IDENTIFYING THE SPATIO-TEMPORAL DISTRIBUTION AND DRIVERS OF HUMAN-CARNIVORE CONFLICT IN EPUPA AND OKANGUATI CONSERVANCIES, KUNENE REGION NAMIBIA.

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Thesis submitted in partial fulfillment of the requirements for the degree of Master of Natural Resources Management at the Namibia University of Science and Technology

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Declaration

I, *Ailla-Tessa Nangula Iiyambula*, hereby declare that the work contained in the thesis entitled: *Identifying the spatio-temporal distribution and drivers of human-carnivore conflict in Epupa and Okanguati Conservancies, Kunene Region Namibia* is my own original work and that I have not previously in its entirety or in part submitted it at any university or higher education institution for the award of a degree.

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Acronyms and abbreviations

CBNRM	Community Based Natural Resources Management
EC	Pupae Conservancy
DEM	Digital Elevation Model
WP	Water points
OC	Okanguati Conservancy
MEFT	Ministry of Environment Forest and Tourism
SCIONA-TCP	Skeleton Coast Iona Trans-Frontier Conservation Park
HWCSRC	Human-Wildlife Conflict Self Reliance Scheme
HWC	Human-Wildlife Conflict
HCC	Human-Carnivore Conflict
IRDNC	Integrated Rural Development for Nature Conservation
NACSO	Namibia Association of CBNRM Support Organisation

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I am forever grateful.

Dedication

This thesis is dedicated to me (Ailla-Tessa N. Iiyambula) for all the years and hard work I have put into my academics since the start of my Natural Resources Management career in 2014.

Abstract

Habitat fragmentation has increased the prospect of human and wildlife encounters consequently resulting in conflict. In an agriculture-focused landscape, conflict occurs when wildlife including carnivores destroy property and prey on livestock. Conservancies in Namibia have monitored natural resources inclusive of Human-Carnivore Conflict (HCC) and analysed the temporal trend of conflict over the years. However, the spatial distribution of livestock predation, including potential anthropogenic and environmental risk factors have not been assessed.

Using binary logistic regression modelling (GLM), selected environmental (EV) and anthropogenic (AV) variables associated with the occurrence of livestock predation in Epupa (EC) and Okanguati (OC) Conservancies by leopard, caracal, hyena (spotted and brown), cheetah and jackal were investigated. The following data were collected; i) livestock predation data for modelling spatial and temporal distribution, ii) household interviews on livestock predation experience, iii) vegetation structure at killing sites and iv) kraal structure assessment.

A total of 425 incidents were reported in EC between 2014-2020 and 523 in OC between 2012-2020 with the highest number of incidents in both conservancies recorded during the wet season. The majority of cases in OC are attributed to cheetah while caracal was responsible for the majority of incidents in EC. Vegetation structure and visibility differed by hunting preferences of the different carnivores. Cheetah hunted in areas with average visibility of 69.5m ± 40.8m, leopard (31.8m ± 29.1m), caracal (49.1m ±18.4m), jackal (68.6m±38.5m) and hyena (50.8m ±17.42m). Leopard killing sites had the lowest tree and shrub density per 50m^2.

Distance to natural and artificial water points is identified as a determinant of livestock predation in both conservancies. The probability of conflict occurrence was higher in proximity to water points. In addition, elevation, distance from houses and fields were also important predictors. The risk of livestock attacks is predicted within the livestock zone, around villages and houses. The structure of kraals that experienced livestock attacks was poor in comparison to kraals that did not experience livestock attacks. The presence of a kraal at some households did not guarantee livestock enclosure at night hence attacks around the house. Furthermore, livestock herding did not prove effective.

Livestock predator conflict is a nationwide problem, therefore the application of modelling as a tool of identifying risk areas to align management and mitigation measures could be useful for natural resources managers. In light of the above results, the study recommends strategic location and distribution of water points inclusive of wildlife areas, and conservancies to enforce overnight livestock kraaling in conflict hotspots. Wild prey and carnivore populations are a crucial component in managing and determining the causes of conflict hence conservancies must conduct regular game counts. In addition, the reintroduction of wildlife in the areas should be considered to foster wild prey population growth.

Keywords: Anthropogenic drivers, Epupa Conservancy, Environmental drivers, GLM, Human-Wildlife Conflict, Human-Carnivore Conflict, Livestock predation, Kraals, Mitigation, and Okanguati Conservancy.

Chapter 1: Introduction

1.1. Human-Wildlife Conflict and History

Human-Wildlife Conflict (HWC) is the hostility resulting in competition between wildlife and people for resources, where the needs and behaviour of either people or wildlife negatively impact the other (Draheim *et al.* 2015, Nyhus 2016). HWC is believed to have existed since the interaction of people and wildlife with evidence older than recorded in history (Hewitt 2004, Tripp *et al.* 2014, Raheer *et al.* 2015, Nyhus 2016, Mayengo *et al.* 2017).

Wildlife damage management strategies and retaliation measures in the ancient world started simply as farmers using nets to capture and kill birds destroying grain yards (Hewitt 2004). Over time, humans have adapted and developed predator avoidance tactics such as effective vigilance, and social adaptations, for example, the formation of small groups for protection (Treves and Palmqvist 2007). Hominins occupying savannas and woodland habitats have expressed behavioural adaptations enabling co-existence with wildlife. The use of stone tool technologies such as fire deterrents, modern weapons has allowed dominion over wildlife species (Treves and Palmqvist 2007).

First records of wildlife conflict management laws and policies were formulated in Scotland in 1424 for Avis damage control (Hewitt 2004, Begier and Kendrot 2015). Continued wildlife damages have given rise to scientific investigations on causes of conflict and exploration of advanced preventative and mitigation measures functioning in the conservation interests of wildlife and improved livelihoods. Nyhus (2016) documented an exponential increase in the world's HWC and co-existence-related scientific studies since 1995.

The HWC phenomenon has been an issue of concern to environmental managers and governments as it jeopardises the sources of livelihoods, biodiversity conservation, and most importantly for conservationists, the population of threatened carnivore species (Rust *et al.* 2016). Humans have innovated and adapted to become the dominant species in the ecological sphere on the planet, nonetheless that did not eradicated conflict. Eradication of HWC is impossible as long as humans and wildlife occur in the same area. Historical timelines and records indicate that the evolution of humans and its innovative techniques to better compete with wildlife for habitat and resources is to the detriment and diminishing of wildlife populations (Nyhus 2016). The constant damage to infrastructure, crops, and livestock losses has led to resentment and negative attitudes towards wildlife conservation (Artelle *et al.*

2016). In response, farmers retaliate with lethal techniques such as poison, shoot, and traps often resulting in the assassination of non-target species (Treves *et al.* 2004, Miller 2015).

The increasing human population, development, land conversions for agriculture are major contributing factors to habitat fragmentation and driving forces of HWC (Madden 2004, Abade *et al.* 2014). The continued fragmentation of wildlife habitats creates a predicament of limited resources compelling carnivores to seek livestock as alternative prey (Miller, Jhala, Jena, *et al.* 2015). The magnitude and severity of damage differ between species; primates raid gardens, large herbivores destroy crop fields, carnivores predate and kill livestock, fear of attack and human deaths, and rodents preying on seeds to as little as a mice chewing a hole in a cereal box (Hewitt 2004, Dickman 2010, Barlow *et al.* 2010, Nyhus 2016). Comparingly, elephants raiding an entire crop field and carnivores preying on one livestock, the damage induced by an elephant carries lasting impacts. Additionally, a strong component of human wildlife conflict and against wildlife arises as wildlife crimes and/or exploitation of wildlife resources such as ivory, scales or other animal products (Abotsi *et al.* 2015). These components of human-wildlife conflict have tremendous impacts on the conservation of wildlife populations pushing vulnerable and endangered towards extinction.

People perceive HWC differently and it is highly dependent on individual perspectives (Hewitt 2004). The phenomenon is however not one way, the interaction yields both negative and positive results. While living with wildlife, opportunities for improved livelihoods arise. In the context of rural conservation, communities utilize natural resources for recreation and tourism, ploughing economic and social benefits. In addition, wildlife diversity stabilizes ecosystems (Nyhus 2016).

1.2. Human-Carnivore Conflict in general

The interaction and conflict between carnivores and humans are manifested by human activities extending to carnivore areas or vice versa, carnivore predation on livestock, and humans retaliating. Large carnivore hostility is globally increasing as a result of the never ending carnivore-livestock conflict and its impacts on communal farmers particularly their source of livelihoods (Miller, Jhala, and Jena 2015, Nyhus 2016).

More than 75% of the world's felid species are in one way or another affected by human-wildlife conflict (Inskip and Zimmermann 2009). Carnivores are at risk of conflict because of large home ranges, habitat fragmentation and diet requirements increasing their chances of encounter with people. Important in an ecosystem, carnivores provide ecosystem stabilizing services such as controlling herbivore populations

(Adrian and Ullas 2003). Specific carnivores are specialized in large, medium and small ungulate hunting; this behaviour and abundance of easy prey permit opportunistic preying on livestock (Adrian and Ullas 2003). The latter has earned carnivores a negative reputation by livestock farmers.

Human Carnivore Conflict (HCC) is worldwide, no area with human and wildlife presence are exempted, it has gone as far as wildlife roaming cities. In China, over 2000 years an estimated 10000 people lost their lives and have been injured by Asian tigers *(Panthera tigris)* inducing retaliation, which led to the eradication of almost the entire tiger population in the region (Nyhus 2016). Further, in Alberta Canada, between 1982 and 1996, wolves (*Canis lupus*) were responsible for the loss of more than 2000 domestic animals. In many of Africa's species-rich regions such as Rwanda, DRC, Malawi and Tanzania, it is believed that conflict is driven by the paucity of resources and anthropogenic ecosystem disturbances whereas Zimbabwe's pastoralists sharing borders with protect areas in Gokwe communal land as any other community bordering national parks, suffer from livestock depredation Pearce 1994, Winter 1997 as cited by (Mayengo *et al.* 2017).

1.3. Human-Carnivore Conflict in Namibia

Namibia has six species of free-ranging large carnivores from the families Canidae, Felidae and Hyaenidae: lion (*Panthera leo*), cheetah (*Acinonyx jubatus*), leopard (*Panthera pardus*), brown hyena (*Hyaena brunnea*), spotted hyena (*Crocuta crocuta*) and wild dog (*Lycaon pictus*) in addition to small carnivores: black-backed jackal (*Canis mesomelas*) and caracal (*Caracal caracal*) (Stuart and Stuart 2015, Naankuse 2018). All have been culprits and victims of HCC on commercial and communal farms. The management of HWC in Namibia is guided by the Revised National Policy on Human-Wildlife Conflict Management 2018-2027 through the Ministry of Environment Forestry and Tourism (MEFT).

With an estimated 3500 commercial farms and about 86 communal conservancies supporting free ranging carnivores, HCC is inevitable (Naankuse 2018, MEFT 2021). Although commercial farms are financially capable of employing carnivore preventative measures such as fencing, conflict persists. According to Naankuse (2018) the inclusion, collaboration and consultation with relevant stakeholders contribute significantly to the management of HCC on commercial farms. In addition, successfully addressing conflict requires the recognition and understanding of its complexity rather than being facile (Rust *et al.* 2016).

Namibia's communal communities manage natural resources through the Community Based Natural Resources Management (CBNRM) programme (Naidoo *et al.* 2011). The CBNRM programme contributes significantly to biodiversity conservation and in turn, communities get benefits such as distribution of meat, income for infrastructure development and employment creation among a few (NACSO 2016). The failure and inability to address HCC could negatively threaten carnivore conservation and jeopardises the potential economic growth of rural communities (Gusset *et al.* 2009). Communal conservancy members are at a disadvantage because wildlife is managed at a large-scale migrating between conservancies, and land-use overlap with wildlife areas defeat fencing as a wildlife management tool. Communal farmers bordering national parks and game farms are exposed to conflict as carnivores escape conservation areas (Thorn *et al.* 2012, Abade *et al.* 2014). HCC, therefore, remains a pertinent issue deserving of solutions because of its adverse effect on livelihoods, and conservation.

MEFT has recognised that HWC is inevitable in the presence of people and wildlife, thus the formulation of the Human-Wildlife Self Reliance Scheme (HWSRS), which offsets farmers for losses by wildlife. Furthermore, to mitigate conflict, farmers are urged to employ husbandry practices such as livestock kraaling, guarding dogs and herding (MET 2018). Other conflict management solutions by MEFT include translocating conflict-causing species, selling and culling individuals of a species identified as a problem-causing animal (Rust *et al.* 2016, MET 2018).

Although these techniques have successfully limited livestock depredation, farmers are still reporting frequent problems with carnivores (NACSO 2018). This is partly the outcome of increasing carnivore populations nationally or could be that the social and ecological root causes of HCC have not been adequately investigated and addressed (Rust *et al.* 2016, NACSO 2018). Addressing conflict requires a good understanding of the geographic location and extent of occurrence (Brown 2011). It is, therefore, a priority to identify HCC hotspots to assist in finding solutions within affected regions.

Predictive modelling of species geographic distribution based on environmental conditions is an important technique in analytical biology. Predation risk modelling reveals information on locations and habitats associated with livestock attacks providing a guide for mitigation interventions. More case studies are needed to illustrate how risk maps can be practically integrated into academic intervention efforts and whether the guidance provided by risk models significantly assist in the reduction of livestock depredation (Miller 2015).

