
R4_33	32.04403333	-7.067317051	32.0435	-7.0672	RW4_33	32.29738657	-7.176312158	32.2971	-7.1768
R4_34	32.06214102	-7.067353838	32.0627	-7.0688	RW4_34	32.31549972	-7.176339422	32.3153	-7.1764

R4_35	32.08024881	-7.06738992	32.0811	-7.0674	RW4_35	32.33361293	-7.17636597	32.3339	-7.1766
R4_36	32.09835669	-7.0674253	32.098	-7.0671	RW4_36	32.35172621	-7.176391804	32.3517	-7.1771

MIele									
	Projected		Real			Projected		Real	
numero	coord_x	coord_y	coord_x	coord_y	numero	coord_x	coord_y	coord_x	coord_y
M1_01	31.7010879	-6.66856416	31.70058	-6.66850	M4_01	31.8460255	-6.57848137		
M1_02	31.6286769	-6.68645531	31.62867	-6.68637	M4_02	31.827895	-6.59652773		
M1_03	31.6467675	-6.68650539	31.64694	-6.68625	M4_03	31.8459837	-6.59656992		
M1_04	31.6648583	-6.68655481	31.66491	-6.68673	M4_04	31.8640726	-6.59661145		
M1_05	31.6829492	-6.68660356	31.68283	-6.68663	M4_05	31.8278524	-6.61461614		
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M1_11	31.6829007	-6.70469091	31.68237	-6.70433	M4_11	31.86399	-6.63278872		
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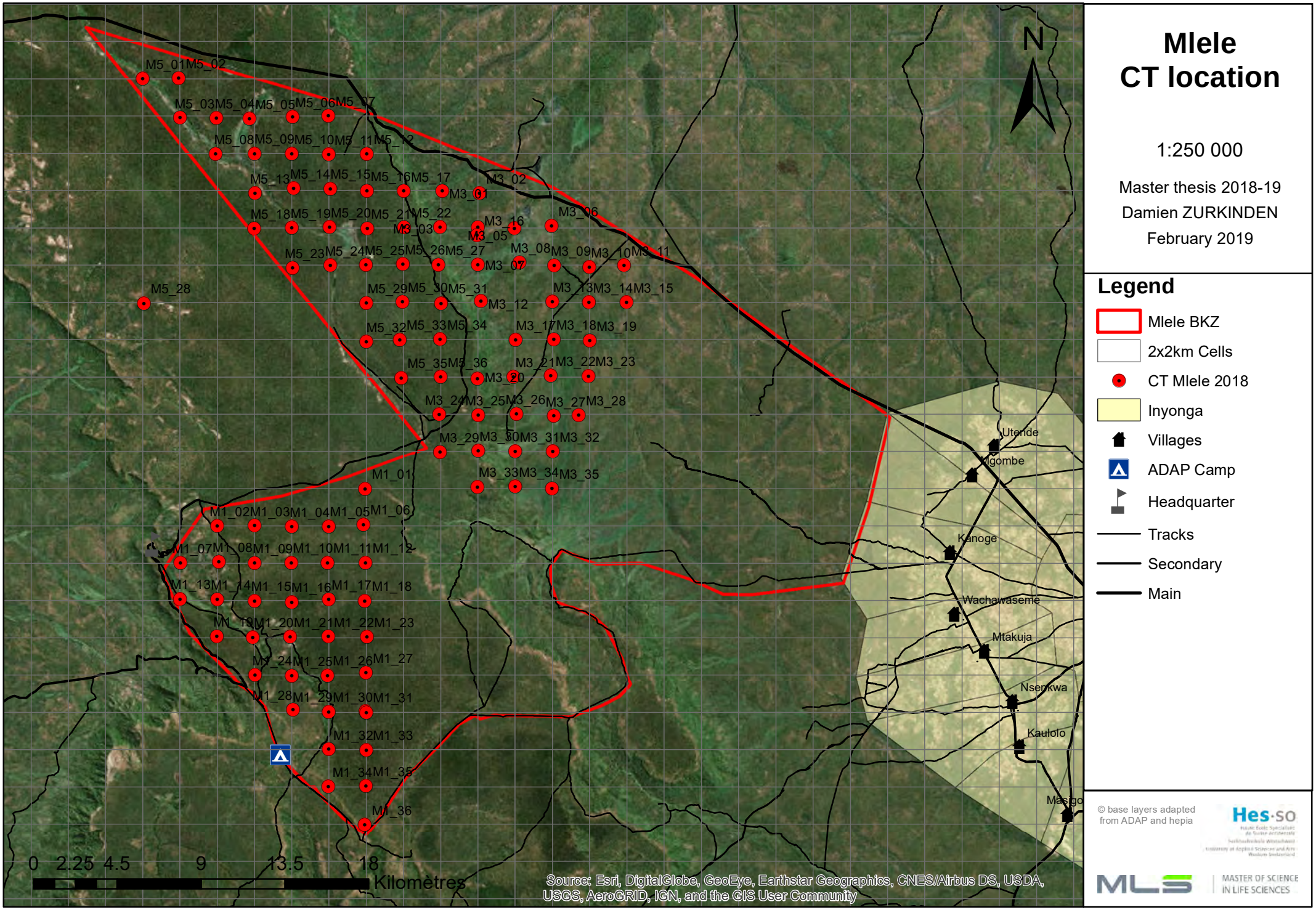

Mlele CT location

1:250 000

Master thesis 2018-19
Damien ZURKINDEN
February 2019

Legend

- Mlele BKZ
- 2x2km Cells
- CT Mlele 2018
- Inyonga
- Villages
- ADAP Camp
- Headquarter
- Tracks
- Secondary
- Main

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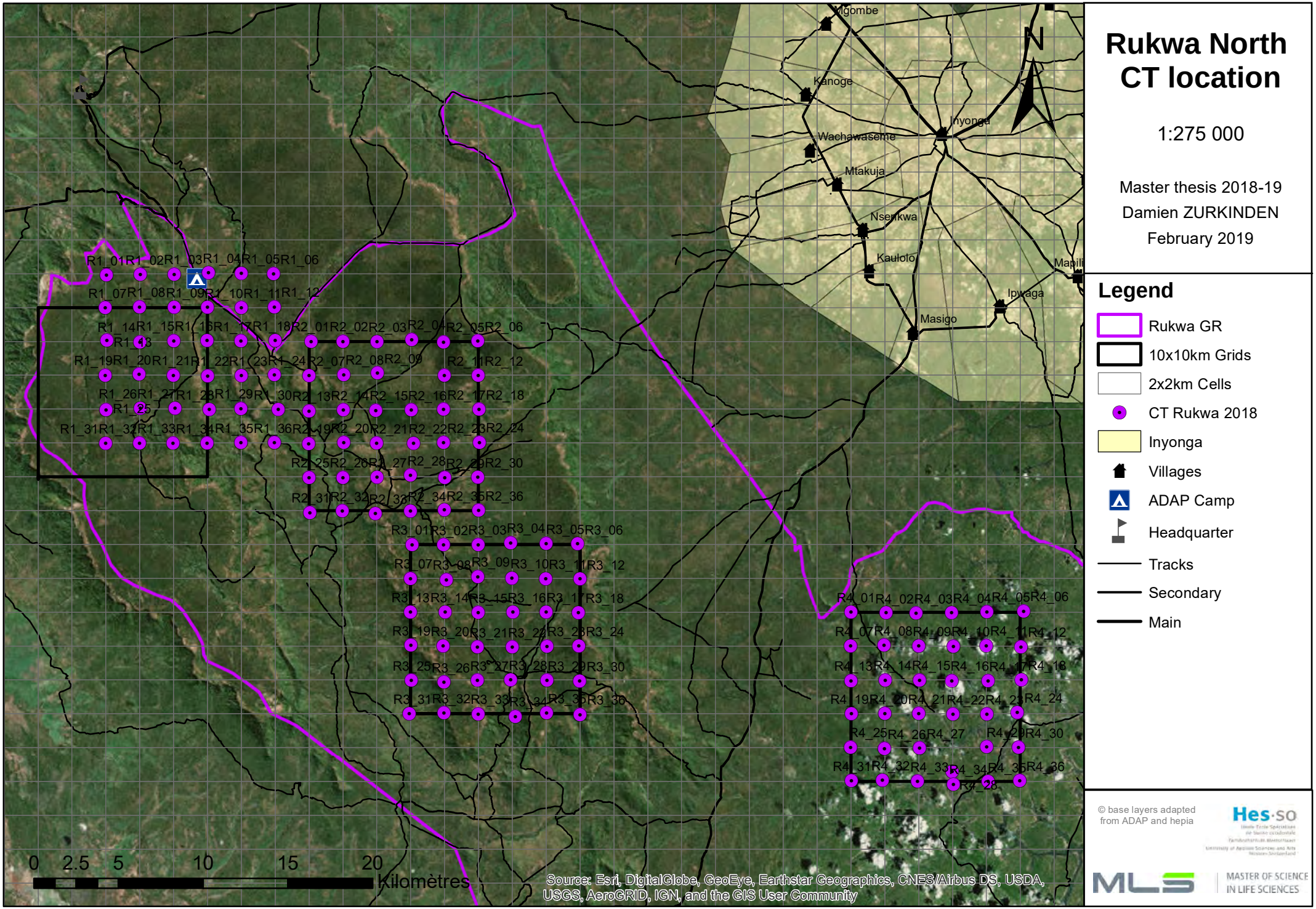

Rukwa North CT location

1:275 000

Master thesis 2018-19
Damien ZURKINDEN
February 2019

Legend

- Rukwa GR
- 10x10km Grids
- 2x2km Cells
- CT Rukwa 2018
- Inyonga
- Villages
- ADAP Camp
- Headquarter
- Tracks
- Secondary
- Main

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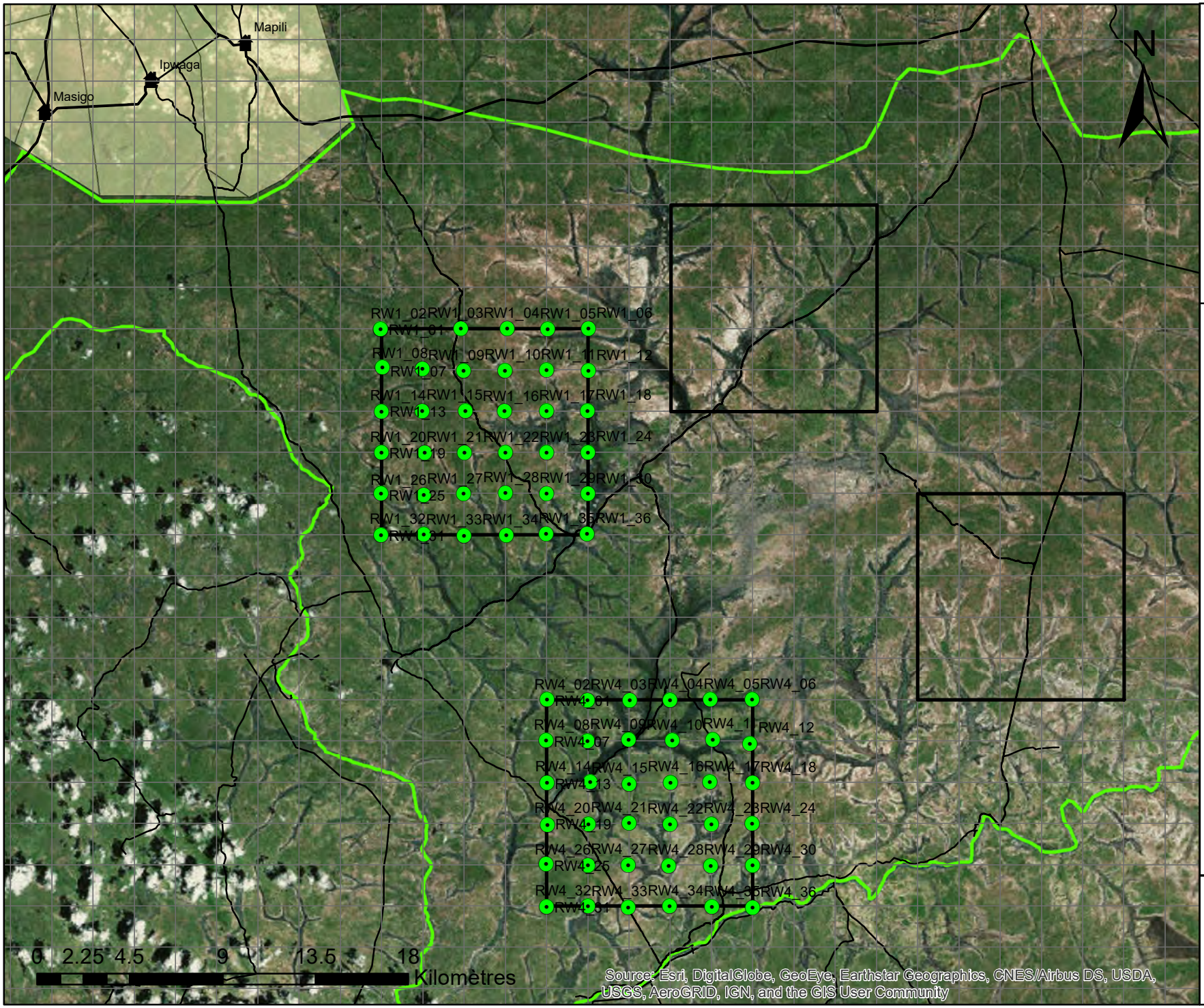

Rungwa River CT location

1:250 000

Master thesis 2018-19
Damien ZURKINDEN
February 2019

Legend

- Rungwa River FR
- 10x10km Grids
- 2x2km Cells
- CT Rungwa 2018
- Inyonga
- Villages
- ADAP Camp
- Headquarter
- Tracks
- Secondary
- Main

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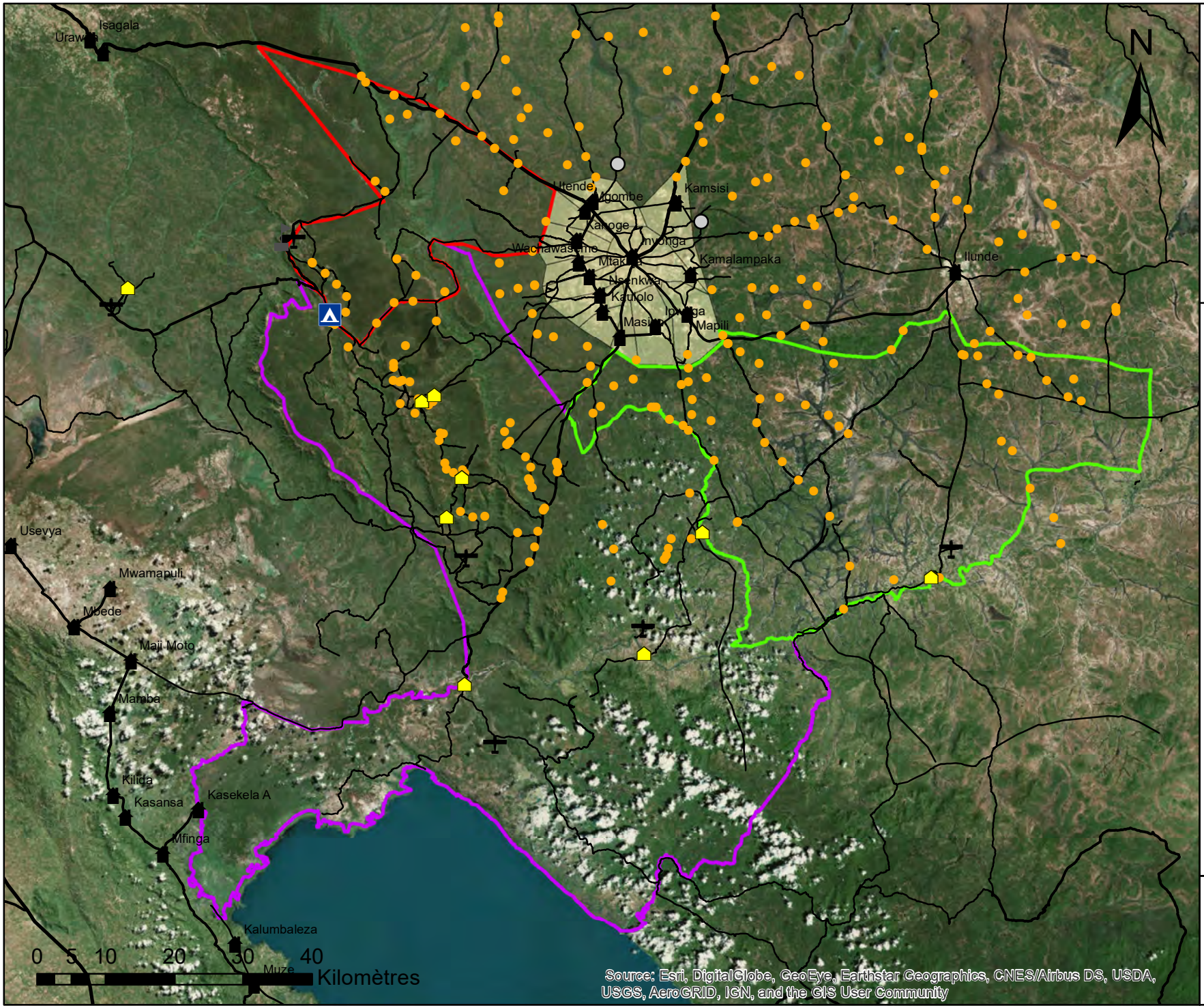
Appendix V: Infrastructures

Source: ESRI, 2017



Infrastructures

1:750 000

Master thesis 2018-19
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August 2018

Legend

- Mlele BKZ
- Rungwa River FR
- Rukwa GR
- Inyonga
- Villages
- new villages (2015)

Roads

- Tracks
- Secondary
- Main
- Headquarter
- ADAP Camp
- Airstrips point
- Hunting camps
- Beekeepers Camps

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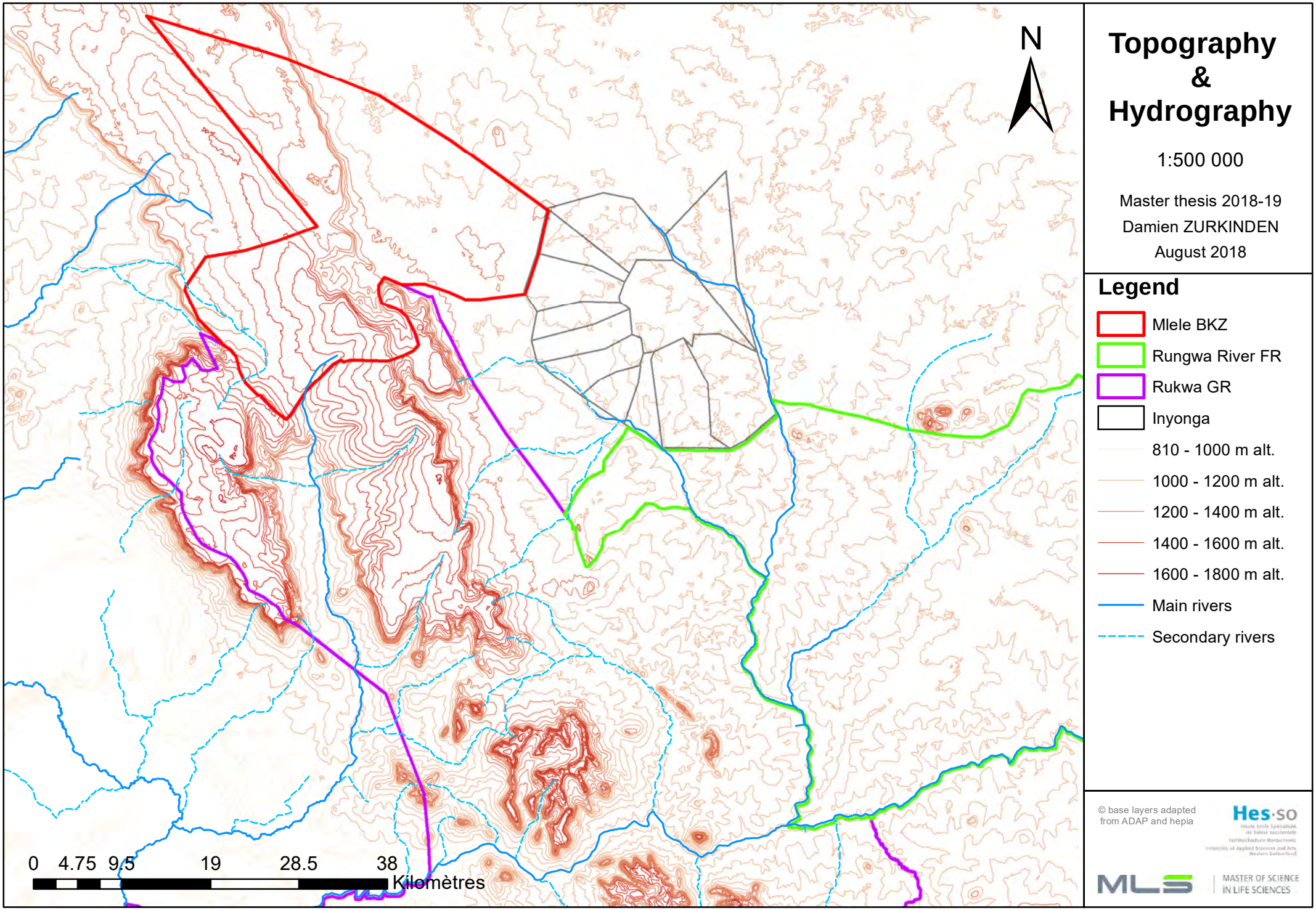
Appendix VI: Topography & Hydrography

Source: ESRI, 2017



Topography & Hydrography

1:500 000

Master thesis 2018-19
Damien ZURKINDEN
August 2018

Legend

- Mlele BKZ
- Rungwa River FR
- Rukwa GR
- Inyonga
- 810 - 1000 m alt.
- 1000 - 1200 m alt.
- 1200 - 1400 m alt.
- 1400 - 1600 m alt.
- 1600 - 1800 m alt.
- Main rivers
- Secondary rivers

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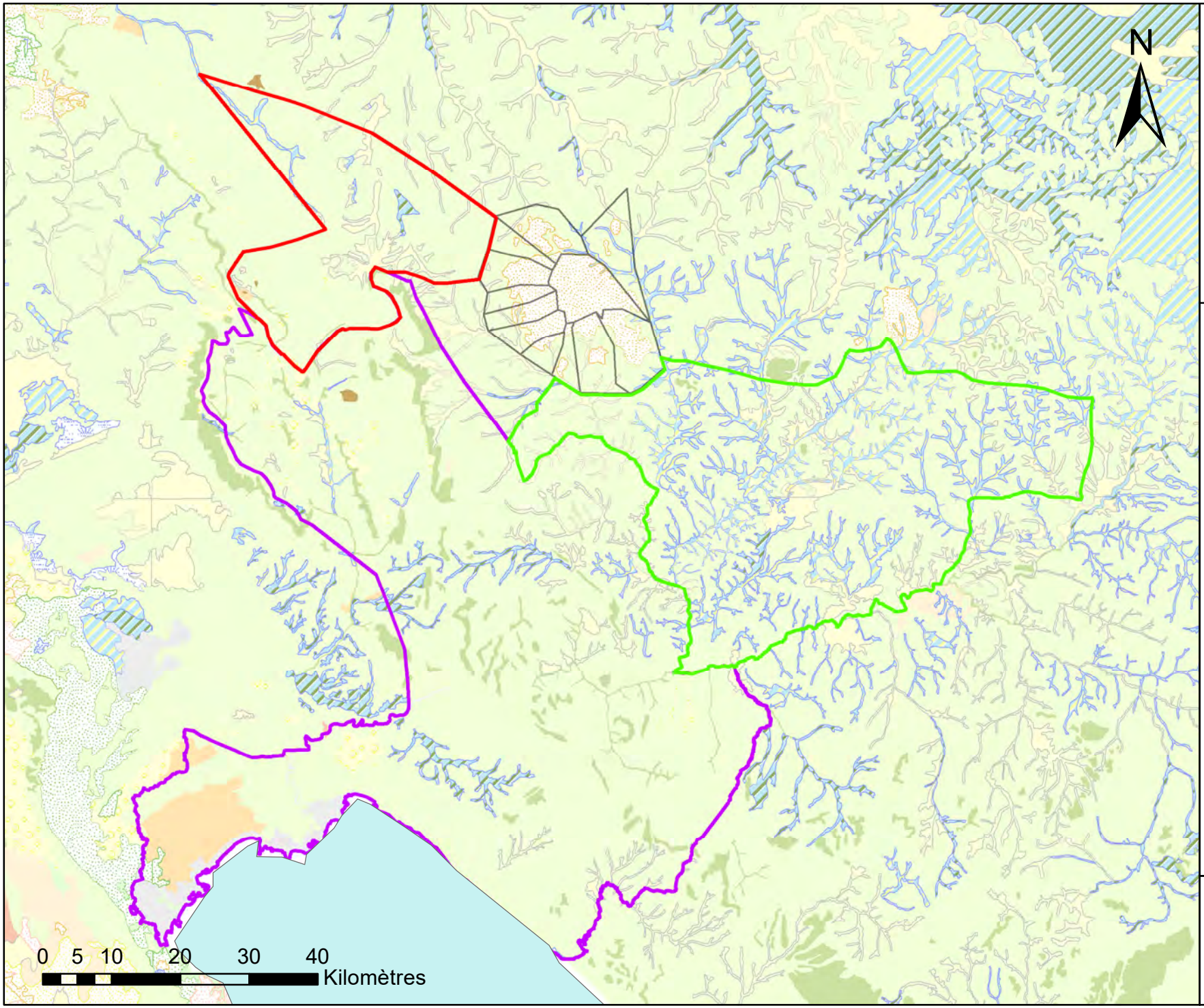
Appendix VII: Vegetation

Source: ESRI, 2017



Vegetation

1:750 000

Master thesis 2018-19
Damien ZURKINDEN
August 2018

Legend

- Mlele BKZ
- Rungwa River FR
- Rukwa GR
- Inyonga
- open grassland seasonally inundated
- open woodland
- dense bushland
- thicket
- urban area
- bare soil
- grassland with scattered cultivation
- bushed grassland
- closed woodland
- woodland with scattered cultivation
- bushland with emergent trees
- swamp
- wooded grassland seasonally inundated
- open bushland
- natural forest
- wooded grassland
- mixed cultivation
- bushland with scattered cultivation
- open grassland
- lake rukwa

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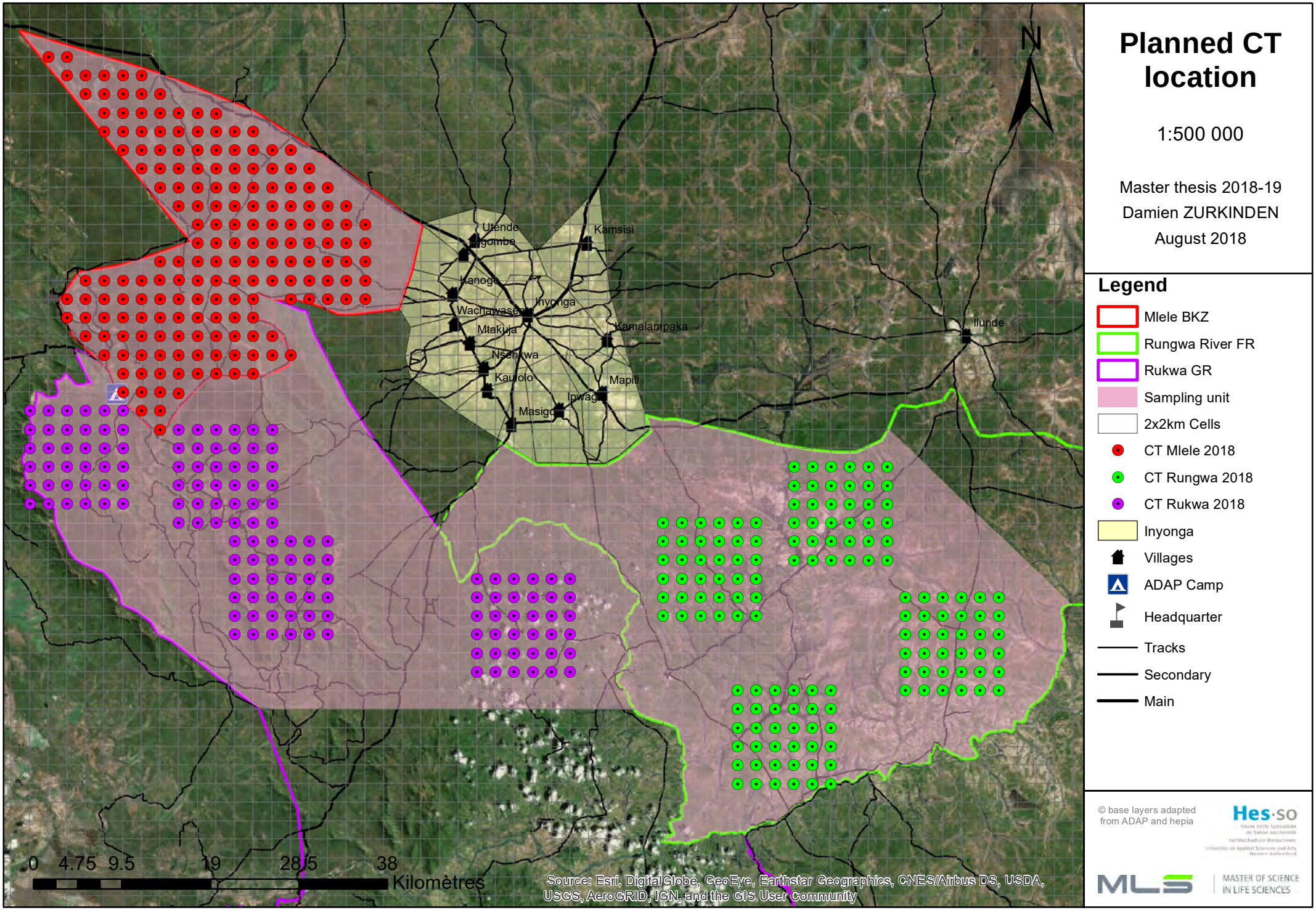
Appendix VIII: Planned Camera Traps Locations

Source: ESRI, 2017



Planned CT location

1:500 000

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Damien ZURKINDEN
August 2018

Legend

- Mlele BKZ
- Rungwa River FR
- Rukwa GR
- Sampling unit
- 2x2km Cells
- CT Mlele 2018
- CT Rungwa 2018
- CT Rukwa 2018
- Inyonga
- Villages
- ADAP Camp
- Headquarter
- Tracks
- Secondary
- Main

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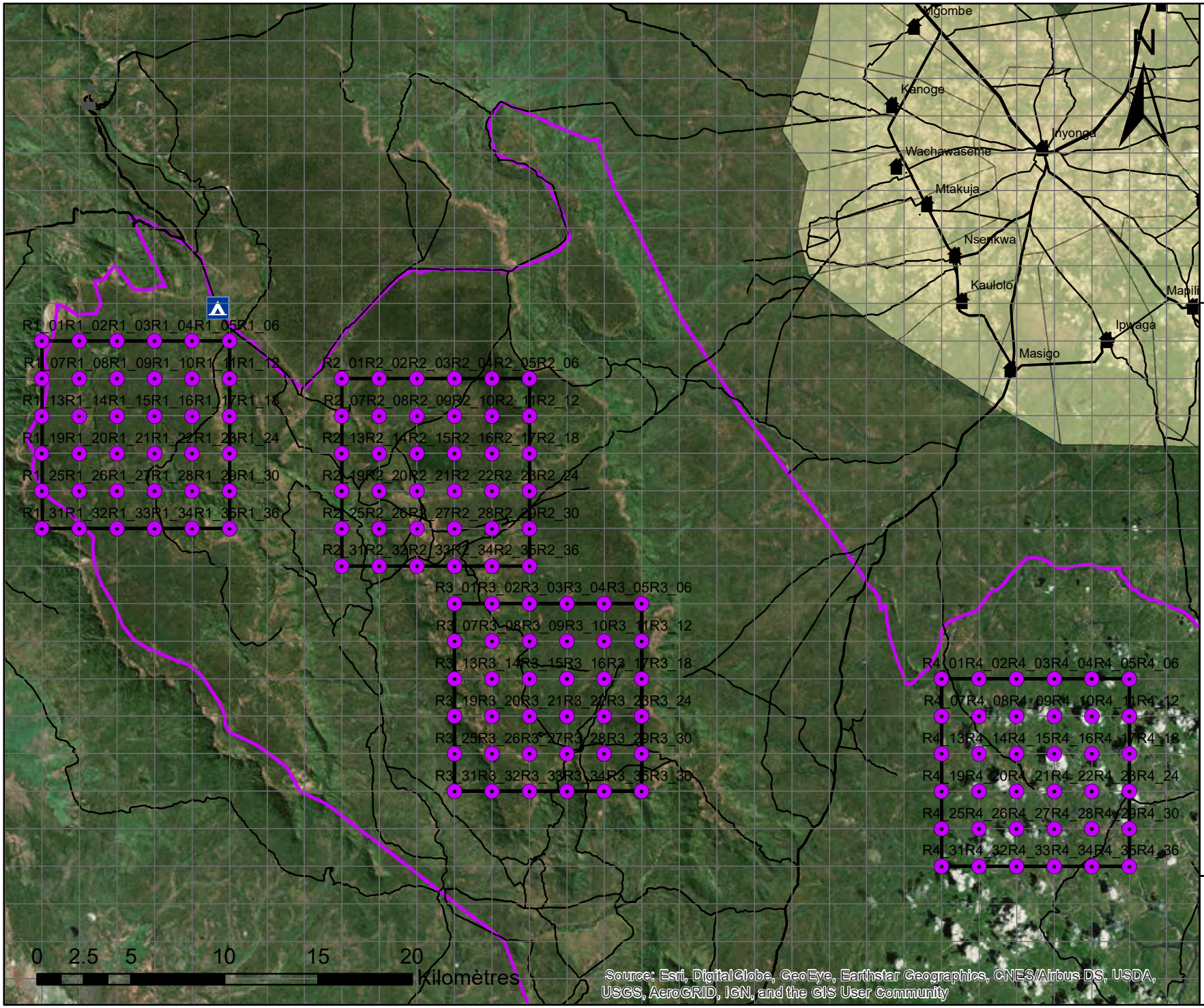

Rukwa North planned CT location

1:275 000

Master thesis 2018-19
Damien ZURKINDEN
August 2018

Legend

- Rukwa GR
- 10x10km Grids
- 2x2km Cells
- CT Rukwa 2018
- Inyonga
- Villages
- ADAP Camp
- Headquarter
- Tracks
- Secondary
- Main

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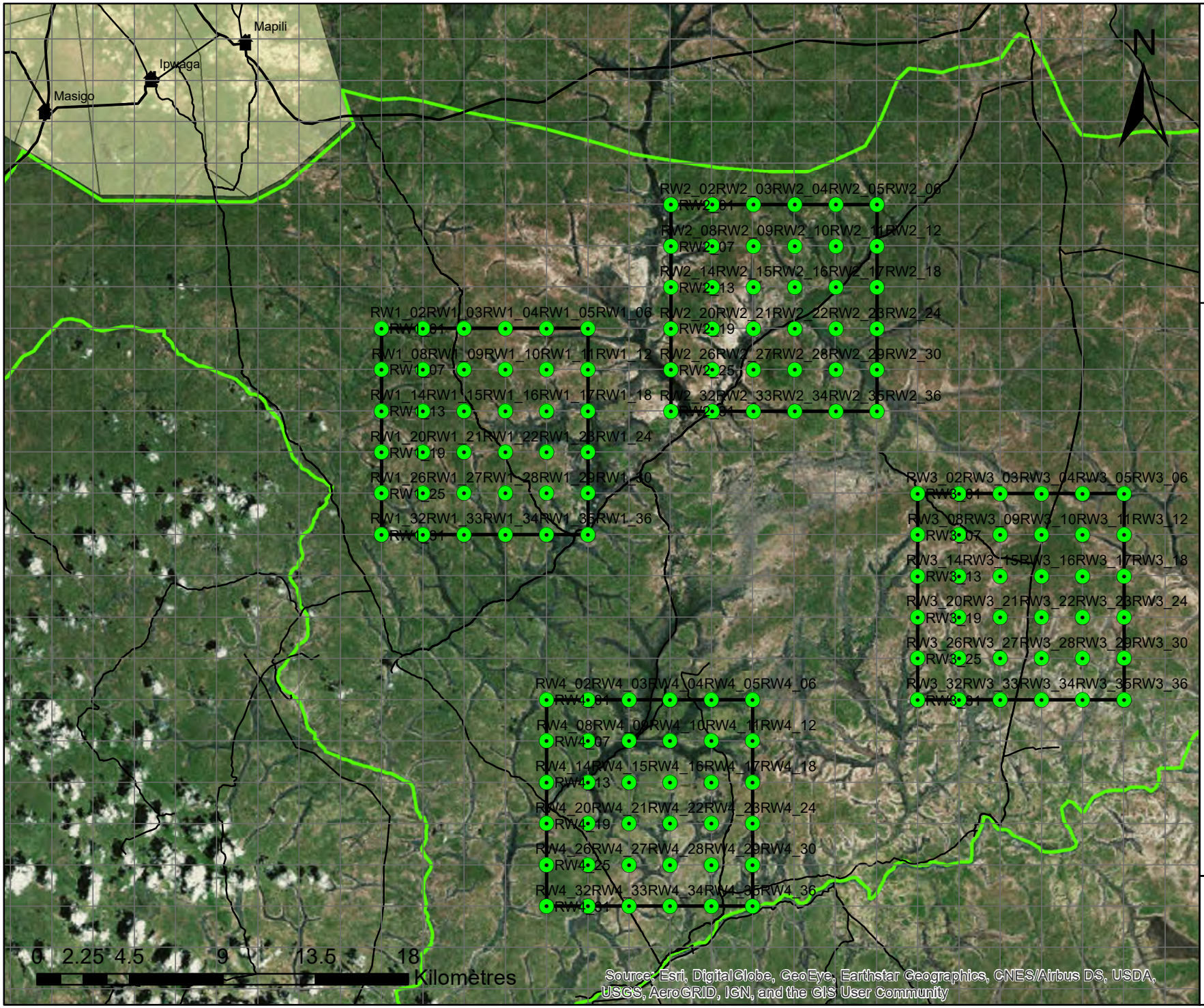

Rungwa River planned CT location

1:250 000

Master thesis 2018-19
Damien ZURKINDEN
August 2018

Legend

- Rungwa River FR
- 10x10km Grids
- 2x2km Cells
- CT Rungwa 2018
- Inyonga
- Villages
- ADAP Camp
- Headquarter
- Tracks
- Secondary
- Main

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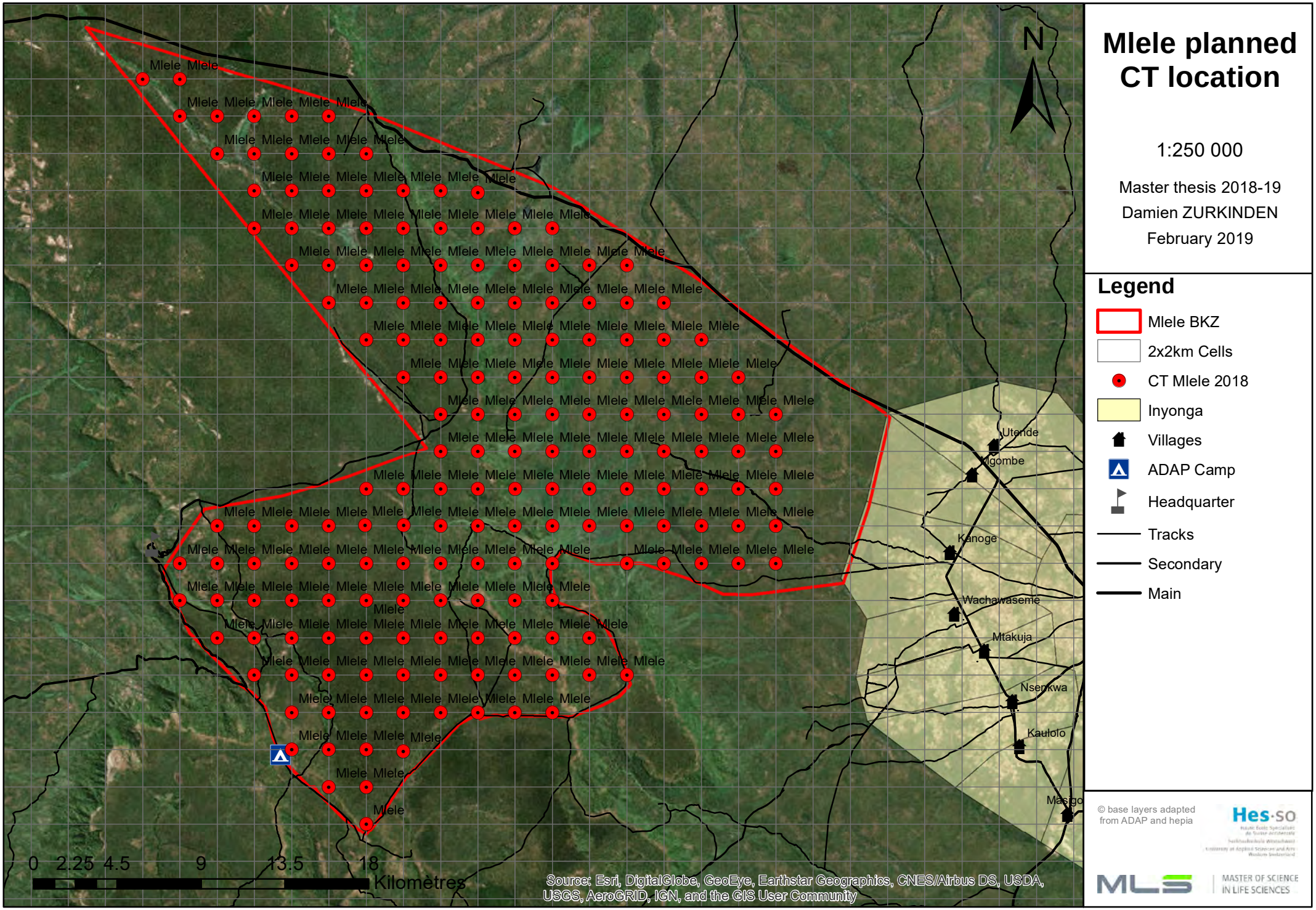
Mlele planned CT location
1:250 000
Master thesis 2018-19
Damien ZURKINDEN
February 2019
Legend
Mlele BKZ
2x2km Cells
CT Mlele 2018
Inyonga
Villages
ADAP Camp
Headquarter
Tracks
Secondary
Main
N
Utende
Igombe
Kanoge
Wachawaseme
Mtakuja
Nsenkwa
Kaulolo
Masigo
0 2.25 4.5 9 13.5 18
Kilomètres
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
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Appendix IX: Camera Traps Protocol

Source: Mermod, 2012

Installation		Informations							Checking batteries			Recovery			
Date	Time	Camera number	Card number	Lock number	Coordinates	Grid number	Cross point number	Time lag	Date	Time	Empty?	Date	Time	Number of pict.	Empty?