Currently, game guards keep records of geo-referenced data on conflict however they lack the expertise and capacity to further analyse the spatial data and there are currently no known conflict distribution maps that exist using game guard collected data. Conservation support institutions have focused on providing conservancies with annual wildlife audit reports and statistics (Okanguati Conservancy 2020, Epupa Conservancy 2020), neglecting the inclusion of wildlife and conflict distribution maps . Herein HCC refers and focuses on livestock predation.

1.4. Problem statement and significance of the study

Grazing is sparse in the Kunene and as a result, livestock travels long distances in search of pasture exposing them to predation (NACSO 2018), and there are no conflict risk maps to advise communities on grazing avoidance areas. Livestock kraaling has reduced the chances of livestock attacks in Kunene south (Gargallo 2021). However, the use of kraals that are not carnivore-proof provide little to no protection. Kraals in Epupa and Okanguati conservancies are traditionally built and the effectiveness of such structures has not been investigated. The influence of environmental and social risk factors and predation risk modelling of livestock predation is rarely assessed. In most cases, actions to deal with livestock predation have been reactive. According to Miller (2015), predation risk modelling could be widely used as a proactive measure to guide mitigation relating to livestock predation. Given the increase in carnivores in the Kunene region (NACSO 2018), such methods should be utilized to avoid grazing livestock in areas where they are vulnerable to carnivore attacks (Miller, Jhala, and Jena 2015).

The relation between livestock predation, environmental and anthropogenic variables is well researched and established in certain parts of the world. The use of analytical tools by ecologists such as species distribution modelling using Ecological Niche Factor (ENF), MaXent and logistic regression modelling is slowly emerging as a problem-solving tool (Karanth *et al.* 2012, Abade *et al.* 2014, Miller, Jhala, and Jena 2015, Miller, Jhala, Jena, *et al.* 2015, Broekhuis *et al.* 2017). However, studies in Namibia have dominantly focused on cost-benefits analysis, stakeholder relations, importance and involvement in carnivore-livestock conflict management (Jones and Barnes 2006, Rust *et al.* 2016, Rust 2017), community perception, temporal trends of conflict neglecting the spatial component (Brown 2011, Mosimane *et al.* 2014). The focus is shifting from trends as the pertinent issue to investigating possible factors of influence, their geographic location, the association of predictor variables with conflict occurrence and conflict hotspots. A study by Verschueren *et al.* (2020) on human conflict with carnivores in Namibia's northeast conservancies recommends spatial modelling of risk areas to prioritize mitigation efforts.

Namibia's northwest conservancies are amongst the rural communities battling livestock predation with limited scientific interventions hence an ideal predator risk mapping case study contributing to the academic efforts on finding solutions to livestock predator conflict in Namibia. By collaborating with Epupa and Okanguati conservancies, these research findings will not only contribute to Namibia’s scientific findings on livestock predator conflict but, provide the conservancies with information necessary to track the spatial changes and distribution, jointly identify risk areas as an early warning system to advise communities, conservation organizations and government on areas of focus to mitigate conflict and safeguard communities (Verschueren *et al.* 2020) and identify low risks areas that may be compatible with livestock grazing (Beattie *et al.* 2020). In addition, the collaboration with conservancies has involved game guards through training in various research areas and the use of technologies in resources monitoring, efforts that will improve the technical skills of locals in research and data collection.

1.4.1. Objectives and research question

Certain species become habituated to traditional conflict preventative measures giving rise to explore new strategies (MET 2018). Understanding the effect of environmental and anthropogenic variables is valuable in areas where livestock poses threat to local communities and carnivore populations (Abade *et al.* 2014). In this study we address the question: What are the anthropogenic and environmental drivers associated with livestock in Epupa and Okanguati Conservancies? The study focused on five common carnivores associated with livestock predation, namely: hyena, cheetah, leopard, jackal and caracal.

1.4.2. Aims and objectives

The study aims to investigate environmental and anthropogenic drivers of livestock-carnivore conflict to propose proactive strategies to assist with conflict management in Epupa and Okanguati conservancies. Specific objectives include:

1. To map the spatial and temporal distribution of livestock predation by hyena, cheetah, leopard, jackal and caracal in the two conservancies.
2. To determine the effect of anthropogenic variables and environmental variables on livestock predation by hyena, cheetah, leopard, jackal and caracal.
3. To predict and map livestock predation risk areas in the two conservancies.
4. To evaluate the effectiveness of kraals structure to protect livestock from carnivore predation.
5. To propose proactive strategies to reduce livestock predation.

Chapter 2: Literature Review

One of the major global challenges to carnivore conservation is the lack of ability to spatially identify human-carnivore risk sites using appropriate tools and existing data. Now emerging is predation risk modelling identifying conflict hotspots and or potential areas of conflict where mitigation measures could be applied (Miller 2015). Modelling is beneficial in ecology, it assists natural resources managers and locals to manage and minimize multi-predator HCC (Ramesh *et al.* 2020).

A collective study by Miller (2015), revealed that most of the generated conflict hotspots maps were used by livestock farmers and natural resources managers to identify areas of intervention priority of which directed efforts were >90% successful in conflict reduction. The tool is low-effort and cost-efficient using already existing data (Miller 2015). Furthermore, a variety of application and approaches of spatial modelling are commonly used namely; correlation modelling, generalized linear models, logistic regression, spatial association and spatial interpolation (Marucco and McIntire 2010, Behdarvand *et al.* 2014, Miller 2015).

Understanding EVs and AVs associated with livestock predation are crucial in HCC landscapes (Murphy and Macdonald, 2010 as cited by (Abade *et al.* 2014). EVs such as proximity to rivers, low elevation, high rainfall and reduced tree cover has been found key determinants of livestock predation by lion, leopard and spotted hyena in Tanzania's Ruaha National Park (Abade *et al.* 2014), whereas in Kenya depredation of livestock by spotted hyena was associated with increased vegetation cover (Kolowski and Holekamp 2006). Further, a study in Mexico found a positive association between variables such as vegetation cover, the abundance of free-roaming grazers and jaguar livestock predation risk (Zarco-González *et al.* 2013). Understanding conflict causal factors, where it is likely to occur and incorporating traditional knowledge is crucial for wildlife conservation and management of conflict (Karanth *et al.* 2012).

The effects of different landscape features, environmental variation differ between geographic locations and species involved. In Pandamatnga village, Botswana, delayed rainfall events are associated with increased severity of livestock attacks by lions (Robertson *et al.* 2020) and predation risks by Africa lion in Tanzania were higher close to surface water (Beattie *et al.* 2020), whereas in the Himalayan region, livestock killing by leopards was predicted to occur higher in areas of less water (increasing distance from water bodies (Naha *et al.* 2020).

Furthermore, livestock, wild prey and carnivore densities are strong predictors of livestock predation (Miller 2015). Some researchers argue on the correlation between wildlife prey and livestock abundance stating that increased wildlife numbers lead to increased livestock attacks, however, this evidence is arguable in HWC because it is a complex topic that should take into account the distribution and movement of both wild prey and livestock (Miller 2015, Zarco-González *et al.* 2013). Addionaly, the risk of livestock depredation is influenced and/or associated with: distribution of carnivores, livestock, wild prey, environmental factors such as (rainfall, vegetation type and elevation), human infrastructure and the quality of livestock husbandry (Thorn *et al.* 2012, Abade *et al.* 2014, Dhungana *et al.* 2017).

HCC is a multifaced problem that should be addressed inclusive of all possible leading factors. In this study, environmental and anthropogenic drivers of HCC are assessed (Abade *et al.* 2014), using binary logistic regression modelling as prescribed by (Miller, Jhala, and Jena 2015). Logistic regression modelling predicts the probability of the occurrence of an event using identified factors. Additionally, logistic regression indicates which of the variables assessed has the influence and is a predictor of event occurrence (Tolles and Meurer 2016, Beattie *et al.* 2020).

Geographic Information System (GIS) technology has been used to map and explain the distribution of events but it remains a top-down approach that excludes and may be less attractive to unskilled local communities (Cinderby 1999, Ruda *et al.* 2018). According to Rust (2017), to effectively manage conflict, stakeholder participation is crucial as involving the affected creates the potential of finding amicable solutions hence the inclusion of game guards, Geographic Positioning System (GPS) training of para-ecologists for data collection in this study.

Chapter 3: Methodology

3.1. Study area

The study was conducted in two conservancies of the Kunene region, Epupa and Okanguati conservancies, *(Figure 1).* where leopard (*Panthera pardus*), cheetah (*Acinonyx jubatus*), caracal (*Caracal caracal*), brown hyaena (*Hyaena brunnea*), spotted hyaena (*Crocuta crocuta*) and jackal (*Canis mesomelas*) frequently predate livestock.

Epupa Conservancy was gazetted in 2014 covering an extent of 2 912 km² whereas Okanguati Conservancy was gazetted in 2012 covering an area of 1159 km². Epupa Conservancy is home to 2 343 inhabitants while Okanguati Conservancy supports 4 879 inhabitants (NACSO Epupa Conservancy 2021, NACSO Okanguati Conservancy 2021). As a mandate by the MEFT, conservancies are required to monitor natural resources using the Event Books system. Natural resources monitoring includes wildlife observations (sighting and spoor), rare and endangered species and other wildlife species (sighting and spoor), rainfall, human-wildlife conflict, mortality, and poaching. Monitoring is carried out by game guards employed by the conservancy.

The area is home to the Ovahimba, Ovazemba and Ovatjimba people farming with small to large stock such as sheep, goats and cattle in addition to seasonal crop farming (Inman *et al.* 2020). Seasonally nomadic, their movement is highly influenced by water availability for human consumption and fodder availability for livestock. The social and economic welfare in the region is supported by subsistence farming complemented by variable income generated from tourism activities (Shilongo 2020). Rainfall in the area is highly variable and sporadic with records varying from 10 - 100mm annually characterizing the area as one of the driest regions in north-west Namibia coupled with recurrent droughts (Inman *et al.* 2020). EC and OC fall amongst areas that have been heavily hit by drought exacerbating the impacts of human-carnivore conflict on the livelihoods.

The area falls within the Acacia Tree and shrub savanna specified as the western highlands (Coleen and Barbara 2018). The flora is highly dominated by *Colophospermum mopane*, and sparsely *Catophractes alexandrii*. Wildlife such as kudu (*Tragelaphus strepsiceros*), black-faced impala (*Aepyceros melampus petersi*), vervet monkey (*Chlorocebus pygerythrus*), and chacma baboon (*Papio ursinus*) roam freely between conservancies. The landscape is characterized by mountains, valleys, ephemeral rivers and dry streams creating suitable habitats for carnivores. Kunene's tradition of livestock farming has been passed from generation to generation and losing livestock to predators becomes increasingly difficult to find a realistic solution that will benefit both the environment and people (Inman *et al.* 2020).

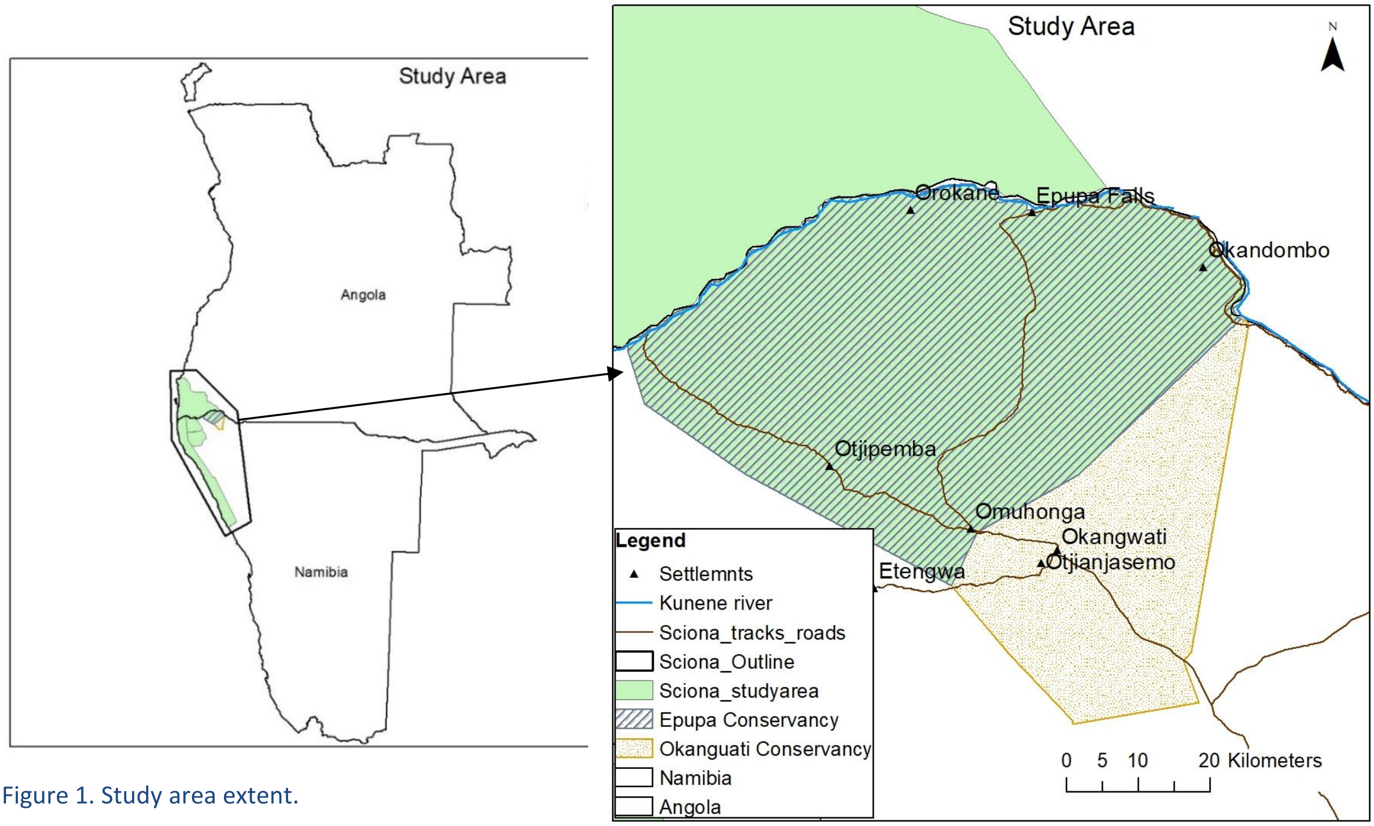


Figure 1. Study area extent.

3.2. Data collection

3.2.1. Event Book Review of livestock predation data and para-ecologists training

This study followed a quantitative research design and analysis method utilizing primary and secondary data from conservancies. Carnivores responsible for most of the conflict in the study area were identified through focused group discussions with communities following the Participatory Rural Appraisal (PRA) technique. Past geo-referenced data on livestock predation was gathered from Event books. Event book review strictly focused on the five identified land carnivores and not inclusive of crocodiles and other emerging conflict causing species such as honey badger, baboons and monkeys.

To establish a reliable, independent conflict reporting and data collection system, a total of four para-ecologists (two per conservancy) were provided with basic GPS training. Para-ecologists were selected from game guards and conservancy personal based on: experience in predator identification and investigating livestock predation in the conservancy, and the ability to read and write. The training entailed handling a GPS device; i.e. recording and georeferencing incidents. Additionally, training included a structured review of the data collection sheet. To avoid the language barrier, data sheets were translated into the local language (Otjiherero) and only information on livestock predation cases reported by victims and the veracity confirmed by a game guard as part of the investigation for offset was recorded (Woodroffe, Lindsey, *et al.* 2005, Abade *et al.* 2014). Livestock predation sites were geo-referenced using an eTrex 10 GARMIN GPS, these represented presence data. There were no known sites of no livestock predation hence points were randomly generated across the landscape of each conservancy in QGIS representing pseudo-absence points for modelling (see *Appendix 15 and Appendix 16* for presence and pseudo-absence livestock predation data).

Using a structured close-ended questionnaire or datasheet, interviews were conducted during an incident investigation. The questionnaire included information on the date and place of incident, livestock demography, livestock husbandry or predator deterrent measures present the day of the incident, the identified responsible carnivore species and the number of livestock killed (Woodroffe *et al.* 2005, Woodroffe *et al.* 2007). Data was collected for a period of nine months between September 2019 to May 2020 and inclusive of all areas accessible to para-ecologists where livestock was lost as a result of predation. For temporal data, we defined the wet season from November to April and the dry season from May to October of each year.

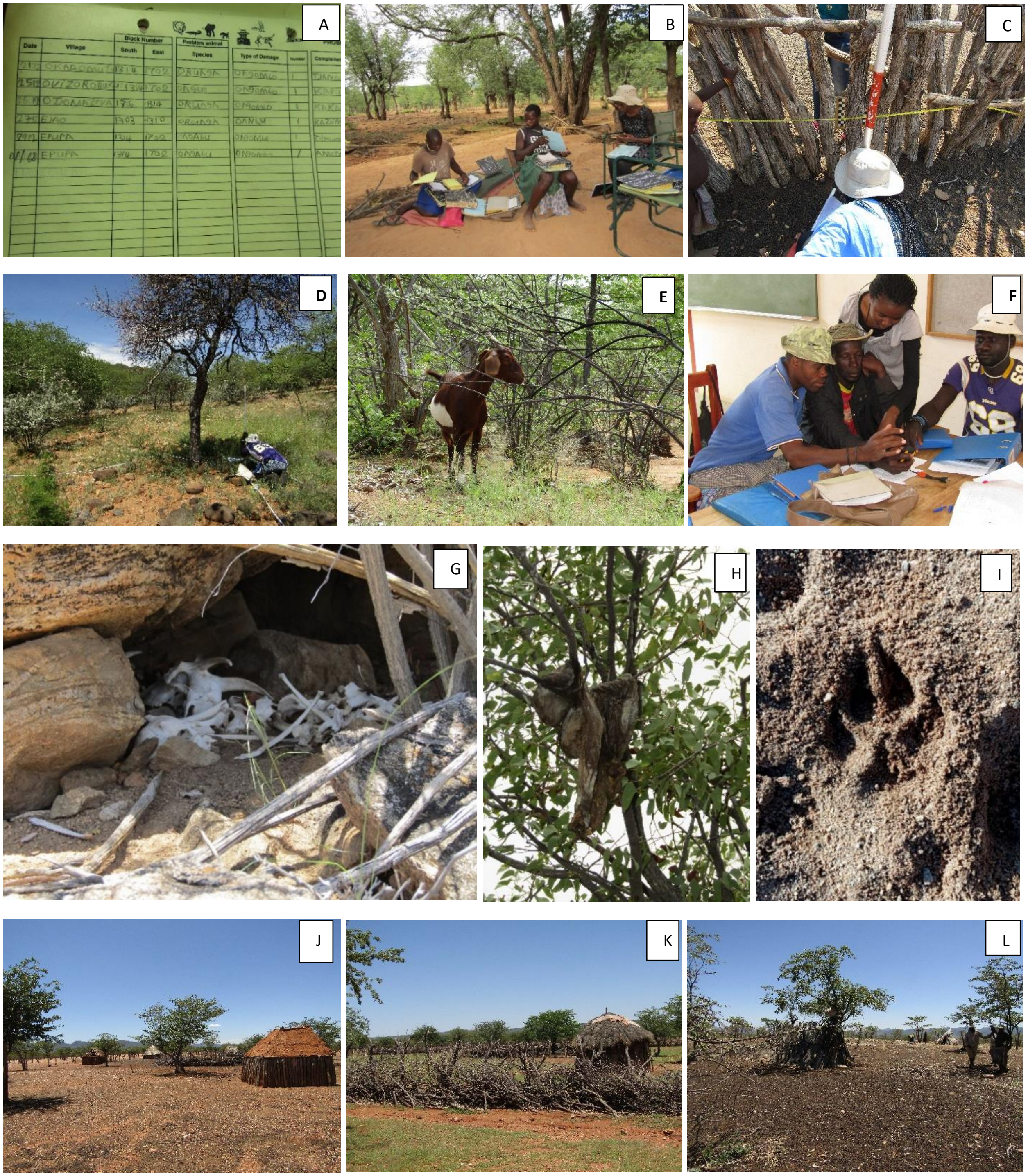


Figure 2. Field data collection image summary (a) Event book - problem animals, (b) event books review with game guards, (c) kraal structure assessment, (d) vegetation structure assessment, (e) livestock grazing (f) para-ecologist GPS training, (g) a predator feeding den, (h) goat carcass remains killed by a caracal as identified by game guards, (i) hyena spoor in Okanguati, (j) house with no fence but has a kraal, (k) house with a fence and a kraal, (l) house with no kraal and no fence, goats overnight around the house, the small structure is a kraal for kids and lambs.

3.2.2. Household interviews and kraal structure assessment

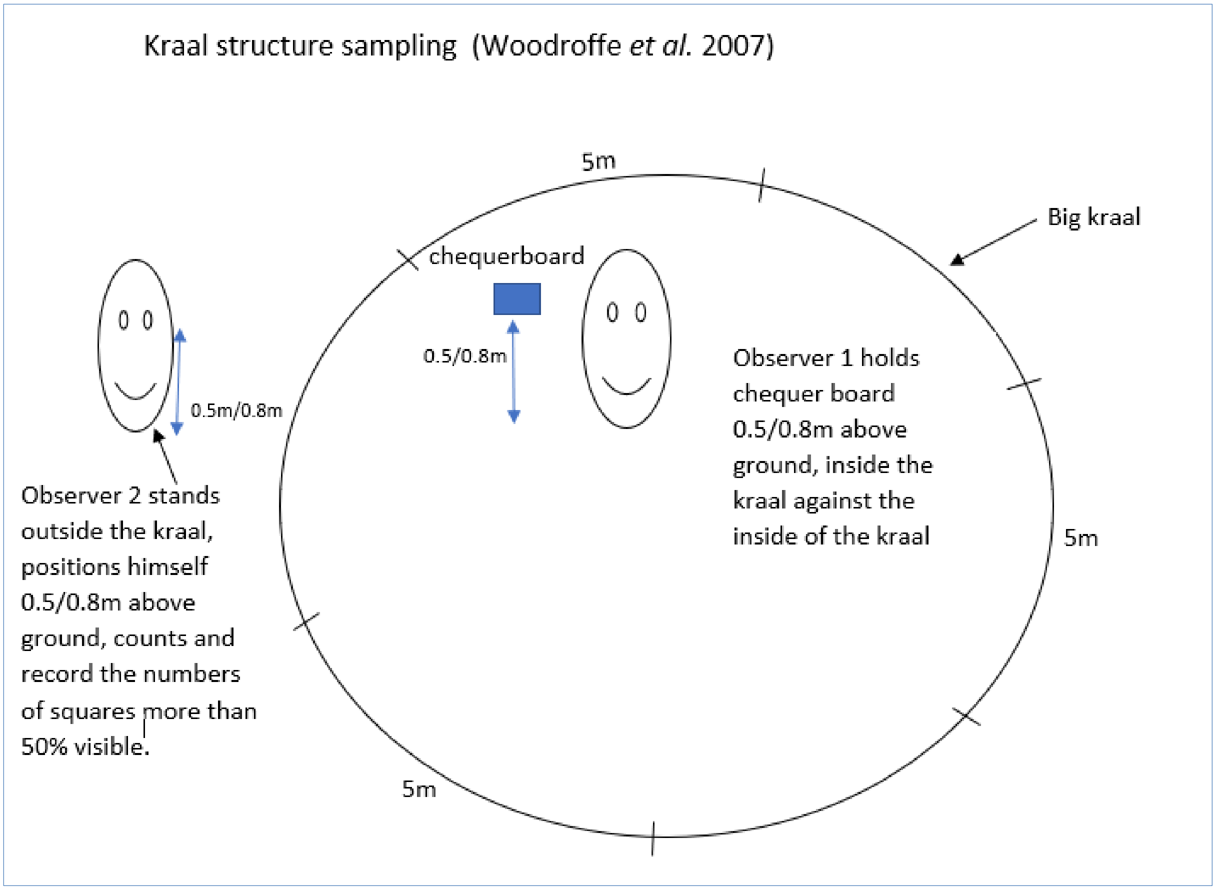
Data was collected from households that experienced and those that did not experience livestock predation for comparison of preventative measures and livestock husbandry practices between households. At the end of every rainy season approaching the dry season (September - November), farmers move to temporary areas and cattle posts in search of livestock grazing fodder and water. Data collection for Okanguati Conservancy (OC) was conducted during the wet season (February 2020) whereas for Epupa Conservancy (EC) it was collected during the dry season (November 2019) when the majority of permanent houses and villages were vacant.

Interviewed households were selected and sample size based on occupant's availability and only households logistically accessible were interviewed. Nonetheless, each conservancy is demarcated into monitoring and patrol zones: Epupa Conservancy has seven zones' namely; Epupa, Okandombo, Omuramba, Omuhonga, Okanjandi, Ondendu and Ongondjanambari, whereas Okanguati Conservancy has; Oomiore, Ombaka, Otjomuru, Otjeme, Otjihandjasemo, Omuangete and Ohamaremba. Each zone was surveyed to fully represent the conservancy.

All households were interviewed on the livestock husbandry measures in place, and their experience of livestock predation followed by kraal structure assessment. Respondents were only asked about the most recent events to rule out memory error. Recent incidents were defined as incidents involving livestock and carnivores that occurred 12 months to the day of the interview. The time frame of 12 months concurs with the recommended time recall period of 2 to 14 months (Sudman and Bradburn 1973, Karanth *et al.* 2012, Kjellsson *et al.* 2014). Extended recall periods influence results by the possibility of interviewee pretermitting events and confounding incidents between multiples years.

Kraal structures were assessed at every household interviewed except where interviews were done at water points. For case-control comparison, case and neighbouring control kraals were sampled. Case kraals are livestock enclosures with a record of in kraal livestock attacks. Kraal measurements included the following: the height of the kraal, type of material used, thickness of the kraal wall, visibility and direction of kraal material (Woodroffe *et al.* 2007).

Kraal height, thickness, and visibility/transparency were measured at an interval of 5m for big kraals and at an interval of 1m for small kraals using a calibrated (m) pole. The direction of kraal material was recorded observing the inward, outward, vertical and horizontal laying of the material. To measure thickness, a calibrated pole was pushed through the kraal wall. Transparency was measured using a chequerboard marked with 100 2cm*2cm squares shaded alternately black and white. From inside the kraal, a checkerboard was held against the inside of the kraal at a height of 0.5m (for caracal and jackal) and at 0.80m from the ground for leopard, cheetah and hyena. An observer outside the kraal, eye-level at 0.5m or 0.8m from the ground facing the chequerboard through the kraal fence, counted and record the number of white squares which were more than 50% visible (hence maximum transparency received a score of 50) se*e Figure 3,* (Woodroffe *et al.* 2007). The measurements heights are adopted from Stuart and Stuart (2015) carnivore shoulder height as a proxy for eye-level. Only farmers/herders with experience and understanding of livestock predator conflict were interviewed.