Appendix X: Camera Traps Manual

Adapted from Mermod, 2012

Set up Camera Traps (CT)

1. Check that you have all the equipment before you go: camera traps, batteries, memory cards, chains, padlocks, keys with key chains, protocols, GPS and batteries for the GPS.

2. Record with the GPS the coordinates of each CTsites.

3. Go by car to the nearest CT point: take the GPS point of the vehicle when you leave it and do not put the batteries in the CT!

4. Follow the direction indicated by the GPS.

5. At the site, choose a location within a 100m radius according to the following criteria (adapted from Rovero et al., 2010, Juget, 2008):

- At least at 3 m from an animal pass (trails, tracks, carcass, water point, ...) and 15 m maximum (detection of animals up to 15 m in front of the device according to the manufacturer);
- Choose a solid tree that resists damage to animals and does not move under the influence of wind;
- Position the CT at 0.6 - 1 m from the ground (50 cm according to Rovero & Zimmermann, 2016). Can be higher or lower depending on the terrain configuration. In this case, the inclination of the CT will be necessary;
- Clear / remove vegetation in front of the CT;
- Pay attention to sunlight exposure.

6. Insert the memory card and then the batteries into the device.

7. Set the device: date, time and set to "test" mode.

8. Secure the CT to the trunk with the strap

9. Test the trigger by walking past the ideal spot.

10. Arm 3 pictures at an interval of 30s., close and lock the CT.

11. Make the START photo with a white sheet were the following are marked: START, CT No, habitat type, coordinates, date and time. Warning: wait 40 seconds before the first picture is triggered, do not leave before!

12. Complete the field protocol and take a picture (remote) of the area where the CT was placed. Do not forget to record the coordinates of the final location of the CT.

Removing Camera Traps

1. Make the END photo with a white sheet were the following are marked: END, CT No, date and time.

2. Note number of pictures taken, time and date on the protocol.

3. Put the CT on off, put the memory card in a holster (or leave them in the traps if no safe place to put them) and remove the batteries.

4. Remove the CT.

Appendix XI: Management Effectiveness Tracking Tool

Source: Stolton et al., 2007

Reporting Progress at Protected Area Sites: Data Sheet 1

Name, affiliation and contact details for person responsible for completing the METT (email etc.)				
Date assessment carried out				
Name of protected area				
WDPA site code (these codes can be found on www.unep-wcmc.org/wdpa/)				
Designations	National	IUCN Category	International (please also complete sheet overleaf)	
Country				
Location of protected area (province and if possible map reference)				
Date of establishment				
Ownership details (please tick)	State	Private	Community	Other
Management Authority				
Size of protected area (ha)				
Number of staff	Permanent	Temporary		
Annual budget (US$) – excluding staff salary costs	Recurrent (operational) funds	Project or other supplementary funds		
What are the main values for which the area is designated				
List the two primary protected area management objectives				
Management objective 1				
Management objective 2				

No. of people involved in completing assessment				
Including: (tick boxes)	PA manager ☐	PA staff ☐	Other PA agency staff ☐	NGO ☐
	Local community ☐	Donors ☐	External experts ☐	Other ☐
Please note if assessment was carried out in association with a particular project, on behalf of an organisation or donor.				

Information on International Designations			
UNESCO World Heritage site (see: whc.unesco.org/en/list)			
Date listed	Site name	Site area	Geographical co-ordinates
Criteria for designation (i.e. criteria i to x)			
Statement of Outstanding Universal Value			
Ramsar site (see: www.wetlands.org/RSDB/)			
Date listed	Site name	Site area	Geographical number
Reason for Designation (see Ramsar Information Sheet)			
UNESCO Man and Biosphere Reserves (see: www.unesco.org/mab/wnbrs.shtml)			
Date listed	Site name	Site area Total: Core: Buffer: Transition:	Geographical co-ordinates
Criteria for designation			
Fulfilment of three functions of MAB (conservation, development and logistic support.)			
Please list other designations (i.e. ASEAN Heritage, Natura 2000) and any supporting information below			
Name:	Detail:		
Name:	Detail:		
Name:	Detail:		
Name:	Detail:		
Name:	Detail:		
Name:	Detail:		

Protected Areas Threats: Data Sheet 2

Please tick all relevant existing threats as either of high, medium or low significance. Threats ranked as of **high** significance are those which are seriously degrading values; **medium** are those threats having some negative impact and those characterised as **low** are threats which are present but not seriously impacting values or **N/A** where the threat is not present or not applicable in the protected area.

1. Residential and commercial development within a protected area

Threats from human settlements or other non-agricultural land uses with a substantial footprint

High	Medium	Low	N/A	
				1.1 Housing and settlement
				1.2 Commercial and industrial areas
				1.3 Tourism and recreation infrastructure

2. Agriculture and aquaculture within a protected area

Threats from farming and grazing as a result of agricultural expansion and intensification, including silviculture, mariculture and aquaculture

High	Medium	Low	N/A	
				2.1 Annual and perennial non-timber crop cultivation
				2.1a Drug cultivation
				2.2 Wood and pulp plantations
				2.3 Livestock farming and grazing
				2.4 Marine and freshwater aquaculture

3. Energy production and mining within a protected area

Threats from production of non-biological resources

High	Medium	Low	N/A	
				3.1 Oil and gas drilling
				3.2 Mining and quarrying
				3.3 Energy generation, including from hydropower dams

4. Transportation and service corridors within a protected area

Threats from long narrow transport corridors and the vehicles that use them including associated wildlife mortality

High	Medium	Low	N/A	
				4.1 Roads and railroads (include road-killed animals)
				4.2 Utility and service lines (e.g. electricity cables, telephone lines,)
				4.3 Shipping lanes and canals
				4.4 Flight paths

5. Biological resource use and harm within a protected area

Threats from consumptive use of "wild" biological resources including both deliberate and unintentional harvesting effects; also persecution or control of specific species (note this includes hunting and killing of animals)

High	Medium	Low	N/A	
				5.1 Hunting, killing and collecting terrestrial animals (including killing of animals as a result of human/wildlife conflict)
				5.2 Gathering terrestrial plants or plant products (non-timber)
				5.3 Logging and wood harvesting
				5.4 Fishing, killing and harvesting aquatic resources

6. Human intrusions and disturbance within a protected area

Threats from human activities that alter, destroy or disturb habitats and species associated with non-consumptive uses of biological resources

High	Medium	Low	N/A	
				6.1 Recreational activities and tourism
				6.2 War, civil unrest and military exercises
				6.3 Research, education and other work-related activities in protected areas
				6.4 Activities of protected area managers (e.g. construction or vehicle use, artificial watering points and dams)
				6.5 Deliberate vandalism, destructive activities or threats to protected area staff and visitors

7. Natural system modifications

Threats from other actions that convert or degrade habitat or change the way the ecosystem functions

High	Medium	Low	N/A	
				7.1 Fire and fire suppression (including arson)
				7.2 Dams, hydrological modification and water management/use
				7.3a Increased fragmentation within protected area
				7.3b Isolation from other natural habitat (e.g. deforestation, dams without effective aquatic wildlife passages)
				7.3c Other 'edge effects' on park values
				7.3d Loss of keystone species (e.g. top predators, pollinators etc)

8. Invasive and other problematic species and genes

Threats from terrestrial and aquatic non-native and native plants, animals, pathogens/microbes or genetic materials that have or are predicted to have harmful effects on biodiversity following introduction, spread and/or increase

High	Medium	Low	N/A	
				8.1 Invasive non-native/alien plants (weeds)
				8.1a Invasive non-native/alien animals
				8.1b Pathogens (non-native or native but creating new/increased problems)
				8.2 Introduced genetic material (e.g. genetically modified organisms)

9. Pollution entering or generated within protected area

Threats from introduction of exotic and/or excess materials or energy from point and non-point sources

High	Medium	Low	N/A	
				9.1 Household sewage and urban waste water
				9.1a Sewage and waste water from protected area facilities (e.g. toilets, hotels etc)
				9.2 Industrial, mining and military effluents and discharges (e.g. poor water quality discharge from dams, e.g. unnatural temperatures, de-oxygenated, other pollution)
				9.3 Agricultural and forestry effluents (e.g. excess fertilizers or pesticides)
				9.4 Garbage and solid waste
				9.5 Air-borne pollutants
				9.6 Excess energy (e.g. heat pollution, lights etc)

10. Geological events

Geological events may be part of natural disturbance regimes in many ecosystems. But they can be a threat if a species or habitat is damaged and has lost its resilience and is vulnerable to disturbance. Management capacity to respond to some of these changes may be limited.

High	Medium	Low	N/A	
				10.1 Volcanoes
				10.2 Earthquakes/Tsunamis
				10.3 Avalanches/ Landslides
				10.4 Erosion and siltation/ deposition (e.g. shoreline or riverbed changes)

11. Climate change and severe weather

Threats from long-term climatic changes which may be linked to global warming and other severe climatic/weather events outside of the natural range of variation

High	Medium	Low	N/A	
				11.1 Habitat shifting and alteration
				11.2 Droughts
				11.3 Temperature extremes
				11.4 Storms and flooding

12. Specific cultural and social threats

High	Medium	Low	N/A	
				12.1 Loss of cultural links, traditional knowledge and/or management practices
				12.2 Natural deterioration of important cultural site values
				12.3 Destruction of cultural heritage buildings, gardens, sites etc

Assessment Form

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
1. Legal status Does the protected area have legal status (or in the case of private reserves is covered by a covenant or similar)? *Context*	The protected area is not gazetted/covenanted	0			
	There is agreement that the protected area should be gazetted/covenanted but the process has not yet begun	1			
	The protected area is in the process of being gazetted/covenanted but the process is still incomplete (includes sites designated under international conventions, such as Ramsar, or local/traditional law such as community conserved areas, which do not yet have national legal status or covenant)	2			
	The protected area has been formally gazetted/covenanted	3			
2. Protected area regulations Are appropriate regulations in place to control land use and activities (e.g. hunting)? *Planning*	There are no regulations for controlling land use and activities in the protected area	0			
	Some regulations for controlling land use and activities in the protected area exist but these are major weaknesses	1			
	Regulations for controlling land use and activities in the protected area exist but there are some weaknesses or gaps	2			
	Regulations for controlling inappropriate land use and activities in the protected area exist and provide an excellent basis for management	3			
3. Law enforcement Can staff (i.e. those with responsibility for managing the site) enforce protected area rules well enough? *Input*	The staff have no effective capacity/resources to enforce protected area legislation and regulations	0			
	There are major deficiencies in staff capacity/resources to enforce protected area legislation and regulations (e.g. lack of skills, no patrol budget, lack of institutional support)	1			
	The staff have acceptable capacity/resources to enforce protected area legislation and regulations but some deficiencies remain	2			
	The staff have excellent capacity/resources to enforce protected area legislation and regulations	3			

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
4. Protected area objectives Is management undertaken according to agreed objectives? *Planning*	No firm objectives have been agreed for the protected area	0			
	The protected area has agreed objectives, but is not managed according to these objectives	1			
	The protected area has agreed objectives, but is only partially managed according to these objectives	2			
	The protected area has agreed objectives and is managed to meet these objectives	3			
5. Protected area design Is the protected area the right size and shape to protect species, habitats, ecological processes and water catchments of key conservation concern? *Planning*	Inadequacies in protected area design mean achieving the major objectives of the protected area is very difficult	0			
	Inadequacies in protected area design mean that achievement of major objectives is difficult but some mitigating actions are being taken (e.g. agreements with adjacent land owners for wildlife corridors or introduction of appropriate catchment management)	1			
	Protected area design is not significantly constraining achievement of objectives, but could be improved (e.g. with respect to larger scale ecological processes)	2			
	Protected area design helps achievement of objectives; it is appropriate for species and habitat conservation; and maintains ecological processes such as surface and groundwater flows at a catchment scale, natural disturbance patterns etc	3			
6. Protected area boundary demarcation Is the boundary known and demarcated? *Process*	The boundary of the protected area is not known by the management authority or local residents/neighbouring land users	0			
	The boundary of the protected area is known by the management authority but is not known by local residents/neighbouring land users	1			
	The boundary of the protected area is known by both the management authority and local residents/neighbouring land users but is not appropriately demarcated	2			
	The boundary of the protected area is known by the management authority and local residents/neighbouring land users and is appropriately demarcated	3			

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
7. Management plan Is there a management plan and is it being implemented? *Planning*	There is no management plan for the protected area	0			
	A management plan is being prepared or has been prepared but is not being implemented	1			
	A management plan exists but it is only being partially implemented because of funding constraints or other problems	2			
	A management plan exists and is being implemented	3			
Additional points: *Planning*					
7a. Planning process	The planning process allows adequate opportunity for key stakeholders to influence the management plan	+1			
7b. Planning process	There is an established schedule and process for periodic review and updating of the management plan	+1			
7c. Planning process	The results of monitoring, research and evaluation are routinely incorporated into planning	+1			
8. Regular work plan Is there a regular work plan and is it being implemented *Planning/Outputs*	No regular work plan exists	0			
	A regular work plan exists but few of the activities are implemented	1			
	A regular work plan exists and many activities are implemented	2			
	A regular work plan exists and all activities are implemented	3			
9. Resource inventory Do you have enough information to manage the area? *Input*	There is little or no information available on the critical habitats, species and cultural values of the protected area	0			
	Information on the critical habitats, species, ecological processes and cultural values of the protected area is not sufficient to support planning and decision making	1			
	Information on the critical habitats, species, ecological processes and cultural values of the protected area is sufficient for most key areas of planning and decision making	2			
	Information on the critical habitats, species, ecological processes and cultural values of the protected area is sufficient to support all areas of planning and decision making	3			

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
10. Protection systems Are systems in place to control access/resource use in the protected area? *Process/Outcome*	Protection systems (patrols, permits etc) do not exist or are not effective in controlling access/resource use	0			
	Protection systems are only partially effective in controlling access/resource use	1			
	Protection systems are moderately effective in controlling access/resource use	2			
	Protection systems are largely or wholly effective in controlling access/ resource use	3			
11. Research Is there a programme of management-orientated survey and research work? *Process*	There is no survey or research work taking place in the protected area	0			
	There is a small amount of survey and research work but it is not directed towards the needs of protected area management	1			
	There is considerable survey and research work but it is not directed towards the needs of protected area management	2			
	There is a comprehensive, integrated programme of survey and research work, which is relevant to management needs	3			
12. Resource management Is active resource management being undertaken? *Process*	Active resource management is not being undertaken	0			
	Very few of the requirements for active management of critical habitats, species, ecological processes and cultural values are being implemented	1			
	Many of the requirements for active management of critical habitats, species, ecological processes and, cultural values are being implemented but some key issues are not being addressed	2			
	Requirements for active management of critical habitats, species, ecological processes and, cultural values are being substantially or fully implemented	3			
13. Staff numbers Are there enough people employed to manage the protected area? *Inputs*	There are no staff	0			
	Staff numbers are inadequate for critical management activities	1			
	Staff numbers are below optimum level for critical management activities	2			
	Staff numbers are adequate for the management needs of the protected area	3			

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
14. Staff training Are staff adequately trained to fulfil management objectives? *Inputs/Process*	Staff lack the skills needed for protected area management	0			
	Staff training and skills are low relative to the needs of the protected area	1			
	Staff training and skills are adequate, but could be further improved to fully achieve the objectives of management	2			
	Staff training and skills are aligned with the management needs of the protected area	3			
15. Current budget Is the current budget sufficient? *Inputs*	There is no budget for management of the protected area	0			
	The available budget is inadequate for basic management needs and presents a serious constraint to the capacity to manage	1			
	The available budget is acceptable but could be further improved to fully achieve effective management	2			
	The available budget is sufficient and meets the full management needs of the protected area	3			
16. Security of budget Is the budget secure? *Inputs*	There is no secure budget for the protected area and management is wholly reliant on outside or highly variable funding	0			
	There is very little secure budget and the protected area could not function adequately without outside funding	1			
	There is a reasonably secure core budget for regular operation of the protected area but many innovations and initiatives are reliant on outside funding	2			
	There is a secure budget for the protected area and its management needs	3			
17. Management of budget Is the budget managed to meet critical management needs? *Process*	Budget management is very poor and significantly undermines effectiveness (e.g. late release of budget in financial year)	0			
	Budget management is poor and constrains effectiveness	1			
	Budget management is adequate but could be improved	2			
	Budget management is excellent and meets management needs	3			

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
18. Equipment Is equipment sufficient for management needs? *Input*	There are little or no equipment and facilities for management needs	0			
	There are some equipment and facilities but these are inadequate for most management needs	1			
	There are equipment and facilities, but still some gaps that constrain management	2			
	There are adequate equipment and facilities	3			
19. Maintenance of equipment Is equipment adequately maintained? *Process*	There is little or no maintenance of equipment and facilities	0			
	There is some *ad hoc* maintenance of equipment and facilities	1			
	There is basic maintenance of equipment and facilities	2			
	Equipment and facilities are well maintained	3			
20. Education and awareness Is there a planned education programme linked to the objectives and needs? *Process*	There is no education and awareness programme	0			
	There is a limited and *ad hoc* education and awareness programme	1			
	There is an education and awareness programme but it only partly meets needs and could be improved	2			
	There is an appropriate and fully implemented education and awareness programme	3			
21. Planning for land and water use Does land and water use planning recognise the protected area and aid the achievement of objectives? *Planning*	Adjacent land and water use planning does not take into account the needs of the protected area and activities/policies are detrimental to the survival of the area	0			
	Adjacent land and water use planning does not takes into account the long term needs of the protected area, but activities are not detrimental the area	1			
	Adjacent land and water use planning partially takes into account the long term needs of the protected area	2			
	Adjacent land and water use planning fully takes into account the long term needs of the protected area	3			

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
Additional points: Land and water planning					
21a: Land and water planning for habitat conservation	Planning and management in the catchment or landscape containing the protected area incorporates provision for adequate environmental conditions (e.g. volume, quality and timing of water flow, air pollution levels etc) to sustain relevant habitats.	+1			
21b: Land and water planning for connectivity	Management of corridors linking the protected area provides for wildlife passage to key habitats outside the protected area (e.g. to allow migratory fish to travel between freshwater spawning sites and the sea, or to allow animal migration).	+1			
21c: Land and water planning for ecosystem services & species conservation	"Planning adresses ecosystem-specific needs and/or the needs of particular species of concern at an ecosystem scale (e.g. volume, quality and timing of freshwater flow to sustain particular species, fire management to maintain savannah habitats etc.)"	+1			
22. State and commercial neighbours Is there co-operation with adjacent land and water users? *Process*	There is no contact between managers and neighbouring official or corporate land and water users	0			
	There is contact between managers and neighbouring official or corporate land and water users but little or no cooperation	1			
	There is contact between managers and neighbouring official or corporate land and water users, but only some co-operation	2			
	There is regular contact between managers and neighbouring official or corporate land and water users, and substantial co-operation on management	3			
23. Indigenous people Do indigenous and traditional peoples resident or regularly using the protected area have input to management decisions? *Process*	Indigenous and traditional peoples have no input into decisions relating to the management of the protected area	0			
	Indigenous and traditional peoples have some input into discussions relating to management but no direct role in management	1			
	Indigenous and traditional peoples directly contribute to some relevant decisions relating to management but their involvement could be improved	2			
	Indigenous and traditional peoples directly participate in all relevant decisions relating to management, e.g. co-management	3			

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
24. Local communities Do local communities resident or near the protected area have input to management decisions? *Process*	Local communities have no input into decisions relating to the management of the protected area	0			
	Local communities have some input into discussions relating to management but no direct role in management	1			
	Local communities directly contribute to some relevant decisions relating to management but their involvement could be improved	2			
	Local communities directly participate in all relevant decisions relating to management, e.g. co-management	3			
Additional points *Local communities/indigenous people*					
24 a. Impact on communities	There is open communication and trust between local and/or indigenous people, stakeholders and protected area managers	+1			
24b. Impact on communities	Programmes to enhance community welfare, while conserving protected area resources, are being implemented	+1			
24c. Impact on communities	Local and/or indigenous people actively support the protected area	+1			
25. Economic benefit Is the protected area providing economic benefits to local communities, e.g. income, employment, payment for environmental services? *Outcomes*	The protected area does not deliver any economic benefits to local communities	0			
	Potential economic benefits are recognised and plans to realise these are being developed	1			
	There is some flow of economic benefits to local communities	2			
	There is a major flow of economic benefits to local communities from activities associated with the protected area	3			
26. Monitoring and evaluation Are management activities monitored against performance? *Planning/Process*	There is no monitoring and evaluation in the protected area	0			
	There is some *ad hoc* monitoring and evaluation, but no overall strategy and/or no regular collection of results	1			
	There is an agreed and implemented monitoring and evaluation system but results do not feed back into management	2			
	A good monitoring and evaluation system exists, is well implemented and used in adaptive management	3			

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
27. Visitor facilities Are visitor facilities adequate? *Outputs*	There are no visitor facilities and services despite an identified need	0			
	Visitor facilities and services are inappropriate for current levels of visitation	1			
	Visitor facilities and services are adequate for current levels of visitation but could be improved	2			
	Visitor facilities and services are excellent for current levels of visitation	3			
28. Commercial tourism operators Do commercial tour operators contribute to protected area management? *Process*	There is little or no contact between managers and tourism operators using the protected area	0			
	There is contact between managers and tourism operators but this is largely confined to administrative or regulatory matters	1			
	There is limited co-operation between managers and tourism operators to enhance visitor experiences and maintain protected area values	2			
	There is good co-operation between managers and tourism operators to enhance visitor experiences, and maintain protected area values	3			
29. Fees If fees (i.e. entry fees or fines) are applied, do they help protected area management? *Inputs/Process*	Although fees are theoretically applied, they are not collected	0			
	Fees are collected, but make no contribution to the protected area or its environs	1			
	Fees are collected, and make some contribution to the protected area and its environs	2			
	Fees are collected and make a substantial contribution to the protected area and its environs	3			
30. Condition of values What is the condition of the important values of the protected area as compared to when it was first designated? *Outcomes*	Many important biodiversity, ecological or cultural values are being severely degraded	0			
	Some biodiversity, ecological or cultural values are being severely degraded	1			
	Some biodiversity, ecological and cultural values are being partially degraded but the most important values have not been significantly impacted	2			
	Biodiversity, ecological and cultural values are predominantly intact	3			

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
Additional Points: Condition of values					
30a: Condition of values	The assessment of the condition of values is based on research and/or monitoring	+1			
30b: Condition of values	Specific management programmes are being implemented to address threats to biodiversity, ecological and cultural values	+1			
30c: Condition of values	Activities to maintain key biodiversity, ecological and cultural values are a routine part of park management	+1			
TOTAL SCORE					

Appendix XII: R Script

Source: RStudio Team, 2017

```
library(dplyr)
library(tidyr)
library(vegan)
library(ggplot2)

dir <-c("C:\\Users\\Damien\\Desktop\\Documents\\HES\\Master\\TM\\Donnees\\Results\\
Session_2018\\")

#Importation fichiers données pièges photos
files <- c("M1_2018.csv",
           "M3_2018.csv",
           "M5_2018.csv",
           "R1_2018.csv",
           "R2_2018.csv",
           "R3_2018.csv",
           "R4_2018.csv",
           "RW1_2018.csv",
           "RW4_2018.csv")

files <- paste0(dir,files)
M1 <- read.csv( files [1], sep =',' , header=TRUE , fill=TRUE , stringsAsFactors = FALSE)
M3 <- read.csv( files [2], sep =',' , header=TRUE , fill=TRUE , stringsAsFactors = FALSE)
M5 <- read.csv( files [3], sep =',' , header=TRUE , fill=TRUE , stringsAsFactors = FALSE)
R1 <- read.csv( files [4], sep =',' , header=TRUE , fill=TRUE , stringsAsFactors = FALSE)
R2 <- read.csv( files [5], sep =',' , header=TRUE , fill=TRUE , stringsAsFactors = FALSE)
R3 <- read.csv( files [6], sep =',' , header=TRUE , fill=TRUE , stringsAsFactors = FALSE)
R4 <- read.csv( files [7], sep =',' , header=TRUE , fill=TRUE , stringsAsFactors = FALSE)
RW1 <- read.csv( files [8], sep =',' , header=TRUE , fill=TRUE , stringsAsFactors = FALSE)
RW4 <- read.csv( files [9], sep =',' , header=TRUE , fill=TRUE , stringsAsFactors = FALSE)

data_piege <- rbind(M1,M3,M5,R1,R2,R3,R4,RW1,RW4)

rm(M1,M3,M5,R1,R2,R3,R4,RW1,RW4)

#Nettoyage des données
data_piege <-  data_piege %>%
  mutate (Species = paste(Species_A , Species_B , Species_C)) %>%
  mutate (Species = trimws (gsub("0", "" , Species)) ) %>%
  mutate (Species = ifelse( Species=="n/a" , NA, Species)) %>%
  mutate (Place = trimws (gsub ("2-" , "", Place))) %>%
  select (-Species_A, -Species_B, -Species_C) %>%
  mutate (From = as.POSIXct(From)) %>%
  mutate (to = as.POSIXct(to))

#Afin de reparti mongoose sp. et genetta sp. au même groupe que les autres mangoustes et les autres genettes
mais en attribuant toutes les observations a tous les groupes (ce que produit des lignes à double.)
data_piege <- data_piege %>%
  mutate(Species = recode(.$Species,"Genetta sp." = "Genetta angolensis")) %>%
  rbind(data_piege %>%
          filter(Species == "Genetta sp.") %>%
          mutate(Species = recode(.$Species,"Genetta sp." = "Genetta maculata")))
```

```
nb_mangoose_sp <- nrow(data_piege %>% filter(Species == "Mongoose sp."))
mangoustes <- c("Atilax paludinosus", "Bdeogale crassicauda", "Mungos mungo",
                "Helogale parvula", "Ichneumia albicauda","Rhynchogale melleri")

data_piege <-  data_piege %>%
  rbind(data_piege %>%
          filter(Species == "Mongoose sp.") %>%
          .[rep(row.names(.), length(mangoustes)),] %>%
          mutate(Species = rep(mangoustes, each = nb_mangoose_sp))) %>%
  .[.$Species != "Mongoose sp.",]

# Importation table des facteurs
file_factors <- paste0(dir,"Tables_Factors.csv")

factors <- read.csv( file_factors, sep =';' , header=TRUE , fill=TRUE , stringsAsFactors = FALSE,
                     na.strings = "N/A")

name_factors <- factors$X

factors_data <- factors[,-1] %>%
  t %>%
  as.data.frame()

colnames(factors_data) <- name_factors

factors_data <-
  factors_data %>%
  mutate (Place = row.names (factors_data))

# Importation des données GPS
file_GPS <- paste0(dir,"Coordonnees_GPS.csv")

GPS <- read.csv( file_GPS, sep =';' , header=TRUE , fill=TRUE , stringsAsFactors = FALSE)

# On détermine la date ou la caméra a été posée et enlevée à partir des protocoles
file_date <- paste0(dir,"Pose_Depose.csv")

dates <- read.csv( file_date, sep =';' , header=TRUE , fill=TRUE , stringsAsFactors = FALSE,
                   na.strings = "N/A")

dates <- dates %>%
  mutate (Pose_Date_Heure = paste(Pose_Date,Pose_Heure, sep=" ")) %>%
  mutate (Pose_Date_Heure = as.POSIXct(Pose_Date_Heure, format = "%d.%m.%Y %H:%M")) %>%
  mutate (Depose_Date_Heure = paste(Depose_Date,Depose_Heure, sep=" ")) %>%
  mutate (Depose_Date_Heure = as.POSIXct(Depose_Date_Heure, format = "%d.%m.%Y %H:%M")) %>%
  select( Place ,Pose_Date_Heure, Depose_Date_Heure )

# Fusion de toutes les données
Tanz<- data_piege %>%
  left_join(factors_data , by = "Place") %>%
  left_join (GPS , by = "Place" ) %>%
  left_join (dates , by = "Place") %>%
  arrange (Place , From) %>%
  group_by(Place) %>%
```

```
  mutate(Days_effort = difftime(Depose_Date_Heure, Pose_Date_Heure, units ="days") %>% as.numeric) %>%
  ungroup %>%
  mutate (Delay.start.picture = difftime(From , Pose_Date_Heure , units = "days") %>% as.numeric) %>%
  filter(Days_effort > 12 & Delay.start.picture <=21) %>%
  mutate (survey = cut(Delay.start.picture,
                       breaks = c(-1,1,seq(2,21)),
                       right = FALSE,
                       labels = sprintf("survey%02d",seq(1:21))))

######## Mise en place de table pour occupancy
#Avant de commencer on va devoir créer une table "Modèle" ou on a toutes les caméras (mêmes celles qui n'ont pas pris de photos) et avec toutes les espèces d'intérêt (carnivores) pour chaque caméra (même s'ils n'ont pas été détecté --> la non présence est une information)

Carnivores <-  c("Canis adustus",
                 "Canis mesolemas",
                 "Lycaon pictus",
                 "Felis caracal",
                 "Leptailurus serval",
                 "Felis sylvestris",
                 "Panthera pardus",
                 "Panthera leo",
                 "Atilax paludinosus",
                 "Bdeogale crassicauda",
                 "Mungos mungo",
                 "Mongoose sp.",
                 "Helogale parvula",
                 "Herpestes ichneumon",
                 "Herpestes sanguinea",
                 "Ichneumia albicauda",
                 "Rhynchogale melleri",
                 "Crocuta crocuta",
                 "Proteles cristatus",
                 "Mellivora capensis",
                 "Ictonyx striatus",
                 "Nandinia binotata",
                 "Civettictis civetta",
                 "Genetta angolensis",
                 "Genetta genetta",
                 "Genetta maculata",
                 "Genetta servalina",
                 "Genetta sp.")

Model <- factors_data %>%
  slice (rep (1:n(), each = length(Carnivores))) %>%
  arrange(Place) %>%
  mutate( Species = rep(Carnivores,length(unique (factors_data$Place)))) %>%
  left_join (dates , by = "Place") %>%
  group_by(Place) %>%
  mutate(Days_effort = difftime(Depose_Date_Heure, Pose_Date_Heure, units ="days") %>% as.numeric) %>%
  ungroup

#Table d'occupancy avec les données brutes
Tanz_occu_brut <- Tanz %>%
  mutate(trick = 1) %>%
```

```
  spread(survey, trick, fill = 0) %>%
  select(Place,Species,survey01:survey21) %>%
  group_by (Place, Species) %>%
  summarise_all(funs(sum))

# Fusion de la table modéle avec la table d'occupancy brute
Tanz_occu <- Model %>%
  left_join(Tanz_occu_brut , by =c("Place","Species")) %>%
  mutate_at(vars(survey01:survey21) ,funs(replace(.,is.na(.),0))) %>% #Remplace NA par 0
  mutate (Presence = rowSums(select(. , starts_with("survey")))) %>%
  mutate_at(vars(survey01:Presence) ,funs(replace(.,.>1,1))) %>% #Remplace valeurs au dessus de 1 par 1
  #(présence plutôt que nombre de photos)
  mutate(Reserve = recode(Management, `74`="Rukwa", `72`="Mlele" ,`50` = "Rungwa")) %>%
  mutate(Jours_presence = rowSums(select(. , starts_with("survey")))) %>%
  mutate(Species = gsub(" ", "_",Species))%>%
  select(Altitude:Days_effort,Presence,Jours_presence,Reserve,survey01:survey21)

#Ici on rajoute des NA à la fin pour les caméras qui ont duré moins de 21 jours
for (i in 1:nrow(Tanz_occu)){
  if (ceiling(Tanz_occu$Days_effort[i])>=21|
      is.na (ceiling(Tanz_occu$Days_effort[i]))) next
  if (ceiling(Tanz_occu$Days_effort[i])<21)
  {Tanz_occu[i, (ncol(Tanz_occu) -20 + ceiling(Tanz_occu$Days_effort[i])) : ncol(Tanz_occu)] =NA }
}

### Naive occupancy
table_Naive_occu <- Tanz_occu %>% group_by(Species) %>%
  summarise(Nb.cameras.presence = sum(Presence),
            Naive.occupancy = sum(Presence)/length(unique(Place)),
            Nb.cameras.presence.Mlele = sum(Presence[Reserve == "Mlele"], na.rm=T),
            Naive.occupancy.Mlele = sum(Presence[Reserve == "Mlele"], na.rm=T)/length(unique(Place[Reserve ==
"Mlele"])),

            Nb.cameras.presence.Rukwa = sum(Presence[Reserve == "Rukwa"], na.rm=T),
            Naive.occupancy.Rukwa = sum(Presence[Reserve == "Rukwa"],na.rm=T)/length(unique(Place[Reserve
== "Rukwa"])),
            Nb.cameras.presence.Rungwa = sum(Presence[Reserve == "Rungwa"], na.rm=T),
            Naive.occupancy.Rungwa = sum(Presence[Reserve == "Rungwa"],
na.rm=T)/length(unique(Place[Reserve == "Rungwa"]))
  )

### Courbe d'accumulation
Gen=as.data.frame.matrix(table(Tanz$From,Tanz$Species)) %>%
  select(-Uncertain, -Bird, -`Bat sp.`,- V1, -`[TEAM]`, -`Bos taurus africanus`, -`Canis lupus familiaris`,-roden)
specaccum(Gen)
plot(specaccum(Gen), ci.col="gray50") #Ce graphique n'est pas totalement juste, il faudrait prendre en compte
les jours ou la caméra n'as pas detecté d'espèces.
#Cependant ca donne déjà une idée que le sampling a permis d'arriver à un plateau au niveau des espèces
detectées.

Mlele=Tanz %>%
  filter(Governance == 3)
curve=as.data.frame.matrix(table(Mlele$From,Mlele$Species)) %>%
  select(-Uncertain, -Bird, -V1, -`[TEAM]`)
specaccum(curve)
```

```
plot(specaccum(curve), ci.col="gray50")

Rungwa=Tanz %>%
  filter(Governance == 2)
curve=as.data.frame.matrix(table(Rungwa$From,Rungwa$Species)) %>%
  select(-Uncertain, -Bird, -`Bat sp.`,- V1, -`[TEAM]`, -`Bos taurus africanus`, -`Canis lupus familiaris`,-roden)
specaccum(curve)
plot(specaccum(curve), ci.col="gray50")

Rukwa=Tanz %>%
  filter(Governance == 1)
curve=as.data.frame.matrix(table(Rukwa$From,Rukwa$Species)) %>%
  select(-Bird,- V1, -`[TEAM]`)
specaccum(curve)
plot(specaccum(curve), ci.col="gray50")

### Single season occupancy
#Pour calculer la single season occupancy on recrée la table Tanz_occu mais cette fois en format wide pour
nous faciliter la tâche. Aussi, on efface toutes les espèces qui n'ont pas été detectées.

Tanz_occu_wide <-
  Tanz_occu %>%
  group_by(Species) %>%
  filter(sum(Presence)>0) %>%
  ungroup() %>%
  gather(variable,value,-c(Altitude:Days_effort,Reserve)) %>%
  unite (temp,Species,variable) %>%
  spread (temp, value)

#On va tester dabord si les postulats sont respectés pour les covariées.
#Test de normalité (meilleur si on utilise la racine carrée et on standardise les valeurs)
library(psych)

multi.hist(Tanz_occu_wide %>% select(Altitude:D_Timbering, -
c(Habitat_Type,Status,Governance,Management)))

Tanz_occu_wide <-
  Tanz_occu_wide %>%
  mutate_at( vars (Altitude:D_Timbering, -c(Habitat_Type,Status,Governance,Management)),
             .funs = funs(s = scale(sqrt(.)) ))

multi.hist(Tanz_occu_wide %>% select(Altitude_s:D_Timbering_s))

#Test multicolinearité (variables numériques)
cor(Tanz_occu_wide %>% select(Altitude_s:D_Timbering_s),use="pairwise.complete.obs")

#Test multicolinearité (variables catégorielles)
table(Tanz_occu_wide$Habitat_Type,Tanz_occu_wide$Status)
table(Tanz_occu_wide$Governance,Tanz_occu_wide$Status)
table(Tanz_occu_wide$Management,Tanz_occu_wide$Status)
table(Tanz_occu_wide$Governance,Tanz_occu_wide$Management)

#Conserver seulement une des variables entre Status, Governance et Reserve(qui est égale à Management)
#Variance Inflation factor = indice de multicolinearité.
#Collinearité elevée si supérieure à 10
```

```
library(car)

lm(Genetta_angolensis_Presence~Altitude_s+
    D_Water_s+
    D_Roads_s+
    D_Camps_s+
    D_Villages_s+
    D_PA_s+
    D_Poaching_s+
    D_Timbering_s+
    as.character(Habitat_Type)+
    Reserve, data=Tanz_occu_wide) %>% vif

#Ici je crée une fonction pour éviter de répeter la même chose pour l'occupancy de chaque espèce.
df.specie <- function(Specie) {
  Tanz_occu_wide %>%
    select(starts_with(Specie))  %>%
    select(matches("survey"))
}

site.covs <- Tanz_occu_wide %>% select(Altitude_s:D_Timbering_s, Reserve,Habitat_Type)

library(unmarked)
library(MuMIn)

##### Occupancy Canis adustus
Canis <- unmarkedFrameOccu(y= df.specie("Canis_adustus"), siteCovs = site.covs)

full <- occu(~1~Altitude_s+
               D_Water_s+
               D_Roads_s+
               D_Camps_s+
               D_Villages_s+
               D_PA_s+
               D_Poaching_s+
               Habitat_Type,Canis)

AICCanis <- dredge(full, rank=AIC) %>% as.data.frame %>% filter(delta<2)

View(AICCanis)

AICCanis %>% summarise_at (vars (`psi(Altitude_s)`:`psi(Habitat_Type)`),
                           .funs=funs(sum(weight [!is.na(.)]))) %>% sort(decreasing=TRUE)

best=occu(~1~D_Roads_s+
            D_Water_s+
            D_Camps_s+
            D_Villages_s+
            Habitat_Type,Canis)

best2=occu(~1~D_Roads_s+
             D_Water_s+
             D_Camps_s+
             D_Villages_s+
             Habitat_Type+
```

```
            Reserve,Canis)

best2

newData =
  data.frame(
    Reserve = c("Mlele","Rukwa","Rungwa"),
    D_Roads_s=c(0,0,0),
    D_Water_s=c(0,0,0),
    D_Camps_s=c(0,0,0),
    D_Villages_s=c(0,0,0),
    Habitat_Type=c(3,3,3))

pred = predict(best2, type="state", newdata=newData, appendData=T)
pred

ggplot(pred, aes(x = Reserve,y = Predicted))+
  geom_point(size = 4)+
  ylab("Occupancy")+
  theme_bw()+
  geom_errorbar(aes(ymin = Predicted-SE,ymax = Predicted+SE), width = .2)+
  theme(axis.text = element_text(size = 16),
        axis.title=element_text(size = 16, face="bold"))

##### Occupancy Lycaon pictus
Lyca <- unmarkedFrameOccu(y= df.specie("Lycaon_pictus"), siteCovs = site.covs)

full <- occu(~1~Altitude_s+
               D_Water_s+
               D_Roads_s+
               D_Camps_s+
               D_Villages_s+
               D_PA_s+
               D_Poaching_s+
               Habitat_Type,Lyca)

AICLyca <- dredge(full, rank=AIC) %>% as.data.frame %>% filter(delta<2)

View(AICLyca)

AICLyca %>% summarise_at (vars (`psi(Altitude_s)`:`psi(Habitat_Type)`),
                          .funs=funs(sum(weight [!is.na(.)]))) %>% sort(decreasing=TRUE)

best=occu(~1~D_Camps_s+
            D_Roads_s+
            Habitat_Type+
            D_Water_s+
            D_PA_s+
            D_Villages_s+
            Altitude_s,Lyca)

best2=occu(~1~D_Camps_s+
             D_Roads_s+
             Habitat_Type+
             D_Water_s+
```

```
            D_PA_s+
            D_Villages_s+
            Altitude_s+
            Reserve,Lyca)

best2

newData =
  data.frame(
    Reserve = c("Mlele","Rukwa","Rungwa"),
    D_Camps_s=c(0,0,0),
    D_Roads_s=c(0,0,0),
    Habitat_Type=c(3,3,3),
    D_Water_s=c(0,0,0),
    D_Villages_s=c(0,0,0),
    Altitude_s=c(0,0,0),
    D_PA_s=c(0,0,0))

pred = predict(best2, type="state", newdata=newData, appendData=T)
pred

ggplot(pred, aes(x = Reserve,y = Predicted))+
  geom_point(size = 4)+
  ylab("Occupancy")+
  theme_bw()+
  geom_errorbar(aes(ymin = Predicted-SE,ymax = Predicted+SE), width = .2)+
  theme(axis.text = element_text(size = 16),
        axis.title=element_text(size = 16, face="bold"))

##### Occupancy Leptailurus serval
Lept <- unmarkedFrameOccu(y= df.specie("Leptailurus_serval"), siteCovs = site.covs)

full <- occu(~1~Altitude_s+
               D_Water_s+
               D_Roads_s+
               D_Camps_s+
               D_Villages_s+
               D_PA_s+
               D_Poaching_s+
               Habitat_Type,Lept)

AICLept <- dredge(full, rank=AIC) %>% as.data.frame %>% filter(delta<2)

View(AICLept)

AICLept %>% summarise_at (vars (`psi(Altitude_s)`:`psi(Habitat_Type)`),
                          .funs=funs(sum(weight [!is.na(.)]))) %>% sort(decreasing=TRUE)

best=occu(~1~D_Camps_s+
            D_Poaching_s+
            D_Roads_s+
            D_Water_s+
            Habitat_Type+
            Altitude_s,Lept)
```

```
best2=occu(~1~D_Camps_s+
            D_Poaching_s+
            D_Roads_s+
            D_Water_s+
            Habitat_Type+
            Altitude_s+
            Reserve,Lept)

best2

newData =
  data.frame(
    Reserve = c("Mlele","Rukwa","Rungwa"),
    D_Camps_s=c(0,0,0),
    D_Poaching_s=c(0,0,0),
    D_Roads_s=c(0,0,0),
    D_Water_s=c(0,0,0),
    Habitat_Type=c(3,3,3),
    Altitude_s=c(0,0,0))

pred = predict(best2, type="state", newdata=newData, appendData=T)
pred

ggplot(pred, aes(x = Reserve,y = Predicted))+
  geom_point(size = 4)+
  ylab("Occupancy")+
  theme_bw()+
  geom_errorbar(aes(ymin = Predicted-SE,ymax = Predicted+SE), width = .2)+
  theme(axis.text = element_text(size = 16),
        axis.title=element_text(size = 16, face="bold"))

##### Occupancy Felis silvestris
Felis <- unmarkedFrameOccu(y= df.specie("Felis_silvestris"), siteCovs = site.covs)

full <- occu(~1~Altitude_s+
               D_Water_s+
               D_Roads_s+
               D_Camps_s+
               D_Villages_s+
               D_PA_s+
               D_Poaching_s+
               Habitat_Type,Felis)

AICFelis <- dredge(full, rank=AIC) %>% as.data.frame %>% filter(delta<2)

View(AICFelis)

AICFelis %>% summarise_at (vars (`psi(Altitude_s)`:`psi(Habitat_Type)`),
                           .funs=funs(sum(weight [!is.na(.)]))) %>% sort(decreasing=TRUE)

best=occu(~1~D_Camps_s+
            D_Poaching_s+
            D_Roads_s+
            D_Water_s+
            Habitat_Type+
```

```
          Altitude_s,Felis)

best2=occu(~1~D_Camps_s+
           D_Poaching_s+
           D_Roads_s+
           D_Water_s+
           Habitat_Type+
           Altitude_s+
           Reserve,Felis)

best2

newData =
  data.frame(
    Reserve = c("Mlele","Rukwa","Rungwa"),
    D_Camps_s=c(0,0,0),
    D_Poaching_s=c(0,0,0),
    D_Roads_s=c(0,0,0),
    D_Water_s=c(0,0,0),
    Habitat_Type=c(3,3,3),
    Altitude_s=c(0,0,0))

pred = predict(best2, type="state", newdata=newData, appendData=T)
pred

ggplot(pred, aes(x = Reserve,y = Predicted))+
  geom_point(size = 4)+
  ylab("Occupancy")+
  theme_bw()+
  geom_errorbar(aes(ymin = Predicted-SE,ymax = Predicted+SE), width = .2)+
  theme(axis.text = element_text(size = 16),
        axis.title=element_text(size = 16, face="bold"))

##### Occupancy Panthera pardus
Pantp <- unmarkedFrameOccu(y= df.specie("Panthera_pardus"), siteCovs = site.covs)

full <- occu(~1~Altitude_s+
               D_Water_s+
               D_Roads_s+
               D_Camps_s+
               D_Villages_s+
               D_PA_s+
               D_Poaching_s+
               Habitat_Type,Pantp)

AICPantp <- dredge(full, rank=AIC) %>% as.data.frame %>% filter(delta<2)

View(AICPantp)

AICPantp %>% summarise_at (vars (`psi(Altitude_s)`:`psi(Habitat_Type)`),
                           .funs=funs(sum(weight [!is.na(.)]))) %>% sort(decreasing=TRUE)

best=occu(~1~Habitat_Type+
            D_Roads_s+
            D_Camps_s+
```

```
          D_Poaching_s+
          D_PA_s+
          Altitude_s+
          D_Water_s,Pantp)

best2=occu(~1~Habitat_Type+
           D_Roads_s+
           D_Camps_s+
           D_Poaching_s+
           D_PA_s+
           Altitude_s+
           D_Water_s+
           Reserve,Pantp)

best2

newData =
  data.frame(
    Reserve = c("Mlele","Rukwa","Rungwa"),
    Habitat_Type=c(3,3,3),
    D_Roads_s=c(0,0,0),
    D_Camps_s=c(0,0,0),
    D_Poaching_s=c(0,0,0),
    D_PA_s=c(0,0,0),
    Altitude_s=c(0,0,0),
    D_Water_s=c(0,0,0))

pred = predict(best2, type="state", newdata=newData, appendData=T)
pred

ggplot(pred, aes(x = Reserve,y = Predicted))+
  geom_point(size = 4)+
  ylab("Occupancy")+
  theme_bw()+
  geom_errorbar(aes(ymin = Predicted-SE,ymax = Predicted+SE), width = .2)+
  theme(axis.text = element_text(size = 16),
        axis.title=element_text(size = 16, face="bold"))

##### Occupancy Panthera leo
Pantl <- unmarkedFrameOccu(y= df.specie("Panthera_leo"), siteCovs = site.covs)

full <- occu(~1~Altitude_s+
             D_Water_s+
             D_Roads_s+
             D_Camps_s+
             D_Villages_s+
             D_PA_s+
             D_Poaching_s+
             Habitat_Type,Pantl)

AICPantl <- dredge(full, rank=AIC) %>% as.data.frame %>% filter(delta<2)

View(AICPantl)

AICPantl %>% summarise_at (vars (`psi(Altitude_s)`:`psi(Habitat_Type)`),
```

```
                    .funs=funs(sum(weight [!is.na(.)]))) %>% sort(decreasing=TRUE)

best=occu(~1~Altitude_s+
          D_Water_s+
          D_Poaching_s+
          Habitat_Type+
          D_Roads_s,Pantl)

best2=occu(~1~Altitude_s+
           D_Water_s+
           D_Poaching_s+
           Habitat_Type+
           D_Roads_s+
           Reserve,Pantl)

best2



newData =
  data.frame(
    Reserve = c("Mlele","Rukwa","Rungwa"),
    Altitude_s=c(0,0,0),
    D_Water_s=c(0,0,0),
    D_Poaching_s=c(0,0,0),
    Habitat_Type=c(3,3,3),
    D_Roads_s=c(0,0,0))

pred = predict(best2, type="state", newdata=newData, appendData=T)
pred

ggplot(pred, aes(x = Reserve,y = Predicted))+
  geom_point(size = 4)+
  ylab("Occupancy")+
  theme_bw()+
  geom_errorbar(aes(ymin = Predicted-SE,ymax = Predicted+SE), width = .2)+
  theme(axis.text = element_text(size = 16),
        axis.title=element_text(size = 16, face="bold"))

##### Occupancy Atilax paludinosus
Atil <- unmarkedFrameOccu(y= df.specie("Atilax_paludinosus"), siteCovs = site.covs)

full <- occu(~1~Altitude_s+
               D_Water_s+
               D_Roads_s+
               D_Camps_s+
               D_Villages_s+
               D_PA_s+
               D_Poaching_s+
               Habitat_Type,Atil)

AICAtil <- dredge(full, rank=AIC) %>% as.data.frame %>% filter(delta<2)

View(AICAtil)
```

```
AICAtil %>% summarise_at (vars (`psi(Altitude_s)`:`psi(Habitat_Type)`),
                          .funs=funs(sum(weight [!is.na(.)]))) %>% sort(decreasing=TRUE)

best=occu(~1~Habitat_Type+
            D_Poaching_s+
            D_Water_s+
            Altitude_s+
            D_Roads_s+
            D_Villages_s+
            D_PA_s+
            D_Camps_s,Atil)

best2=occu(~1~Habitat_Type+
             D_Poaching_s+
             D_Water_s+
             Altitude_s+
             D_Roads_s+
             D_Villages_s+
             D_PA_s+
             D_Camps_s+
             Reserve,Atil)

best2

newData =
  data.frame(
    Reserve = c("Mlele","Rukwa","Rungwa"),
    Habitat_Type=c(3,3,3),
      D_Poaching_s=c(0,0,0),
      D_Water_s=c(0,0,0),
      Altitude_s=c(0,0,0),
      D_Roads_s=c(0,0,0),
      D_Villages_s=c(0,0,0),
      D_PA_s=c(0,0,0),
      D_Camps_s=c(0,0,0))

pred = predict(best2, type="state", newdata=newData, appendData=T)
pred

ggplot(pred, aes(x = Reserve,y = Predicted))+
  geom_point(size = 4)+
  ylab("Occupancy")+
  theme_bw()+
  geom_errorbar(aes(ymin = Predicted-SE,ymax = Predicted+SE), width = .2)+
  theme(axis.text = element_text(size = 16),
        axis.title=element_text(size = 16, face="bold"))

### Occupancy Bdeogale Crassicauda
Bdeo <- unmarkedFrameOccu(y= df.specie("Bdeogale_crassicauda"), siteCovs = site.covs)

full <- occu(~1~Altitude_s+
               D_Water_s+
               D_Roads_s+
               D_Camps_s+
               D_Villages_s+
```

```
            D_PA_s+
            D_Poaching_s+
            Habitat_Type,Bdeo)

AICBdeo <- dredge(full, rank=AIC) %>% as.data.frame %>% filter(delta<2)

View(AICBdeo)

AICBdeo %>% summarise_at (vars (`psi(Altitude_s)`:`psi(Habitat_Type)`),
                    .funs=funs(sum(weight [!is.na(.)]))) %>% sort(decreasing=TRUE)

best=occu(~1~Altitude_s+
          D_PA_s+
          D_Camps_s+
          D_Villages_s+
          D_Roads_s,Bdeo)

best2=occu(~1~Altitude_s+
           D_PA_s+
           D_Camps_s+
           D_Villages_s+
           D_Roads_s+
           Reserve,Bdeo)

best2

newData =
  data.frame(
    Reserve = c("Mlele","Rukwa","Rungwa"),
    Altitude_s=c(0,0,0),
    D_PA_s=c(0,0,0),
    D_Camps_s=c(0,0,0),
    D_Villages_s=c(0,0,0),
    D_Roads_s=c(0,0,0))

pred = predict(best2, type="state", newdata=newData, appendData=T)
pred

ggplot(pred, aes(x = Reserve,y = Predicted))+
  geom_point(size = 4)+
  ylab("Occupancy")+
  theme_bw()+
  geom_errorbar(aes(ymin = Predicted-SE,ymax = Predicted+SE), width = .2)+
  theme(axis.text = element_text(size = 16),
        axis.title=element_text(size = 16, face="bold"))

##### Occupancy Mungos mungo
Mung <- unmarkedFrameOccu(y= df.specie("Mungos_mungo"), siteCovs = site.covs)

full <- occu(~1~Altitude_s+
             D_Water_s+
             D_Roads_s+
             D_Camps_s+
             D_Villages_s+
             D_PA_s+
```

```
            D_Poaching_s+
            Habitat_Type,Mung)

AICMung <- dredge(full, rank=AIC) %>% as.data.frame %>% filter(delta<2)

View(AICMung)

AICMung %>% summarise_at (vars (`psi(Altitude_s)`:`psi(Habitat_Type)`),
                  .funs=funs(sum(weight [!is.na(.)]))) %>% sort(decreasing=TRUE)


best=occu(~1~D_Roads_s+
          D_PA_s,+
          Altitude_s,Mung)

best2=occu(~1~D_Roads_s+
           D_PA_s+
           Altitude_s+
           Reserve,Mung)

best2

newData =
  data.frame(
    Reserve = c("Mlele","Rukwa","Rungwa"),
    D_Villages_s=c(0,0,0),
    D_Roads_s=c(0,0,0))

pred = predict(best2, type="state", newdata=newData, appendData=T)
pred

ggplot(pred, aes(x = Reserve,y = Predicted))+
  geom_point(size = 4)+
  ylab("Occupancy")+
  theme_bw()+
  geom_errorbar(aes(ymin = Predicted-SE,ymax = Predicted+SE), width = .2)+
  theme(axis.text = element_text(size = 16),
        axis.title=element_text(size = 16, face="bold"))

##### Occupancy Helogale parvula
Helo <- unmarkedFrameOccu(y= df.specie("Helogale_parvula"), siteCovs = site.covs)

full <- occu(~1~Altitude_s+
            D_Water_s+
            D_Roads_s+
            D_Camps_s+
            D_Villages_s+
            D_PA_s+
            D_Poaching_s+
            Habitat_Type,Helo)

AICHelo <- dredge(full, rank=AIC) %>% as.data.frame %>% filter(delta<2)

View(AICHelo)
```

```
AICHelo %>% summarise_at (vars (`psi(Altitude_s)`:`psi(Habitat_Type)`),
                           .funs=funs(sum(weight [!is.na(.)]))) %>% sort(decreasing=TRUE)

best=occu(~1~Altitude_s+
            D_Poaching_s+
            D_Water_s+
            D_Roads_s+
            D_PA_s+
            D_Villages_s+
            D_Camps_s,Helo)

best2=occu(~1~Altitude_s+
             D_Poaching_s+
             D_Water_s+
             D_Roads_s+
             D_PA_s+
             D_Villages_s+
             D_Camps_s+
             Reserve,Helo)

best2

newData =
  data.frame(
    Reserve = c("Mlele","Rukwa","Rungwa"),
    Altitude_s=c(0,0,0),
      D_Poaching_s=c(0,0,0),
      D_Water_s=c(0,0,0),
      D_Roads_s=c(0,0,0),
      D_PA_s=c(0,0,0),
      D_Villages_s=c(0,0,0),
      D_Camps_s=c(0,0,0))

pred = predict(best2, type="state", newdata=newData, appendData=T)
pred

ggplot(pred, aes(x = Reserve,y = Predicted))+
  geom_point(size = 4)+
  ylab("Occupancy")+
  theme_bw()+
  geom_errorbar(aes(ymin = Predicted-SE,ymax = Predicted+SE), width = .2)+
  theme(axis.text = element_text(size = 16),
        axis.title=element_text(size = 16, face="bold"))

##### Occupancy Ichneumia albicauda
Ich <- unmarkedFrameOccu(y= df.specie("Ichneumia_albicauda"), siteCovs = site.covs)

full <- occu(~1~Altitude_s+
               D_Water_s+
               D_Roads_s+
               D_Camps_s+
               D_Villages_s+
               D_PA_s+
               D_Poaching_s+
               Habitat_Type,Ich)
```

```
AICIch <- dredge(full, rank=AIC) %>% as.data.frame %>% filter(delta<2)

View(AICIch)

AICIch %>% summarise_at (vars (`psi(Altitude_s)`:`psi(Habitat_Type)`),
                         .funs=funs(sum(weight [!is.na(.)]))) %>% sort(decreasing=TRUE)

best=occu(~1~Altitude_s+
            D_Poaching_s+
            D_Water_s+
            D_Roads_s+
            Habitat_Type+
            D_Villages_s+
            D_Camps_s+
            D_PA_S,Ich)

best2=occu(~1~Altitude_s+
             D_Poaching_s+
             D_Water_s+
             D_Roads_s+
             Habitat_Type+
             D_Villages_s+
             D_Camps_s+
             D_PA_S+
             Reserve,Ich)

best2

newData =
  data.frame(
    Reserve = c("Mlele","Rukwa","Rungwa"),
    Altitude_s=c(0,0,0),
      D_Poaching_s=c(0,0,0),
      D_Water_s=c(0,0,0),
      D_Roads_s=c(0,0,0),
      Habitat_Type=c(3,3,3),
      D_Villages_s=c(0,0,0),
      D_Camps_s=c(0,0,0),
      D_PA_S=c(0,0,0))

pred = predict(best2, type="state", newdata=newData, appendData=T)
pred

ggplot(pred, aes(x = Reserve,y = Predicted))+
  geom_point(size = 4)+
  ylab("Occupancy")+
  theme_bw()+
  geom_errorbar(aes(ymin = Predicted-SE,ymax = Predicted+SE), width = .2)+
  theme(axis.text = element_text(size = 16),
        axis.title=element_text(size = 16, face="bold"))

##### Occupancy Rhynchogale melleri
Rhyn <- unmarkedFrameOccu(y= df.specie("Rhynchogale_melleri"), siteCovs = site.covs)
```

```
full <- occu(~1~Altitude_s+
               D_Water_s+
               D_Roads_s+
               D_Camps_s+
               D_Villages_s+
               D_PA_s+
               D_Poaching_s+
               Habitat_Type,Rhyn)

AICRhyn <- dredge(full, rank=AIC) %>% as.data.frame %>% filter(delta<2)

View(AICRhyn)

AICRhyn %>% summarise_at (vars (`psi(Altitude_s)`:`psi(Habitat_Type)`),
                          .funs=funs(sum(weight [!is.na(.)]))) %>% sort(decreasing=TRUE)

best=occu(~1~Altitude_s+
            D_Roads_s+
            Habitat_Type+
            D_Villages_s+
            D_PA_s+
            D_Camps_s+
            D_Poaching_s+
            D_Water_s,Rhyn)

best2=occu(~1~Altitude_s+
             D_Roads_s+
             Habitat_Type+
             D_Villages_s+
             D_PA_s+
             D_Camps_s+
             D_Poaching_s+
             D_Water_s+
             Reserve,Rhyn)

best2

newData =
  data.frame(
    Reserve = c("Mlele","Rukwa","Rungwa"),
    Altitude_s=c(0,0,0),
      D_Roads_s=c(0,0,0),
      Habitat_Type=c(3,3,3),
      D_Villages_s=c(0,0,0),
      D_PA_s=c(0,0,0),
      D_Camps_s=c(0,0,0),
      D_Poaching_s=c(0,0,0),
      D_Water_s=c(0,0,0))

pred = predict(best2, type="state", newdata=newData, appendData=T)
pred

ggplot(pred, aes(x = Reserve,y = Predicted))+
  geom_point(size = 4)+
  ylab("Occupancy")+
```

```
  theme_bw()+
  geom_errorbar(aes(ymin = Predicted-SE,ymax = Predicted+SE), width = .2)+
  theme(axis.text = element_text(size = 16),
        axis.title=element_text(size = 16, face="bold"))

##### Occupancy Crocuta crocuta
Croc <- unmarkedFrameOccu(y= df.specie("Crocuta_crocuta"), siteCovs = site.covs)

full <- occu(~1~Altitude_s+
               D_Water_s+
               D_Roads_s+
               D_Camps_s+
               D_Villages_s+
               D_PA_s+
               D_Poaching_s+
               Habitat_Type,Croc)

AICCroc <- dredge(full, rank=AIC) %>% as.data.frame %>% filter(delta<2)

View(AICCroc)

AICCroc %>% summarise_at (vars (`psi(Altitude_s)`:`psi(Habitat_Type)`),
                          .funs=funs(sum(weight [!is.na(.)]))) %>% sort(decreasing=TRUE)

best=occu(~1~D_Poaching_s+
            D_PA_s+
            Habitat_Type,Croc)

best2=occu(~1~D_Poaching_s+
             D_PA_s+
             Habitat_Type+
             Reserve,Croc)

best2

newData =
  data.frame(
    Reserve = c("Mlele","Rukwa","Rungwa"),
    D_Poaching_s=c(0,0,0),
    D_PA_s=c(0,0,0),
    Habitat_Type=c(3,3,3))

pred = predict(best2, type="state", newdata=newData, appendData=T)
pred

ggplot(pred, aes(x = Reserve,y = Predicted))+
  geom_point(size = 4)+
  ylab("Occupancy")+
  theme_bw()+
  geom_errorbar(aes(ymin = Predicted-SE,ymax = Predicted+SE), width = .2)+
  theme(axis.text = element_text(size = 16),
        axis.title=element_text(size = 16, face="bold"))

##### Occupancy Mellivora capensis
Mell <- unmarkedFrameOccu(y= df.specie("Mellivora_capensis"), siteCovs = site.covs)
```

```
full <- occu(~1~Altitude_s+
               D_Water_s+
               D_Roads_s+
               D_Camps_s+
               D_Villages_s+
               D_PA_s+
               D_Poaching_s+
               Habitat_Type,Mell)

AICMell <- dredge(full, rank=AIC) %>% as.data.frame %>% filter(delta<2)

View(AICMell)

AICMell %>% summarise_at (vars (`psi(Altitude_s)`:`psi(Habitat_Type)`),
                          .funs=funs(sum(weight [!is.na(.)]))) %>% sort(decreasing=TRUE)

best=occu(~1~D_Poaching_s+
            D_Water_s+
            D_PA_s+
            D_Roads_s+
            Altitude_s+
            D_Camps_s,Mell)

best2=occu(~1~D_Poaching_s+
             D_Water_s+
             D_PA_s+
             D_Roads_s+
             Altitude_s+
             D_Camps_s+
             Reserve,Mell)

best2

newData =
  data.frame(
    Reserve = c("Mlele","Rukwa","Rungwa"),
    D_Poaching_s=c(0,0,0),
    D_Water_s=c(0,0,0),
    D_PA_s=c(0,0,0),
    D_Roads_s=c(0,0,0),
    Altitude_s=c(0,0,0),
    D_Camps_s=c(0,0,0))

pred = predict(best2, type="state", newdata=newData, appendData=T)
pred

ggplot(pred, aes(x = Reserve,y = Predicted))+
  geom_point(size = 4)+
  ylab("Occupancy")+
  theme_bw()+
  geom_errorbar(aes(ymin = Predicted-SE,ymax = Predicted+SE), width = .2)+
  theme(axis.text = element_text(size = 16),
        axis.title=element_text(size = 16, face="bold"))
```

```
##### Occupancy Civettictis civetta
Cive <- unmarkedFrameOccu(y= df.specie("Civettictis_civetta"), siteCovs = site.covs)

full <- occu(~1~Altitude_s+
               D_Water_s+
               D_Roads_s+
               D_Camps_s+
               D_Villages_s+
               D_PA_s+
               D_Poaching_s+
               Habitat_Type,Cive)

AICCive <- dredge(full, rank=AIC) %>% as.data.frame %>% filter(delta<2)

View(AICCive)

AICCive %>% summarise_at (vars (`psi(Altitude_s)`:`psi(Habitat_Type)`),
                          .funs=funs(sum(weight [!is.na(.)]))) %>% sort(decreasing=TRUE)

best=occu(~1~D_Water_s+
            D_Villages_s+
            D_Poaching_s+
            D_PA_s+
            Habitat_Type,Cive)

best2=occu(~1~D_Water_s+
             D_Villages_s+
             D_Poaching_s+
             D_PA_s+
             Habitat_Type+
             Reserve,Cive)

best2

newData =
  data.frame(
    Reserve = c("Mlele","Rukwa","Rungwa"),
    D_Water_s=c(0,0,0),
    D_Villages_s=c(0,0,0),
    D_Poaching_s=c(0,0,0),
    D_PA_s=c(0,0,0),
    Habitat_Type=c(3,3,3))

pred = predict(best2, type="state", newdata=newData, appendData=T)
pred

ggplot(pred, aes(x = Reserve,y = Predicted))+
  geom_point(size = 4)+
  ylab("Occupancy")+
  theme_bw()+
  geom_errorbar(aes(ymin = Predicted-SE,ymax = Predicted+SE), width = .2)+
  theme(axis.text = element_text(size = 16),
        axis.title=element_text(size = 16, face="bold"))

##### Occupancy Genetta angolensis
```

```
Geneta <- unmarkedFrameOccu(y= df.specie("Genetta_angolensis"), siteCovs = site.covs)

full <- occu(~1~Altitude_s+
               D_Water_s+
               D_Roads_s+
               D_Camps_s+
               D_Villages_s+
               D_PA_s+
               D_Poaching_s+
               Habitat_Type,Geneta)

AICGeneta <- dredge(full, rank=AIC) %>% as.data.frame %>% filter(delta<2)

View(AICGeneta)

AICGeneta %>% summarise_at (vars (`psi(Altitude_s)`:`psi(Habitat_Type)`),
                            .funs=funs(sum(weight [!is.na(.)]))) %>% sort(decreasing=TRUE)

best=occu(~1~Altitude_s+
            Habitat_Type+
            D_Villages_s+
            D_PA_s+
            D_Poaching_s,Geneta)

best2=occu(~1~Altitude_s+
             Habitat_Type+
             D_Villages_s+
             D_PA_s+
             D_Poaching_s+
             Reserve,Geneta)

best2

newData =
  data.frame(
    Reserve = c("Mlele","Rukwa","Rungwa"),
    Altitude_s=c(0,0,0),
    Habitat_Type=c(3,3,3),
    D_Villages_s=c(0,0,0),
    D_PA_s=c(0,0,0),
    D_Poaching_s=c(0,0,0))

pred = predict(best2, type="state", newdata=newData, appendData=T)
pred

ggplot(pred, aes(x = Reserve,y = Predicted))+
  geom_point(size = 4)+
  ylab("Occupancy")+
  theme_bw()+
  geom_errorbar(aes(ymin = Predicted-SE,ymax = Predicted+SE), width = .2)+
  theme(axis.text = element_text(size = 16),
        axis.title=element_text(size = 16, face="bold"))

##### Occupancy Genetta maculata
Genetm <- unmarkedFrameOccu(y= df.specie("Genetta_maculata"), siteCovs = site.covs)
```

```
full <- occu(~1~Altitude_s+
               D_Water_s+
               D_Roads_s+
               D_Camps_s+
               D_Villages_s+
               D_PA_s+
               D_Poaching_s+
               Habitat_Type,Genetm)

AICGenetm <- dredge(full, rank=AIC) %>% as.data.frame %>% filter(delta<2)

View(AICGenetm)

AICGenetm %>% summarise_at (vars (`psi(Altitude_s)`:`psi(Habitat_Type)`),
                            .funs=funs(sum(weight [!is.na(.)]))) %>% sort(decreasing=TRUE)

best=occu(~1~D_Water_s+
            Habitat_Type+
            Altitude_s+
            D_PA_s+
            D_Villages_s+
            D_Roads_s,Genetm)

best2=occu(~1~D_Water_s+
             Habitat_Type+
             Altitude_s+
             D_PA_s+
             D_Villages_s+
             D_Roads_s+
             Reserve,Genetm)

best2

newData =
  data.frame(
    Reserve = c("Mlele","Rukwa","Rungwa"),
    D_Water_s=c(0,0,0),
    Habitat_Type=c(0,0,0),
    Altitude_s=c(0,0,0),
    D_PA_s=c(0,0,0),
    D_Villages_s=c(0,0,0),
    D_Roads_s=c(0,0,0))

pred = predict(best2, type="state", newdata=newData, appendData=T)
pred

ggplot(pred, aes(x = Reserve,y = Predicted))+
  geom_point(size = 4)+
  ylab("Occupancy")+
  theme_bw()+
  geom_errorbar(aes(ymin = Predicted-SE,ymax = Predicted+SE), width = .2)+
  theme(axis.text = element_text(size = 16),
        axis.title=element_text(size = 16, face="bold"))
```

```
##### Occupancy Maps

Predmap = read.csv("C:\\Users\\Damien\\Desktop\\Documents\\HES\\Master\\TM\\Donnees\\Results\\
Session_2018\\Map_occu_Factors.csv")
Tanz_occu_wide = read.csv("C:\\Users\\Damien\\Desktop\\Documents\\HES\\Master\\TM\\Donnees\\Results\\
Session_2018\\Donnees_pour_cartes.csv")

names(Predmap) <- c("OBJECTID",
                    "coord_x",
                    "coord_y",
                    "D_Water",
                    "D_Roads",
                    "D_Camps",
                    "D_Villages",
                    "Habitat_Type",
                    "Altitude",
                    "Reserve")

Predmap <-
  Predmap %>%
  mutate_at(vars(D_Water:D_Villages,Altitude),
            .funs = funs(s = scale(sqrt(.)) ))

df.specie <- function(Specie) {
  Tanz_occu_wide %>%
    select(starts_with(Specie))  %>%
    select(matches("survey"))
}

site.covs <- Tanz_occu_wide %>% select(Altitude_s:D_Timbering_s, Reserve,Habitat_Type)

Bdeo <- unmarkedFrameOccu(y= df.specie("Bdeogale_crassicauda"), siteCovs = site.covs)

best.bdeo = occu(~1~Altitude_s+
                 D_Camps_s+
                 D_Villages_s+
                 D_Roads_s+
                 Reserve,Bdeo)

Cive <- unmarkedFrameOccu(y= df.specie("Civettictis_civetta"), siteCovs = site.covs)

best.civet = occu(~1~D_Water_s+
                  D_Villages_s+
                  Habitat_Type+
                  Reserve,Cive)
```

```
Geneta.a <- unmarkedFrameOccu(y= df.specie("Genetta_angolensis"), siteCovs = site.covs)

best.genet.a=occu(~1~Altitude_s+
        Habitat_Type+
        D_Villages_s+
        Reserve,Geneta.a)

Genet.m<- unmarkedFrameOccu(y= df.specie("Genetta_maculata"), siteCovs = site.covs)

best.genet.m = occu(~1~D_Water_s+
        Habitat_Type+
        Altitude_s+
        D_Villages_s+
        D_Roads_s+
        Reserve,Genet.m)

Predmap.complet=
  predict(best.bdeo, type="state", newdata=Predmap, appendData=T) %>%
  select(-c("SE","lower","upper")) %>%
  {names(.)[1] <- c("Predicted.Bdeo")
  .} %>%
  predict(best.civet, type="state", newdata=., appendData=T) %>%
  select(-c("SE","lower","upper")) %>%
  {names(.)[1] <- c("Predicted.Civet")
  .} %>%
  predict(best.genet.a, type="state", newdata=., appendData=T) %>%
  select(-c("SE","lower","upper")) %>%
  {names(.)[1] <- c("Predicted.Genet.a")
  .} %>%
  predict(best.genet.m, type="state", newdata=., appendData=T) %>%
  select(-c("SE","lower","upper")) %>%
  {names(.)[1] <- c("Predicted.Genet.m")
  .}


write.xlsx(Predmap.complet,("C:\\Users\\Damien\\Desktop\\Documents\\HES\\Master\\TM\\Donnees\\Results\\
Session_2018\\Predmap.xlsx"))
```

Appendix XIII: Rukwa GR, Rungwa FR & GCA and Mlele BKZ Management Effectiveness Tracking Tool

Adapted from Stolton et al., 2007

Reporting Progress at Protected Area Sites: Data Sheet 1

Name, affiliation and contact details for person responsible for completing the METT (email etc.)	Damien Zurkinden - Master student damien.zurkinden@master.hes-so.ch			
Date assessment carried out	22.11.2018			
Name of protected area	Rukwa Game Reserve			
WDPA site code (these codes can be found on www.unep-wcmc.org/wdpa/)	555623798			
Designations	National National	IUCN Category IV	International (please also complete sheet overleaf) /	
Country	Tanzania			
Location of protected area (province and if possible map reference)	Mlele District, Katavi Region	S: 7, 7, 42.5 E: 32, 5, 1.48		
Date of establishment	1995			
Ownership details (please tick)	State X	Private	Community	Other
Management Authority	TANZANIA WILDLIFE MANAGEMENT AUTHORITY (TAWA)			
Size of protected area (ha)	4323 km2			
Number of staff	Permanent 39	Temporary /		
Annual budget (US$) – excluding staff salary costs	Recurrent (operational) funds Government + Game fees and fines	Project or other supplementary funds Donors (WCS)		
What are the main values for which the area is designated	Large African elephants population; large herds of endemic Puku; hot water springs at Maji Moto; 350 bird species; largest population of crocodile			
List the two primary protected area management objectives				
Management objective 1	Preservation of wildlife and its habitat for present and future generation			
Management objective 2	Maintaning sustainable use of wildlife resources			

No. of people involved in completing assessment	5			
Including: (tick boxes)	PA manager ☒	PA staff ☒	Other PA agency staff ☐	NGO ☐
	Local community ☐	Donors ☐	External experts ☐	Other ☐
Please note if assessment was carried out in association with a particular project, on behalf of an organisation or donor.	Master thesis for Master HES-SO in Life Science - Natural Resources Management in association with hepia and ADAP			

Information on International Designations			
UNESCO World Heritage site (see: whc.unesco.org/en/list)			
Date listed	Site name	Site area	Geographical co-ordinates
Criteria for designation (i.e. criteria i to x)			
Statement of Outstanding Universal Value			
Ramsar site (see: www.wetlands.org/RSDB/)			
Date listed	Site name	Site area	Geographical number
Reason for Designation (see Ramsar Information Sheet)			
UNESCO Man and Biosphere Reserves (see: www.unesco.org/mab/wnbrs.shtml)			
Date listed	Site name	Site area Total: Core: Buffer: Transition:	Geographical co-ordinates
Criteria for designation			
Fulfilment of three functions of MAB (conservation, development and logistic support.)			
Please list other designations (i.e. ASEAN Heritage, Natura 2000) and any supporting information below			
Name:	Detail:		
Name:	Detail:		
Name:	Detail:		
Name:	Detail:		
Name:	Detail:		
Name:	Detail:		

Protected Areas Threats: Data Sheet 2

Please tick all relevant existing threats as either of high, medium or low significance. Threats ranked as of **high** significance are those which are seriously degrading values; **medium** are those threats having some negative impact and those characterised as **low** are threats which are present but not seriously impacting values or **N/A** where the threat is not present or not applicable in the protected area.

1. Residential and commercial development within a protected area

Threats from human settlements or other non-agricultural land uses with a substantial footprint

High	Medium	Low	N/A	
			X	1.1 Housing and settlement
			X	1.2 Commercial and industrial areas
		X		1.3 Tourism and recreation infrastructure

2. Agriculture and aquaculture within a protected area

Threats from farming and grazing as a result of agricultural expansion and intensification, including silviculture, mariculture and aquaculture

High	Medium	Low	N/A	
			X	2.1 Annual and perennial non-timber crop cultivation
			X	2.1a Drug cultivation
			X	2.2 Wood and pulp plantations
		X		2.3 Livestock farming and grazing
			X	2.4 Marine and freshwater aquaculture

3. Energy production and mining within a protected area

Threats from production of non-biological resources

High	Medium	Low	N/A	
			X	3.1 Oil and gas drilling
		X		3.2 Mining and quarrying
			X	3.3 Energy generation, including from hydropower dams

4. Transportation and service corridors within a protected area

Threats from long narrow transport corridors and the vehicles that use them including associated wildlife mortality

High	Medium	Low	N/A	
		X		4.1 Roads and railroads (include road-killed animals)
			X	4.2 Utility and service lines (e.g. electricity cables, telephone lines,)
			X	4.3 Shipping lanes and canals
			X	4.4 Flight paths

5. Biological resource use and harm within a protected area

Threats from consumptive use of "wild" biological resources including both deliberate and unintentional harvesting effects; also persecution or control of specific species (note this includes hunting and killing of animals)

High	Medium	Low	N/A	
		X		5.1 Hunting, killing and collecting terrestrial animals (including killing of animals as a result of human/wildlife conflict)
		X		5.2 Gathering terrestrial plants or plant products (non-timber)
		X		5.3 Logging and wood harvesting
		X		5.4 Fishing, killing and harvesting aquatic resources

6. Human intrusions and disturbance within a protected area

Threats from human activities that alter, destroy or disturb habitats and species associated with non-consumptive uses of biological resources

High	Medium	Low	N/A	
	X			6.1 Recreational activities and tourism
			X	6.2 War, civil unrest and military exercises
		X		6.3 Research, education and other work-related activities in protected areas
		X		6.4 Activities of protected area managers (e.g. construction or vehicle use, artificial watering points and dams)
			X	6.5 Deliberate vandalism, destructive activities or threats to protected area staff and visitors

7. Natural system modifications

Threats from other actions that convert or degrade habitat or change the way the ecosystem functions

High	Medium	Low	N/A	
		X		7.1 Fire and fire suppression (including arson)
			X	7.2 Dams, hydrological modification and water management/use
			X	7.3a Increased fragmentation within protected area
			X	7.3b Isolation from other natural habitat (e.g. deforestation, dams without effective aquatic wildlife passages)
			X	7.3c Other 'edge effects' on park values
			X	7.3d Loss of keystone species (e.g. top predators, pollinators etc)

8. Invasive and other problematic species and genes

Threats from terrestrial and aquatic non-native and native plants, animals, pathogens/microbes or genetic materials that have or are predicted to have harmful effects on biodiversity following introduction, spread and/or increase

High	Medium	Low	N/A	
			X	8.1 Invasive non-native/alien plants (weeds)
			X	8.1a Invasive non-native/alien animals
			X	8.1b Pathogens (non-native or native but creating new/increased problems)
			X	8.2 Introduced genetic material (e.g. genetically modified organisms)

9. Pollution entering or generated within protected area

Threats from introduction of exotic and/or excess materials or energy from point and non-point sources

High	Medium	Low	N/A	
			X	9.1 Household sewage and urban waste water
			X	9.1a Sewage and waste water from protected area facilities (e.g. toilets, hotels etc)
			X	9.2 Industrial, mining and military effluents and discharges (e.g. poor water quality discharge from dams, e.g. unnatural temperatures, de-oxygenated, other pollution)
			X	9.3 Agricultural and forestry effluents (e.g. excess fertilizers or pesticides)
			X	9.4 Garbage and solid waste
			X	9.5 Air-borne pollutants
			X	9.6 Excess energy (e.g. heat pollution, lights etc)

10. Geological events

Geological events may be part of natural disturbance regimes in many ecosystems. But they can be a threat if a species or habitat is damaged and has lost its resilience and is vulnerable to disturbance. Management capacity to respond to some of these changes may be limited.