Observer 1 holds chequer board 0.5/0.8m above ground, inside the kraal against the inside of the kraal

Observer 2 stands outside the kraal, positions himself 0.5/0.8m above ground, counts and record the numbers of squares more than 50% visible.

Figure 3. Illustration of kraal structure assessment.

3.2.3. Environmental and anthropogenic variables

Environmental Variables (EV) are environmental factors that are known to influence livestock predation by large carnivores whereas Anthropogenic Variables (AV) are human-induced factors that are known to influence carnivore presence and livestock predation (Miller, Jhala, and Jena 2015, Miller, Jhala, Jena, *et al.* 2015).

These predictor variables were selected based on their known influence on carnivore distribution, human and livestock interaction and from similar research on human carnivore conflict dynamics (Woodroffe *et al.* 2007, Kissling *et al.* 2009, Karanth *et al.* 2012, Abade *et al.* 2014, Miller, Jhala, Jena, *et al.* 2015, Kuiper *et al.* 2015, Mbiba *et al.* 2018). AVs considered in this study include distance from water points (these includes artificial water points and springs), distance from houses, distance from fields and distance from roads whereas EVs include: elevation, slope, distance from water points, Normalized Difference Vegetation Index (NDVI) and/or vegetation structure, and distance from rivers or streams. Rivers and streams refer to perennial and ephemeral river courses.

Coordinates of houses, villages, and waterpoints were recorded during household interviews. Additionally, areas that were inaccessible due terrain, resulted in digitization of features (water points/springs, roads, houses and fields) using Google Earth Pro v. 7.3. Digitizing was done on available image tiles for the years 2007, 2012, 2016 to 2018 at a spatial resolution of 394m to 1km.

Digital Elevation Model (DEM) images applied for elevation are products of United States Geological Survey (USGS) Earth Explorer whereas the features; slope, elevation, and rivers/streams were extracted from DEM images using the Spatial Analyst tool, Stream Order Network in ArcGIS 10.6.1. The 10m resolution NDVI images used as a proxy for vegetation cover are a source of the European Space Agency Copernicus (ESA), type Sentinel 2A–M2A below the atmosphere. Sentinel 2A provides images of Bottom of Atmosphere (BOA) reflectance derived from the associated level – 1C products. Each image of S2A is 100 by 100km² tiles in cartographic geometry (UTM/WGS84 projection) (ESA 2021). The images were downloaded, merged, cropped and fitted to the study areas in Quantam GIS (QGIS) v3.60. The images covered a time frame between January 2019 and May 2020, monthly images were downloaded at a difference of 15-20 days and each killing site's NDVI value extracted from the image of the month the incident occurred. NDVI was equated in QGIS using the Near-Infra Red band (NIR) and RED band (Red light):

$$NDVI = \frac{NIR \qquad - RED}{NIR \qquad + RED}$$

The units of measure were specific to variables, distances and elevation were measured in meters (m) and slope in degrees (D). Distance was measured from each killing site to the nearest feature. Concurrently, slope and elevation values were extracted for each killing site using ArcMap the 10. 6. 1 software.

Table 1. Summary table of data sources.

Data	Resolution	Sources and links	Units
Environmental variables			
NDVI	10m	ESA – Sentinel 2A https://scihub.copernicus.eu/dhus/#/home	-
SRTM (DEM)	-	Earth Explorer USGS https://earthexplorer.usgs.gov/	-
Rivers and Streams network	-	DEM	-
Elevation	-	DEM	meters
Slope	-	DEM	degree
Anthropogenic variables			
Distance from roads	394m to 1km	Field data and Google Earth Pro v. 7.3	meters
Distance from houses	394m to 1km	Field data and Google Earth Pro v. 7.3	meters
Distance from fields	394m to 1km	Field data and Google Earth Pro v. 7.3	meters
Distance from water points	394m to 1km	Field data and Google Earth Pro v. 7.3	meters

3.2.4. Vegetation structure

Vegetation structure was assessed at a spatial grain of a 50m² plot following the variable quadrat method, *Figure 4*, (Coetzee and Gertenbach 1977). The parameters measured at killing sites are vegetation density, height and visibility. These parameters were measured for all growth forms (trees, shrubs and grass) (Miller, Jhala, Jena, *et al.* 2015, Muvengwi 2017). A fraction 21 of the 75 sampled plots were reduced in size due to obstruction by landscape features such as steep mountains, and rocks impending accessibility and assessment of the entire plot covering 50m².

Visibility was measured in meters as the distance from the center of a livestock killing site into the four main compass directions (North, East, South, West) using a GPS (Muvengwi 2007) and captured at different carnivore species shoulder heights. Caracal and black-backed jackal visibility were observed at 0.50 m, whereas cheetah, leopard, and hyena were taken at 0.80 above the ground.

The first observer stood at the midpoint of the plot; eye positioned on a demarcated pole at the eye-level of the carnivore under investigation facing the second observer. The second observer walked away in the direction of one of the major compass directions until he/she is out of sight of the first observer. The second observer then informs the second observer out of sight, upon which the latter returns at midpoint keeping track of distance using a GPS. This was repeated in all four directions, north, east, west and south resulting in four records of visibility at a kill site.

Table 2. The different vegetation growth forms and height classes.

Growth form	**Class**	**Height (m)**
Trees	TH1	0.5-1
	TH2	2-5
	TH3	>5
Shrubs	SH1	>0.5
	SH2	1-2
	SH3	2-5
Herbs/grasses	GH1	>0.5
	GH2	0.5-1

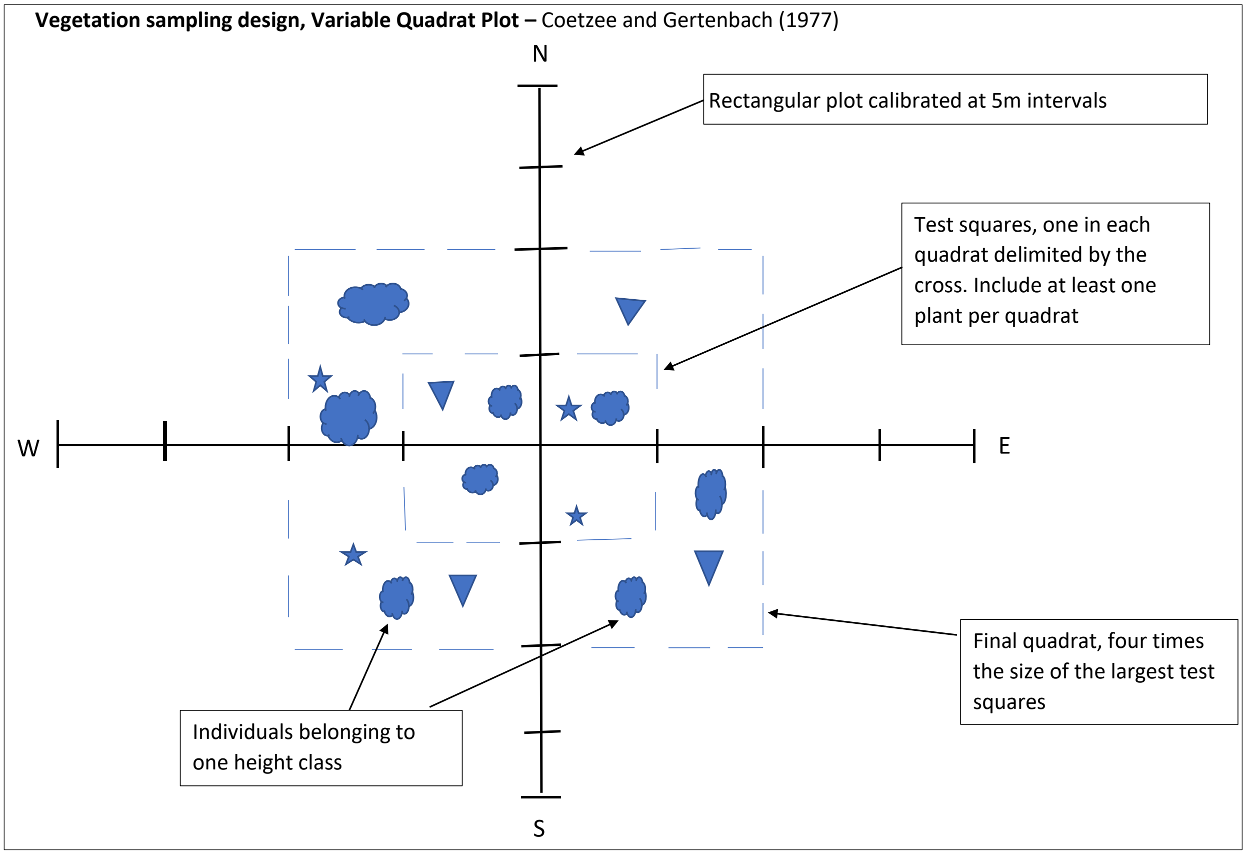


Figure 4. Illustration of vegetation structure assessment and directions of visibility assessment.

3.3. Data analysis

All descriptive, inferential statistics and modelling were conducted in RStudio v 1.2.5033**.** Conflict distribution and probability maps were produced in ArcMap 10.6.1 using the Kernel Density tool, Spatial Analyst Extension. Vegetation structure and kraal structure for both conservancies (OC and EC) were merged to permit inferential statistics consequence of a small sample size per conservancy.

3.3.1. Vegetation structure

The study compared vegetation structure between killing sites of the different carnivores. Data were tested for normality using a Shapiro Wilk test and considered normally distributed at a p.value greater than the significance levels of 0.05. Parameters not normally distributed were tested for the difference using the Kruskal Wallis test and additionally a post hoc Dunn test for comparison of group means. Visibility at each killing site was average to get a representative value. All statistics were evaluated at a

95% confidence interval hence all p. values greater than 0.05 were considered not significant and inversely.

3.3.2. Kraal structure

Kraal structure data was analyzed using Wilcoxon-Mann-Whitney test for comparison of kraals with and without livestock attacks. Each parameter (kraal height, kraal thickness and kraal visibility) was compared between kraals. The minimum height, width, and maximum transparency were used for analysis (Woodroffe *et al.* 2007).

3.3.3. Identifying and predicting conflict hotspot (modelling)

This study focused on binary logistic regression modelling (GLMs). The AVs and EVs values extracted for each conflict point were used to build models and predict the probability of livestock predation (Karanth *et al.* 2012, Midi *et al.* 2013). A split sample validation method was used, 70% of the data was handled for model training and 30% retained for model testing. Lastly, samples of a pixel size 0.10km*0.10km resolution were randomly selected for predicting probability of predation occurrence at unknown sites using the best-selected model(s). Variables were pairwise tested for collinearity using a Pearson's correlation test. Variables were eligible for elimination at collinearity exceeding 0.80 - equivalent to 80% (Midi *et al.* 2013). However, none of the input variables exceeded the collinearity threshold, see test results presented in *Appendix 4 Appendix 5 Appendix 10 Appendix 12.*

Model building and selection started with a global model (inclusive of all variables) followed by backward elimination based on the significant value of the variables and the model's Akaike Information Criterion value (AICc). Backward variable elimination method operated by retaining variables with a significant p.value and omitting non-significant variables from the models. The method was concurrently applied with the model's Akaike information Criterion (AICc) for model selection see *Appendix 6*, *Appendix 7*, *Appendix 8*, *Appendix 9*, *Appendix 11* and *Appendix 13*, (Karanth *et al.* 2012).

The estimated effect of independent variables on the probability of conflict occurrence was examined by multimodal inference modelling using the MuMIN R Package (a tool for performing model selection and model averaging) see *Table 3, Table 4, Table 6, Table 7, Table 9, and Table 10* (Schomaker and Heumann 2014). AIC is an estimator of prediction error that is used to compare multiple competing models (Symonds and Moussalli 2011). Variable parsimony and model fit selection preference was given to models with low AIC which represents low information loss. It is imperative to note that for this study adapted Akaike

Information Criterion corrected (AICc) for sample average less than 40 (the average number of samples divided by parameters is less than 40) (Burnham and Anderson 2002, Karanth *et al.* 2012, Miller, Jhala, Jena, *et al.* 2015, Broekhuis *et al.* 2017, Naha *et al.* 2020).

Raw AIC in isolation tends to make it difficult to unambiguously interpret the observed AIC differences in terms of a continuous measure such as probability thus AIC was transformed to Akaike weight (AICΔ) which can be directly interpreted as relative support for each model. Akaike weight provides a measure of the strength of evidence of the preferred model over the omitted models (Wagenmakers and Farrell 2004). Further, the contribution of each predictor variable in averaged models was assessed by the measure of variable importance varying between 0 and 1. One represents a variable's strong contribution to the averaged models with importance decreasing closer to 0, these are equivalent to a range of 0-100%. For example, 0.20 variable importance is equivalent to 20% variable importance.

Each model and variable consisting thereof is a hypothesis of the potential influence on conflict occurrence. Consequently, based on AIC, a single model is superior to the others in the set. If the predicted value differs significantly across the models, then it is risky to base the prediction on only the selected model (Burnham and Anderson 2002). Furthermore, this procedure of selection ignores variables not included in the chosen model (Wang *et al.* 2004). Hence model averaging eliminate model selection uncertainty (Schomaker and Heumann 2014). Basing prediction of the probability of conflict occurrence on a set of averaged models that assembles >0.95 of prediction uncertainty (Karanth *et al.* 2012). Lastly, the Area Under Receiver Operator Curve (AUC) was used as a measure of model performance by weighing specificity and sensitivity of each model at every classification threshold. The AUC close to a value of 1 (one) is considered a perfect model and AUC = 0.5 indicates that the model performed not better than random (Perger *et al.* 2021).