High	Medium	Low	N/A	
			X	10.1 Volcanoes
			X	10.2 Earthquakes/Tsunamis
			X	10.3 Avalanches/ Landslides
	X			10.4 Erosion and siltation/ deposition (e.g. shoreline or riverbed changes)

11. Climate change and severe weather

Threats from long-term climatic changes which may be linked to global warming and other severe climatic/weather events outside of the natural range of variation

High	Medium	Low	N/A	
		X		11.1 Habitat shifting and alteration
	X			11.2 Droughts
			X	11.3 Temperature extremes
			X	11.4 Storms and flooding

12. Specific cultural and social threats

High	Medium	Low	N/A	
			X	12.1 Loss of cultural links, traditional knowledge and/or management practices
			X	12.2 Natural deterioration of important cultural site values
			X	12.3 Destruction of cultural heritage buildings, gardens, sites etc

Assessment Form

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
1. Legal status Does the protected area have legal status (or in the case of private reserves is covered by a covenant or similar)? *Context*	The protected area is not gazetted/covenanted	0		- Nationaly gazzeted - Wildlife concervation Act No 5 of 2009 - Beekeeping Act No 15 of 2002 - Established in 1995 - IUCN categ. IV	
	There is agreement that the protected area should be gazetted/covenanted but the process has not yet begun	1			
	The protected area is in the process of being gazetted/covenanted but the process is still incomplete (includes sites designated under international conventions, such as Ramsar, or local/traditional law such as community conserved areas, which do not yet have national legal status or covenant)	2			
	The protected area has been formally gazetted/covenanted	3	X		
2. Protected area regulations Are appropriate regulations in place to control land use and activities (e.g. hunting)? *Planning*	There are no regulations for controlling land use and activities in the protected area	0		- Wildlife Policy (2007) - Wildlife Conservation Act (2009) - Wildlife Conservation Regulation - Beekeeping Act (2002) - Beekeeping Regulation - Action Plan	
	Some regulations for controlling land use and activities in the protected area exist but these are major weaknesses	1			
	Regulations for controlling land use and activities in the protected area exist but there are some weaknesses or gaps	2			
	Regulations for controlling inappropriate land use and activities in the protected area exist and provide an excellent basis for management	3	X		
3. Law enforcement Can staff (i.e. those with responsibility for managing the site) enforce protected area rules well enough? *Input*	The staff have no effective capacity/resources to enforce protected area legislation and regulations	0		- Staff (39 --> 20-25 in the field) vs PA (4194 km2) --> not enough - Financial resources not enough --> can't do all is planned - Limited resources (ex. some vehicles are not in good conditions) Actual --> 4 vehicles for patrols (only 2 are operational) + 2 vehicles for administrative purpose	Needed 6 vehicles for patrol + 1 for community-conservation
	There are major deficiencies in staff capacity/resources to enforce protected area legislation and regulations (e.g. lack of skills, no patrol budget, lack of institutional support)	1			
	The staff have acceptable capacity/resources to enforce protected area legislation and regulations but some deficiencies remain	2	X		
	The staff have excellent capacity/resources to enforce protected area legislation and regulations	3			

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
4. Protected area objectives Is management undertaken according to agreed objectives? *Planning*	No firm objectives have been agreed for the protected area	0		- Make sure that wildlife is secure (protection/conservation) - Sustainable use of wildlife resources - Income generator (ex. 25% of Trophy hunting revenues goes to the District council --> to local communities	
	The protected area has agreed objectives, but is not managed according to these objectives	1			
	The protected area has agreed objectives, but is only partially managed according to these objectives	2			
	The protected area has agreed objectives and is managed to meet these objectives	3	X		
5. Protected area design Is the protected area the right size and shape to protect species, habitats, ecological processes and water catchments of key conservation concern? *Planning*	Inadequacies in protected area design mean achieving the major objectives of the protected area is very difficult	0		Heterogenous habitat support a great variety of species (55 species of mammals including elephants, buffalos lions, leopard and the rare and endemic puku as well as 350 species of birds Rivers & waterfalls makes the GR a water source for local communities living outside the reserve Lake Rukwa act as breeding site for fish species as 500m of lakeshore are protected by the GR which in turns is usefull for local communities	
	Inadequacies in protected area design mean that achievement of major objectives is difficult but some mitigating actions are being taken (e.g. agreements with adjacent land owners for wildlife corridors or introduction of appropriate catchment management)	1			
	Protected area design is not significantly constraining achievement of objectives, but could be improved (e.g. with respect to larger scale ecological processes)	2			
	Protected area design helps achievement of objectives; it is appropriate for species and habitat conservation; and maintains ecological processes such as surface and groundwater flows at a catchment scale, natural disturbance patterns etc	3	X		
6. Protected area boundary demarcation Is the boundary known and demarcated? *Process*	The boundary of the protected area is not known by the management authority or local residents/neighbouring land users	0		The boundary is demarcated on paper by the authority as well on the ground by demarcation elements + the access to the GR is controlled during routine patrol as well as by raising awareness toward local comunities during educational missions	
	The boundary of the protected area is known by the management authority but is not known by local residents/neighbouring land users	1			
	The boundary of the protected area is known by both the management authority and local residents/neighbouring land users but is not appropriately demarcated	2			
	The boundary of the protected area is known by the management authority and local residents/neighbouring land users and is appropriately demarcated	3	X		

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
7. Management plan Is there a management plan and is it being implemented? *Planning*	There is no management plan for the protected area	0		Their is not a management plan per say but an action plan that implement in Rukwa GR the strategic plan of GRs This action plan is not well implemented but regarding the resources at disposal it's ok	
	A management plan is being prepared or has been prepared but is not being implemented	1			
	A management plan exists but it is only being partially implemented because of funding constraints or other problems	2	X		
	A management plan exists and is being implemented	3			
Additional points: *Planning*					
7a. Planning process	The planning process allows adequate opportunity for key stakeholders to influence the management plan	+1	X	1) Workshop (only during the creation of the action plan)	
7b. Planning process	There is an established schedule and process for periodic review and updating of the management plan	+1		2) Meetings (involves local communitie in the decision process) ~~3) Visite to schools~~	
7c. Planning process	The results of monitoring, research and evaluation are routinely incorporated into planning	+1		4) Follow up of benefits (Security; Education; Job creation)	
8. Regular work plan Is there a regular work plan and is it being implemented *Planning/Outputs*	No regular work plan exists	0		- Routine patrols (Anti-poaching activities & surveillance) - Investigations - Response team - Protection of wildlife - Supervision of Hunting companies - Sending people to court - Ecological monitoring (aerial sensing)	
	A regular work plan exists but few of the activities are implemented	1			
	A regular work plan exists and many activities are implemented	2	X		
	A regular work plan exists and all activities are implemented	3			
9. Resource inventory Do you have enough information to manage the area? *Input*	There is little or no information available on the critical habitats, species and cultural values of the protected area	0		With community-conservation engagement (involvement of locals in the decision process, education, protection of people by the patrols and job creation as well as income generator) people are more aware (become innocent & informant) and support conservation effort	
	Information on the critical habitats, species, ecological processes and cultural values of the protected area is not sufficient to support planning and decision making	1			
	Information on the critical habitats, species, ecological processes and cultural values of the protected area is sufficient for most key areas of planning and decision making	2			
	Information on the critical habitats, species, ecological processes and cultural values of the protected area is sufficient to support all areas of planning and decision making	3	X		

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
10. Protection systems Are systems in place to control access/resource use in the protected area? *Process/Outcome*	Protection systems (patrols, permits etc) do not exist or are not effective in controlling access/resource use	0		- Marketing (?) - Patrols - Education (raising awareness that it is not allowed) - Permanent advenced control posts (ex. Lake Rukwa/Kaololo/Kavu beach)	
	Protection systems are only partially effective in controlling access/resource use	1			
	Protection systems are moderately effective in controlling access/resource use	2			
	Protection systems are largely or wholly effective in controlling access/ resource use	3	X		
11. Research Is there a programme of management-orientated survey and research work? *Process*	There is no survey or research work taking place in the protected area	0		- Ecological monitoring (Aerial sensing) - Patrol (field protocol) - Trough hunting companies (effective removal + direct observations)	
	There is a small amount of survey and research work but it is not directed towards the needs of protected area management	1			
	There is considerable survey and research work but it is not directed towards the needs of protected area management	2			
	There is a comprehensive, integrated programme of survey and research work, which is relevant to management needs	3	X		
12. Resource management Is active resource management being undertaken? *Process*	Active resource management is not being undertaken	0		- HQ in Mlele - 4x4 vehicles - Boats - Fire arms - GPS - Tents	
	Very few of the requirements for active management of critical habitats, species, ecological processes and cultural values are being implemented	1			
	Many of the requirements for active management of critical habitats, species, ecological processes and, cultural values are being implemented but some key issues are not being addressed	2			
	Requirements for active management of critical habitats, species, ecological processes and, cultural values are being substantially or fully implemented	3	X		
13. Staff numbers Are there enough people employed to manage the protected area? *Inputs*	There are no staff	0		39 permanant staff member where only 20-25 persons do patrols in the field for an area of 4194 km2 --> not enough	
	Staff numbers are inadequate for critical management activities	1	X		
	Staff numbers are below optimum level for critical management activities	2			
	Staff numbers are adequate for the management needs of the protected area	3			

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
14. Staff training Are staff adequately trained to fulfil management objectives? *Inputs/Process*	Staff lack the skills needed for protected area management	0		Active training by TANAPA instructors: - Paramilitary activities - Anti- poaching & corruption activities - GIS trainning (GPS; Maps; Compass) - Leadership - Physical fitness - Tracking skills - Weapon utilisation & care - Knowledge of relevant laws - Patriotism	
	Staff training and skills are low relative to the needs of the protected area	1			
	Staff training and skills are adequate, but could be further improved to fully achieve the objectives of management	2			
	Staff training and skills are aligned with the management needs of the protected area	3	X		
15. Current budget Is the current budget sufficient? *Inputs*	There is no budget for management of the protected area	0		The financial resources come from two major sources: 1) TAWA HQ (government) 2) Donors (International NGO's, ex WCS --> contribution to fieul, food, boots, ...) --> Financial resources are not enough, so can't do all is planned	
	The available budget is inadequate for basic management needs and presents a serious constraint to the capacity to manage	1			
	The available budget is acceptable but could be further improved to fully achieve effective management	2	X		
	The available budget is sufficient and meets the full management needs of the protected area	3			
16. Security of budget Is the budget secure? *Inputs*	There is no secure budget for the protected area and management is wholly reliant on outside or highly variable funding	0		The major source of income (TAWA HQ) is secure and the main income of Rukwa GR that are Game fees and contribution of the anti-poaching patrol (fines) also. But without the help of international NGO, the management of the GR whouldn't be sustainable	
	There is very little secure budget and the protected area could not function adequately without outside funding	1			
	There is a reasonably secure core budget for regular operation of the protected area but many innovations and initiatives are reliant on outside funding	2	X		
	There is a secure budget for the protected area and its management needs	3			
17. Management of budget Is the budget managed to meet critical management needs? *Process*	Budget management is very poor and significantly undermines effectiveness (e.g. late release of budget in financial year)	0		For instance, their is a problem in the system, the Hunting companies present in Rukwa GR have to pay their fees to TAWA HQ --> their is no return of money from them to Rukwa GR directly	
	Budget management is poor and constrains effectiveness	1			
	Budget management is adequate but could be improved	2	X		
	Budget management is excellent and meets management needs	3			

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
18. Equipment Is equipment sufficient for management needs? *Input*	There are little or no equipment and facilities for management needs	0		Actual: - 4 vehicles for patrols (only two are operational); - 2 vehicles for administrative purpose Needed: - 6 vehicles for patrols; - 1 vehicle for community-conservation purpose	
	There are some equipment and facilities but these are inadequate for most management needs	1			
	There are equipment and facilities, but still some gaps that constrain management	2	X		
	There are adequate equipment and facilities	3			
19. Maintenance of equipment Is equipment adequately maintained? *Process*	There is little or no maintenance of equipment and facilities	0		In Mlele HQ their is mecanics and a garage where basic maintenance can be achieved but some major problems can't be solved at the HQ	
	There is some *ad hoc* maintenance of equipment and facilities	1			
	There is basic maintenance of equipment and facilities	2	X		
	Equipment and facilities are well maintained	3			
20. Education and awareness Is there a planned education programme linked to the objectives and needs? *Process*	There is no education and awareness programme	0		An Education programme exist were TAWA goes to school to raiseawarness of what they do + visite the villages to involve the local communities for combating illegal activities & avoid people/wildlife conflict	
	There is a limited and *ad hoc* education and awareness programme	1			
	There is an education and awareness programme but it only partly meets needs and could be improved	2			
	There is an appropriate and fully implemented education and awareness programme	3	X		
21. Planning for land and water use Does land and water use planning recognise the protected area and aid the achievement of objectives? *Planning*	Adjacent land and water use planning does not take into account the needs of the protected area and activities/policies are detrimental to the survival of the area	0		ex. Cattle grazing is a big problem as Sukuma are nomade they came to the region because their land were over-exploited. At the begining it was only a problem during dry season but now, it is also a problem during rainy season as they are cultivaiting crops. So, to avoid their own corps deterioration, they make their cattle grazz in the GR	
	Adjacent land and water use planning does not takes into account the long term needs of the protected area, but activities are not detrimental the area	1	X		
	Adjacent land and water use planning partially takes into account the long term needs of the protected area	2			
	Adjacent land and water use planning fully takes into account the long term needs of the protected area	3			

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
Additional points: Land and water planning					
21a: Land and water planning for habitat conservation	Planning and management in the catchment or landscape containing the protected area incorporates provision for adequate environmental conditions (e.g. volume, quality and timing of water flow, air pollution levels etc) to sustain relevant habitats.	+1			
21b: Land and water planning for connectivity	Management of corridors linking the protected area provides for wildlife passage to key habitats outside the protected area (e.g. to allow migratory fish to travel between freshwater spawning sites and the sea, or to allow animal migration).	+1			
21c: Land and water planning for ecosystem services & species conservation	"Planning adresses ecosystem-specific needs and/or the needs of particular species of concern at an ecosystem scale (e.g. volume, quality and timing of freshwater flow to sustain particular species, fire management to maintain savannah habitats etc.)"	+1			
22. State and commercial neighbours Is there co-operation with adjacent land and water users? *Process*	There is no contact between managers and neighbouring official or corporate land and water users	0		First 25% of Trophy hunting revenues goes to the District council to support local communities. Second, some cooperation between TAWA and other management bodies (WD, TFS) exist were joint patrols are organised from time to time	
	There is contact between managers and neighbouring official or corporate land and water users but little or no cooperation	1			
	There is contact between managers and neighbouring official or corporate land and water users, but only some co-operation	2	X		
	There is regular contact between managers and neighbouring official or corporate land and water users, and substantial co-operation on management	3			
23. Indigenous people Do indigenous and traditional peoples resident or regularly using the protected area have input to management decisions? *Process*	Indigenous and traditional peoples have no input into decisions relating to the management of the protected area	0			
	Indigenous and traditional peoples have some input into discussions relating to management but no direct role in management	1			
	Indigenous and traditional peoples directly contribute to some relevant decisions relating to management but their involvement could be improved	2			
	Indigenous and traditional peoples directly participate in all relevant decisions relating to management, e.g. co-management	3			

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
24. Local communities Do local communities resident or near the protected area have input to management decisions? *Process*	Local communities have no input into decisions relating to the management of the protected area	0		Decissions are taken at the govenmental level with the strategic plan. Then it is back up by the action plan at the GR level. It's were local communities are involved in the decision process. Then when decissions are agreed, local people leave the management to TAWA	
	Local communities have some input into discussions relating to management but no direct role in management	1	X		
	Local communities directly contribute to some relevant decisions relating to management but their involvement could be improved	2			
	Local communities directly participate in all relevant decisions relating to management, e.g. co-management	3			
Additional points *Local communities/indigenous people*					
24 a. Impact on communities	There is open communication and trust between local and/or indigenous people, stakeholders and protected area managers	+1	X	Conservation Education By doing anti-poaching activities, TAWA	
24b. Impact on communities	Programmes to enhance community welfare, while conserving protected area resources, are being implemented	+1	X	also protect the people living neerby the GR, also help avoid human/wildlife	Community development projects
24c. Impact on communities	Local and/or indigenous people actively support the protected area	+1	X	conflic and offers job opportunities (Ranger & Tourism hunting)	Compensation from damages caused by wildlife
25. Economic benefit Is the protected area providing economic benefits to local communities, e.g. income, employment, payment for environmental services? *Outcomes*	The protected area does not deliver any economic benefits to local communities	0		- 25% of Trophy hunting companies revenues goes to the District council - Job opportunities eigther as ranger or in the Trophy hunting industy - By pemiting beekeepers to havest in the GR	
	Potential economic benefits are recognised and plans to realise these are being developed	1			
	There is some flow of economic benefits to local communities	2	X		
	There is a major flow of economic benefits to local communities from activities associated with the protected area	3			
26. Monitoring and evaluation Are management activities monitored against performance? *Planning/Process*	There is no monitoring and evaluation in the protected area	0		The trend that illegal activities are decreasing is very clear: - animal around (aerial survey, patrols) - illegal infrastructures (patrols) - tree cut down (patrols) - 95% of cattle grazing away (only at the boundary as Sukumas are entering the GR only from time to as they are living outside the GR)	
	There is some *ad hoc* monitoring and evaluation, but no overall strategy and/or no regular collection of results	1	X		
	There is an agreed and implemented monitoring and evaluation system but results do not feed back into management	2			
	A good monitoring and evaluation system exists, is well implemented and used in adaptive management	3			

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
27. Visitor facilities Are visitor facilities adequate? *Outputs*	There are no visitor facilities and services despite an identified need	0		As only 1 hunting bloc out of 3 is operating, facilities on the 2 non operating blocs need reparation as they are not suitable to welcome customers. Also, photographic tourisme is planned to be setup in the GR and would need the counstruction of new facilities	
	Visitor facilities and services are inappropriate for current levels of visitation	1			
	Visitor facilities and services are adequate for current levels of visitation but could be improved	2	X		
	Visitor facilities and services are excellent for current levels of visitation	3			
28. Commercial tourism operators Do commercial tour operators contribute to protected area management? *Process*	There is little or no contact between managers and tourism operators using the protected area	0		The tour operators per say are not taking part in the management but the Hunting companies do. Their main task is to patrol (wildlife monitoring and anti-poaching) the area they occupay	
	There is contact between managers and tourism operators but this is largely confined to administrative or regulatory matters	1			
	There is limited co-operation between managers and tourism operators to enhance visitor experiences and maintain protected area values	2			
	There is good co-operation between managers and tourism operators to enhance visitor experiences, and maintain protected area values	3	X		
29. Fees If fees (i.e. entry fees or fines) are applied, do they help protected area management? *Inputs/Process*	Although fees are theoretically applied, they are not collected	0		After the two main incomes (donors & government), Game fees and fines from the anti-poaching patrols are the main income of Rukwa GR	
	Fees are collected, but make no contribution to the protected area or its environs	1			
	Fees are collected, and make some contribution to the protected area and its environs	2			
	Fees are collected and make a substantial contribution to the protected area and its environs	3	X		
30. Condition of values What is the condition of the important values of the protected area as compared to when it was first designated? *Outcomes*	Many important biodiversity, ecological or cultural values are being severely degraded	0		- Poaching/Fishing --> direct impact on species - Illegal logging --> destruction of habitat - Illegal cattle grazing --> destruction of habitat + resource competition with wildlife But in the woul, the Katavi/Rukwa ecosystem is preserved and is one out of the 6 ecosystem of great importance for elephant	
	Some biodiversity, ecological or cultural values are being severely degraded	1			
	Some biodiversity, ecological and cultural values are being partially degraded but the most important values have not been significantly impacted	2	X		
	Biodiversity, ecological and cultural values are predominantly intact	3			

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
Additional Points: Condition of values					
30a: Condition of values	The assessment of the condition of values is based on research and/or monitoring	+1	X	Ecological monitoring (aerial sensing, field patrols, Hunting companies)	
30b: Condition of values	Specific management programmes are being implemented to address threats to biodiversity, ecological and cultural values	+1	X	ex. Site MIKE Officer	
30c: Condition of values	Activities to maintain key biodiversity, ecological and cultural values are a routine part of park management	+1			
TOTAL SCORE			73/96		

Context: (3/3)*100 = 100%
Planning: (13/24)*100 = 54.16%
Inputs: (18/24)*100 = 75%
Process: (35/42)*100 = 83.33%
Outputs: (6/9)*100 = 66.66%
Outcomes: (9/12)*100 = 75%

Reporting Progress at Protected Area Sites: Data Sheet 1

Name, affiliation and contact details for person responsible for completing the METT (email etc.)	Lucile Daudet - Master student lucile.daudet@master.hes-so.ch			
Date assessment carried out	25.11.2018			
Name of protected area	Rungwa River Forest Reserve (FR) Rungwa River Game Controlled Area (GCA)			
WDPA site code (these codes can be found on www.unep-wcmc.org/wdpa/)	555623795			
Designations	National National	IUCN Category VI	International (please also complete sheet overleaf) /	
Country	Tanzania			
Location of protected area (province and if possible map reference)	Mlele District, Katavi Region	S: 7, 7, 42.5 E: 32, 5, 1.48		
Date of establishment	1954			
Ownership details (please tick)	State X	Private	Community	Other
Management Authority	FR : TFS GCA : Wildlife Division			
Size of protected area (ha)	2480 km2			
Number of staff	Permanent TFS : 10 GCA : 3	Temporary TFS : 6 GCA : 0		
Annual budget (US$) – excluding staff salary costs	Recurrent (operational) funds	Project or other supplementary funds		
What are the main values for which the area is designated	Wildlife and Vegetation of Miombo Ecosystem			
List the two primary protected area management objectives				
Management objective 1	Maintenance of stable ecosystems and biological diversity			
Management objective 2	Ensure that flora and fauna, which are the main components of watershed areas in Tanzania, are protected			
No. of people involved in completing assessment	28			
Including: (tick boxes)	PA manager ☒	PA staff ☒	Other PA agency staff ☐	NGO ☐
	Local community ☒	Donors ☐	External experts ☐	Other ☐
Please note if assessment was carried out in association with a particular project, on behalf of an organisation or donor.	Master thesis for Master HES-SO in Life Science - Natural Resources Management in association with hepia and ADAP			

Information on International Designations			
UNESCO World Heritage site (see: whc.unesco.org/en/list)			
Date listed	Site name	Site area	Geographical co-ordinates
Criteria for designation (i.e. criteria i to x)			
Statement of Outstanding Universal Value			
Ramsar site (see: www.wetlands.org/RSDB/)			
Date listed	Site name	Site area	Geographical number
Reason for Designation (see Ramsar Information Sheet)			
UNESCO Man and Biosphere Reserves (see: www.unesco.org/mab/wnbrs.shtml)			
Date listed	Site name	Site area Total: Core: Buffer: Transition:	Geographical co-ordinates
Criteria for designation			
Fulfilment of three functions of MAB (conservation, development and logistic support.)			
Please list other designations (i.e. ASEAN Heritage, Natura 2000) and any supporting information below			
Name:	Detail:		
Name:	Detail:		
Name:	Detail:		
Name:	Detail:		
Name:	Detail:		
Name:	Detail:		

Protected Areas Threats: Data Sheet 2

Please tick all relevant existing threats as either of high, medium or low significance. Threats ranked as of **high** significance are those which are seriously degrading values; **medium** are those threats having some negative impact and those characterised as **low** are threats which are present but not seriously impacting values or **N/A** where the threat is not present or not applicable in the protected area.

1. Residential and commercial development within a protected area

Threats from human settlements or other non-agricultural land uses with a substantial footprint

High	Medium	Low	N/A	
X				1.1 Housing and settlement
	X			1.2 Commercial and industrial areas
		X		1.3 Tourism and recreation infrastructure

2. Agriculture and aquaculture within a protected area

Threats from farming and grazing as a result of agricultural expansion and intensification, including silviculture, mariculture and aquaculture

High	Medium	Low	N/A	
X				2.1 Annual and perennial non-timber crop cultivation
			X	2.1a Drug cultivation
			X	2.2 Wood and pulp plantations
	X			2.3 Livestock farming and grazing
			X	2.4 Marine and freshwater aquaculture

3. Energy production and mining within a protected area

Threats from production of non-biological resources

High	Medium	Low	N/A	
			X	3.1 Oil and gas drilling
		X		3.2 Mining and quarrying
			X	3.3 Energy generation, including from hydropower dams

4. Transportation and service corridors within a protected area

Threats from long narrow transport corridors and the vehicles that use them including associated wildlife mortality

High	Medium	Low	N/A	
	X			4.1 Roads and railroads (include road-killed animals)
			X	4.2 Utility and service lines (e.g. electricity cables, telephone lines,)
			X	4.3 Shipping lanes and canals
			X	4.4 Flight paths

5. Biological resource use and harm within a protected area

Threats from consumptive use of "wild" biological resources including both deliberate and unintentional harvesting effects; also persecution or control of specific species (note this includes hunting and killing of animals)

High	Medium	Low	N/A	
X				5.1 Hunting, killing and collecting terrestrial animals (including killing of animals as a result of human/wildlife conflict)
	X			5.2 Gathering terrestrial plants or plant products (non-timber)
X				5.3 Logging and wood harvesting
	X			5.4 Fishing, killing and harvesting aquatic resources

6. Human intrusions and disturbance within a protected area

Threats from human activities that alter, destroy or disturb habitats and species associated with non-consumptive uses of biological resources

High	Medium	Low	N/A	
		X		6.1 Recreational activities and tourism
		X		6.2 War, civil unrest and military exercises
		X		6.3 Research, education and other work-related activities in protected areas
	X			6.4 Activities of protected area managers (e.g. construction or vehicle use, artificial watering points and dams)
			X	6.5 Deliberate vandalism, destructive activities or threats to protected area staff and visitors

7. Natural system modifications

Threats from other actions that convert or degrade habitat or change the way the ecosystem functions

High	Medium	Low	N/A	
	X			7.1 Fire and fire suppression (including arson)
			X	7.2 Dams, hydrological modification and water management/use
			X	7.3a Increased fragmentation within protected area
			X	7.3b Isolation from other natural habitat (e.g. deforestation, dams without effective aquatic wildlife passages)
	X			7.3c Other 'edge effects' on park values
		X		7.3d Loss of keystone species (e.g. top predators, pollinators etc)

8. Invasive and other problematic species and genes

Threats from terrestrial and aquatic non-native and native plants, animals, pathogens/microbes or genetic materials that have or are predicted to have harmful effects on biodiversity following introduction, spread and/or increase

High	Medium	Low	N/A	
			X	8.1 Invasive non-native/alien plants (weeds)
			X	8.1a Invasive non-native/alien animals
			X	8.1b Pathogens (non-native or native but creating new/increased problems)
			X	8.2 Introduced genetic material (e.g. genetically modified organisms)

9. Pollution entering or generated within protected area

Threats from introduction of exotic and/or excess materials or energy from point and non-point sources

High	Medium	Low	N/A	
		X		9.1 Household sewage and urban waste water
		X		9.1a Sewage and waste water from protected area facilities (e.g. toilets, hotels etc)
		X		9.2 Industrial, mining and military effluents and discharges (e.g. poor water quality discharge from dams, e.g. unnatural temperatures, de-oxygenated, other pollution)
	X			9.3 Agricultural and forestry effluents (e.g. excess fertilizers or pesticides)
		X		9.4 Garbage and solid waste
			X	9.5 Air-borne pollutants
			X	9.6 Excess energy (e.g. heat pollution, lights etc)

10. Geological events

Geological events may be part of natural disturbance regimes in many ecosystems. But they can be a threat if a species or habitat is damaged and has lost its resilience and is vulnerable to disturbance. Management capacity to respond to some of these changes may be limited.

High	Medium	Low	N/A	
			X	10.1 Volcanoes
			X	10.2 Earthquakes/Tsunamis
			X	10.3 Avalanches/ Landslides
	X			10.4 Erosion and siltation/ deposition (e.g. shoreline or riverbed changes)

11. Climate change and severe weather

Threats from long-term climatic changes which may be linked to global warming and other severe climatic/weather events outside of the natural range of variation

High	Medium	Low	N/A	
		X		11.1 Habitat shifting and alteration
	X			11.2 Droughts
			X	11.3 Temperature extremes
		X		11.4 Storms and flooding

12. Specific cultural and social threats

High	Medium	Low	N/A	
	X			12.1 Loss of cultural links, traditional knowledge and/or management practices
	X			12.2 Natural deterioration of important cultural site values
			X	12.3 Destruction of cultural heritage buildings, gardens, sites etc

Assessment Form

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
1. Legal status Does the protected area have legal status (or in the case of private reserves is covered by a covenant or similar)? *Context*	The protected area is not gazetted/covenanted	0		- Nationaly gazzeted - Forest Act No 14 of 2002 - Wildlife concervation Act No 5 of 2009 - Beekeeping Act No 15 of 2002 - Established in 1954 - IUCN categ. VI	
	There is agreement that the protected area should be gazetted/covenanted but the process has not yet begun	1			
	The protected area is in the process of being gazetted/covenanted but the process is still incomplete (includes sites designated under international conventions, such as Ramsar, or local/traditional law such as community conserved areas, which do not yet have national legal status or covenant)	2			
	The protected area has been formally gazetted/covenanted	3	X		
2. Protected area regulations Are appropriate regulations in place to control land use and activities (e.g. hunting)? *Planning*	There are no regulations for controlling land use and activities in the protected area	0		- Forest Policy (1998) - Forest Act (2002) - Forest Regulation - Beekeeping Act (2002) - Beekeeping Regulation - Wildlife Policy (2007) - Wildlife Conservation Act (2009) - Wildlife Conservation Regulation - Management plan (TFS) - Action Plan (WD)	
	Some regulations for controlling land use and activities in the protected area exist but these are major weaknesses	1			
	Regulations for controlling land use and activities in the protected area exist but there are some weaknesses or gaps	2			
	Regulations for controlling inappropriate land use and activities in the protected area exist and provide an excellent basis for management	3	X		
3. Law enforcement Can staff (i.e. those with responsibility for managing the site) enforce protected area rules well enough? *Input*	The staff have no effective capacity/resources to enforce protected area legislation and regulations	0		- Forest Officer (7) - Beekeeping Officer (2) - Wildlife Officer (3) Overall lack of personnel, material and financial support does not allow TFS / WD to enforce laws	- Develop an action plan for each FR - Set in place per month Patrols - Employ qualified and trained staff - Promote establishment of hunting company in Rungwa block
	There are major deficiencies in staff capacity/resources to enforce protected area legislation and regulations (e.g. lack of skills, no patrol budget, lack of institutional support)	1	X		
	The staff have acceptable capacity/resources to enforce protected area legislation and regulations but some deficiencies remain	2			
	The staff have excellent capacity/resources to enforce protected area legislation and regulations	3			

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
4. Protected area objectives Is management undertaken according to agreed objectives? *Planning*	No firm objectives have been agreed for the protected area	0		The management of Rungwa River FR / GCA does not have specific objectives for this PA. These are global targets imposed for all FR / GCA in the country For TFS, a first management plan was created last year (2017), they are gradually implementing all planned activities but the budget is lacking	- Create specific goals for Rungwa River FR / GCA - Design actions related to the specific objectives of the area and achievable in relation to the means given
	The protected area has agreed objectives, but is not managed according to these objectives	1	X		
	The protected area has agreed objectives, but is only partially managed according to these objectives	2			
	The protected area has agreed objectives and is managed to meet these objectives	3			
5. Protected area design Is the protected area the right size and shape to protect species, habitats, ecological processes and water catchments of key conservation concern? *Planning*	Inadequacies in protected area design mean achieving the major objectives of the protected area is very difficult	0		The PA size (2480 km2) is adequate to maintain habitats and shelter wildlife. It is part of an PA network and the Katavi / Rukwa corridor, which allows the transfer and genetic exchange of wildlife, and the maintenance of ecosystems. On the other hand, the PA is too big in comparaison to allocated number of staff, means and budget	- Establish intervention strategies. Identify the most at-risk areas within the FR / GCA and intensify protective actions in these areas - Increase the number of staff in line with the size of the PA - Acquire additional vehicles, GPS and means to ensure law enforcment
	Inadequacies in protected area design mean that achievement of major objectives is difficult but some mitigating actions are being taken (e.g. agreements with adjacent land owners for wildlife corridors or introduction of appropriate catchment management)	1	X		
	Protected area design is not significantly constraining achievement of objectives, but could be improved (e.g. with respect to larger scale ecological processes)	2			
	Protected area design helps achievement of objectives; it is appropriate for species and habitat conservation; and maintains ecological processes such as surface and groundwater flows at a catchment scale, natural disturbance patterns etc	3			
6. Protected area boundary demarcation Is the boundary known and demarcated? *Process*	The boundary of the protected area is not known by the management authority or local residents/neighbouring land users	0		The bondary of the FR / GCA are not clearly defined. No map of the different FR / GCA was found at TFS office. They also do not have GPS points of the on ground demarcation elements (installed in 2017) Everything seems to be at the Head Quarter in Tabora Newcomers say never had any information upon arrival and are not aware of PA real bondary	- Establish communication between TFS Head Quarter and Inyonga Office - Obtain maps for Inyonga Office - Inform users of current bondary
	The boundary of the protected area is known by the management authority but is not known by local residents/neighbouring land users	1	X		
	The boundary of the protected area is known by both the management authority and local residents/neighbouring land users but is not appropriately demarcated	2			
	The boundary of the protected area is known by the management authority and local residents/neighbouring land users and is appropriately demarcated	3			

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
7. Management plan Is there a management plan and is it being implemented? *Planning*	There is no management plan for the protected area	0		For TFS, a management plan was created in 2017. It is currently being implemented For the GCA, their is not a management plan per say but an action plan that implement in Rungwa the strategic plan of GCAs All actions can not be implemented in the FR / GCA due to lack of staff, means and funding	- Follow the management plan established for each FR and adopt a more specific management - Realize a management plan for each GCA - Design measures related to the specific objectives of PA
	A management plan is being prepared or has been prepared but is not being implemented	1			
	A management plan exists but it is only being partially implemented because of funding constraints or other problems	2	X		
	A management plan exists and is being implemented	3			
Additional points: *Planning*					
7a. Planning process	The planning process allows adequate opportunity for key stakeholders to influence the management plan	+1			
7b. Planning process	There is an established schedule and process for periodic review and updating of the management plan	+1			
7c. Planning process	The results of monitoring, research and evaluation are routinely incorporated into planning	+1			
8. Regular work plan Is there a regular work plan and is it being implemented *Planning/Outputs*	No regular work plan exists	0		For the FR, an Operations Annual Plan is established according to the 2017 Management Plan and a Work Plan is drawn up each week For the GCA, there is no regular Work Plan but they base their actions on the Action Plan of the year	For the GCA, establish a smaller scale Action Plan to achieve maximum goal over the year
	A regular work plan exists but few of the activities are implemented	1			
	A regular work plan exists and many activities are implemented	2	X		
	A regular work plan exists and all activities are implemented	3			
9. Resource inventory Do you have enough information to manage the area? *Input*	There is little or no information available on the critical habitats, species and cultural values of the protected area	0		A vegetation monitoring was conducted in 2016. No other species or habitat studies have been undertaken For wildlife management, there is no monitoring in place. The only information they have is personal observations or observations from villagers	Implement regular monitoring system that allow assessment of NR evolution and obtain regular information on the resources of the FR / GCA
	Information on the critical habitats, species, ecological processes and cultural values of the protected area is not sufficient to support planning and decision making	1	X		
	Information on the critical habitats, species, ecological processes and cultural values of the protected area is sufficient for most key areas of planning and decision making	2			
	Information on the critical habitats, species, ecological processes and cultural values of the protected area is sufficient to support all areas of planning and decision making	3			

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
10. Protection systems Are systems in place to control access/resource use in the protected area? *Process/Outcome*	Protection systems (patrols, permits etc) do not exist or are not effective in controlling access/resource use	0		- 17 days patrols / years (2017/2018) are far from enough - Most of the time they patrol villages to find information and arrest offenders - No on foot patrols - A Licensing System and A Check Point Systemis is in place to control legal activities - To verify beekeeping practices, a Registration System of beekeepers' camps was reestablished this year	Strengthen protection system with a regular implementation of on ground patrols
	Protection systems are only partially effective in controlling access/resource use	1	X		
	Protection systems are moderately effective in controlling access/resource use	2			
	Protection systems are largely or wholly effective in controlling access/ resource use	3			
11. Research Is there a programme of management-orientated survey and research work? *Process*	There is no survey or research work taking place in the protected area	0		There is no research program in place, the last research was the 2016 vegetation monitoring	Plan the implementation of regular monitoring for Rungwa River FR / GCA
	There is a small amount of survey and research work but it is not directed towards the needs of protected area management	1	X		
	There is considerable survey and research work but it is not directed towards the needs of protected area management	2			
	There is a comprehensive, integrated programme of survey and research work, which is relevant to management needs	3			
12. Resource management Is active resource management being undertaken? *Process*	Active resource management is not being undertaken	0	X	There is no proper management of resources. TFS does not do its work on logging procedures. The operators have "free access". Regarding species sizes to exploit, few controls are done	Implement a monitoring system to control managers activities. Systems that would verify that procedures are well implemented, that planned activities are undertaken
	Very few of the requirements for active management of critical habitats, species, ecological processes and cultural values are being implemented	1			
	Many of the requirements for active management of critical habitats, species, ecological processes and, cultural values are being implemented but some key issues are not being addressed	2			
	Requirements for active management of critical habitats, species, ecological processes and, cultural values are being substantially or fully implemented	3			
13. Staff numbers Are there enough people employed to manage the protected area? *Inputs*	There are no staff	0		There is a real lack of employees to manage the area. 7 Forest Officers, 2 Beekeeping Officers and 3 Game Officers	Increase the number of qualified staff for the management of Rungwa River FR / GCA
	Staff numbers are inadequate for critical management activities	1	X		
	Staff numbers are below optimum level for critical management activities	2			
	Staff numbers are adequate for the management needs of the protected area	3			

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
14. Staff training Are staff adequately trained to fulfil management objectives? *Inputs/Process*	Staff lack the skills needed for protected area management	0		The Forest, Beekeeping and Wildlife Officers have skills in the NRM areas. In addition, they have about one training a year, but the trainings are not sufficient according to the manager	Call on paramilitary trainers who will provide the skills to patrol, enforce the law and arrest offenders
	Staff training and skills are low relative to the needs of the protected area	1			
	Staff training and skills are adequate, but could be further improved to fully achieve the objectives of management	2	X		
	Staff training and skills are aligned with the management needs of the protected area	3			
15. Current budget Is the current budget sufficient? *Inputs*	There is no budget for management of the protected area	0		The budget required according to the 2017/2018 management plan is 351'108 TSH for Rungwa River FR but 459'329'000 TSH are allocated for the 5 FRs. The budget is therefore insufficient to ensure the implementation of actions necessary for the proper management of Rungwa River FR The budget for managing GCA is totally inadequate. Indeed, 11'000'000 TSH are allocated to all GCAs for the year 2018 which is 42 times less than the budget allocated for the FRs	- Make requests for funds from the government and external donors - Reorganize TFS revenue distribution between local and central government - Promote GCA as hunting block for trophy hunting companies to allow management to strengthen the area
	The available budget is inadequate for basic management needs and presents a serious constraint to the capacity to manage	1	X		
	The available budget is acceptable but could be further improved to fully achieve effective management	2			
	The available budget is sufficient and meets the full management needs of the protected area	3			
16. Security of budget Is the budget secure? *Inputs*	There is no secure budget for the protected area and management is wholly reliant on outside or highly variable funding	0		For the FR, about 70% of the annual budget comes from the revenue collection and the Tanzanian Found Forest. Regarding the collection of income it is mainly fees, royalties, and other items. These revenues are relatively stable and provide some security for the budget For GCAs, the budget is directly dependent on the District Council. It is variable depending on the year, but overall remains in the same price range and is therefore more or less secure	See above
	There is very little secure budget and the protected area could not function adequately without outside funding	1			
	There is a reasonably secure core budget for regular operation of the protected area but many innovations and initiatives are reliant on outside funding	2	X		
	There is a secure budget for the protected area and its management needs	3			
17. Management of budget Is the budget managed to meet critical management needs? *Process*	Budget management is very poor and significantly undermines effectiveness (e.g. late release of budget in financial year)	0		For FR, budget management is done internally by TFS District Manger. Priority are put on important maters such as Sukuma forests invasion and implementation of patrols For GCA, budget management is done by the Game Manager. The Action Plan allows to manage the budget and therfore seems to be well managed	Ensure sustainable budget management at Inyonga's TFS and DLNRO with frequent financial reporting and auditing systems
	Budget management is poor and constrains effectiveness	1			
	Budget management is adequate but could be improved	2	X		
	Budget management is excellent and meets management needs	3			

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
18. Equipment Is equipment sufficient for management needs? *Input*	There are little or no equipment and facilities for management needs	0		- Office (1) - Computers (6) - GPS (2) - Car (2) - Motorcycle (1) - Weapon (1) - Tent (1)	The provision of vehicles and additional equipment such as weapons and GPS would allow different teams to work and strengthen the management of the area
	There are some equipment and facilities but these are inadequate for most management needs	1	X		
	There are equipment and facilities, but still some gaps that constrain management	2			
	There are adequate equipment and facilities	3			
19. Maintenance of equipment Is equipment adequately maintained? *Process*	There is little or no maintenance of equipment and facilities	0		Equipment, listed in an inventory presented in the annual reports, is in order and well maintained	
	There is some *ad hoc* maintenance of equipment and facilities	1			
	There is basic maintenance of equipment and facilities	2			
	Equipment and facilities are well maintained	3	X		
20. Education and awareness Is there a planned education programme linked to the objectives and needs? *Process*	There is no education and awareness programme	0		For FR, managers say they are putting in place training for beekeepers and sustainable forest management. The Beekeeping Officer states that they implement this type of training 6 times a year, but no training is reported in the 2016-2017 report. Regarding GCA, the District Wildlife Manager explains that training is being implemented for the villagers. These awareness programs are mainly based on the explanation of the benefits perceived by the villagers by conserving the forest and the fauna. It is mainly about explanation and information to the villagers about the sharing of benefits between the hunting companies, the District and the villagers	- Strengthen education and information programs with local stakeholders involved in the management and conservation of the environment - Maintain open communication and reinforce cooperation with various organizations and institutions so as to collaborate and facilitate the establishment of educational programs and easily transfer skills
	There is a limited and *ad hoc* education and awareness programme	1	X		
	There is an education and awareness programme but it only partly meets needs and could be improved	2			
	There is an appropriate and fully implemented education and awareness programme	3			
21. Planning for land and water use Does land and water use planning recognise the protected area and aid the achievement of objectives? *Planning*	Adjacent land and water use planning does not take into account the needs of the protected area and activities/policies are detrimental to the survival of the area	0		???	
	Adjacent land and water use planning does not takes into account the long term needs of the protected area, but activities are not detrimental the area	1			
	Adjacent land and water use planning partially takes into account the long term needs of the protected area	2	X		
	Adjacent land and water use planning fully takes into account the long term needs of the protected area	3			

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
Additional points: Land and water planning					
21a: Land and water planning for habitat conservation	Planning and management in the catchment or landscape containing the protected area incorporates provision for adequate environmental conditions (e.g. volume, quality and timing of water flow, air pollution levels etc) to sustain relevant habitats.	+1			
21b: Land and water planning for connectivity	Management of corridors linking the protected area provides for wildlife passage to key habitats outside the protected area (e.g. to allow migratory fish to travel between freshwater spawning sites and the sea, or to allow animal migration).	+1			
21c: Land and water planning for ecosystem services & species conservation	"Planning adresses ecosystem-specific needs and/or the needs of particular species of concern at an ecosystem scale (e.g. volume, quality and timing of freshwater flow to sustain particular species, fire management to maintain savannah habitats etc.)"	+1			
22. State and commercial neighbours Is there co-operation with adjacent land and water users? *Process*	There is no contact between managers and neighbouring official or corporate land and water users	0		???	
	There is contact between managers and neighbouring official or corporate land and water users but little or no cooperation	1			
	There is contact between managers and neighbouring official or corporate land and water users, but only some co-operation	2	X		
	There is regular contact between managers and neighbouring official or corporate land and water users, and substantial co-operation on management	3			
23. Indigenous people Do indigenous and traditional peoples resident or regularly using the protected area have input to management decisions? *Process*	Indigenous and traditional peoples have no input into decisions relating to the management of the protected area	0			
	Indigenous and traditional peoples have some input into discussions relating to management but no direct role in management	1			
	Indigenous and traditional peoples directly contribute to some relevant decisions relating to management but their involvement could be improved	2			
	Indigenous and traditional peoples directly participate in all relevant decisions relating to management, e.g. co-management	3			

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
24. Local communities Do local communities resident or near the protected area have input to management decisions? *Process*	Local communities have no input into decisions relating to the management of the protected area	0		For FR, communities have virtually no decision-making power over FR management but can, through committees, influence logging procedures For GCA, according to District Wildlife Manager information, local communities have no direct power over wildlife management and GCA	- Establish meetings and lines of communication more present between local communities and managers - Open the discussion and take into account some proposals
	Local communities have some input into discussions relating to management but no direct role in management	1	X		
	Local communities directly contribute to some relevant decisions relating to management but their involvement could be improved	2			
	Local communities directly participate in all relevant decisions relating to management, e.g. co-management	3			
Additional points *Local communities/indigenous people*					
24 a. Impact on communities	There is open communication and trust between local and/or indigenous people, stakeholders and protected area managers	+1			
24b. Impact on communities	Programmes to enhance community welfare, while conserving protected area resources, are being implemented	+1			
24c. Impact on communities	Local and/or indigenous people actively support the protected area	+1			
25. Economic benefit Is the protected area providing economic benefits to local communities, e.g. income, employment, payment for environmental services? *Outcomes*	The protected area does not deliver any economic benefits to local communities	0		- From TFS revenues, 5% are redistributed to the District Council - 25% of Trophy Hunting profit goes to the District Council - No jobs offered to local communities - By pemiting beekeepers to havest in the FR / GCA	- Rethink, or reorganize benefit sharing between government and local communities to limit illegal activities - Facilitate access to PA for local communities in a controlled manner
	Potential economic benefits are recognised and plans to realise these are being developed	1			
	There is some flow of economic benefits to local communities	2	X		
	There is a major flow of economic benefits to local communities from activities associated with the protected area	3			
26. Monitoring and evaluation Are management activities monitored against performance? *Planning/Process*	There is no monitoring and evaluation in the protected area	0		- Vegetation monitoring 2016 - Registration of the Beekeepers' Camps 2018 - Animal census to difine hunting quotas in accordance with species birth rate	Implement NR monitoting system for all activities practiced in the PA
	There is some *ad hoc* monitoring and evaluation, but no overall strategy and/or no regular collection of results	1	X		
	There is an agreed and implemented monitoring and evaluation system but results do not feed back into management	2			
	A good monitoring and evaluation system exists, is well implemented and used in adaptive management	3			

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
27. Visitor facilities Are visitor facilities adequate? *Outputs*	There are no visitor facilities and services despite an identified need	0		???	
	Visitor facilities and services are inappropriate for current levels of visitation	1	X		
	Visitor facilities and services are adequate for current levels of visitation but could be improved	2			
	Visitor facilities and services are excellent for current levels of visitation	3			
28. Commercial tourism operators Do commercial tour operators contribute to protected area management? *Process*	There is little or no contact between managers and tourism operators using the protected area	0		???	
	There is contact between managers and tourism operators but this is largely confined to administrative or regulatory matters	1	X		
	There is limited co-operation between managers and tourism operators to enhance visitor experiences and maintain protected area values	2			
	There is good co-operation between managers and tourism operators to enhance visitor experiences, and maintain protected area values	3			
29. Fees If fees (i.e. entry fees or fines) are applied, do they help protected area management? *Inputs/Process*	Although fees are theoretically applied, they are not collected	0		For FR, Forest Royalities, Registration fees and Compounding fees contribute at a hight of 60% to the total revenue of the year With regard to GCA, hunting companies distribute 25% of their total benefit to the District Council, where 40% of it goes directly to the DLNR department. In addition, permits issued and hiring of hunting blocs make a substantial contribution to the budget	
	Fees are collected, but make no contribution to the protected area or its environs	1			
	Fees are collected, and make some contribution to the protected area and its environs	2			
	Fees are collected and make a substantial contribution to the protected area and its environs	3	X		
30. Condition of values What is the condition of the important values of the protected area as compared to when it was first designated? *Outcomes*	Many important biodiversity, ecological or cultural values are being severely degraded	0		For the majority of managers and officers, Rungwa River FR is not too degraded. On the other hand, when we ask external people, the answers are more negative. The forest is increasingly degraded by pastoralist activities and no restrictions prevent it. Loggers admit that forest management is not sustainable According to the District Game Manager, 70% of GCA are in good conditions but areas near villages are degraded by agriculture. For him, the conditions are good in Rungwa River GCA but for wildlife the situation could be better if means would be appropriate	
	Some biodiversity, ecological or cultural values are being severely degraded	1			
	Some biodiversity, ecological and cultural values are being partially degraded but the most important values have not been significantly impacted	2	X		
	Biodiversity, ecological and cultural values are predominantly intact	3			

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
Additional Points: Condition of values					
30a: Condition of values	The assessment of the condition of values is based on research and/or monitoring	+1			
30b: Condition of values	Specific management programmes are being implemented to address threats to biodiversity, ecological and cultural values	+1			
30c: Condition of values	Activities to maintain key biodiversity, ecological and cultural values are a routine part of park management	+1			
TOTAL SCORE			45/96		

Context: (3/3)*100 = 100%
Planning: (12/24)*100 = 50%
Inputs: (12/24)*100 = 50%
Process: (19/42)*100 = 45.24%
Outputs: (3/9)*100 = 33.33%
Outcomes: (5/12)*100 = 41.66%

Reporting Progress at Protected Area Sites: Data Sheet 1

Name, affiliation and contact details for person responsible for completing the METT (email etc.)	Lucile Daudet - Master student lucile.daudet@master.hes-so.ch			
Date assessment carried out	25.11.2018			
Name of protected area	Mlele Beekeeping Zone			
WDPA site code (these codes can be found on www.unep-wcmc.org/wdpa/)				
Designations	National National	IUCN Category VI	International (please also complete sheet overleaf) /	
Country	Tanzania			
Location of protected area (province and if possible map reference)	Mlele District, Katavi Region	S: 7, 7, 42.5 E: 32, 5, 1.48		
Date of establishment	2011			
Ownership details (please tick)	State X	Private	Community	Other
Management Authority	Inyonga Beekeepers Association			
Size of protected area (ha)	850 km2			
Number of staff	Permanent 6	Temporary 25-30		
Annual budget (US$) – excluding staff salary costs	Recurrent (operational) funds	Project or other supplementary funds		
What are the main values for which the area is designated	Wildlife, vegatation and bee product of miombo forest ecosystem			
List the two primary protected area management objectives				
Management objective 1	Sustainably manage forestry and beekeeping resources			
Management objective 2	Generate incomes that benefit local livelihoods			
No. of people involved in completing assessment	35			
Including: (tick boxes)	PA manager ☒	PA staff ☒	Other PA agency staff ☐	NGO ☒
	Local community ☒	Donors ☐	External experts ☐	Other ☐
Please note if assessment was carried out in association with a particular project, on behalf of an organisation or donor.	Master thesis for Master HES-SO in Life Science - Natural Resources Management in association with hepia and ADAP			

Information on International Designations			
UNESCO World Heritage site (see: whc.unesco.org/en/list)			
Date listed	Site name	Site area	Geographical co-ordinates
Criteria for designation (i.e. criteria i to x)			
Statement of Outstanding Universal Value			
Ramsar site (see: www.wetlands.org/RSDB/)			
Date listed	Site name	Site area	Geographical number
Reason for Designation (see Ramsar Information Sheet)			
UNESCO Man and Biosphere Reserves (see: www.unesco.org/mab/wnbrs.shtml)			
Date listed	Site name	Site area Total: Core: Buffer: Transition:	Geographical co-ordinates
Criteria for designation			
Fulfilment of three functions of MAB (conservation, development and logistic support.)			
Please list other designations (i.e. ASEAN Heritage, Natura 2000) and any supporting information below			
Name:	Detail:		
Name:	Detail:		
Name:	Detail:		
Name:	Detail:		
Name:	Detail:		
Name:	Detail:		

Protected Areas Threats: Data Sheet 2

Please tick all relevant existing threats as either of high, medium or low significance. Threats ranked as of **high** significance are those which are seriously degrading values; **medium** are those threats having some negative impact and those characterised as **low** are threats which are present but not seriously impacting values or **N/A** where the threat is not present or not applicable in the protected area.

1. Residential and commercial development within a protected area

Threats from human settlements or other non-agricultural land uses with a substantial footprint

High	Medium	Low	N/A	
		X		1.1 Housing and settlement
			X	1.2 Commercial and industrial areas
		X		1.3 Tourism and recreation infrastructure

2. Agriculture and aquaculture within a protected area

Threats from farming and grazing as a result of agricultural expansion and intensification, including silviculture, mariculture and aquaculture

High	Medium	Low	N/A	
			X	2.1 Annual and perennial non-timber crop cultivation
			X	2.1a Drug cultivation
			X	2.2 Wood and pulp plantations
			X	2.3 Livestock farming and grazing
			X	2.4 Marine and freshwater aquaculture

3. Energy production and mining within a protected area

Threats from production of non-biological resources

High	Medium	Low	N/A	
			X	3.1 Oil and gas drilling
		X		3.2 Mining and quarrying
			X	3.3 Energy generation, including from hydropower dams

4. Transportation and service corridors within a protected area

Threats from long narrow transport corridors and the vehicles that use them including associated wildlife mortality

High	Medium	Low	N/A	
		X		4.1 Roads and railroads (include road-killed animals)
			X	4.2 Utility and service lines (e.g. electricity cables, telephone lines,)
			X	4.3 Shipping lanes and canals
		X		4.4 Flight paths

5. Biological resource use and harm within a protected area

Threats from consumptive use of "wild" biological resources including both deliberate and unintentional harvesting effects; also persecution or control of specific species (note this includes hunting and killing of animals)

High	Medium	Low	N/A	
		X		5.1 Hunting, killing and collecting terrestrial animals (including killing of animals as a result of human/wildlife conflict)
		X		5.2 Gathering terrestrial plants or plant products (non-timber)
	X			5.3 Logging and wood harvesting
		X		5.4 Fishing, killing and harvesting aquatic resources

6. Human intrusions and disturbance within a protected area

Threats from human activities that alter, destroy or disturb habitats and species associated with non-consumptive uses of biological resources

High	Medium	Low	N/A	
		X		6.1 Recreational activities and tourism
		X		6.2 War, civil unrest and military exercises
		X		6.3 Research, education and other work-related activities in protected areas
		X		6.4 Activities of protected area managers (e.g. construction or vehicle use, artificial watering points and dams)
			X	6.5 Deliberate vandalism, destructive activities or threats to protected area staff and visitors

7. Natural system modifications

Threats from other actions that convert or degrade habitat or change the way the ecosystem functions

High	Medium	Low	N/A	
		X		7.1 Fire and fire suppression (including arson)
			X	7.2 Dams, hydrological modification and water management/use
			X	7.3a Increased fragmentation within protected area
			X	7.3b Isolation from other natural habitat (e.g. deforestation, dams without effective aquatic wildlife passages)
	X			7.3c Other 'edge effects' on park values
		X		7.3d Loss of keystone species (e.g. top predators, pollinators etc)

8. Invasive and other problematic species and genes

Threats from terrestrial and aquatic non-native and native plants, animals, pathogens/microbes or genetic materials that have or are predicted to have harmful effects on biodiversity following introduction, spread and/or increase

High	Medium	Low	N/A	
			X	8.1 Invasive non-native/alien plants (weeds)
			X	8.1a Invasive non-native/alien animals
			X	8.1b Pathogens (non-native or native but creating new/increased problems)
			X	8.2 Introduced genetic material (e.g. genetically modified organisms)

9. Pollution entering or generated within protected area

Threats from introduction of exotic and/or excess materials or energy from point and non-point sources

High	Medium	Low	N/A	
		X		9.1 Household sewage and urban waste water
		X		9.1a Sewage and waste water from protected area facilities (e.g. toilets, hotels etc)
		X		9.2 Industrial, mining and military effluents and discharges (e.g. poor water quality discharge from dams, e.g. unnatural temperatures, de-oxygenated, other pollution)
	X			9.3 Agricultural and forestry effluents (e.g. excess fertilizers or pesticides)
		X		9.4 Garbage and solid waste
			X	9.5 Air-borne pollutants
			X	9.6 Excess energy (e.g. heat pollution, lights etc)

10. Geological events

Geological events may be part of natural disturbance regimes in many ecosystems. But they can be a threat if a species or habitat is damaged and has lost its resilience and is vulnerable to disturbance. Management capacity to respond to some of these changes may be limited.

High	Medium	Low	N/A	
			X	10.1 Volcanoes
			X	10.2 Earthquakes/Tsunamis
			X	10.3 Avalanches/ Landslides
	X			10.4 Erosion and siltation/ deposition (e.g. shoreline or riverbed changes)

11. Climate change and severe weather

Threats from long-term climatic changes which may be linked to global warming and other severe climatic/weather events outside of the natural range of variation

High	Medium	Low	N/A	
		X		11.1 Habitat shifting and alteration
		X		11.2 Droughts
			X	11.3 Temperature extremes
		X		11.4 Storms and flooding

12. Specific cultural and social threats

High	Medium	Low	N/A	
	X			12.1 Loss of cultural links, traditional knowledge and/or management practices
		X		12.2 Natural deterioration of important cultural site values
			X	12.3 Destruction of cultural heritage buildings, gardens, sites etc

Assessment Form

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
1. Legal status Does the protected area have legal status (or in the case of private reserves is covered by a covenant or similar)? *Context*	The protected area is not gazetted/covenanted	0		Gazettment is the official designation or, more explicitly, the administrative procedure that allows to register an area as such. The BKZ was demarcated and flagged with signs and beacons, but not formally classified as such. It's a formality, if worries with the MNRT are settled soon it will be gazetted	Obtain a meeting with the MNRT-FBD, TFS, TAWA and the WD for formalizing and gazetting the BKZ
	There is agreement that the protected area should be gazetted/covenanted but the process has not yet begun	1			
	The protected area is in the process of being gazetted/covenanted but the process is still incomplete (includes sites designated under international conventions, such as Ramsar, or local/traditional law such as community conserved areas, which do not yet have national legal status or covenant)	2	X		
	The protected area has been formally gazetted/covenanted	3			
2. Protected area regulations Are appropriate regulations in place to control land use and activities (e.g. hunting)? *Planning*	There are no regulations for controlling land use and activities in the protected area	0		- Forest Policy (1998) - Forest Act (2002) - Forest Regulation - Beekeeping Act (2002) - Beekeeping Regulation - Wildlife Policy (2007) - Wildlife Conservation Act (2009) - Wildlife Conservation Regulation - MoU - Management Plan 2007 and 2015	Obtain the signature of the 2016 Management Plan in order to clarify IBA rights over the management of the MBKZ
	Some regulations for controlling land use and activities in the protected area exist but these are major weaknesses	1			
	Regulations for controlling land use and activities in the protected area exist but there are some weaknesses or gaps	2			
	Regulations for controlling inappropriate land use and activities in the protected area exist and provide an excellent basis for management	3	X		
3. Law enforcement Can staff (i.e. those with responsibility for managing the site) enforce protected area rules well enough? *Input*	The staff have no effective capacity/resources to enforce protected area legislation and regulations	0		- Staff (6 management staff + 25-30 VGS) - Two sessions of 7 days / month - 1 vehicle at disposal + 10km on foot patrols are organized - 1 weapon at disposal - Training sessions are followed by VGS - 1,000,000 TSH / 7 days patrol - Arrested people are brought to the police and then presented to the court	Change patrols schedule to make patrols less conspicuous to interested peoples (illegal activities) in order to make it more effective
	There are major deficiencies in staff capacity/resources to enforce protected area legislation and regulations (e.g. lack of skills, no patrol budget, lack of institutional support)	1			
	The staff have acceptable capacity/resources to enforce protected area legislation and regulations but some deficiencies remain	2			
	The staff have excellent capacity/resources to enforce protected area legislation and regulations	3	X		

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
4. Protected area objectives Is management undertaken according to agreed objectives? *Planning*	No firm objectives have been agreed for the protected area	0		- Patrols - VGS and Staff formations - Trainings for sustainable forest management and the sustainable practice of beekeeping - Collection of fees and funds for the financial autonomy of IBA - Biodiversity and vegetation monitoring	Find solutions and continue to maintain communication between the TFS and MNRT to obtain the right of collecting rejects timber. Favor more cooperation between beekeepers and IBA. Find a favorable market for the sale of honey. Be stricter regarding the collection of fees and income from the issue of permits
	The protected area has agreed objectives, but is not managed according to these objectives	1			
	The protected area has agreed objectives, but is only partially managed according to these objectives	2	X		
	The protected area has agreed objectives and is managed to meet these objectives	3			
5. Protected area design Is the protected area the right size and shape to protect species, habitats, ecological processes and water catchments of key conservation concern? *Planning*	Inadequacies in protected area design mean achieving the major objectives of the protected area is very difficult	0		The area contributes to the maintenance of this ecosystem and the quality of its habitat, promotes the reception and free movement of wildlife The current size allows employees to manage it without too much difficulty and to practice beekeeping in a sustainable manner	Propose an extension of the BKZ on the whole Mlele Hills FR in order to limit conflicts of interest between managers
	Inadequacies in protected area design mean that achievement of major objectives is difficult but some mitigating actions are being taken (e.g. agreements with adjacent land owners for wildlife corridors or introduction of appropriate catchment management)	1			
	Protected area design is not significantly constraining achievement of objectives, but could be improved (e.g. with respect to larger scale ecological processes)	2			
	Protected area design helps achievement of objectives; it is appropriate for species and habitat conservation; and maintains ecological processes such as surface and groundwater flows at a catchment scale, natural disturbance patterns etc	3	X		
6. Protected area boundary demarcation Is the boundary known and demarcated? *Process*	The boundary of the protected area is not known by the management authority or local residents/neighbouring land users	0		The boundary is demarcated on paper by the authority as well on the ground by demarcation elements + the access to the GR is controlled during routine patrol as well as by raising awareness toward local comunities during educational missions	
	The boundary of the protected area is known by the management authority but is not known by local residents/neighbouring land users	1			
	The boundary of the protected area is known by both the management authority and local residents/neighbouring land users but is not appropriately demarcated	2			
	The boundary of the protected area is known by the management authority and local residents/neighbouring land users and is appropriately demarcated	3	X		

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
7. Management plan Is there a management plan and is it being implemented? *Planning*	There is no management plan for the protected area	0		The first management plan was set in place in 2007. In 2014 it was review and is currently under revision and awaiting validation by MNRT and TFS Actions or objectives can not all be achieved in view of the current relations and the non-validation of the Management Plan between the TFS and IBA	Obtain meeting and maintain open communication with MNRT, TFS, TAWA and WD to formalize the implementation of the management plan and promote the renewal of the MoU between IBA and MNRT / TFS
	A management plan is being prepared or has been prepared but is not being implemented	1			
	A management plan exists but it is only being partially implemented because of funding constraints or other problems	2	X		
	A management plan exists and is being implemented	3			
Additional points: *Planning*					
7a. Planning process	The planning process allows adequate opportunity for key stakeholders to influence the management plan	+1	X	Meetings and open discussion + composition of The Central Committee (12 representatives -> 1 for each village) -> Represented during meetings (every three months) Interviews with villagers, registration of beekeepers' camps and the production of honey allows to see the evolution of production Report patrols, monitoring and academic research allow to see if the efforts put in place are beneficial for the environment	
7b. Planning process	There is an established schedule and process for periodic review and updating of the management plan	+1			
7c. Planning process	The results of monitoring, research and evaluation are routinely incorporated into planning	+1	X		
8. Regular work plan Is there a regular work plan and is it being implemented *Planning/Outputs*	No regular work plan exists	0		Internal duties are always accomplished. The only obstacles are related to the actions or activities in relation with other actors	
	A regular work plan exists but few of the activities are implemented	1			
	A regular work plan exists and many activities are implemented	2	X		
	A regular work plan exists and all activities are implemented	3			
9. Resource inventory Do you have enough information to manage the area? *Input*	There is little or no information available on the critical habitats, species and cultural values of the protected area	0		- Vegetation monitoring (2004, 2013, 2017) - Wildlife monitoring (since 2008 until now, every years) - Beekeeping monitoring(2017) - Patrols report with illegal activities (2017) - Village survey (2002) - Annual report	
	Information on the critical habitats, species, ecological processes and cultural values of the protected area is not sufficient to support planning and decision making	1			
	Information on the critical habitats, species, ecological processes and cultural values of the protected area is sufficient for most key areas of planning and decision making	2	X		
	Information on the critical habitats, species, ecological processes and cultural values of the protected area is sufficient to support all areas of planning and decision making	3			

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
10. Protection systems Are systems in place to control access/resource use in the protected area? *Process/Outcome*	Protection systems (patrols, permits etc) do not exist or are not effective in controlling access/resource use	0		- Patrols conducted mainly by VGS and sometimes in collaboration with other actors such as TFS or TAWA - Establishment of permit system to control activities - Information by villagers around the area - 2 permanent guards at the Mlele camps	- Set up checkpoints at entrance areas - Set up irregular patrol - Meetings with District, TFS, MNRT and IBA to clarify license fees - Maintain open communication between users, villagers and politicians
	Protection systems are only partially effective in controlling access/resource use	1			
	Protection systems are moderately effective in controlling access/resource use	2			
	Protection systems are largely or wholly effective in controlling access/ resource use	3	X		
11. Research Is there a programme of management-orientated survey and research work? *Process*	There is no survey or research work taking place in the protected area	0		- Various monitoring mentionned at question 9 - Thirty or so research work and Bachelor or Master thesis are available and provide information on the management of the BKZ	Maintain monitorings, research works and meetings
	There is a small amount of survey and research work but it is not directed towards the needs of protected area management	1			
	There is considerable survey and research work but it is not directed towards the needs of protected area management	2			
	There is a comprehensive, integrated programme of survey and research work, which is relevant to management needs	3	X		
12. Resource management Is active resource management being undertaken? *Process*	Active resource management is not being undertaken	0		For now, it can be said that the BKZ is well managed, and is locally recognized as the best managed area in the District For the moment the number of patrols, VGS and their qualifications are sufficient to manage the area	
	Very few of the requirements for active management of critical habitats, species, ecological processes and cultural values are being implemented	1			
	Many of the requirements for active management of critical habitats, species, ecological processes and, cultural values are being implemented but some key issues are not being addressed	2	X		
	Requirements for active management of critical habitats, species, ecological processes and, cultural values are being substantially or fully implemented	3			
13. Staff numbers Are there enough people employed to manage the protected area? *Inputs*	There are no staff	0		- 1 Manager - 1 Cashier - 1 Accountant - 1 ADAP project supervisor - 1 Documentation Monitoring Capitalisation Officer (DMC0) - 1 VGS Manager - 25-30 VGS - 1 IBA secretary - 1 IBA chairperson - 1 IBA vis-chair person - 1 IBA village représentative par village	
	Staff numbers are inadequate for critical management activities	1			
	Staff numbers are below optimum level for critical management activities	2			
	Staff numbers are adequate for the management needs of the protected area	3	X		

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
14. Staff training Are staff adequately trained to fulfil management objectives? *Inputs/Process*	Staff lack the skills needed for protected area management	0		Training by District, WD, TAWA and ADAP : - Paramilitary activities - Anti- poaching & corruption activities - GIS trainning (GPS; Maps; Compass) - Physical fitness - Tracking skills - Weapon utilisation & care - Knowledge of relevant laws	
	Staff training and skills are low relative to the needs of the protected area	1			
	Staff training and skills are adequate, but could be further improved to fully achieve the objectives of management	2	X		
	Staff training and skills are aligned with the management needs of the protected area	3			
15. Current budget Is the current budget sufficient? *Inputs*	There is no budget for management of the protected area	0		Overall it is satisfactory to do all the necessary activities of "protection" for the BKZ, but could be improved to : - Employ truly qualified people for the management team - Buy all honey production to beekeepers and sell it to big buyers and get a great price and a source of money for IBA - Build and supply modern hives at an affordable price for the association beekeepers	Go towards IBA autonomy : - Validate the Management Plan so that the money collected from the arrest, permit fees, honey tax, ect., are applied - Find an agreement with beekeepers regarding the harvesting of honey and sale to big buyers - Application for local financing like Tanzanian Forest Funds - Dynamism of the association, open and frequent communication between IBA committee and villager
	The available budget is inadequate for basic management needs and presents a serious constraint to the capacity to manage	1			
	The available budget is acceptable but could be further improved to fully achieve effective management	2	X		
	The available budget is sufficient and meets the full management needs of the protected area	3			
16. Security of budget Is the budget secure? *Inputs*	There is no secure budget for the protected area and management is wholly reliant on outside or highly variable funding	0	X	IBA is currently not financially self-sufficient. The vast majority of the budget comes from external funds (ADAP) and almost no local source of income supports the management of the BKZ (fees, honey sales)	Same as above
	There is very little secure budget and the protected area could not function adequately without outside funding	1			
	There is a reasonably secure core budget for regular operation of the protected area but many innovations and initiatives are reliant on outside funding	2			
	There is a secure budget for the protected area and its management needs	3			
17. Management of budget Is the budget managed to meet critical management needs? *Process*	Budget management is very poor and significantly undermines effectiveness (e.g. late release of budget in financial year)	0		Budget management is currently done by ADAP in Switzerland. IBA then receives the instructions for use and is responsible for following them	Budget management could be done in a participative maner between IBA and ADAP in order to lead the BKZ managers towards the autonomy and the sustainable management of the PA
	Budget management is poor and constrains effectiveness	1			
	Budget management is adequate but could be improved	2	X		
	Budget management is excellent and meets management needs	3			

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
18. Equipment Is equipment sufficient for management needs? *Input*	There are little or no equipment and facilities for management needs	0		- Office and special room to collect and sell honey - Computers (5) - Printer (1) - Harvest equipment - Beehive manufacturing (1) - Cars (2) - Motorbike (1) - GPS (6) - Tentes (3) - Camera traps (100) - VGS equipment	
	There are some equipment and facilities but these are inadequate for most management needs	1			
	There are equipment and facilities, but still some gaps that constrain management	2	X		
	There are adequate equipment and facilities	3			
19. Maintenance of equipment Is equipment adequately maintained? *Process*	There is little or no maintenance of equipment and facilities	0		An inventory of all property of IBA is held and the material is checked once a year	Be more assiduous in maintaining the material. Perform a check every 6 months, order equipment and recycle unnecessary material. Repair the disadvantages as quickly as possible if the means allow
	There is some *ad hoc* maintenance of equipment and facilities	1			
	There is basic maintenance of equipment and facilities	2	X		
	Equipment and facilities are well maintained	3			
20. Education and awareness Is there a planned education programme linked to the objectives and needs? *Process*	There is no education and awareness programme	0		IBA provides many training to villagers, particularly beekeepers, but also to women's groups. Communities benefit of such training, on average, at least once a year	
	There is a limited and *ad hoc* education and awareness programme	1			
	There is an education and awareness programme but it only partly meets needs and could be improved	2			
	There is an appropriate and fully implemented education and awareness programme	3	X		
21. Planning for land and water use Does land and water use planning recognise the protected area and aid the achievement of objectives? *Planning*	Adjacent land and water use planning does not take into account the needs of the protected area and activities/policies are detrimental to the survival of the area	0		Previously, ADAP set in place a Land Use Management Plan (PLUM) but, unfortunately, few results are currently present. It is now within the power of the District to put in place this kind of action and to ensure its functionality Good communication between the District, ADAP and the BKZ community management project is present and training for villagers is put in place to promote the sustainable use of forest resources in villages and forests	Maintain open communication between stakeholders involved in the management of NR and informe them on the advanced of the project and make proposals during meetings
	Adjacent land and water use planning does not takes into account the long term needs of the protected area, but activities are not detrimental the area	1			
	Adjacent land and water use planning partially takes into account the long term needs of the protected area	2	X		
	Adjacent land and water use planning fully takes into account the long term needs of the protected area	3			

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
Additional points: Land and water planning					
21a: Land and water planning for habitat conservation	Planning and management in the catchment or landscape containing the protected area incorporates provision for adequate environmental conditions (e.g. volume, quality and timing of water flow, air pollution levels etc) to sustain relevant habitats.	+1			
21b: Land and water planning for connectivity	Management of corridors linking the protected area provides for wildlife passage to key habitats outside the protected area (e.g. to allow migratory fish to travel between freshwater spawning sites and the sea, or to allow animal migration).	+1			
21c: Land and water planning for ecosystem services & species conservation	"Planning adresses ecosystem-specific needs and/or the needs of particular species of concern at an ecosystem scale (e.g. volume, quality and timing of freshwater flow to sustain particular species, fire management to maintain savannah habitats etc.)"	+1			
22. State and commercial neighbours Is there co-operation with adjacent land and water users? *Process*	There is no contact between managers and neighbouring official or corporate land and water users	0		Contact is held with the District, TAWA (where a good collaboration is established), the Tanzania Big Game Safari and TFS, with which the current relations are tense	
	There is contact between managers and neighbouring official or corporate land and water users but little or no cooperation	1			
	There is contact between managers and neighbouring official or corporate land and water users, but only some co-operation	2	X		
	There is regular contact between managers and neighbouring official or corporate land and water users, and substantial co-operation on management	3			
23. Indigenous people Do indigenous and traditional peoples resident or regularly using the protected area have input to management decisions? *Process*	Indigenous and traditional peoples have no input into decisions relating to the management of the protected area	0			
	Indigenous and traditional peoples have some input into discussions relating to management but no direct role in management	1			
	Indigenous and traditional peoples directly contribute to some relevant decisions relating to management but their involvement could be improved	2			
	Indigenous and traditional peoples directly participate in all relevant decisions relating to management, e.g. co-management	3			

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
24. Local communities Do local communities resident or near the protected area have input to management decisions? *Process*	Local communities have no input into decisions relating to the management of the protected area	0		Local communities are involved in the management process through IBA. With the help of meetings (every 3 months) and IBA village representative, villagers receive information and share their ideas and wills concerning the management of the BKZ. Moreover, The BKZ managers are mostly local people	Improving IBA village representative presence during meetings and make regular visits to villages to maintain open communication and information between communities and managers
	Local communities have some input into discussions relating to management but no direct role in management	1			
	Local communities directly contribute to some relevant decisions relating to management but their involvement could be improved	2	X		
	Local communities directly participate in all relevant decisions relating to management, e.g. co-management	3			
Additional points *Local communities/indigenous people*					
24 a. Impact on communities	There is open communication and trust between local and/or indigenous people, stakeholders and protected area managers	+1	X		
24b. Impact on communities	Programmes to enhance community welfare, while conserving protected area resources, are being implemented	+1			
24c. Impact on communities	Local and/or indigenous people actively support the protected area	+1	X		
25. Economic benefit Is the protected area providing economic benefits to local communities, e.g. income, employment, payment for environmental services? *Outcomes*	The protected area does not deliver any economic benefits to local communities	0		- Job opportunities eigther as Staff memeber or as VGS - By becoming a member of IBA and havest bee products in the BKZ	The extension of the BKZ to the entire Mlele Hills Forest Reserve and the supression of the different protection status layers would limit conflicts of interest between stakeholder and would facilitate understanding of laws and rules
	Potential economic benefits are recognised and plans to realise these are being developed	1			
	There is some flow of economic benefits to local communities	2	X		
	There is a major flow of economic benefits to local communities from activities associated with the protected area	3			
26. Monitoring and evaluation Are management activities monitored against performance? *Planning/Process*	There is no monitoring and evaluation in the protected area	0		- Vegetation monitoring - Wildlife monitoring - Beekeeping monitoring - Patrols report with illegal activities - Village survey	
	There is some *ad hoc* monitoring and evaluation, but no overall strategy and/or no regular collection of results	1			
	There is an agreed and implemented monitoring and evaluation system but results do not feed back into management	2			
	A good monitoring and evaluation system exists, is well implemented and used in adaptive management	3	X		

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
27. Visitor facilities Are visitor facilities adequate? *Outputs*	There are no visitor facilities and services despite an identified need	0		Roads and tracks are maintained and repaired as needed each year in order to access the area A camp equipped with bungalow and sanitary is present for the VGS and tourist Inyonga Ecotourism Association (IEA) was created to promote the development of tourism	Set in place more adapted equipment to welcome tourists and develop an eco-tourism component
	Visitor facilities and services are inappropriate for current levels of visitation	1			
	Visitor facilities and services are adequate for current levels of visitation but could be improved	2	X		
	Visitor facilities and services are excellent for current levels of visitation	3			
28. Commercial tourism operators Do commercial tour operators contribute to protected area management? *Process*	There is little or no contact between managers and tourism operators using the protected area	0		The creation of Inyonga Ecotourism Association (IEA) aims at promoting the BKZ as an eco-tourism area. In addition, partnerships are being discussed with tour operators	Open partnership with eco-tourism or rural community tourism agency
	There is contact between managers and tourism operators but this is largely confined to administrative or regulatory matters	1			
	There is limited co-operation between managers and tourism operators to enhance visitor experiences and maintain protected area values	2	X		
	There is good co-operation between managers and tourism operators to enhance visitor experiences, and maintain protected area values	3			
29. Fees If fees (i.e. entry fees or fines) are applied, do they help protected area management? *Inputs/Process*	Although fees are theoretically applied, they are not collected	0		Entry fees are not fully applied. For example, this year, 9 permits for beekeeping were paid to IBA but 45 beekeepers went to the BKZ. This is related to the conflict of interest between TFS, the District and IBA Membership fees for IBA are almost never paid and training is given even in the absence of adhesion	Clarify IBA's rights to institutions involved in co-management Start limiting the implementation of training if members do not participate financially in the association To be more rigorous on the payment of entrance fees for activities within the BKZ
	Fees are collected, but make no contribution to the protected area or its environs	1	X		
	Fees are collected, and make some contribution to the protected area and its environs	2			
	Fees are collected and make a substantial contribution to the protected area and its environs	3			
30. Condition of values What is the condition of the important values of the protected area as compared to when it was first designated? *Outcomes*	Many important biodiversity, ecological or cultural values are being severely degraded	0		For now, the BKZ is well managed and is recognized as the best managed area in the District. and in particulare the preservation of its habitat (vegetaion) and wildlife	Maintain ecological monitoring and integrated Impact Evaluation system in the monitoring of flora and fauna
	Some biodiversity, ecological or cultural values are being severely degraded	1			
	Some biodiversity, ecological and cultural values are being partially degraded but the most important values have not been significantly impacted	2			
	Biodiversity, ecological and cultural values are predominantly intact	3	X		

Issue	Criteria	Score: Tick only one box per question		Comment/Explanation	Next steps
Additional Points: Condition of values					
30a: Condition of values	The assessment of the condition of values is based on research and/or monitoring	+1	X		
30b: Condition of values	Specific management programmes are being implemented to address threats to biodiversity, ecological and cultural values	+1			
30c: Condition of values	Activities to maintain key biodiversity, ecological and cultural values are a routine part of park management	+1			
TOTAL SCORE			72/96		

Context: (2/3)*100 = 66.66%
Planning: (19/24)*100 = 79.16%
Inputs: (15/24)*100 = 62.5%
Process: (32/42)*100 = 76.19%
Outputs: (4/9)*100 = 44.44%
Outcomes: (9/12)*100 = 75%