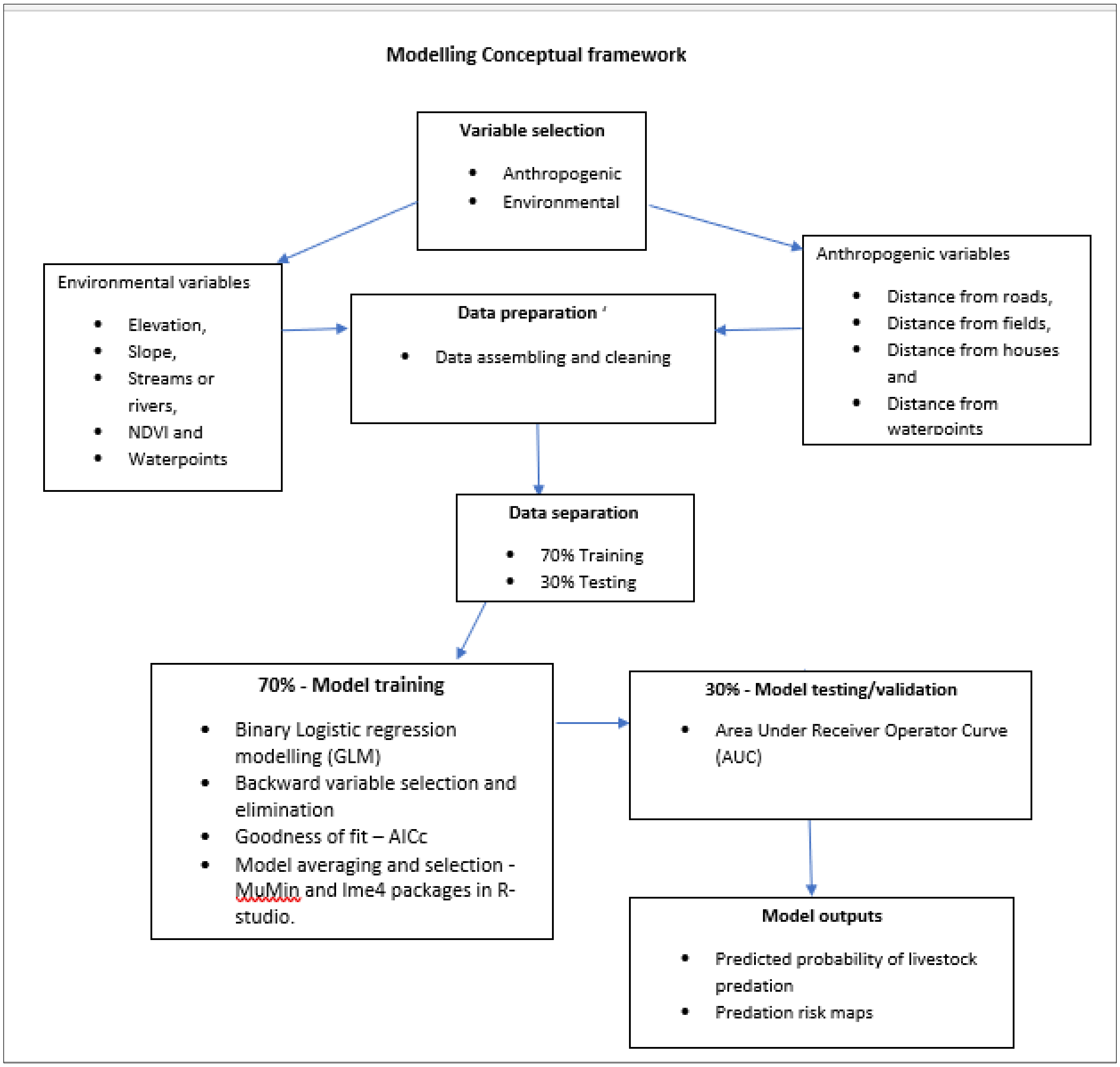


Figure 5. Modelling conceptual framework

Chapter 4: Results

4.1. Temporal distribution of livestock predation

Descriptive graphs include incidents with and without the spatial component and excludes records where the carnivore species or the livestock type involved in the incident was not identified. The data presented for 2020 is only a representation of two out of four Event books for Okanguati Conservancy and one out of eight Event books from Epupa Conservancy. Epupa Conservancy reported 425 carnivore-livestock related incidents between 2014 and 2020 (60 incidents/year). The density of livestock-predation for six years was 0.14 incidents/km². A fluctuating trend is observed with the highest records of over 100 incidents reported in 2014 and the lowest in 2017 *(Figure 6).*

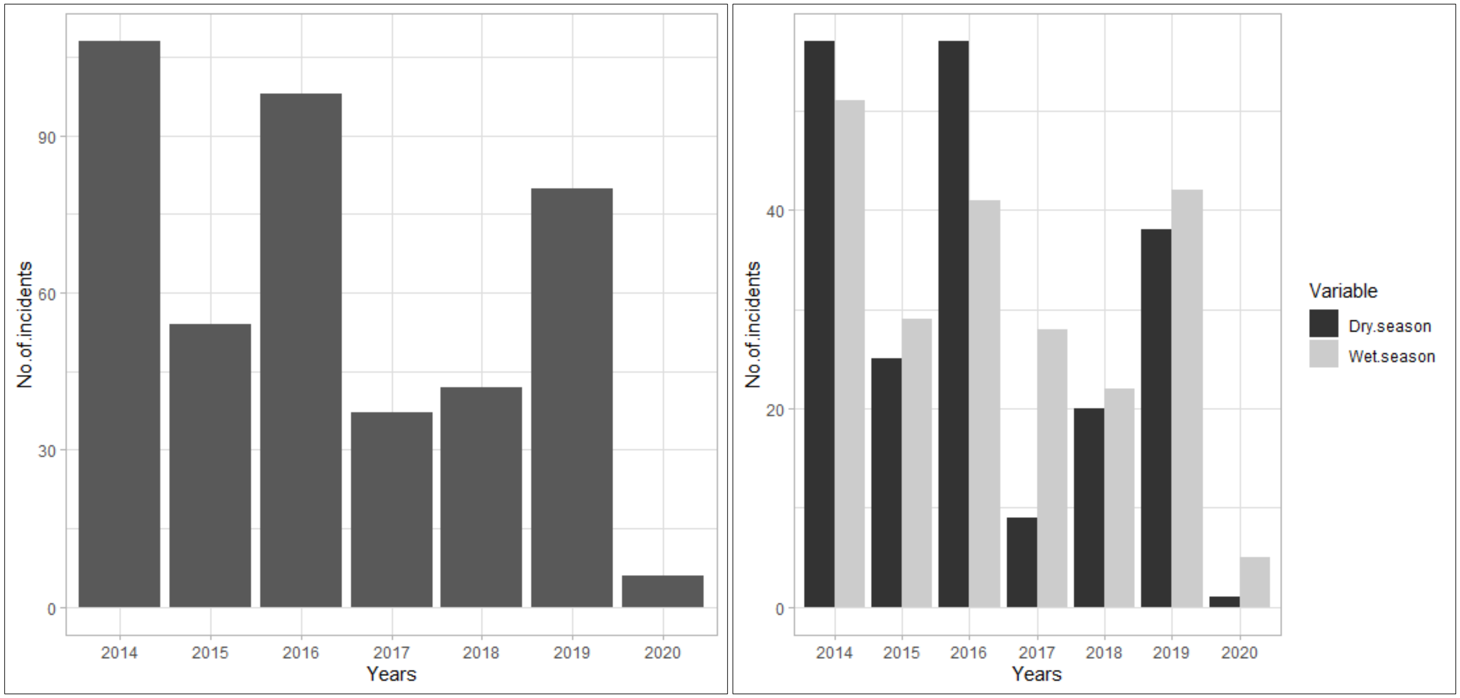


Figure 6. Epupa Conservancy (a) Livestock predation trend 2014-2019 and (b) Livestock predation seasonal trend 2014-2019.

A trend of increasing events is observed between 2017 and 2019, the number of incidents increased from 37 to 80 in two years *(Figure 6a)*. A Kruskal-wallis test reveals a significant difference in the mean number of conflicts between the years (p. value <0.05). These differences are observed between 2014~2017 (0.0009). The years 2014, 2015, 2016 and 2019 were significantly different from 2020 however this difference cannot be concluded as 2020 was only a representation of one event book.

Results of the Wilcoxon test reveals no significant difference between seasons (p-value = 0.36). However, conflict varied across the months with October reporting the highest number of incidents for all the years (70), followed by November (59) and the least is July with 13 incidents. More than half (51%) of the incidents were reported during the wet season in comparison to 49% in the dry season *(Figure 6*b). Caracal was responsible for the majority of incidents accounting for 35% and jackal the least (6%) problem causing species. The percentage proportion of conflict by other carnivores is as follow; cheetah (24%), leopard (24%), hyena (11%) *(see Figure 7b).*

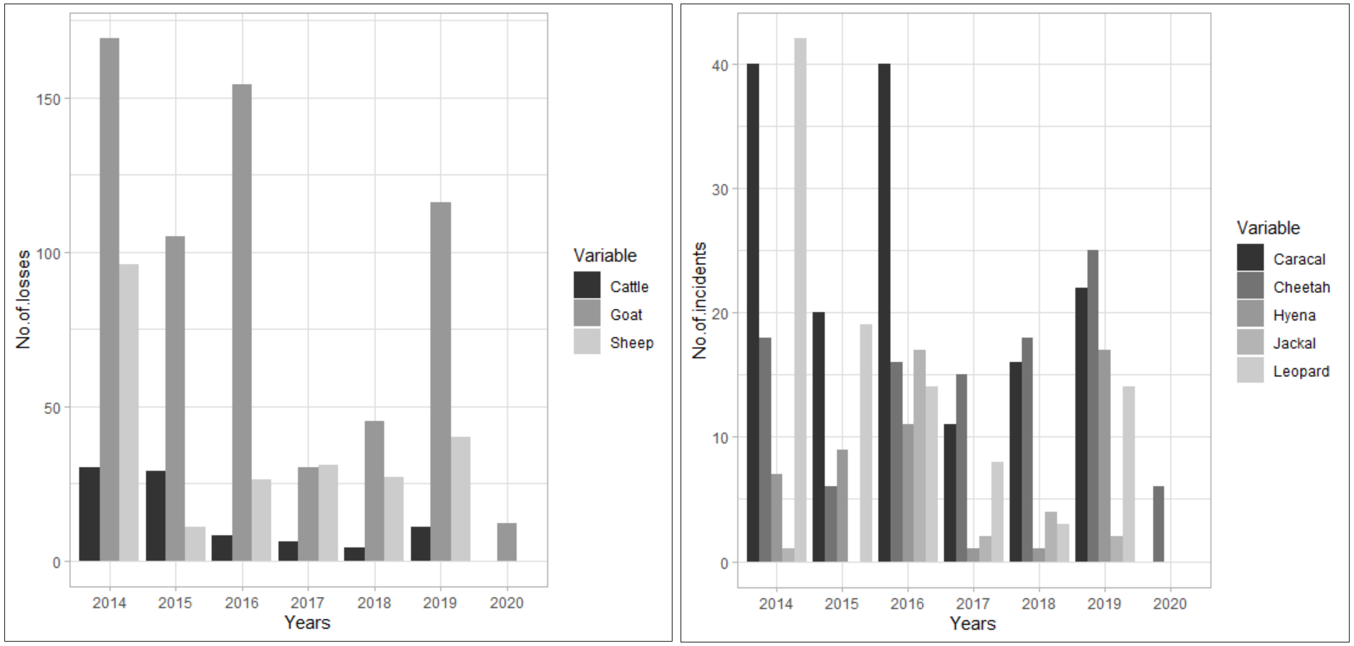


Figure 7. (a) Number of losses per livestock type, (b) a trend of incidents involving each carnivore species for the period 2014-2020, Epupa Conservancy.

Comparingly, Okanguati Conservancy experienced 523 carnivore-livestock related cases, higher than Epupa conservancy but over a longer period between 2012-2020 (58 incidents/year). The density of livestock predation over nine years in Okanguati Conservancy was 0.45 incidents/km². The highest number of incidents was reported in 2013 (110) decreasing sharply to 18 in 2018 *(Figure 8 a).* The number of incidents between the years was significantly different, the variation is between the years (Kruskal-wallis test): 2013~2017(p. value=0.009), 2014~2017(p. value=0.03), 2013~2018 (p. value = 0.0009), and 2014~2018 (p. value = 0.02). The conflict between the years 2013~2020 was different however cannot be included in conclusions as 2020 data is not illustrative of the entire year and all event books but four.