Appendix XIV: Camera Traps Parameters

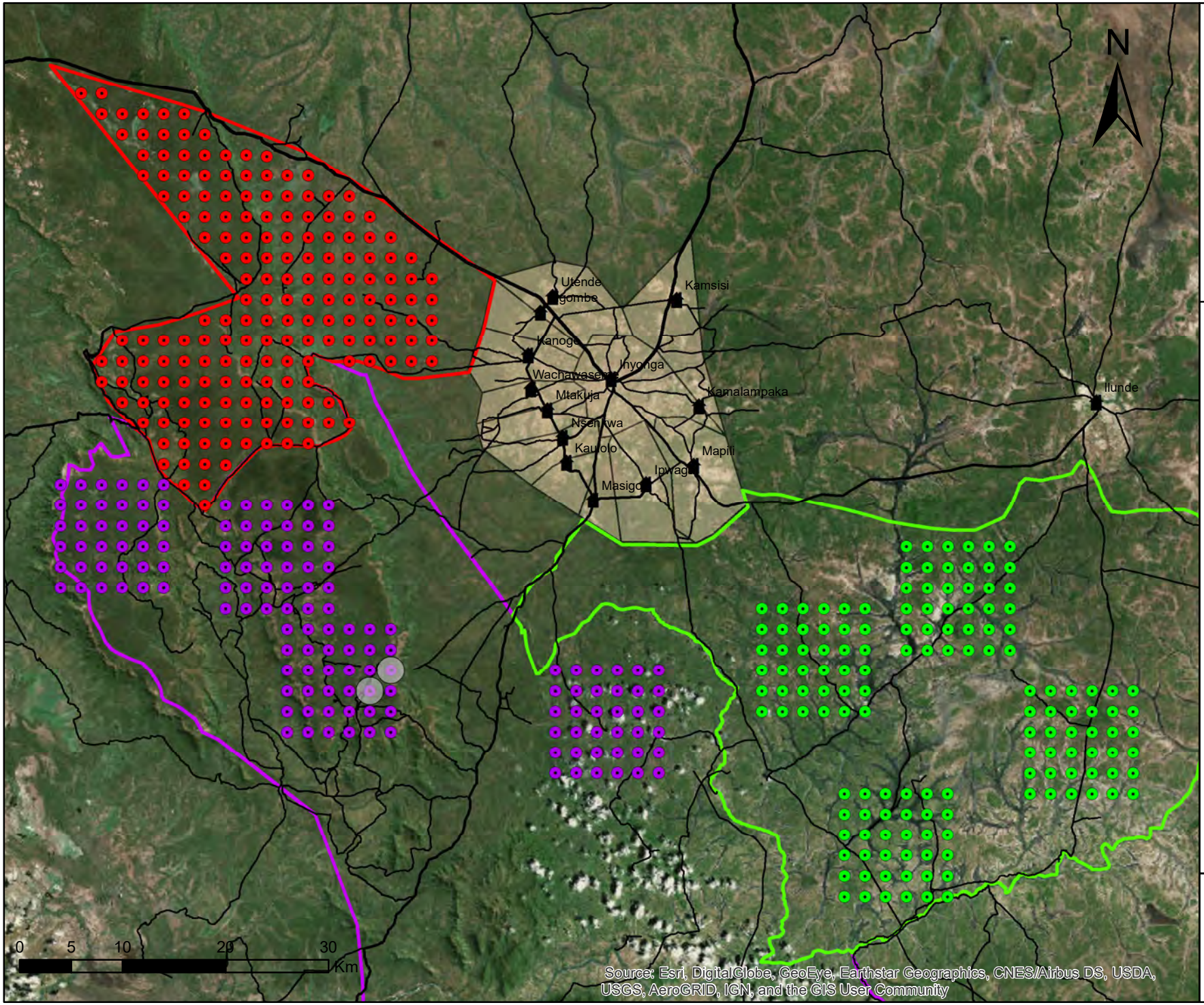
Source: Lepus (Huber, 2018)

	M1_2018	M3_2018	M5_218	M_Tot.	R1_2018	R2_2018	R3_2018	R4_2018	R_Tot.	RW1_2018	RW4_2018	RW_Tot.	TOTAL (3 PA)
Pics	18596	45455	58031	122082	39921	49147	45880	25138	160086	13362	18227	31589	313757
Events	1017	885	1373	3275	1238	2044	1811	1141	6234	1772	1990	3762	13271
CT	33	34	36	103	33	36	36	33	138	35	35	70	311
Taxa	29	31	31	35	27	35	33	33	46	31	38	40	52
CT Days Effort	994	819	864	2677	787	858	830	727	3202	1125	1124	2249	8128

Total species detected	
Leptailurus serval	*Tragelaphus strepsiceros*
Lepus sp.	*Aepyceros melampus*
Loxodonta africana	*Alcelaphus b. lichtensteinii*
Lycaon pictus	*Atilax paludinosus*
Mellivora capensis	*Bdeogale crassicauda*
Mungos mungo	*Bucorvus leadbeateri*
Numida meleagris	*Canis adustus*
Oreotragus oreotragus	*Cercopithecus n. mitis*
Orycteropus afer	*Chlorocebus pygerythrus*
Otolemur c. monteiri	*Civettictis civetta*
Ourebia ourebi	*Cricetomys gambianus*
Panthera pardus	*Crocuta crocuta*
Papio cynocephalus	*Damaliscus lunatus*
Pedetes surdaster	*Equus q. boehmi*
Petrodromus tetradactylus	*Felis silvestris*
Phacochoerus africanus	*Galago senegalensis*
Philantomba monticola	*Galago sp.*
Potamochoerus larvatus	*Genetta angolensis*
Raphicerus sharpei	*Genetta maculata*
Redunca arundinum	*Giraffa c. tippelskirchi*
Rhynchogale melleri	*Helogale parvula*
Smutsia temminckii	*Hippotragus equinus*
Sylvicapra grimmia	*Hippotragus niger*
Syncerus caffer	*Hystrix africaeaustralis*
Taurotragus oryx	*Ichneumia albicauda*
Tragelaphus scriptus	*Kobus ellipsiprymnus*

Appendix XV: Distribution Maps

Source: Lepus (Huber, 2018) & ESRI, 2017



Distribution Map
Canis adustus

1:500 000

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Damien ZURKINDEN
February 2019

Legend

Canis adustus events

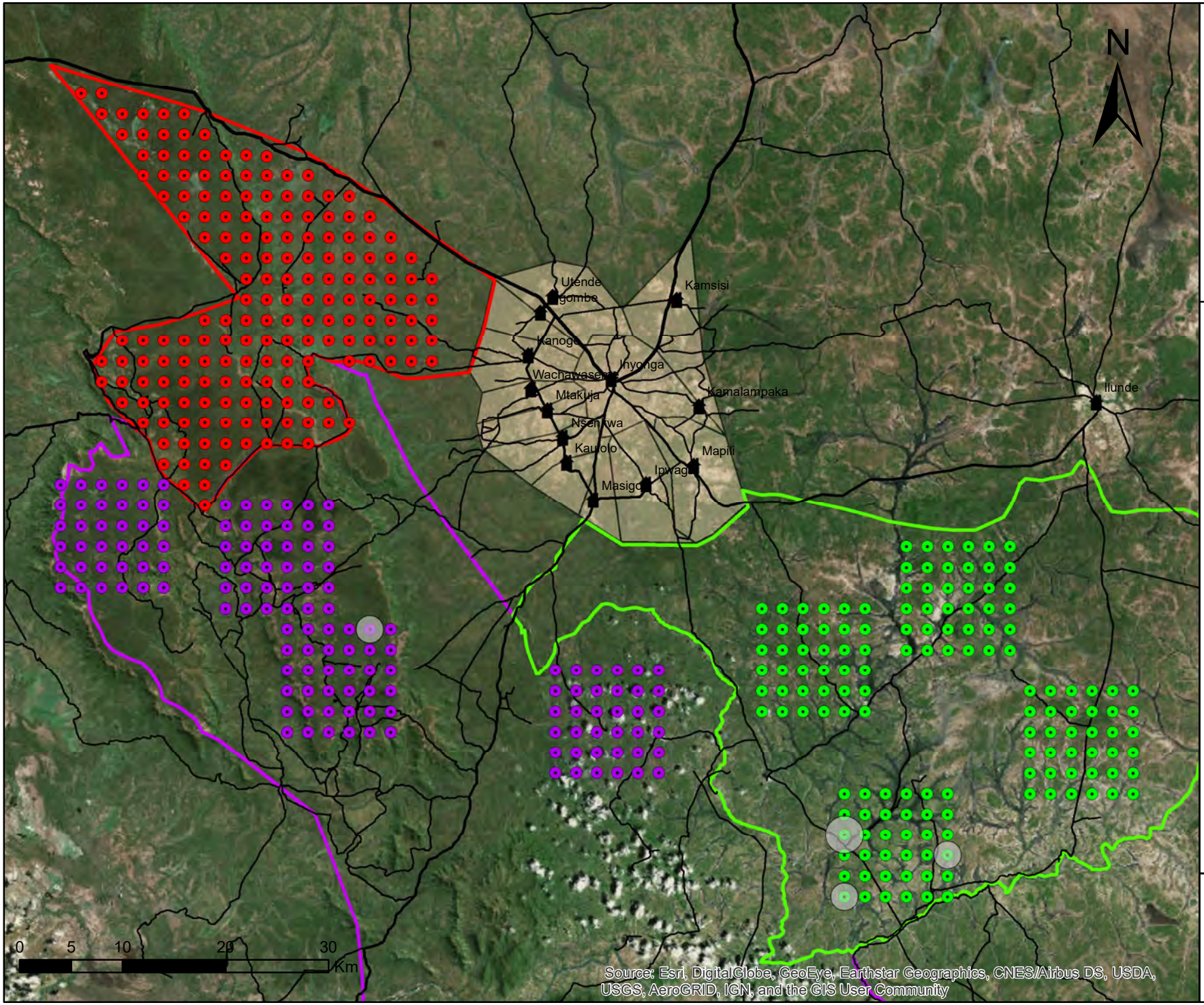
- 1
- CT Rukwa 2018
- CT Rungwa 2018
- CT Mlele 2018
- Rukwa GR
- Rungwa FR & GCA
- Mlele BKZ
- Inyonga

Roads

- Tracks
- Secondary
- Main

Hes·so

MLS MASTER OF SCIENCE IN LIFE SCIENCES



Distribution Map Lycaon pictus

1:500 000

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February 2019

Legend

Lycaon pictus events

- 2
- CT Rukwa 2018
- CT Rungwa 2018
- CT Mlele 2018
- Rukwa GR
- Rungwa FR & GCA
- Mlele BKZ
- Inyonga

Roads

- Tracks
- Secondary
- Main

Hes·so

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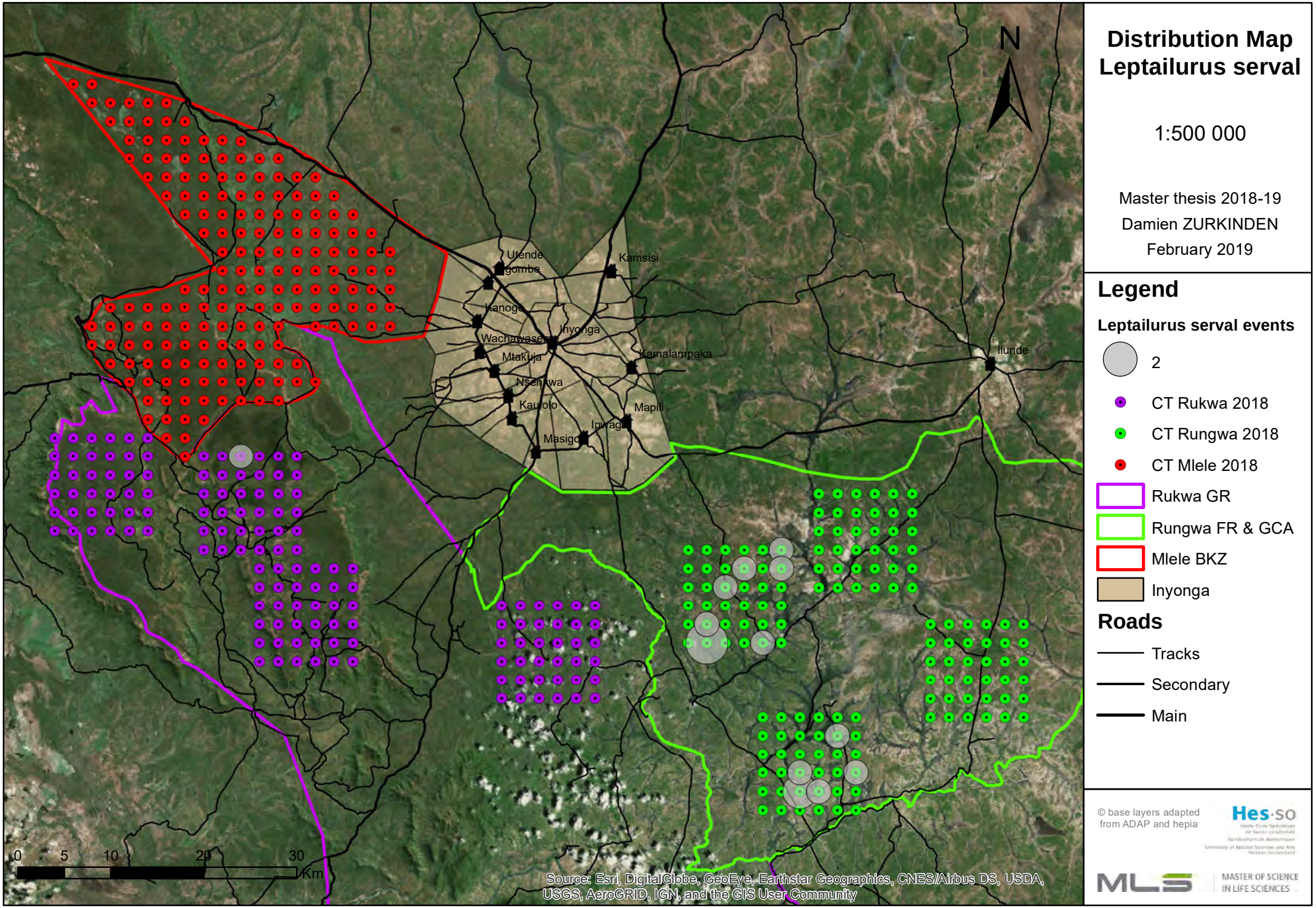

Distribution Map Leptailurus serval

1:500 000

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February 2019

Legend

Leptailurus serval events

- 2
- CT Rukwa 2018
- CT Rungwa 2018
- CT Mlele 2018
- Rukwa GR
- Rungwa FR & GCA
- Mlele BKZ
- Inyonga

Roads

- Tracks
- Secondary
- Main

Hes·so

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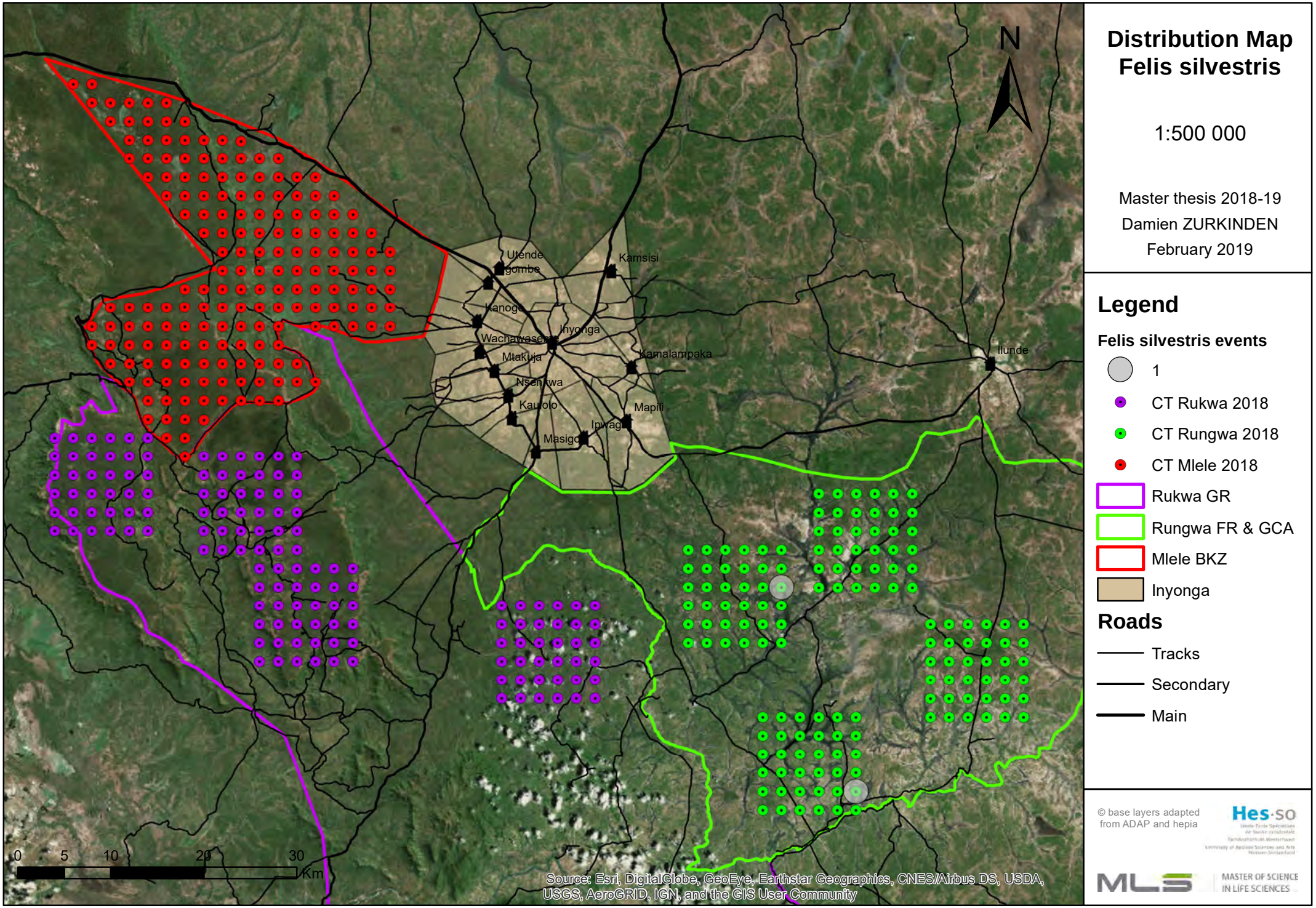

Distribution Map Felis silvestris

1:500 000

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February 2019

Legend

Felis silvestris events

- 1
- CT Rukwa 2018
- CT Rungwa 2018
- CT Mlele 2018
- Rukwa GR
- Rungwa FR & GCA
- Mlele BKZ
- Inyonga

Roads

- Tracks
- Secondary
- Main

Hes·so

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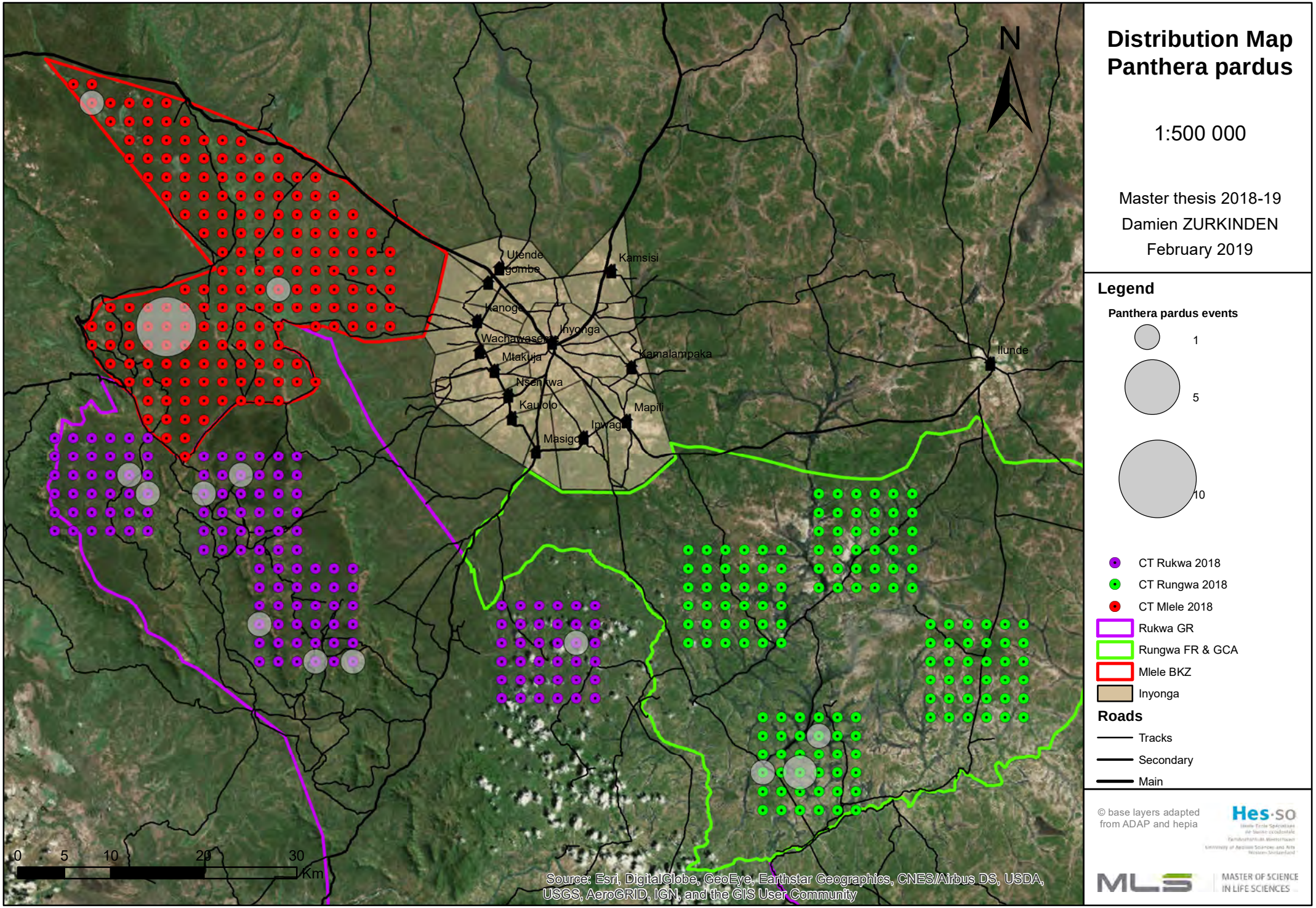

Distribution Map Panthera pardus

1:500 000

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February 2019

Legend

Panthera pardus events

1
5
10

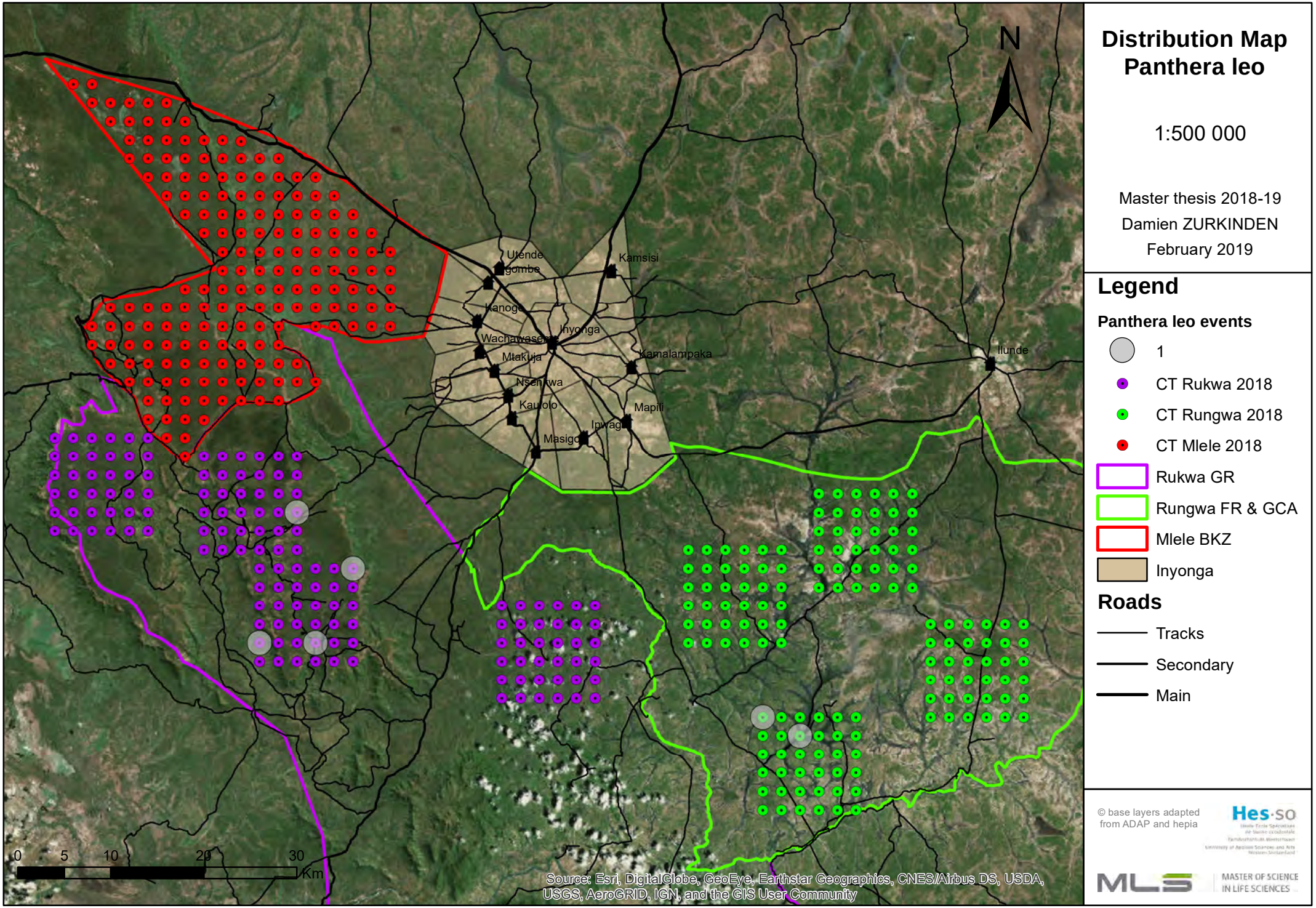
CT Rukwa 2018
CT Rungwa 2018
CT Mlele 2018
Rukwa GR
Rungwa FR & GCA
Mlele BKZ
Inyonga

Roads

Tracks
Secondary
Main

Hes·so

MLS MASTER OF SCIENCE IN LIFE SCIENCES



Distribution Map Panthera leo

1:500 000

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February 2019

Legend

Panthera leo events

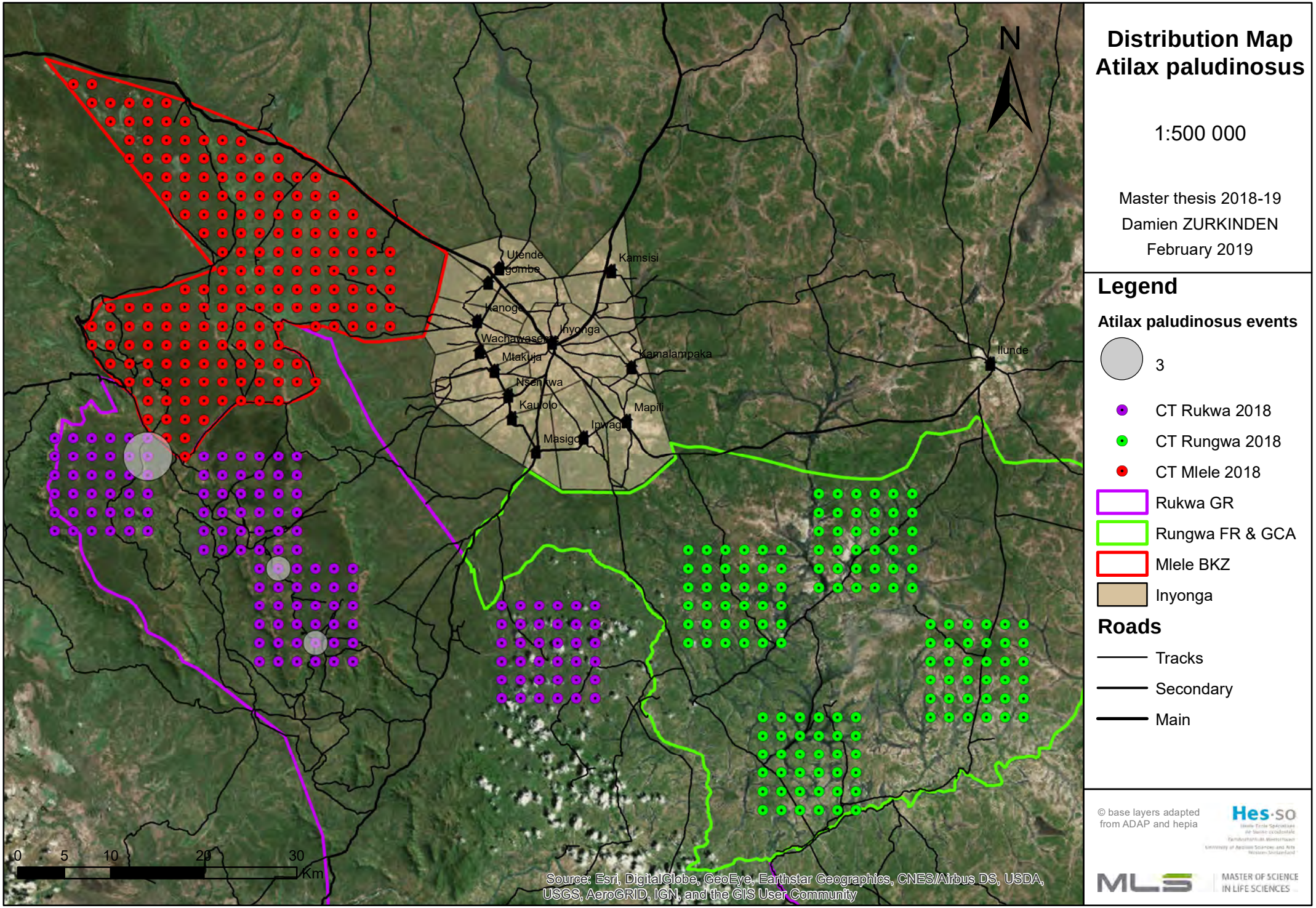
- 1
- CT Rukwa 2018
- CT Rungwa 2018
- CT Mlele 2018
- Rukwa GR
- Rungwa FR & GCA
- Mlele BKZ
- Inyonga

Roads

- Tracks
- Secondary
- Main

Hes·so

MLS MASTER OF SCIENCE IN LIFE SCIENCES



Distribution Map Atilax paludinosus

1:500 000

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February 2019

Legend

Atilax paludinosus events

3

CT Rukwa 2018

CT Rungwa 2018

CT Mlele 2018

Rukwa GR

Rungwa FR & GCA

Mlele BKZ

Inyonga

Roads

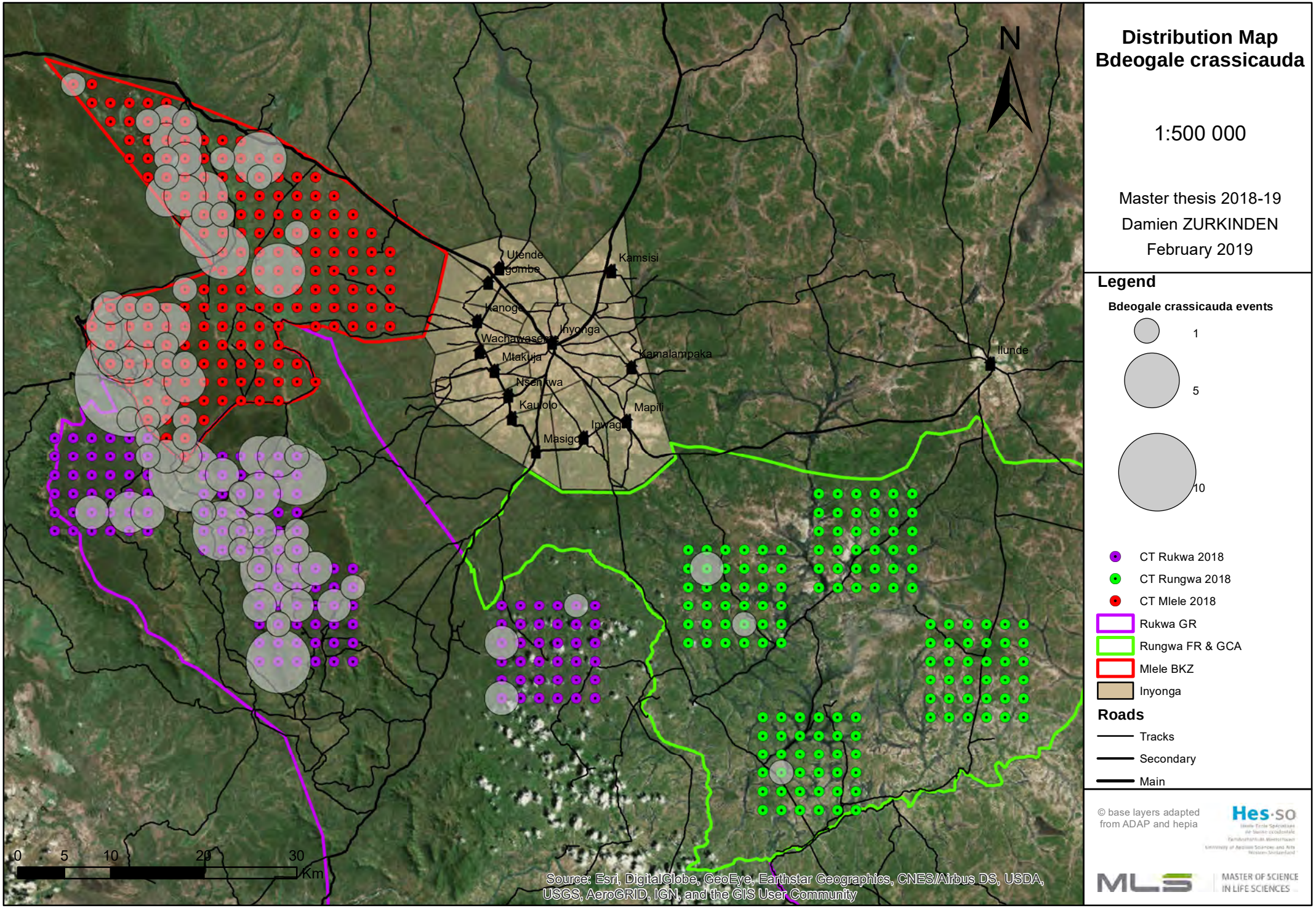
Tracks

Secondary

Main

Hes·so

MLS MASTER OF SCIENCE IN LIFE SCIENCES



Distribution Map Bdeogale crassicauda

1:500 000

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February 2019

Legend

Bdeogale crassicauda events

1
5
10

CT Rukwa 2018
CT Rungwa 2018
CT Mlele 2018
Rukwa GR
Rungwa FR & GCA
Mlele BKZ
Inyonga

Roads

Tracks
Secondary
Main

Hes·so

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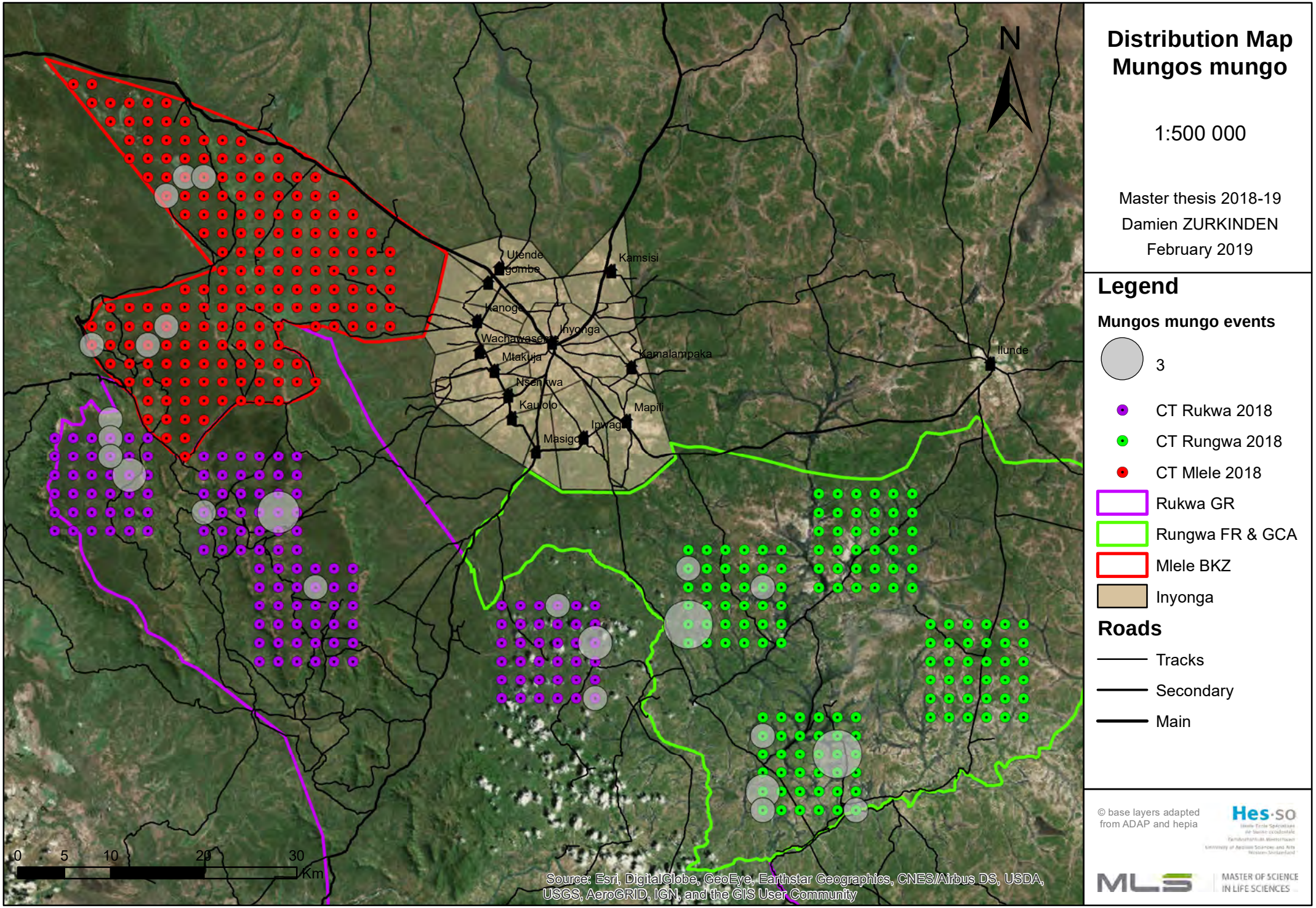

Distribution Map Mungos mungo

1:500 000

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February 2019

Legend

Mungos mungo events

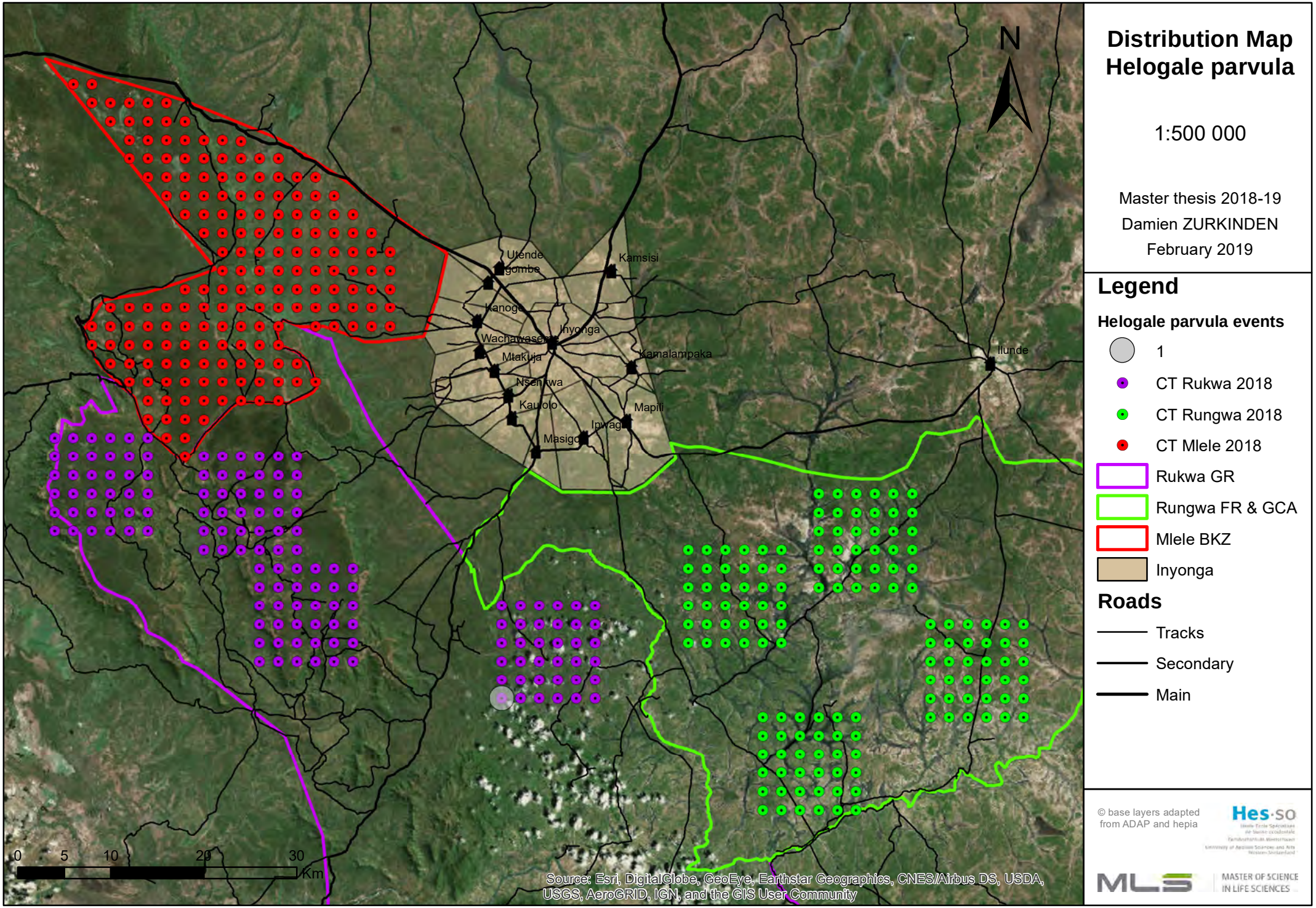
3

CT Rukwa 2018
CT Rungwa 2018
CT Mlele 2018
Rukwa GR
Rungwa FR & GCA
Mlele BKZ
Inyonga

Roads

Tracks
Secondary
Main

Hes·so
MLS MASTER OF SCIENCE IN LIFE SCIENCES



Distribution Map Helogale parvula

1:500 000

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February 2019

Legend

Helogale parvula events

- 1
- CT Rukwa 2018
- CT Rungwa 2018
- CT Mlele 2018
- Rukwa GR
- Rungwa FR & GCA
- Mlele BKZ
- Inyonga

Roads

- Tracks
- Secondary
- Main

Hes·so

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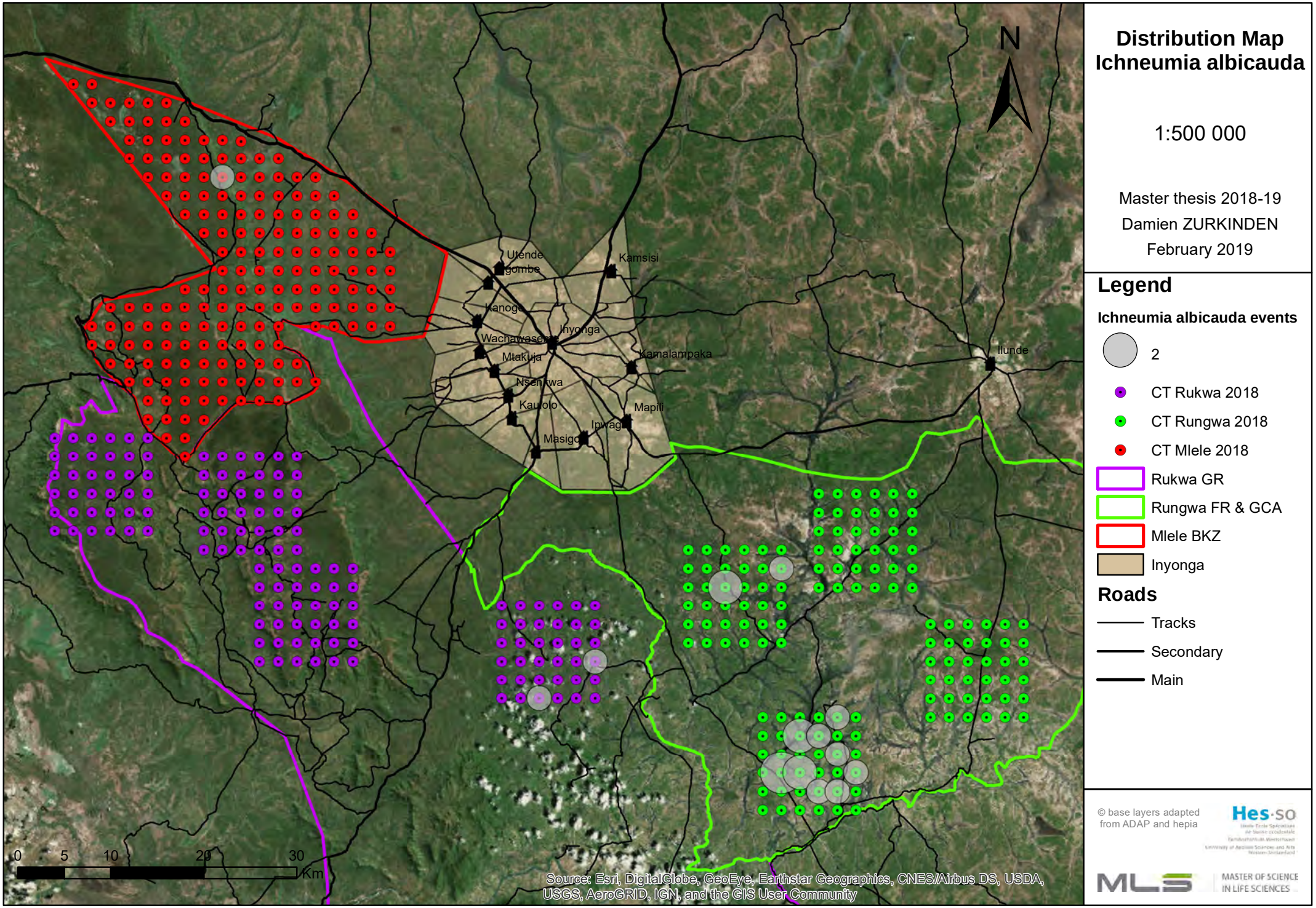

Distribution Map
Ichneumia albicauda

1:500 000

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February 2019

Legend

Ichneumia albicauda events

2

CT Rukwa 2018

CT Rungwa 2018

CT Mlele 2018

Rukwa GR

Rungwa FR & GCA

Mlele BKZ

Inyonga

Roads

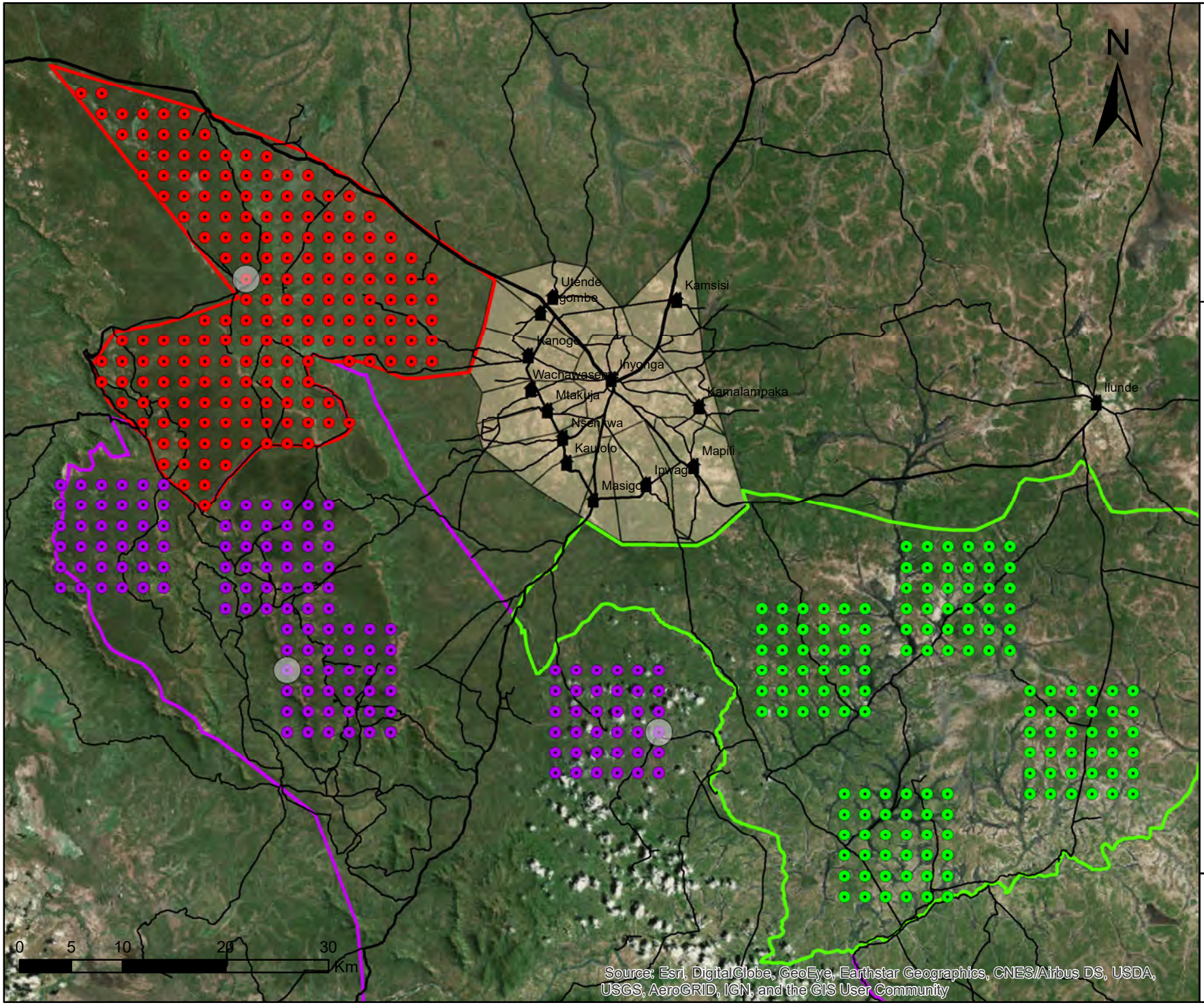
Tracks

Secondary

Main

Hes·so

MLS MASTER OF SCIENCE IN LIFE SCIENCES



Distribution Map Rhynchogale melleri

1:500 000

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Legend

Rhynchogale melleri events

- 1
- CT Rukwa 2018
- CT Rungwa 2018
- CT Mlele 2018
- Rukwa GR
- Rungwa FR & GCA
- Mlele BKZ
- Inyonga

Roads

- Tracks
- Secondary
- Main

Hes·so

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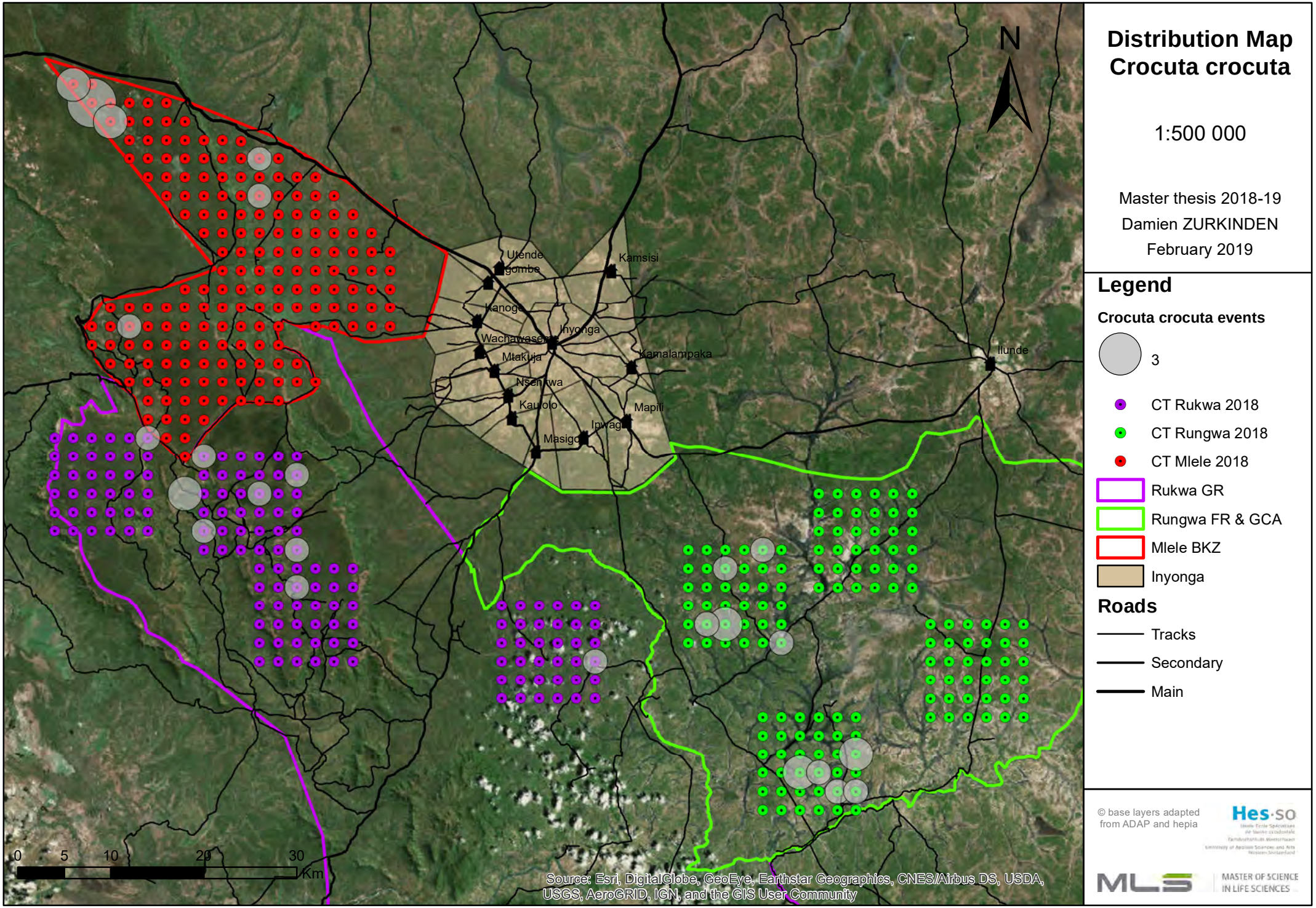

Distribution Map
Crocuta crocuta

1:500 000

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Legend

Crocuta crocuta events

3

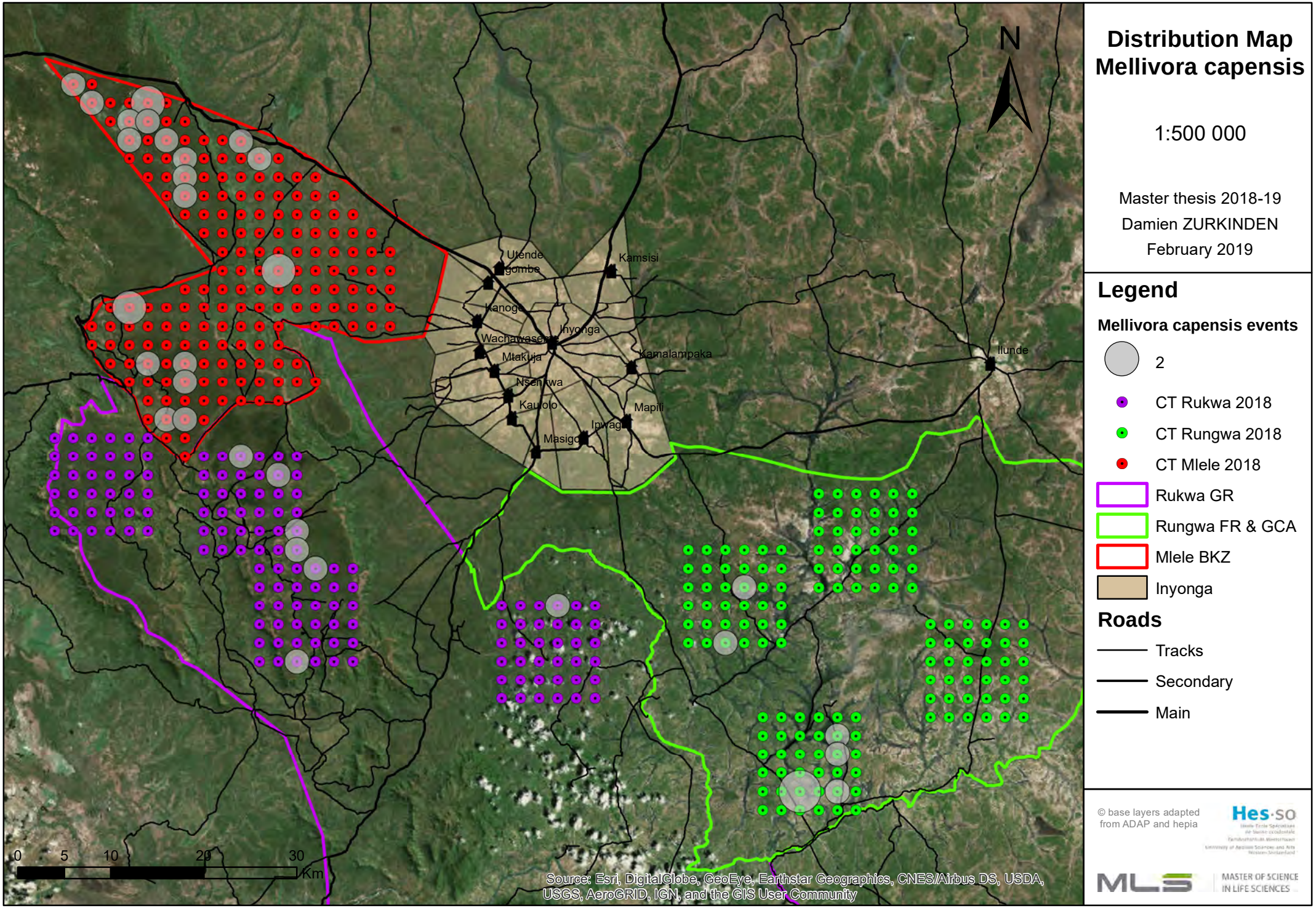
CT Rukwa 2018
CT Rungwa 2018
CT Mlele 2018
Rukwa GR
Rungwa FR & GCA
Mlele BKZ
Inyonga

Roads

Tracks
Secondary
Main

Hes·so

MLS MASTER OF SCIENCE IN LIFE SCIENCES



Distribution Map Mellivora capensis

1:500 000

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February 2019

Legend

Mellivora capensis events

- 2
- CT Rukwa 2018
- CT Rungwa 2018
- CT Mlele 2018
- Rukwa GR
- Rungwa FR & GCA
- Mlele BKZ
- Inyonga

Roads

- Tracks
- Secondary
- Main

Hes·so

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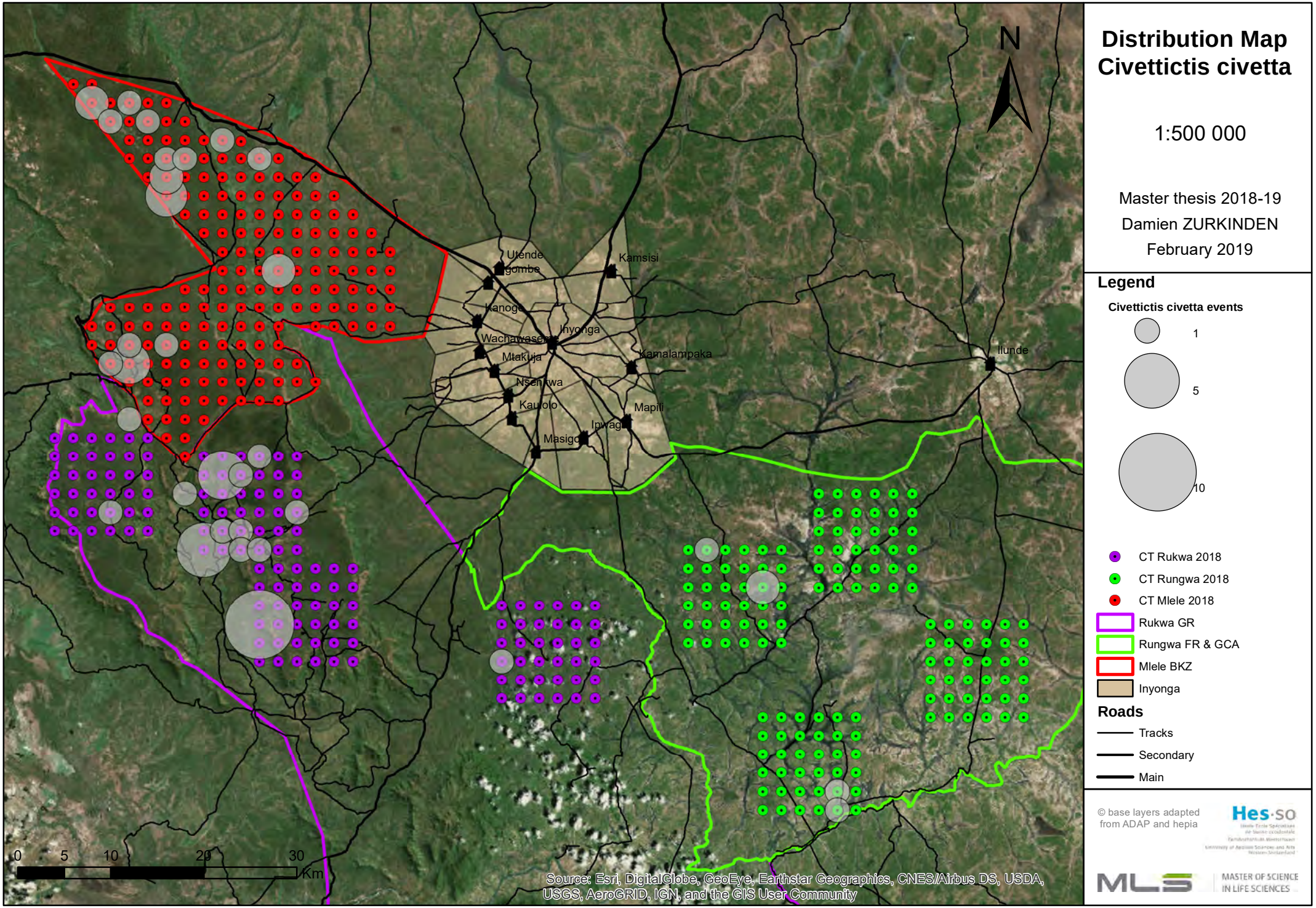

Distribution Map Civettictis civetta

1:500 000

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February 2019

Legend

Civettictis civetta events

1
5
10

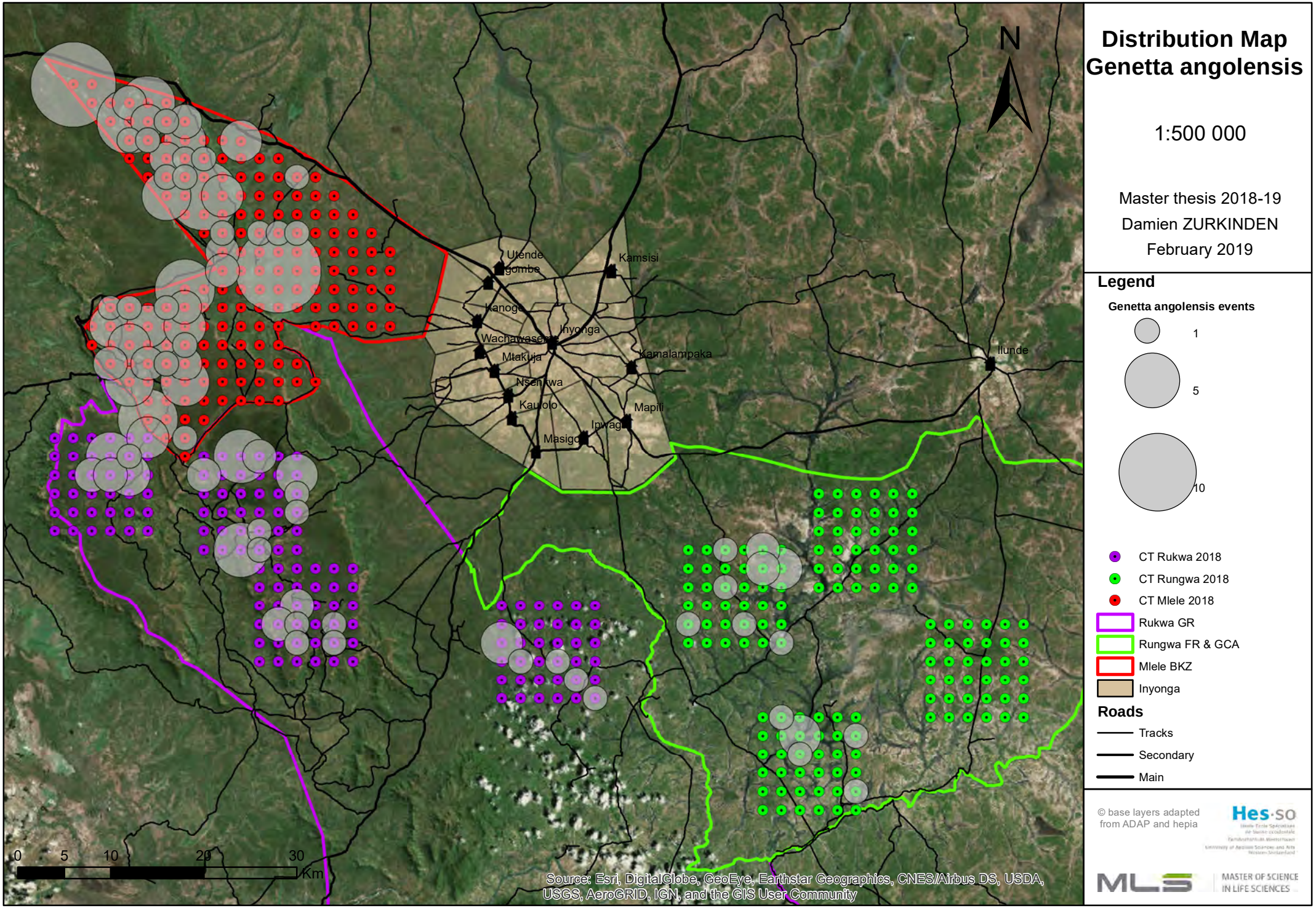
- CT Rukwa 2018
- CT Rungwa 2018
- CT Mlele 2018
- Rukwa GR
- Rungwa FR & GCA
- Mlele BKZ
- Inyonga

Roads

- Tracks
- Secondary
- Main

Hes·so

MLS MASTER OF SCIENCE IN LIFE SCIENCES



Distribution Map Genetta angolensis

1:500 000

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February 2019

Legend

Genetta angolensis events

1
5
10

CT Rukwa 2018
CT Rungwa 2018
CT Mlele 2018
Rukwa GR
Rungwa FR & GCA
Mlele BKZ
Inyonga

Roads

Tracks
Secondary
Main

Hes·so

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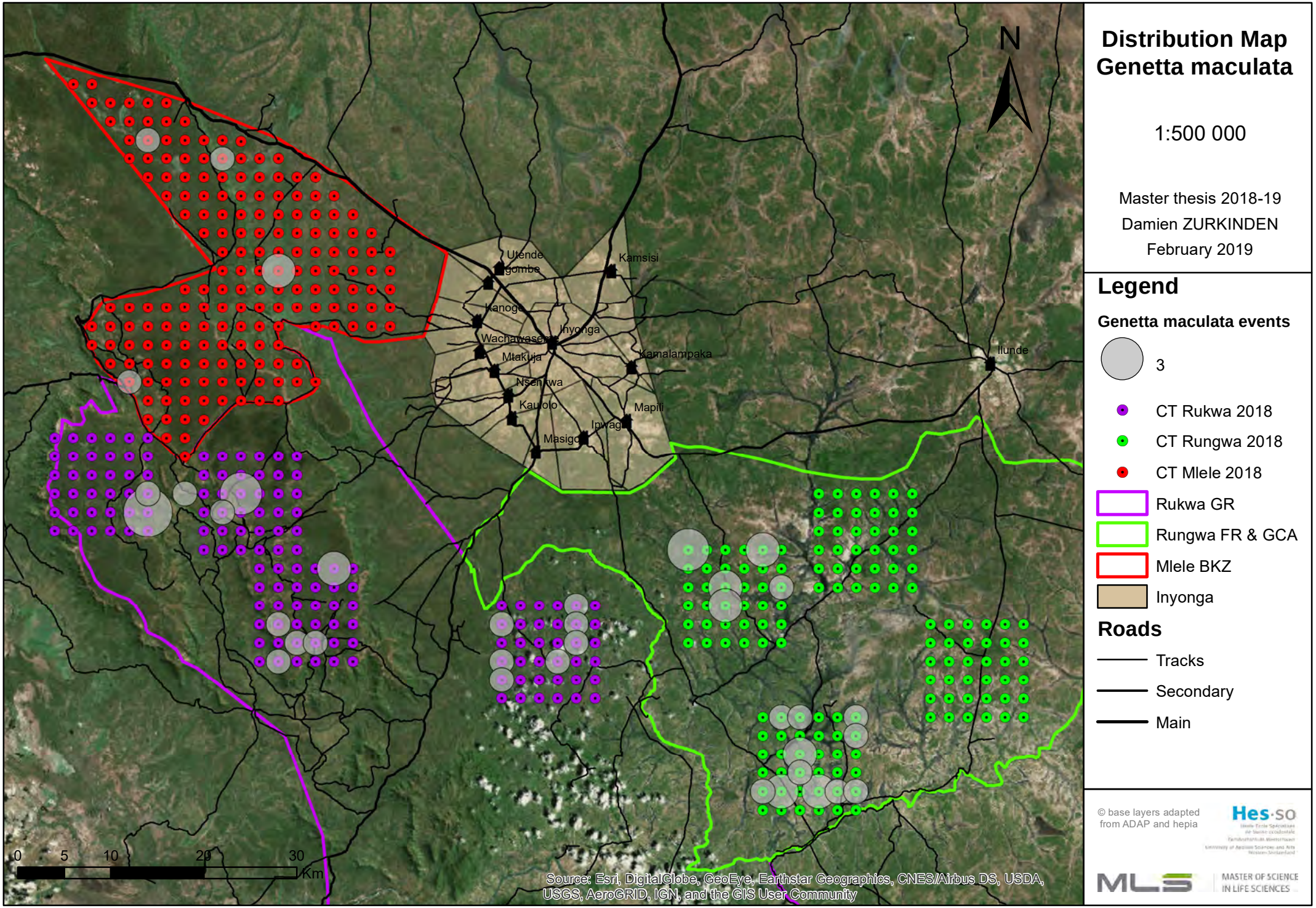

Distribution Map Genetta maculata

1:500 000

Master thesis 2018-19
Damien ZURKINDEN
February 2019

Legend

Genetta maculata events

3

CT Rukwa 2018
CT Rungwa 2018
CT Mlele 2018
Rukwa GR
Rungwa FR & GCA
Mlele BKZ
Inyonga

Roads

Tracks
Secondary
Main

Hes·so

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Appendix XIV: Variance Inflation Factor Results

Source: RStudio Team, 2017

Test multicolinearité (variables numériques)

	Altitude	D_Water	D_Roads	D_Camps	D_Villages	D_PA	D_Poaching	D_Timbering	Grazing
Altitude	1	0.04	-0.08	-0.18	0.23	-0.37	0.20	-0.05	0.09
D_Water	0.04	1	0.05	0.12	-0.16	0.15	0.35	0.10	0.42
D_Roads	-0.08	0.05	1	0.41	-0.19	0.26	-0.03	0.08	0.04
D_Camps	-0.18	0.12	0.41	1	0.01	0.15	-0.03	0.41	-0.52
D_Villages	0.23	-0.16	-0.19	0.01	1	-0.79	-0.34	0.39	0.21
D_PA	-0.37	0.15	0.26	0.15	-0.79	1	0.08	-0.26	0.11
D_Poaching	0.20	0.35	-0.03	-0.03	-0.34	0.08	1	-0.18	-0.06
D_Timbering	-0.05	0.10	0.08	0.41	0.39	-0.26	-0.18	1	-0.39
Grazing	0.09	0.42	0.04	-0.52	0.21	0.11	-0.06	-0.39	1

Test multicolinearité (variables catégorielles)

table(Tanz_occu_wide$Habitat_Type,Tanz_occu_wide$Status)

	4	6
1	1	5
2	4	0
3	108	129
4	29	28
5	2	18

table(Tanz_occu_wide$Governance,Tanz_occu_wide$Status)

	4	6
1	144	0
2	0	72
3	0	108

table(Tanz_occu_wide$Management,Tanz_occu_wide$Status)

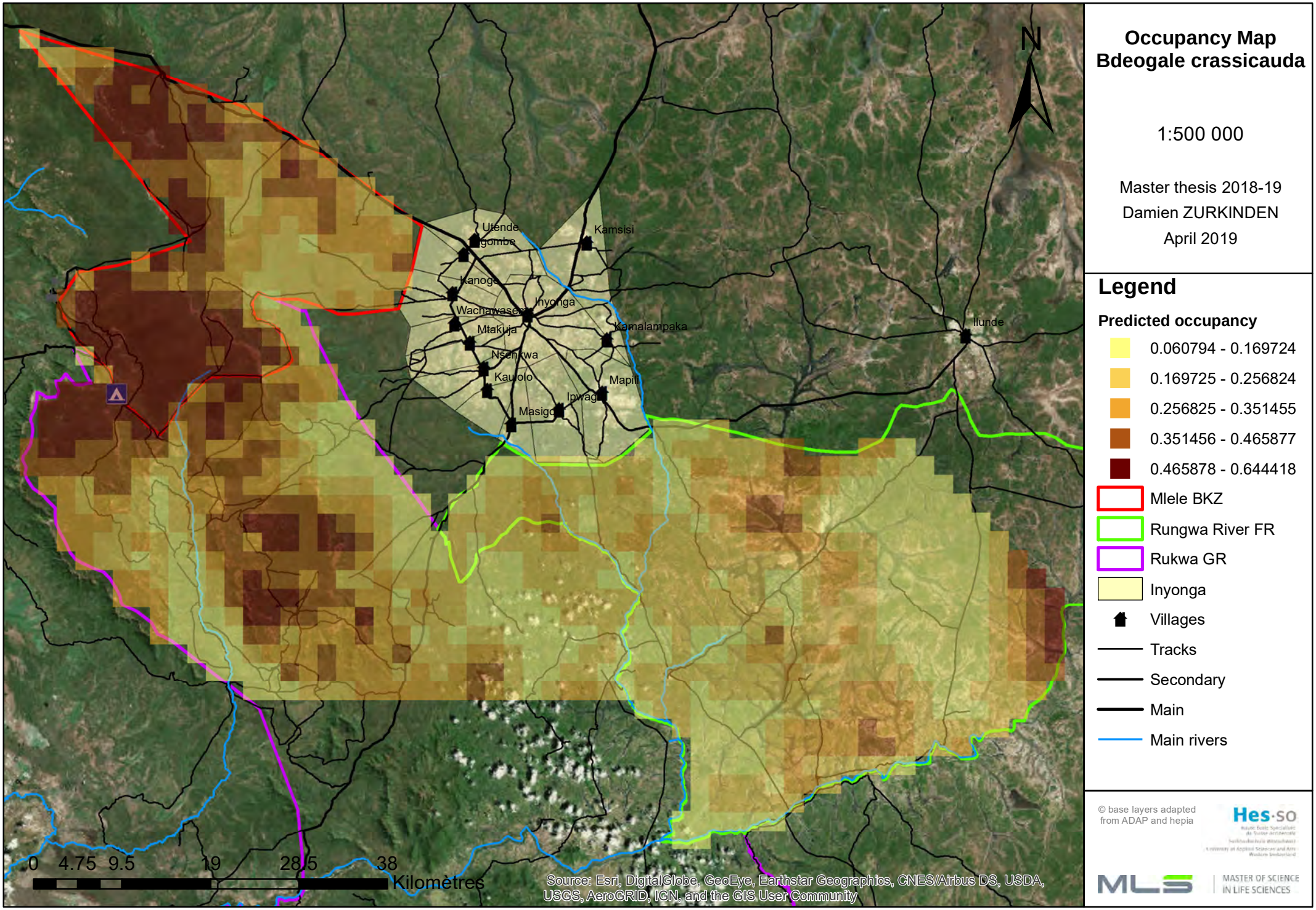
	4	6
50	0	72
72	0	108
74	144	0

table(Tanz_occu_wide$Governance,Tanz_occu_wide$Management)

	50	72	74
1	0	0	144
2	72	0	0
3	0	108	0

Appendix XVII: Occupancy Maps

Source: RStudio Team, 2017 & ESRI, 2017



Occupancy Map
Bdeogale crassicauda

1:500 000

Master thesis 2018-19
Damien ZURKINDEN
April 2019

Legend

Predicted occupancy

- 0.060794 - 0.169724
- 0.169725 - 0.256824
- 0.256825 - 0.351455
- 0.351456 - 0.465877
- 0.465878 - 0.644418
- Mlele BKZ
- Rungwa River FR
- Rukwa GR
- Inyonga
- Villages
- Tracks
- Secondary
- Main
- Main rivers

Hes·so

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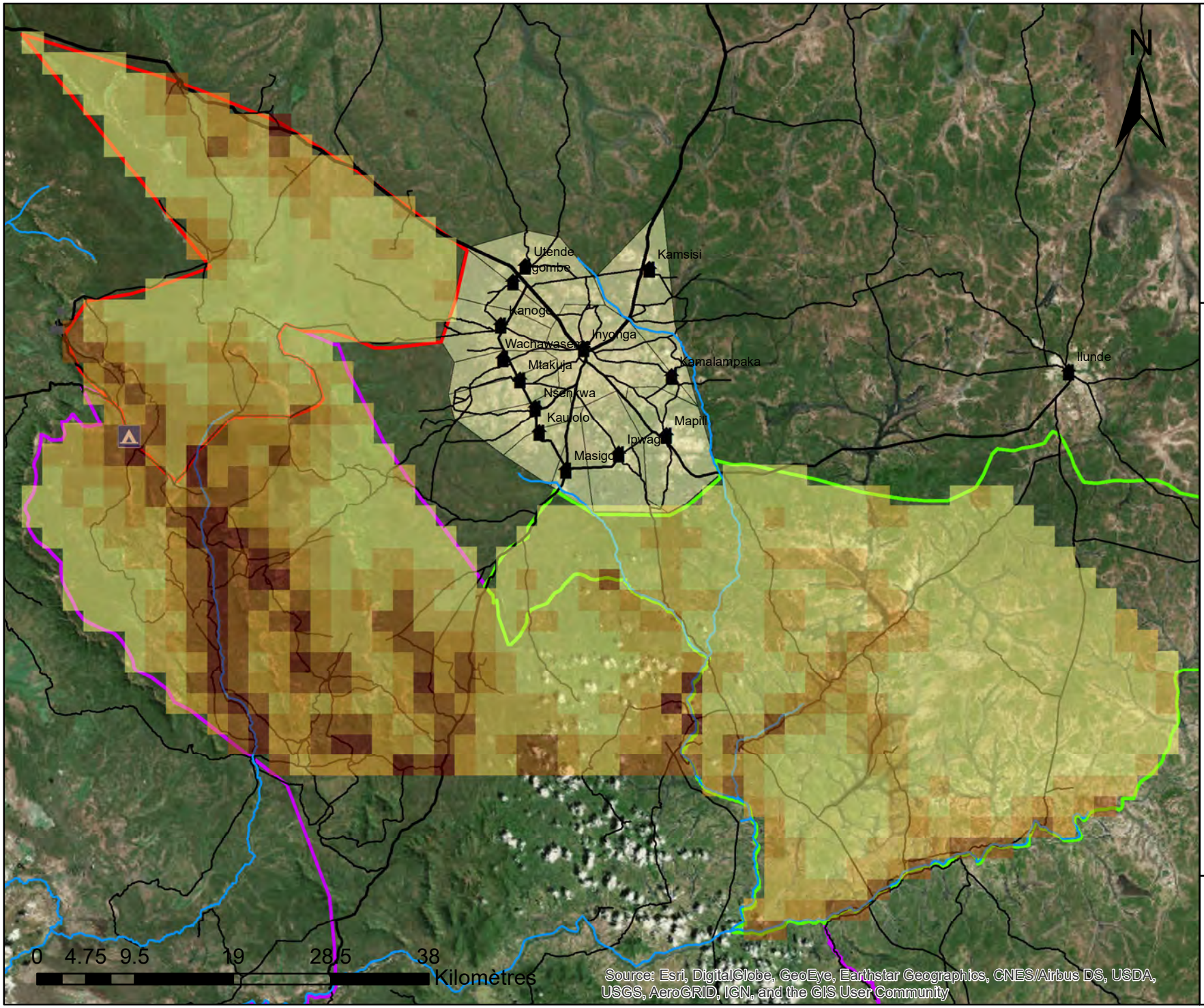

Occupancy Map Civettictis civetta

1:500 000

Master thesis 2018-19
Damien ZURKINDEN
April 2019

Legend

Predicted occupancy

- 0.004225 - 0.081101
- 0.081102 - 0.176818
- 0.176819 - 0.296160
- 0.296161 - 0.472835
- 0.472836 - 0.829171
- Mlele BKZ
- Rungwa River FR
- Rukwa GR
- Inyonga
- Villages
- Tracks
- Secondary
- Main
- Main rivers