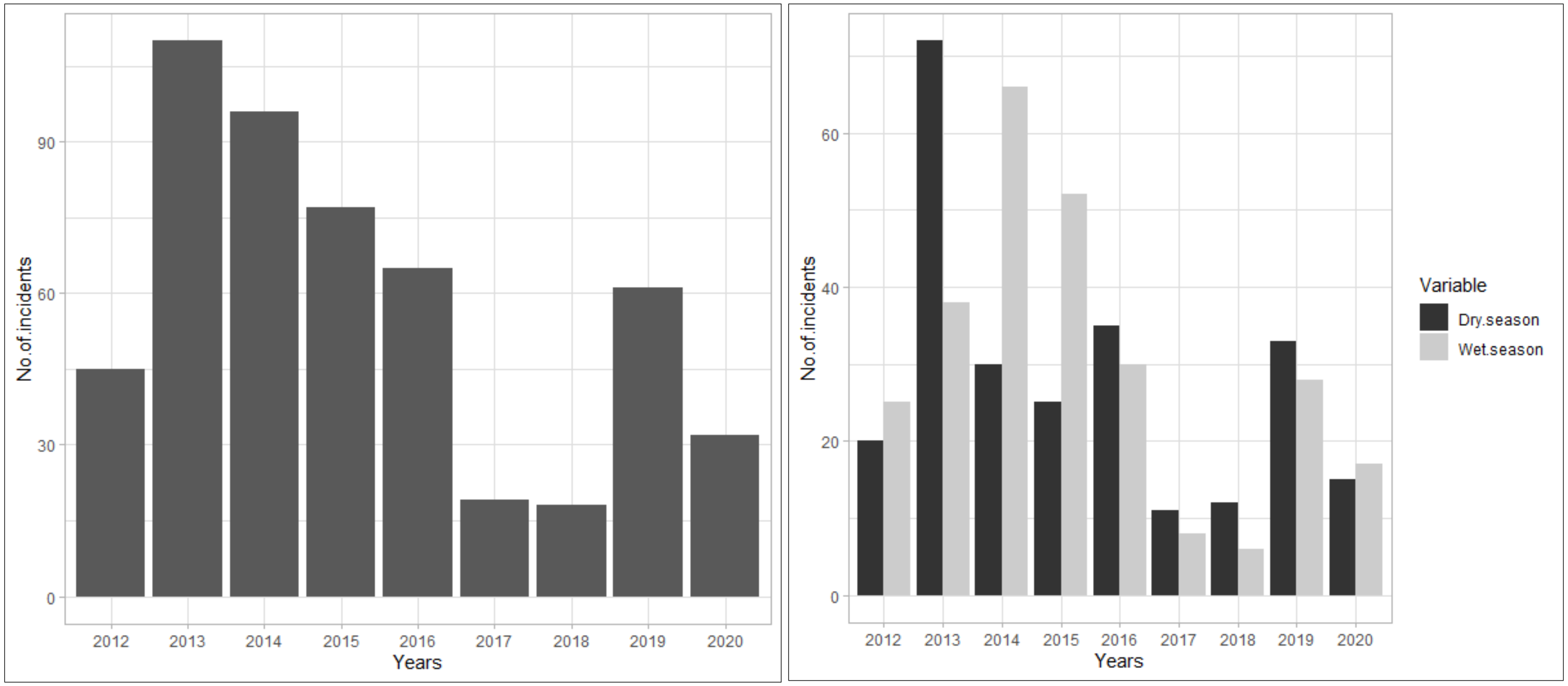


Figure 8. Okanguati Conservancy (a) Livestock predation trend 2012-2020, (b) Livestock predation seasonal trend 2012-2020.

A comparison of seasons indicates that the wet season (Nov-April) recorded the highest incidents (52%), 4% relatively higher than the dry season (May-Oct) (*Figure 8b*). However, according to a Wilcox test, the number of incidents between seasons was not statistically different (p-value = 0.45).

Soaring conflict cases were reported in November (65) and the least in April (15). Overall, cheetah was responsible for (32%) of incidents. The remaining livestock losses are attributed to caracal (24%), hyena (10%), jackal (19%), and leopard (16%) *(Figure 9b).*

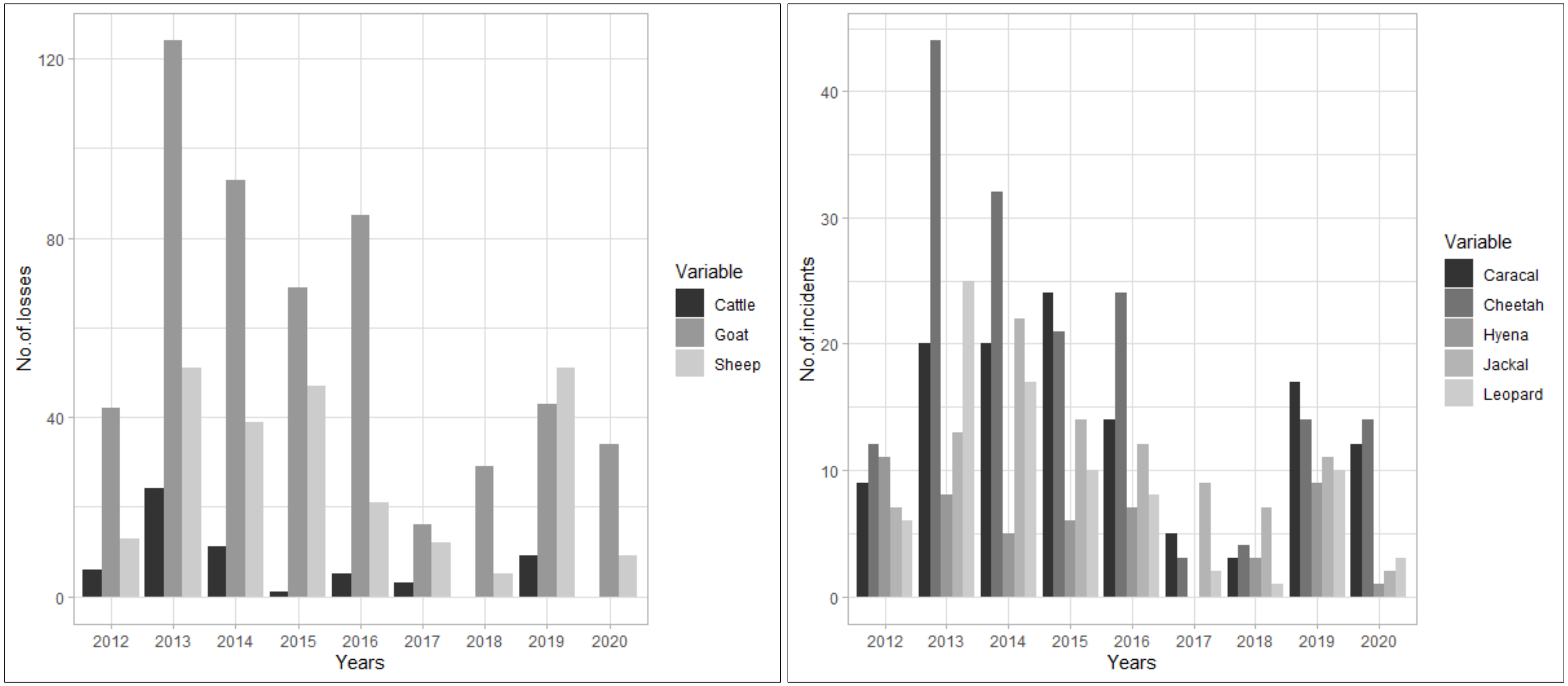


Figure 9. (a) Number of losses per livestock species, (b) a trend of incidents involving each carnivore species for the period 2012-2020, Okanguati Conservancy.

Comparatively between conservancies, Okanguati conservancy conflict monitoring started in 2012 hence the high number of livestock predation events. Livestock losses surpass the number of incidents reported; the rationale is more than one livestock was killed in a single event. A case in point was reported in 2019 when 18 sheep were predated by a leopard in a single attack in Okanguati Conservancy (Okanguati Conservancy 2019 event book). In Epupa Conservancy the highest number of livestock lost in a single attack was 25 herds of sheep in September 2014 by a leopard (Epupa Conservancy 2014 event book). These are however rare events. On average, two livestock are killed in an event. Goats were the most frequently predated livestock in both conservancies *(Figure 7a, Figure 9a).*

4.2. Spatial distribution maps of livestock predation

This section presents Kernel density conflict distribution maps of the 358 geo-referenced event book incidents for (2014-2020), 68 GPS collected incidents (2019-2020) of Epupa Conservancy and 105 GPS collected incidents of Okanguati Conservancy (2019-2020). Incidents are represented at a spatial grain of 0.10km*0.10km. Conflict distribution maps exclude incidents with no spatial reference. Okanguati Conservancy had no existing records of the spatial component of conflict (event book data did not possess coordinates).

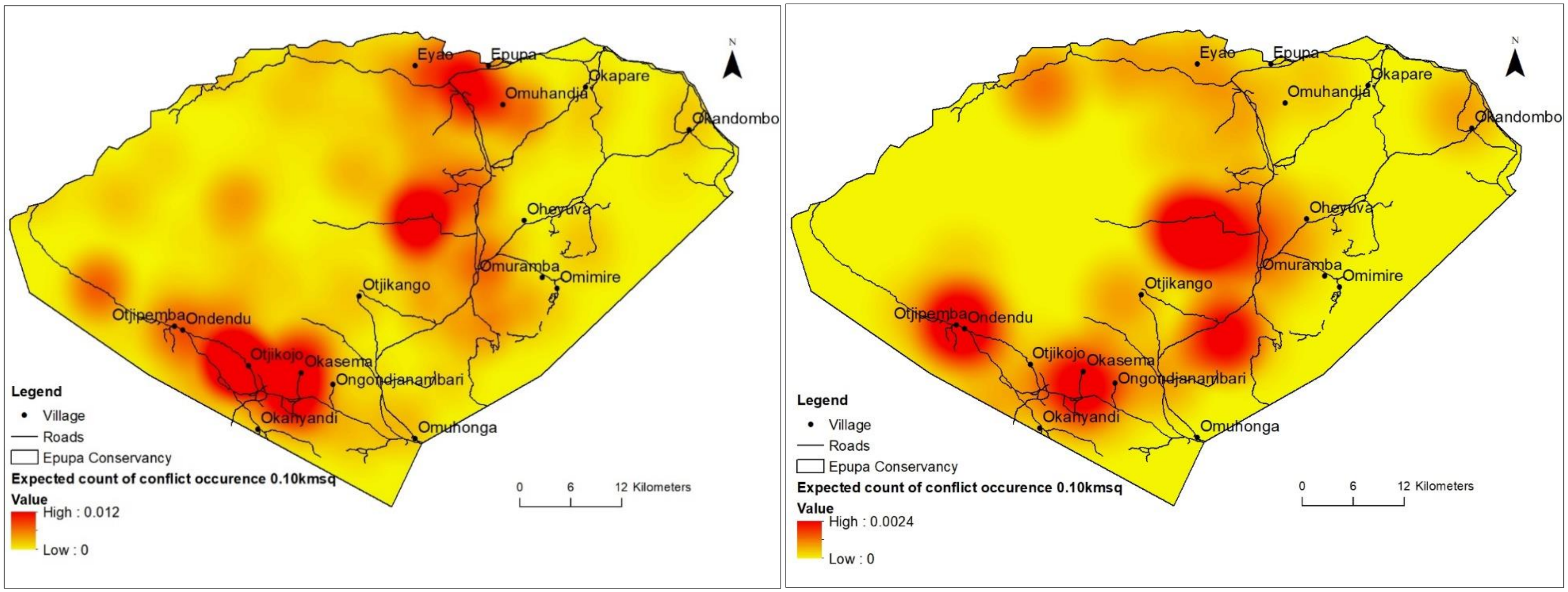


Figure 10. (a) Spatial distribution of livestock losses in Epupa Conservancy 2014-2020 Event book data, (b) spatial distribution of livestock losses in Epupa Conservancy 2019-2020 - GPS collected data.

Areas of permanent human settlements such as Otjikoyo, Okanyandi, Omuramba, Omuhandja and Eyao are identified as hotspots. The area between Otjipemba and Eyao, the west part of Epupa Conservancy is mountainous and mostly utilized as a grazing area with very little human activities according to game guards. The distribution of livestock losses between the event book and GPS collected data for Epupa Conservancy is similar (Figure 10 a and b). However, this observation cannot be deduced for OC due to the non-existing event book spatial data hence only the GPS collected data is presented in *Figure 12*. The distribution of conflict for both conservancies follows the pattern of villages as areas of livestock activities.