Hes·so

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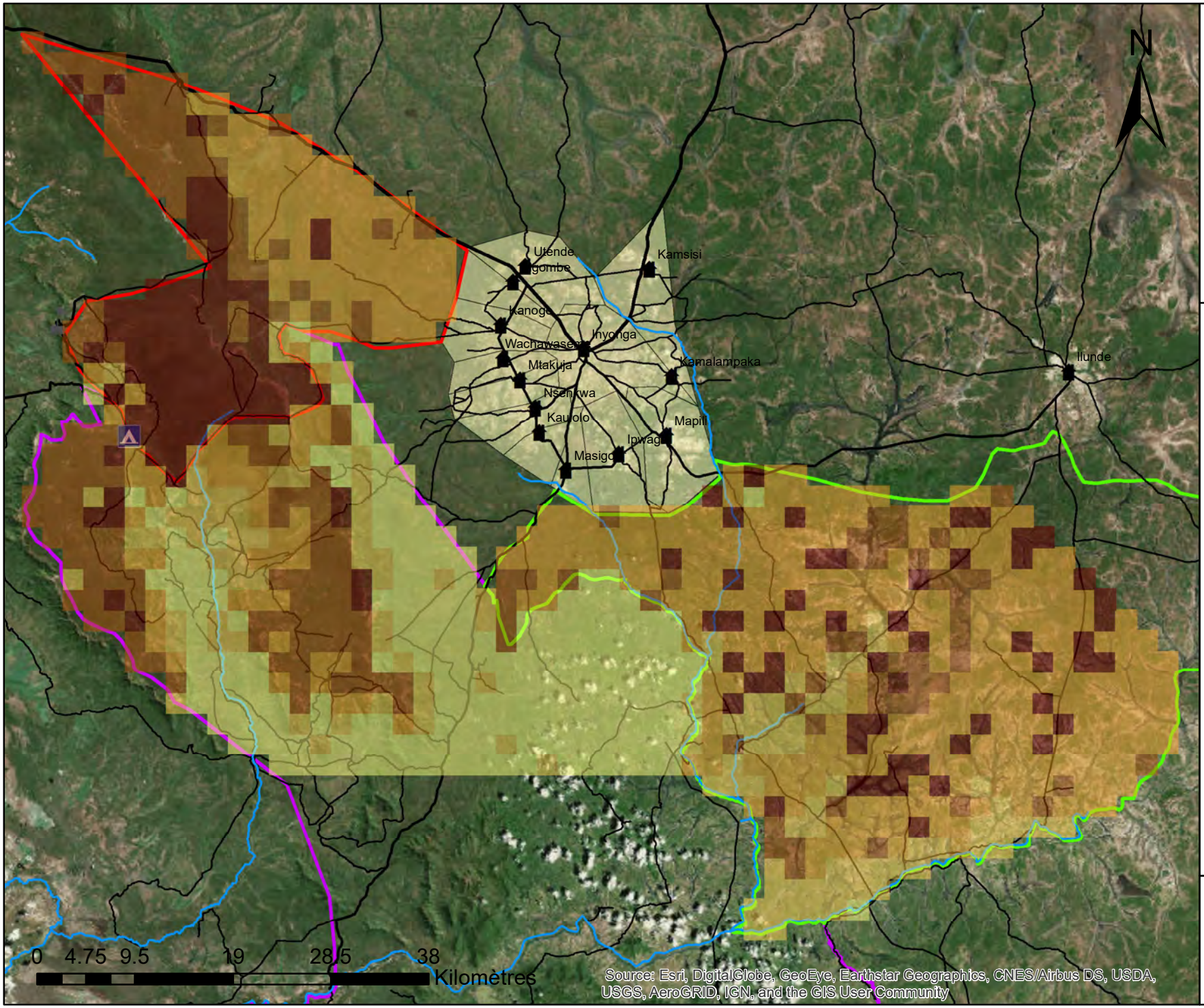


Occupancy Map
Genetta angolensis

1:500 000

Master thesis 2018-19
Damien ZURKINDEN
April 2019

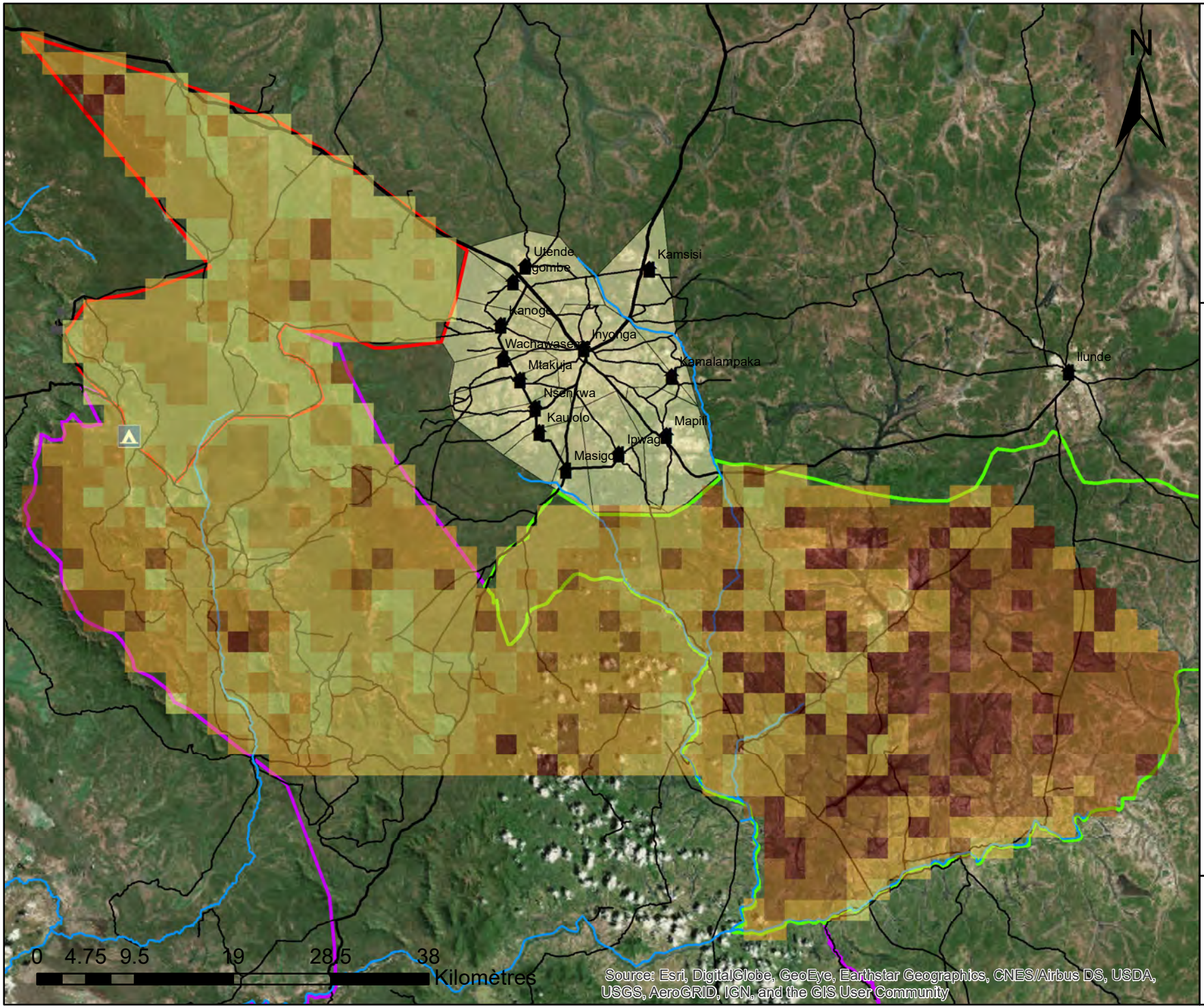
Legend

Predicted occupancy

- 0.073270 - 0.278411
- 0.278412 - 0.387990
- 0.387991 - 0.479186
- 0.479187 - 0.584910
- 0.584911 - 0.822590
- Mlele BKZ
- Rungwa River FR
- Rukwa GR
- Inyonga
- Villages
- Tracks
- Secondary
- Main
- Main rivers

Hes·so

MLS | MASTER OF SCIENCE IN LIFE SCIENCES



Occupancy Map
Genetta maculata

1:500 000

Master thesis 2018-19
Damien ZURKINDEN
April 2019

Legend

Predicted occupancy

- 0.041067 - 0.212695
- 0.212696 - 0.318265
- 0.318266 - 0.437547
- 0.437548 - 0.592119
- 0.592120 - 0.849460
- Mlele BKZ
- Rungwa River FR
- Rukwa GR
- Inyonga
- Villages
- Tracks
- Secondary
- Main
- Main rivers

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Appendix XVI: Katavi-Rukwa Ecosystem Management Plan

Source: MNRT, TANAPA, 2002

PURPOSE AND SIGNIFICANCE

COMMON ECOSYSTEM PROTECTED AREA PURPOSE
To conserve the rift valley together with its natural vegetation
To protect habitat for endangered and threatened species
To protect the habitat of species of exceptional value
To allow for the sustainable utilisation of animals and plants for future generations of Tanzanians and for tourists

KATAVI PURPOSE	RUKWA PURPOSE
To protect:	**To protect :**
A true representation of miombo woodland in Tanzania's national parks	The natural resources of the area and ensure sustainable utilisation
Species which are not found in other places	An area with the second highest concentration of puku in Tanzania
The important wetlands of Katavi and Chada	**To provide**
A core breeding area for animals of the Katavi ecosystem	A high standard of game for tourist trophy hunting
Beautiful scenery, high density of hippos, variety of wetlands and miombo woodland bird species	**To ensure**
An area that is important for wildlife research and studies	Tourist satisfaction and hence raising the economic value of the Rukwa GR
An area with the highest large mammal biomass – second to Ruaha and Serengeti	
Worship sites and other traditional places	
The area as part of a new western tourist circuit	

SUMMARY OF MANAGEMENT OBJECTIVES

KATAVI-RUKWA ECOSYSTEM JOINT MANAGEMENT OBJECTIVES
ADMINISTRATION OBJECTIVES
Ensure that staffing levels, expertise and motivation are adequate
Provide appropriate infrastructure and equipment for effective management of the area
Improve communications at all levels
CONSERVATION OBJECTIVES
Protect the natural resources from illegal use
Ensure that legal use of natural resources is sustainable
Develop and implement a CCS conservation awareness and buffer zone programme
Demarcate boundaries clearly
Develop and implement an appropriate fire management plan
Enhance monitoring and research
VISITOR AND LOCAL COMMUNITY USE OBJECTIVES
Enable local people to benefit from the areas' natural resources by allowing controlled and regulated access
Identify and describe important natural and cultural sites
Regulate and control of use of stock routes and other traffic in the area

KATAVI NP USE OBJECTIVES	RUKWA GR USE OBJECTIVES
Regulate and monitor tourist activities	Regulate and monitor tourist hunting to ensure sustainable quotas, high standards and ethical values
Increase the sources of revenue	Reconcile hunting block boundaries with GR boundaries

RUKWA GAME RESERVE

Category	Objective	Activity
ADMINISTRATION	Ensure that staffing levels, expertise and motivation are adequate	Staffing assessment carried out
		Lobby to secure sufficient staff
		Conduct internal training assessment
		Prepare and implement training programme
		Establish an incentive and reward package for staff
	Provide appropriate infrastructure and equipment for effective management of the area	GMP written and approved
		Detailed development plan written
		Upgrade HQ link road Construct HQ
		Establish joint road unit
		Survey roads as per attached map and carry out PEIA
		Open roads as per attached map
		Upgrade designated roads to all-weather status
		Establish standard facilities for HQ buildings and ranger posts
		Carry out EIA for ranger posts at Lake Rukwa and Lugombe and construct
		Ensure that existing retention scheme is maintained
		Implement MTEF budget
		Secure use of WD prosecutor
		Collaborate with KNP on law enforcement
		Source appropriate vehicles
		Adequate equipment provided to scouts
		Radio network established and maintained
	Improve communications at all levels	CCS strategic action plan
		Establish collaborative mechanisms with stakeholders for conflict resolution
		Internal action plan
		Facilitate preparation of land-use plan for buffer zones

RUKWA GAME RESERVE (Continued)

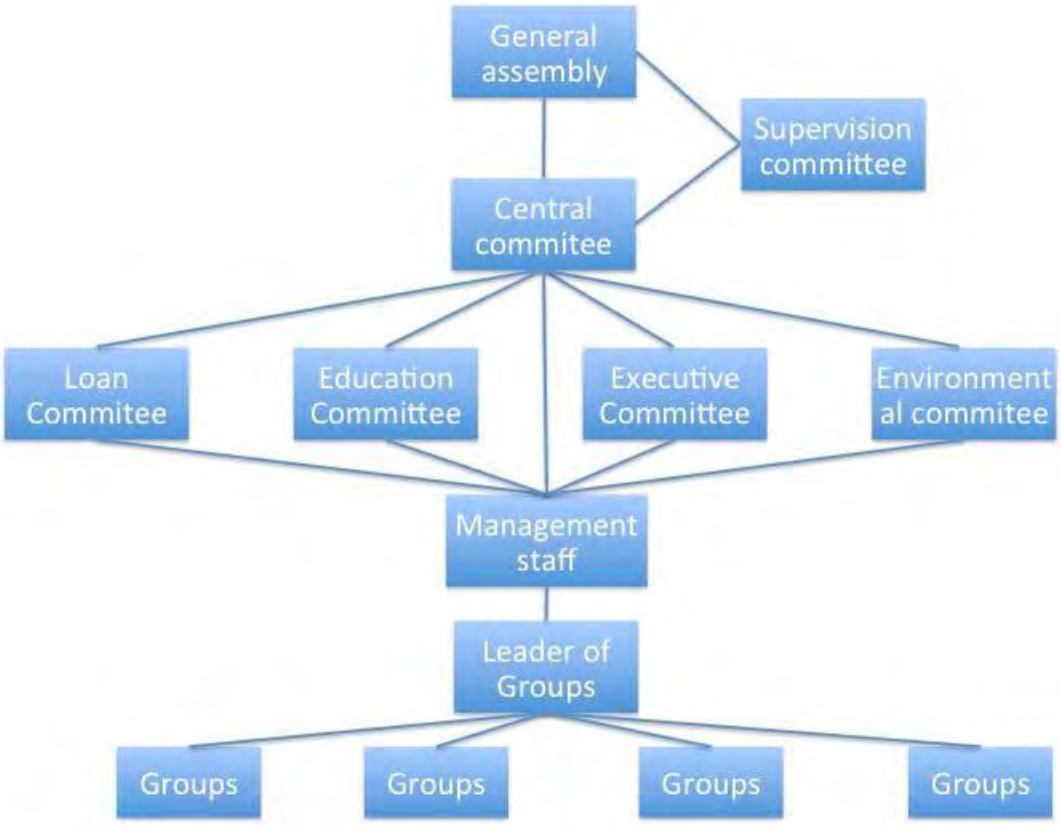
Category	Objective	Activity
CONSERVATION	Protect the natural resources from illegal use	Develop patrol schedule
		Develop a reporting structure and procedure for incidents
		Ensure that response to reported incidents is rapid and effective
		Initiate and maintain an informer network
		Monitor fishing camps along the Lake Rukwa shoreline
		Monitor bee-keeping centres in Kasege CUZ
		Ensure that cattle do not enter the GR unless on an official transit route
		Move the settlement at the Yeye river
	Ensure that legal use of natural resources is sustainable	Finalise strategy for fishing camps – especially locations of camps
		Finalise strategy for bee-keeping activities
		Ensure that relevant data is collected form tourist hunting by scouts – and that this data is processed.
		Carry out EIAs for all developments
	Develop and implement a CCS programme	Define and start capacity building programme for PAC in local communities
		Ensure that detailed records are kept of PAC incidents and response
		Provide direct assistance for PAC when necessary
	Demarcate boundaries clearly	Complete survey
		Open and maintain cutlines
		Ensure that boundaries are communicated to communities
	Develop and implement a fire management plan	Gather available information
		Workshop to develop fire management plan
	Enhance monitoring and research	Complete, prioritise and implement Ecology Department Strategic Action Plan
	Protect water catchments	Support and educate farmers, miners and fishermen to use environmentally friendly methods
		Fire prevention
		Regulate development activities in riverine areas and escarpments
		Support District Authorities to protect catchment areas

RUKWA GAME RESERVE (Continued)

Category	Objective	Activity
USE	Regulate and monitor tourist activities	Assign scouts trained with use of GPS to hunters to monitor hunting and record trophies
		Support marketing of tourism
		Undertake a study of the effect of selective hunting
		Discuss hunting tracks and camp-sites with hunting companies
		Ensure that WD HQ receives information to allow for scientific quota setting
		Demarcate the hunting blocks and ensure that all hunting companies are fully aware of the boundaries
	Enable local people to benefit from the area's natural resources by allowing controlled and regulated access	Identify and describe important natural and cultural sites
		Ensure that guidelines for community use are distributed
		Establish a committee for airing of views from the community
		Facilitate communities to set up resource use associations
	Regulate and control use of stock routes and other traffic in the area	Define legal status of Inyonga-Kibaoni stock-route
		If legal follow same regulations as for other stock routes and enforce

Appendix XVII: Inyonga Beekeepers Association Organization Chart

Source: ADAP, 2012



Appendix XVIII: Tanzania Hunting Concession Allocation for 2013-2018

Source: http://www.africahunting.com/

Tanzania Hunting Concession Allocations For 2013-2018

Hunting Company	Concessions Allocated
African Trophy Hunting Safaris Ltd	Selous GR K5 Selous GR U1
Bartlette Safari Corporation Ltd	Selous GR MT2 Selous GR LL1 Selous GR MHJ2 Selous GR MHJ1
Bushman Hunting Safaris (T)Ltd	Selous GR MHJ3 Maswa GR (N) Rungwa Rungwa GR (E)
Game Frontiers of Tanzania Ltd	Moyowosi/Njingwe GR 2 Rungwa River GCA Ituru Forest/Open Area Ugalla GR (E)
Gerald Pasanisi Safari Corp	Selous GR MB3 Selous GR MT1 Selous GR ML1 Selous GR LU8 Selous GR LL2
Kiboko Hunting Safaris Ltd	Selous GR Block K1 Selous GR Block K2
Kilimanjaro Game Trails Ltd	Burigi GR (W)
Kilombero North Safaris Ltd	Selous GR LU1 – LU2 Kilombero GCA-Mlimba Lake Natron GCA (S)
Luke Samaras Ltd	Selous GR MS1 Selous GR U4 Selous GR LR 1 Selous GR LR 2
Malagarasi Hunting Safaris	Inyonga GCA (E) Selous GR L1
Masailand Hunting Co. Ltd	Selous GR LU4-K3 Selous GR IHI
Miombo Safaris Ltd	Selous GR R3 Rungwa Mpera GR Lukwika/Lumesule GR Msanjesi GR Kipilimbi, Lihonja FR
Mwanauta & Co. Ltd	Rungwa Mwamagembe GR
Northern Hunting Enterprises Ltd	Burigi GR (E) Rungwa Inyonga GR Biharamulo GR Lwafi GR – Nkamba FR
Old Nyika Safaris Ltd	Chunya Lukwati Open Area Piti (W) Open Area Chunya Msami Open Area
Orttelo Business Corp. Ltd	Loliondo GCA
Pori Trackers of Africa	Selous GR LR3 Selous GR M2
Robin Hurt Safaris (T). Ltd	Luganzo GCA Mlele GCA (S) Burko Open Area Rungwa Open Area (S)
Tanzania Game Trackers Safaris Ltd	Ugalla GR (S) Moyowosi-Njigiwe GR1 Maswa Kimali GR Ugalla GR (N) Maswa Mbono GR
Tanzania Wildlife Co. Ltd	Selous GR U3 Selous GR MA 1 Rungwa Ikili GR
Traditional African Safaris Ltd	Irkishbor Selous GR LU3
Grumet Reserves (T) Ltd	Grumeti GR Ikorongo GR
Wengert Windrose Safaris (T) Ltd	Moyowosi GR (S) Lake Natron G.C.A (N-South)
Western Frontiers (T) Ltd	Piti O.A. (E) Selous GR R4 Mtungwe O. A. (Central)
Wild Footprint Ltd	Mlele GCA (N) Kizigo GR (W)
Marera Safari Lodge & Tours (T) Ltd	Muhesi GR (W) Rungwa Rungwa GR (W)
Bunda Safaris Ltd	Mahenge Open Area North Kilwa Open Area North Ruvuma Open Area Mahenge Open Area (South) Mwatisi O.A. (N) – Furua O.A.
Siafu Safaris Ltd	Gombe GCA
SNF Hunting Safaris Ltd	Landanai GCA
Fereck Safaris Ltd	Selous GR N2 Kitwai GCA (SW) Selous R MB4
Eshkesh Safaris Ltd	Masai Open Area (E)
Coastal Sable Safaris Ltd	Masai Open Area (S)
Wembere Hunting Safaris Ltd	Ruhudji/Ifinga Open Area Rungwa North Open Area Handeni GCA Ngaserai Open Area
Maully Tours & Safaris Ltd	Ugalla Niensi Makere FR – Uvinza O.A. Ugalla O.A. (North-East) Ugalla O.A. (North-West)
Mkwawa Hunting Safaris (T) Ltd	Selous GR R1 Selous GR M1 Chunya Open Area (E) Selous GR K4
Green Leaf Ltd	Lake Rukwa GCA Selous GR U2
Giant Hunting Club Ltd	Kilwa O.A. (South)
Mwatisi Safaris Ltd	Msima GCA (W) Rungwa-Mzombe Open Area Kitwai GCA (SE)
African Buffalo Safaris Trackers Ltd	Kizigo GR (E) - 2 Kigosi GR (S) Mto wa mbu GCA
Melami Hunting Safaris Ltd	Simanjiro Kitiangare GCA Muhuwesi GCA
EBN Hunting Safaris Ltd	Kizigo GR (E) – 1
Tanza Guides Ltd	Kitwai GCA (N)
Said Kawawa Hunting Safaris Ltd	Mwatisi O.A. (S) Ibanda Rumanyika GR
Safari Club (T) Ltd	Kilwa O.A. (S) – Mbwemkuru Kilwa O.A. (S) – Nakiu
Tandala Hunting Safaris Ltd	Mwambesi GCA Inyonga GCA (C) Msima GCA (E)
Tanganyika Game Fishing & Photographic Safaris Ltd	Selous GR LU5
Tanganyika Wildlife Safari Corporation	Selous GR LU6 Selous GR MB2 Selous GR MB1 Selous GR LU7 Selous GR N1
Tanzania Bundu Safaris Ltd	Mkungunero GR Lolkisale GCA Masai OA (W)
HSK Safaris Co. Ltd	Simanjiro GCA (W)
Go Wild Hunting Safaris Ltd	Lunda Mkwambi GCA (N)
East African Trophy Hunter Ltd	Kigois (C)
Z.H. Poppe Ltd	Kigosi GR (E)
Royal Frontiers Of (T) Ltd	Moyowosi GR (N) Inyonga GCA (W) Selous GR R2 Talamai O.A.
Rungwa Game Safaris (T) Ltd	Moyowosi-Njingwe GR 3 Wembere GCA (S)
Safari Royal Holding Ltd	Lukwati GR (N)
Muhesi Safaris Ltd	Muhesi GR (E) Monduli Juu Open Area
Palahala Safaris & Hunting Ltd	Kizigo GR (C) Wembere Open Area (Centra 2)
Out of Africa Co. Ltd	Kilombero GCA (S)-B/Ulanga
Michel Mantheakis Lake Safaris Ltd	Natron GCA (South-West) Lukwati GR (S)
Green Miles Co. Ltd	Selous GR MK1 Lake Natron GCA (North)

Appendix XIX: Logging Allowable Cuts 2014-2019 for Rungwa FR and Mlele FR

Source: TFS, 2014

Rungwa

Table 3: Annual allowable cut

Total Area (ha)	Harvestable area (ha)	Total Volume (m3)/ha	Harvestable timber	Remaining Volume as of April 2014	ANNUAL ALLOWABLE CUT 2014/2015-2018/2019				
			Species	V (m3)	2014/2015	2015/2016	2016/2017	2017/2018	2018/2019
401,463	361,316	46	*Brachystegia boehmii*	268,714.00	53,742.80	53,742.80	53,742.80	53,742.80	53,742.80
			Julbernardia globiflora	49,638.00	9,927.60	9,927.60	9,927.60	9,927.60	9,927.60
			Brachystegia spiciformis	167,073.37	33,414.67	33,414.67	33,414.67	33,414.67	33,414.67
			Pericopsis angolensis	54,974.00	10,994.80	10,994.80	10,994.80	10,994.80	10,994.80
			Pterocarpus tintorious	106,519.00	21,303.80	21,303.80	21,303.80	21,303.80	21,303.80
			Selerocarya birrea	112,744.00	22,548.80	22,548.80	22,548.80	22,548.80	22,548.80
Total				**759,662.37**	**151,932.47**	**151,932.47**	**151,932.47**	**151,932.47**	**151,932.47**

Mlele

Table 3: Allowable cut

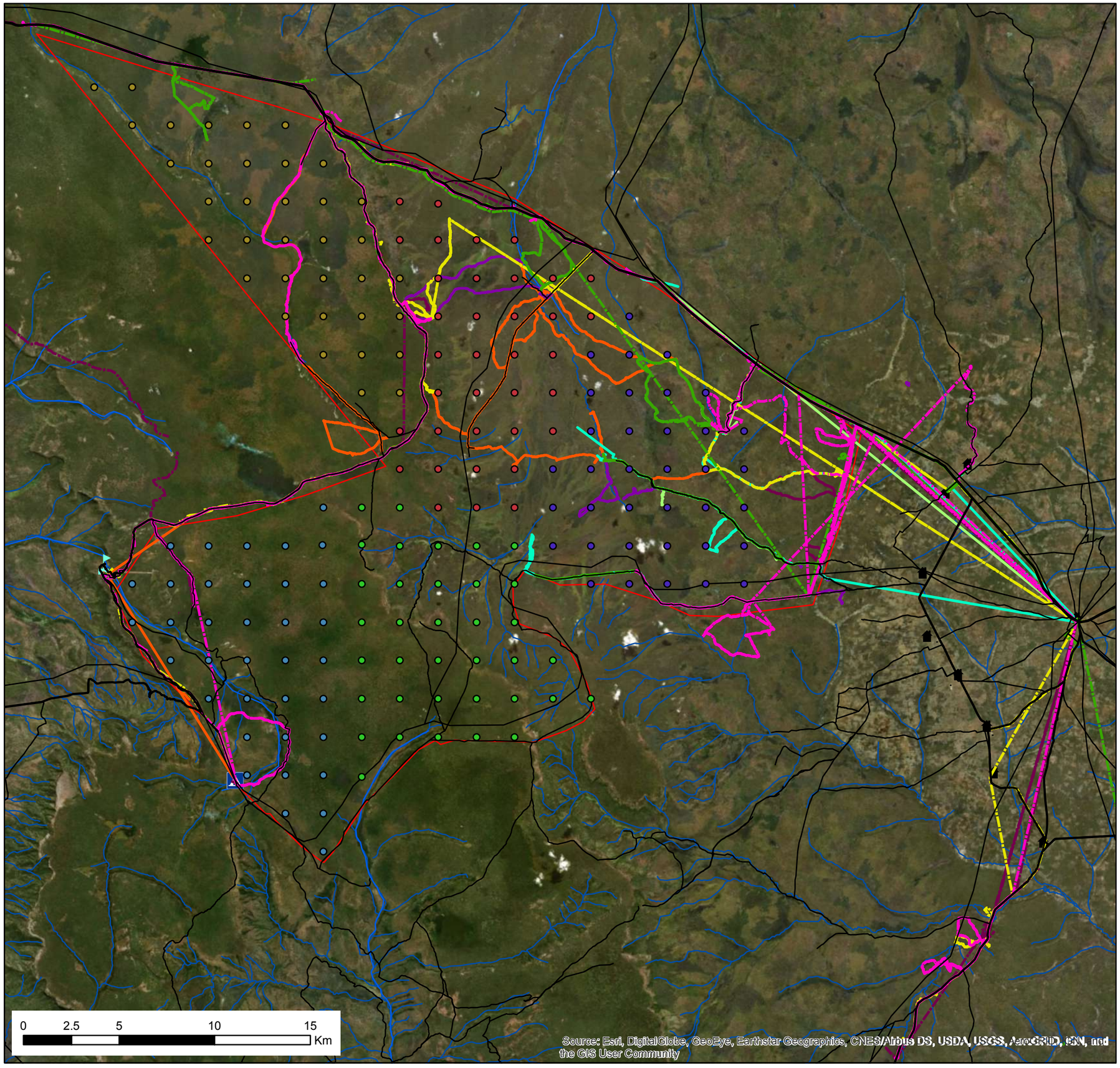
Total Area (ha)	Harvestable area (ha)	Total Volume (m3)/ha	Harvestable timber	Remaining Volume as of April 2014	ANNUAL ALLOWABLE CUT 2014/2015-2018/2019				
			Species	V (m3)	2014/2015	2015/2016	2016/2017	2017/2018	2018/2019
519,295	467365.5	56	*Brachystegia boehmii*	1,189,940	237,988.00	237,988.00	237,988.00	237,988.00	237,988.00
			Brachystegia spiciformis	549,336	109,867.25	109,867.25	109,867.25	109,867.25	109,867.25
			Pterocarpus angolensis	164,996	32,999.20	32,999.20	32,999.20	32,999.20	32,999.20
			Pseudolachynostylis maprouneifolia	47,584	9,516.80	9,516.80	9,516.80	9,516.80	9,516.80
			Julbernardia globiflora	434,921	86,984.20	86,984.20	86,984.20	86,984.20	86,984.20
			Isorberlinia tomentosa	427,203	85,440.60	85,440.60	85,440.60	85,440.60	85,440.60
			Pericopsis angolensis	122,372	24,474.40	24,474.40	24,474.40	24,474.40	24,474.40
			Albizia antunesiana	32,241	6,448.22	6,448.22	6,448.22	6,448.22	6,448.22
			Pterocarpus tintorious	167,049	33,409.80	33,409.80	33,409.80	33,409.80	33,409.80
			Parinari curatellifolia	34,020	6,804.00	6,804.00	6,804.00	6,804.00	6,804.00
			Brachystegia bussei	102,229	20,445.80	20,445.80	20,445.80	20,445.80	20,445.80
			Afzelia quanzensis	132,379	26,475.79	26,475.79	26,475.79	26,475.79	26,475.79
			Swartzia madagascariensis	61,326	12,265.20	12,265.20	12,265.20	12,265.20	12,265.20
			Borassus aethiopium	47,584	9,516.80	9,516.80	9,516.80	9,516.80	9,516.80
			Diospyros mespiliformis	89,243	17,848.60	17,848.60	17,848.60	17,848.60	17,848.60

Appendix XX: Mlele BKZ Patrols Map

Source: Buffard, 2018

Key determinant of the species richness, distribution and abundancy of medium and large mammals in a dry forest ecosystem: environmental or anthropogenic factors?

Appendix 10: Patrols map



Legend

- TZA_roads
- Main rivers
- March 2018
- 22-28 Feb 2018
- 9-14 Feb 2018
- 20-30 Jan 2018
- 21-27 Nov 2017
- 9-10 Nov 2017
- 5-8 Oct 2017
- 8-15 Aug 2017
- Mlele BKZ

Quadrat

- M1
- M2
- M3
- M4
- M5

Source : SITG

Author : Buffard Fabrice. Août 2018

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Appendix XXI: Hunting Quotas for the 2014/2015 & 2015/2016 Period

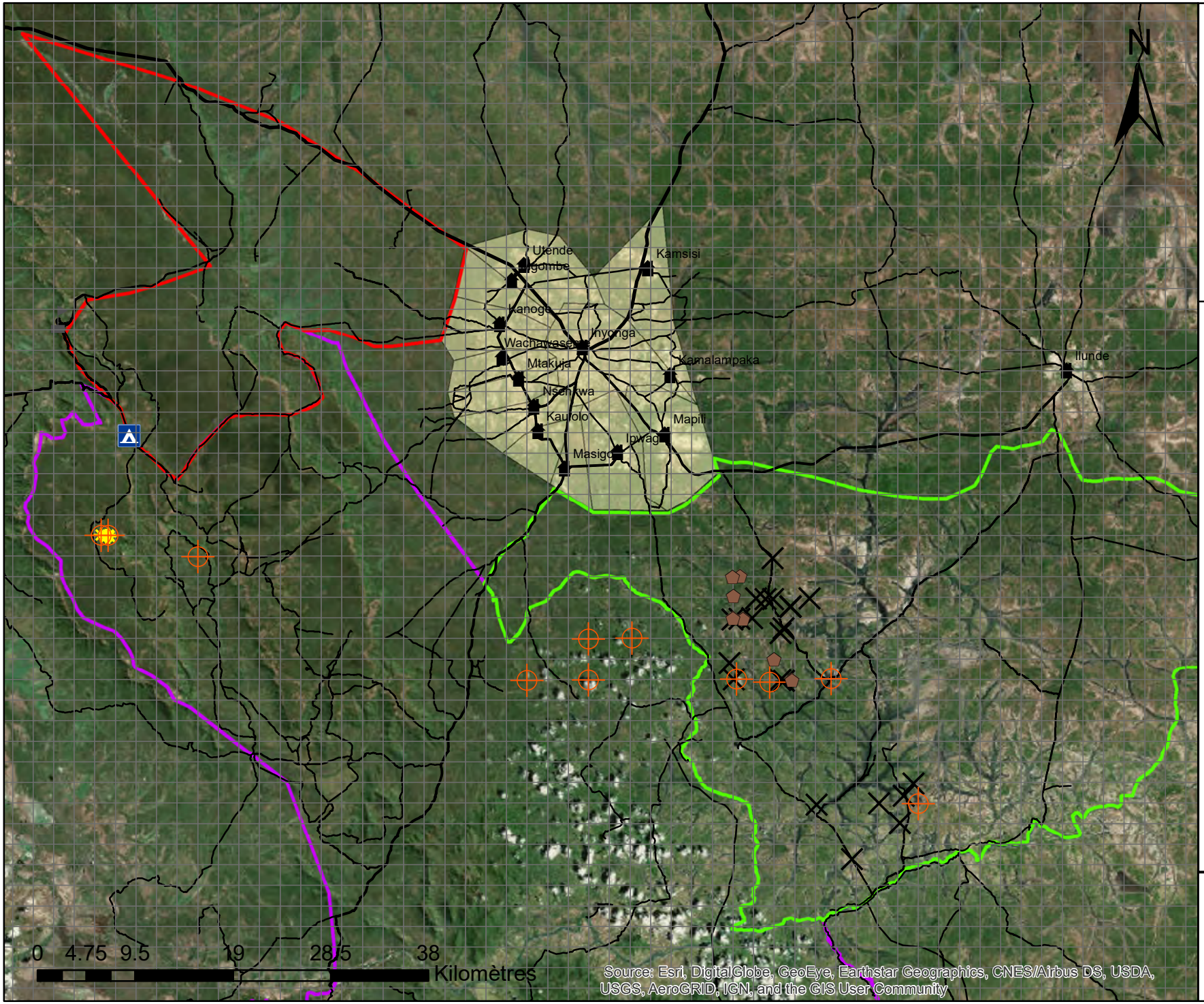
Source: Stampfli, 2016

		Hunting Blocks		
English Name	Scientific Name	Mlele South	Rungwa River	Lake Rukwa
Baboon Yellow	*Papio anubis*	4	3	5
Baboon Olive	*Papio cynocephalus*			
Buffalo African	*Syncerus caffer*	12	14	20
Bushbuck Chobe	*Tragelaphus scriptus omans*	2	3	4
Bushbuck Masai	*Tragelaphus scriptus delameri*			
Bushpig	*Potamocherus larvatus*	2	2	4
Caracal	*Caracal caracal*	0	0	0
Civet African	*Civettictis civetta*	0	1	2
Crocodile Nile	*Crocodilus niloticus*	0	6	4
Dikdik Kirk's	*Madoqua kirkii*	0	4	0
Duiker Abbott's	*Cephalophas spadix*	0	0	0
Dukier Common	*Sylvicapra grimma*	4	3	2
Duiker Natal red	*Cephalophas natalensis*			
Eland Livinstones	*Tragelaphus oryx livingstoni*	2	2	2
Eland Paterson's	*Tragelaphus oryx pattersonius*			
Elephant African	*Loxodonta africana*	0	0	0
Fox Bat-eared	*Otocyon megalotis*	0	0	0
Gazelle Grant's	*Nanger granti granti*	0	0	0
Gazelle Robert's	*Nanger granti robertsi*	0	0	0
Gazelle Thomson's	*Eudorcas thomsonii*	0	0	0
Genet Cap	*genetta tigrina*	2	0	2
Genet Common	*Genetta genetta*			
Generuk	*Litocranius walleri*	0	0	0
Grysbock Sharpe's	*Raphicerus sharpei*	0	2	2
Hare Scrub	*Lepus capensis*	0	0	0
Hare Cape	*Lepus saxtilis*			
Hartebeest Coke's	*Alcelaphus buselaphus cokii*	6	8	12
Hartebeest Lichteinstein's	*Alcelaphus buselaphus lichtensteinii*			
Hippopotamus	*Hippopotamus amphibius*	0	7	5
Hyaena Spotted	*Crocuta crocuta*	1	4	5
Hyaena Striped	*Hyaena hyaena*			
Impala East African	*Aepyceros melampus rendili*	0	10	10
Impala Southern	*Aepyceros melampus melampus*			
Jackal Common	*Canis aureus*	2	2	2
Jackal Side striped	*Canis adustus*			
Jackal Silver backed	*Canis mesomelas*			
Klipspringer	*Oreotragus oreotragus*	2	1	2
Kudu Great	*Tragelophus strepiceros*	1	7	4
Kudu Lesser	*Tragelophus imberbis*	0	0	0
Leopard	*Panthera pardus*	2	4	5
Lion	*Panthera leo*	2	4	4

Mongoose Banded	*Mungos mungo*	0	0	0
Mongoose White tailed	*Ichneumia albicauda*			
Monkey Blue	*Cercopithecus mitis*	0	0	2
Monkey Vervet	*Chlorocebus pygerythrus*			
Oribi Common	*Ourebia ourebi*	0	4	0
Oryx Fringed-eard	*Oryx beisa*	0	0	0
Ostrich	*Struthioformes camelopardalus*	0	0	0
Porcupine Crested	*Hystrix cristata*	0	0	2
Puku	*Kobus vardonii*	0	0	5
Python Rock	*Pythin sebae*	0	0	0
Ratel	*Mellivora capensis*	2	1	0
Reedbuck Bohor	*Redunca redunca*	4	4	4
Reedbuck Mountain	*Redunca fulvorufula*			
Reedbuck Southern	*Redunca arundinum*			
Roan Antelope	*Hippotragus equinus*	2	4	2
Sable Antelope Roosevelt	*Hippotragus niger roosevelti*	3	4	4
Sable Antelope Common	*Hippotragus niger kirkii*			
Serval	*Leptailurus serval*	1	1	2
Sitatunga East African	*Tragelaphus spekii*	0	0	0
Steinbuck	*Raphicerus campestris*	0	1	0
Suni	*Neotragus moschatus*	0	0	0
Topi	*Damaliscus lunatus*	2	8	0
Warthog	*Phactocherus africanus*	4	4	5
Waterbuck Common	*Kobus ellipstprymnus ellipstrymnus*	1	4	5
Waterbuck Defassa	*Kobus ellipstprymnus defassa*			
Wildcat	*Felis sylvestris*	1	1	0
Wilderbeest Estern	*Cannochaetes taurinus albojubatus*	0	0	0
Wilderbeest Western	*Cannochaetes taurinus johnstoni*			
Wilderbeest Nyasa	*Cannochaetes taurinus mearnsi*			
Zebra Burchell's	*Equus quagga bruchelli*	6	4	8
Zorilla	*Ictonyx striatus*	2	0	0
Dove		10	30	10
Duck		20	20	10
Francolin		20	30	10
Geese		10	20	10
Guineafowl		30	20	10
Pigeon		0	0	10
Sandgrouse		0	30	10
Spurfowl		0	0	10
Total Mammal		72	127	135
Total Bird		90	150	80
Total		162	277	215

Appendix XXII: Illegal Activites Map

Source: ESRI, 2017



Illegal activities detected in 2018 for Rukwa GR & Rungwa FR/GCA

1:500 000

Master thesis 2018-19
Damien ZURKINDEN
February 2019

Legende

- Timbering
- Poaching
- Grazing
- Mining
- 2x2km Cells
- Rukwa GR
- Rungwa River FR
- Mlele BKZ
- Inyonga
- Villages
- ADAP Camp
- Headquarter
- Tracks
- Secondary
- Main

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