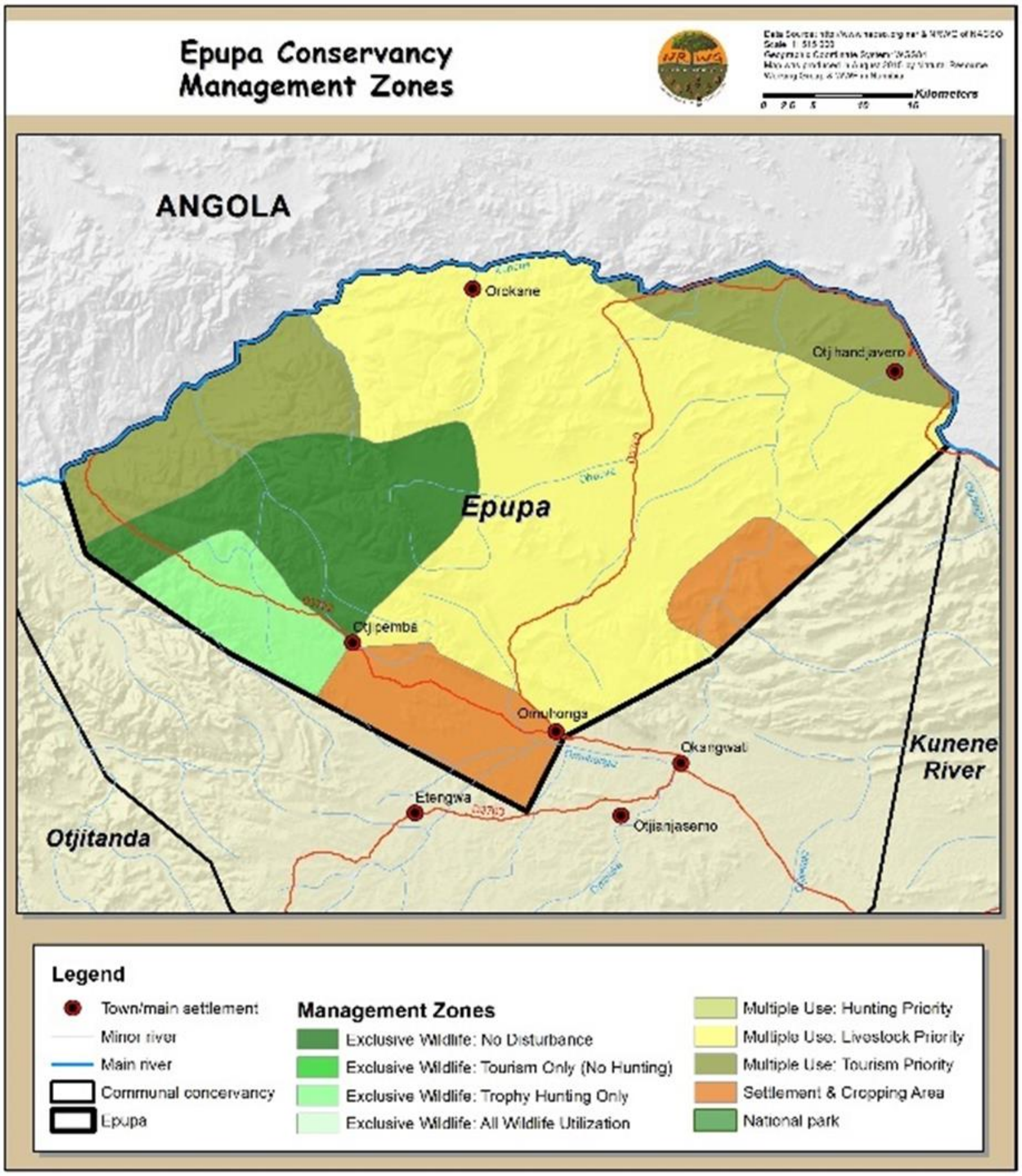


Figure 11. Epupa Conservancy management zones (map by NACSO).

Based on our conflict distribution maps of Epupa conservancy and comparing to NACSO's zonation maps *Figure 11*, conflict is predominantly within the Multiple-use; livestock priority core, Settlement and Cropping area to very few incidents in the Multiple-use; tourism priority, Exclusive wildlife; and Trophy hunting only. Conservancies are demarcated into management zones to allow a fair resources allocation between wildlife and people whilst co-existing and assist in minimizing competition and reducing conflict probabilities.

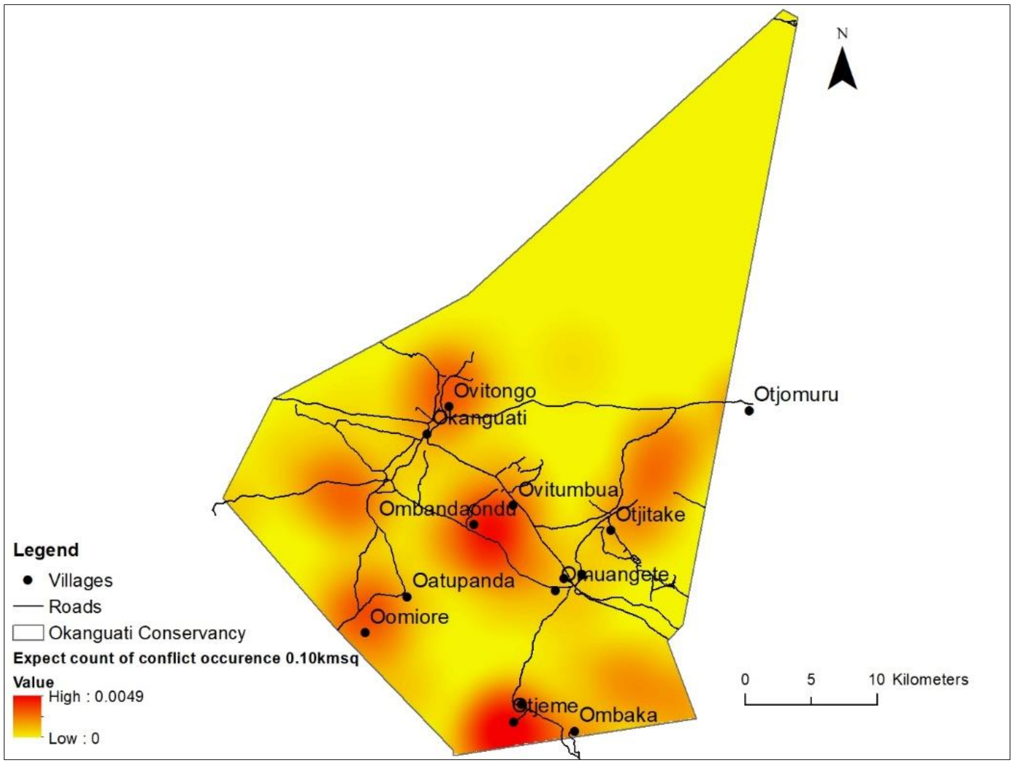


Figure 12. The distribution of livestock predation in Okanguati Conservancy 2019-2020, GPS collected data.

In Okanguati Conservancy, a high risk of conflict is associated again with settlements areas: these are Otjeme, Ombandondu, Oomiore and Ovitongo. These places are in proximity to areas with fewer human activities. The extending stretch of the conservancy is mountainous with rarely any human activities and no incidents have been reported.

4.3. Environmental and anthropogenic variables.

4.3.1. Vegetation structure and visibility assessment

Seventy-five livestock kill sites from both two conservancies were visited for vegetation structure assessment, 43% of the collected conflict data. These killing sites are attributed to the following carnivores; caracal (23), hyena (9), cheetah (30), leopard (8) and Jackal (5).

Visibility, shrubs and tree density data were not normally distributed, therefore the difference in means of parameters between the five different carnivores was tested using the Kruskal-wallis test and additionally a post hoc Dunn test. The overall tree density between carnivores killing sites was significantly different (p-value = 0.037). The post hoc test results reveals the difference between carnivores; caracal ~ leopard (p. value= 0.009), cheetah ~ leopard (0.029), hyena ~ leopard (0.023), and caracal ~ jackal (0.046). However, the observed difference is by unadjusted p. value and not revealed in adjusted p. value.

Hyaena and caracal livestock attacks occurred in areas of high tree density in comparison to other carnivores. The mean tree density and standard deviation of the different carnivores are as follows; caracal (32.6±24.9), cheetah (27.1±21.4), hyaena (37.7±32.6), jackal (13.6±13.8), leopard (11.2±11.9) as presented below *(Figure 13)*.

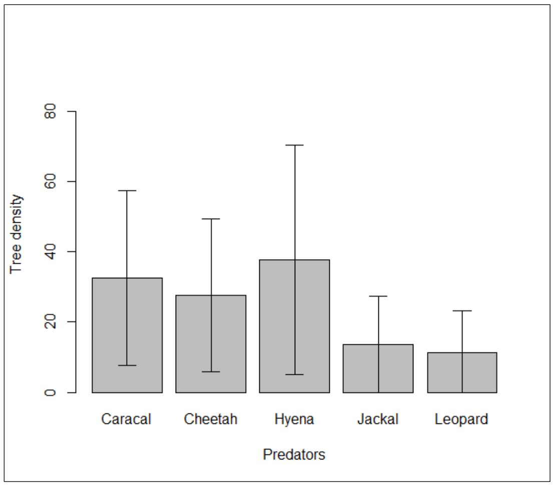


Figure 13. Mean and standard deviation boxplots of tree density at different carnivore-livestock killing sites of 50m² plots.

Shrub density at the different carnivore killing sites was not significantly different (p. value = 0.14). Comparably, cheetah and caracal livestock attacks occurred in areas of high shrub density. The mean and standard deviation of shrub density is as follows; caracal (248.4±197.7), cheetah (240.2±123.2), hyena

(164.3±131.8), jackal (145.2± 82.8), leopard (133.5± 97.5) (see Figure 14). On average, leopard-livestock attacks took place in areas with the lowest tree and shrub densities.

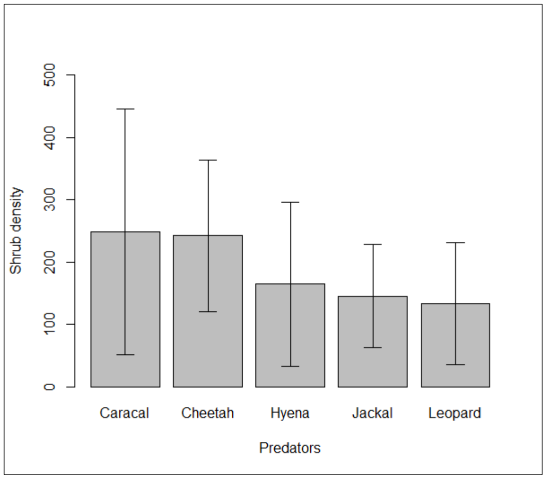


Figure 14. Mean and standard deviation boxplots of shrub density at different carnivore-livestock killing sites of 50m² plots.

Visibility was significantly different between carnivores, the p. value = 0.016<0.05. Post hoc Dunn test: the difference in visibility was only between cheetah~ leopard (p. value = 0.01). Cheetah killing sites had the highest maximum visibility and leopard the lowest minimum visibility. The ratio of the highest and lowest recorded visibility values per carnivore is as follow; caracal (108m:15m), cheetah (190m:16m), jackal (123m:16m), hyena (70m:19m), leopard (77m:10m). Visibility means and standard deviation of the different carnivores: Cheetah (69.5m ± 40.8), leopard (31.8m ± 29.1), caracal (49.1m ±18.4), jackal (68.6±38.5) and hyena (50.8m ±17.42) *(see Figure 15).*

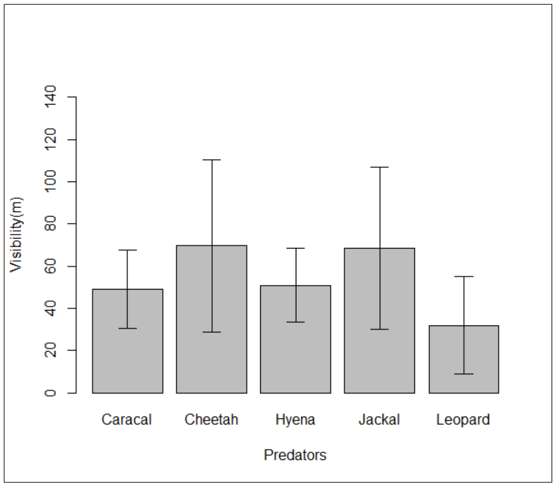


Figure 15. Mean and standard deviation boxplots of visibility at different carnivore-livestock killing sites of 50m² plots.

4.3.2. Environmental variables

None of the paired environmental and anthropogenic variables exceeded the 0.80% Pearson's collinearity threshold hence no variables were excluded from modelling *(Appendix 4, Appendix 5, Appendix 10, and Appendix 12)*. Using binary logistic regression, we derived top-ranking models with cumulative model weights of (*wi*>0.95). The formulated single and combined variable models for anthropogenic and environmental models had cumulative weights (*wi* = < 0.95) (see *Appendix 6*, *Appendix 7*, *Appendix 8*, *Appendix 9*, *Appendix 11*, and *Appendix 13*) hence model averaging of the top models see *Table 3*, *Table 4*, *Table 6*, *Table 7*, *Table 9*, and *Table 10*. The term fields herein refer crop fields.

Presented in *Table 3, Table 4, Table 6, Table 7, Table 9* and *Table 10* are inferences of the top models and averaged models with important factors in the selection and evaluation of models. Factors to note are model weight (wi) - (the predictive weight of a model over other models), *the* composition of variables in each model and their intercept, model AICc and ΔAICc - the difference in AICs between each model and the top model, individual variable importance in averaged models and the AUC of the averaged models.

Our averaged models retained an Area Under Receiver Operator Curve (AUC) above 0.70 (see *Table 3, Table 4, Table 6, Table 7, Table 9* and *Table 10*) falling within the acceptable AUC value (higher than 0.70) (Perger *et al.* 2021). The optimum threshold value identified by a confusion matrix is 0.50. Predicted probabilities above the 50% threshold are regarded as conflict and no conflict below the threshold.

Table 3. Top-ranking averaged model's AICc, mode intercept, variable importance and AUC for predicting livestock-predation occurrence by environmental predictors for Epupa Conservancy.

Models and variables	Model E7	Model E2	Model E3	Model E4	Model-averaged variable intercept	Model-averaged variable importance (%)	AUC (%)
	Wi= 0.684	*Wi= 0.090*	*Wi= 0.076*	*Wi = 0.066*			*Training = 79* *Test: 66*
Intercept	1.194	1.984	2.047	1.867	1.39123		
Elevation (m)	N/A	N/A	-0.00014	-0.000088	-0.000018	0.16	
D. WP (m)	-0.000276	-0.00025	-0.00026	-0.00024	-0.00027	1	
SL (d)	N/A	-0.01542	N/A	-0.01791	-0.0028	0.17	

D. streams (m)	N/A	-0.00025	-0.00027	N/A	-0.000047	0.18	
NDVI	N/A	-2.675	-2.576	-2.680	-0.0028	0.25	
Model AICc	109.0	113.0	113.4	113.7			
ΔAICc	0.00	4	4.4	4.7			

*WP – distance from water points, * NDVI – normalized difference vegetation index, *D distance.

Distance from water points appeared in all four top selected models hence the 100% variable importance, ranking it as the most important variable. All other variables i.e., NDVI, slope, distance from streams, and elevation were relatively lower than 20% important (see *Table 3* for variable importance).

None of the environmental predictor variables are positively associated with conflict occurrence in Epupa Conservancy (see negative intercepts in *Table 3*). Nonetheless, this does not de-signify variable contribution and importance. The probability of conflict occurrence lowered with increased distance from water points and increased NDVI for Epupa Conservancy. The predicted responses are visualized in *Figure 16.*

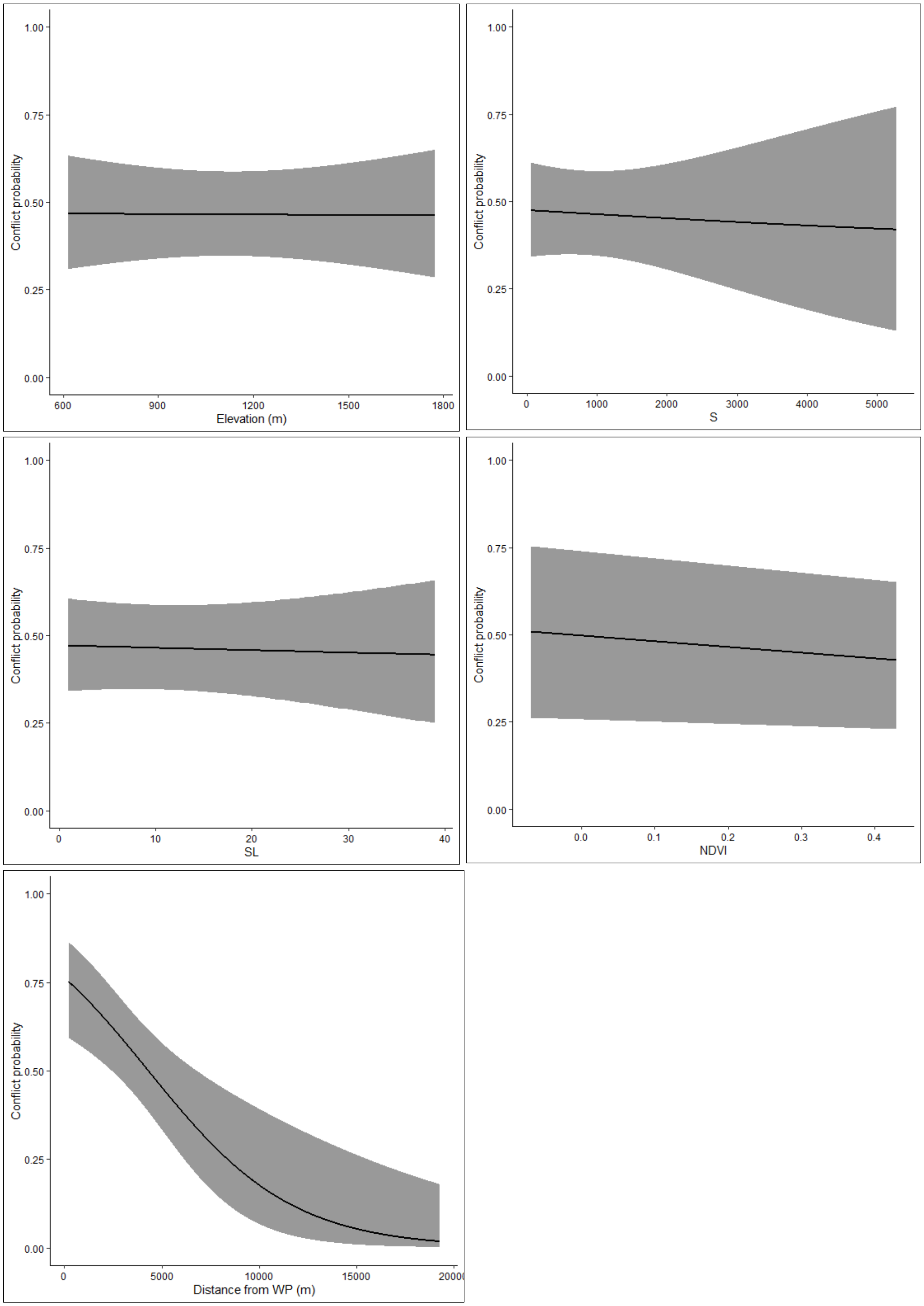


Figure 16. Epupa Conservancy environmental variables averaged models predicted probability of livestock-predation occurrence. Marked in grey is the 95% confidence interval.

Four top-ranking environmental models for Okanguati Conservancy have been selected for model averaging. Again, distance from water points was identified as the most important variable present in all the models, with an importance of 100% followed by elevation with a 56% importance. All other variable's importance (slope, NDVI and distance from streams) are lower than 50% as presented in *Table 4*.

Table 4. Top-ranking averaged model's AICc, mode intercept, variable importance and AUC for predicting livestock-predation occurrence by environmental predictors for Okanguati Conservancy.

Models and variables	Model O8	Model O3	Model O4	Model O5	Model - averaged variable intercept	Model - averaged variable importance (%)	AUC (%)
	Wi= 0.385	*Wi= 0.209*	*Wi= 0.152*	*Wi= 0.138*			*Training = 78* *Test = 73*
intercept	*1.2790*	*-0.8124*	*-0.3863*	*0.8831*	*0.43685*		
Elevation	N/A	0.0024	0.0017	0.00035	0.00094	0.56	
D.WP	-0.00036	-0.00039	-0.00038	-0.00036	-0.00037	1	
Slope	N/A	-0.055	-0.061	N/A	-0.023	0.41	
NDVI	N/A	-1.970	N/A	N/A	-0.46	0.24	
D. streams	N/A	N/A	0.00021	N/A	0.000037	0.17	
Model AICc	171.4	172.6	173.2	173.4			
Δ AICc	0	1.2	1.8	2			

*WP – distance from water points, * NDVI – normalized difference vegetation index, *D - distance.

Elevation and distance from the streams are positively associated with the occurrence of conflict. The probability of conflict occurrence increases with increased elevation and at a further distance from streams for Okanguati Conservancy. The predicted responses are presented in *Figure 17*.

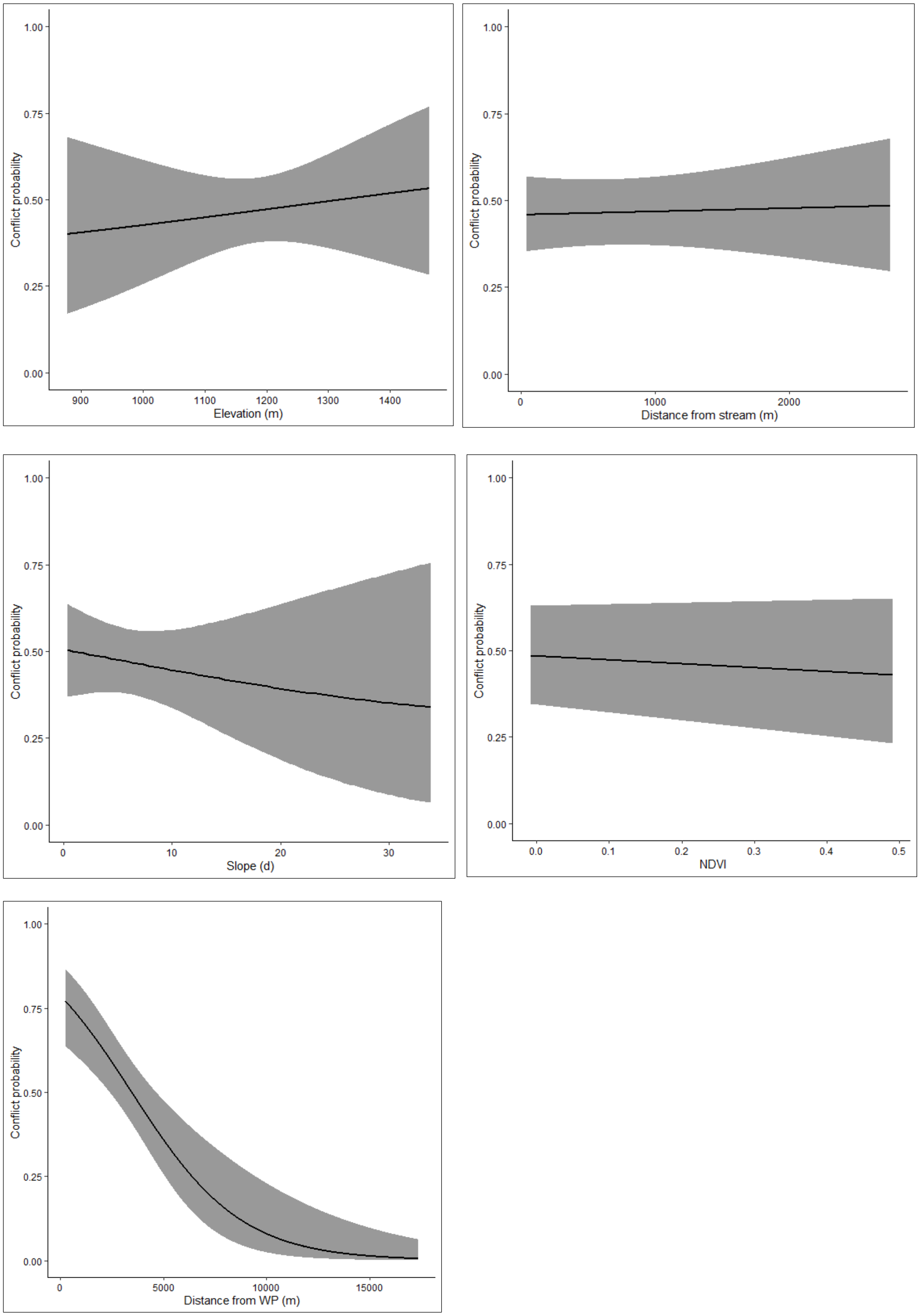


Figure 17. Okanguati Conservancy environmental variables averaged models predicted probability of livestock predation occurrence. Marked in grey is the 95% confidence interval.

Comparing the actual averaged variable values influential in livestock-predation occurrence to the predicted probability results, livestock predation in Epupa conservancy occurred at an average distance of 2727m from waterpoints and at a probability above 50% livestock predation is expected to occur at an average distance of 2539m. Epupa and Okanguati conservancies are high landscape areas hence the elevation above 1000m. On average livestock predation in Okanguati conservancy occurred at 1156m and the risks is predicted higher at an average of 1146m see summary in *Table 5.*

Table 5. A comparison of averaged actual predictor variables values and predicted results, environmental variables.

Variables	Actual values - Epupa conservancy		Predicted - Epupa Conservancy		Actual values - Epupa conservancy		Predicted - Okanguati Conservancy	
	Livestock predation	No livestock predation	Conflict probability <50	Conflict probability >50	Livestock predation	No livestock predation	Conflict probability <50	Conflict Probability >50
Elevation (m)	1079	1103	1171	976	1156	1163	1184	1146
D. WP (m)	2727	5984	9697	2539	2547	5109	7001	2090
NDVI	0.18	0.21	0.23	0.17	0.16	0.21	0.07	0.16
D. streams (m)	700	853	886	736	604	668	759	708
Slope (d)	7.2	9.9	14.3	7.8	5.7	8.5	10.6	6.0

*WP – distance from water points, * NDVI – normalized difference vegetation index, *D - distance.

4.3.3. Anthropogenic variables

Out of the averaged anthropogenic models for Epupa Conservancy, distance from houses and distance from crop fields obtained the highest importance in determining the probability of livestock predation occurrence. Distance from house appeared in all the selected models. The probability of conflict occurrences is positively associated with increasing distance from crop fields. Distance from roads and water points had variable importance less than 30% (see *Table 6)*. Further, *Figure 18* presents the graphic display of the predicted responses.

Table 6. Top-ranking averaged model's AICc, mode intercept, variable importance and AUC for predicting livestock-predation occurrence by anthropogenic predictors for Epupa Conservancy.

Models and variables	Models AE4	Model AE3	Model AE2	Model AE6	Model - averaged intercept	Model - averaged variable importance (%)	AUC (%)
	Wi= 0.287	Wi=0.241	Wi=0.195	Wi=0.143			Training = 77
Intercept (m)	0.68680	0.81710	0.74200	1.06800	0.79850		
D. fields (m)	0.00010	0.00013	0.00011	N/A	0.000099	0.83	Test = 81
D. houses (m)	-0.00091	-0.00073	-0.00073	-0.00073	-0.000792	1	
D. roads (m)	N/A	N/A	-0.00024	N/A	-0.000054	0.22	
D. WP (m)	N/A	-0.00014	N/A	N/A	-0.000039	0.28	
Model AICc	107.5	107.8	108.3	108.9			
ΔAICc	0.00	0.3	0.8	1.4			

*WP – waterpoints, *D - distance.

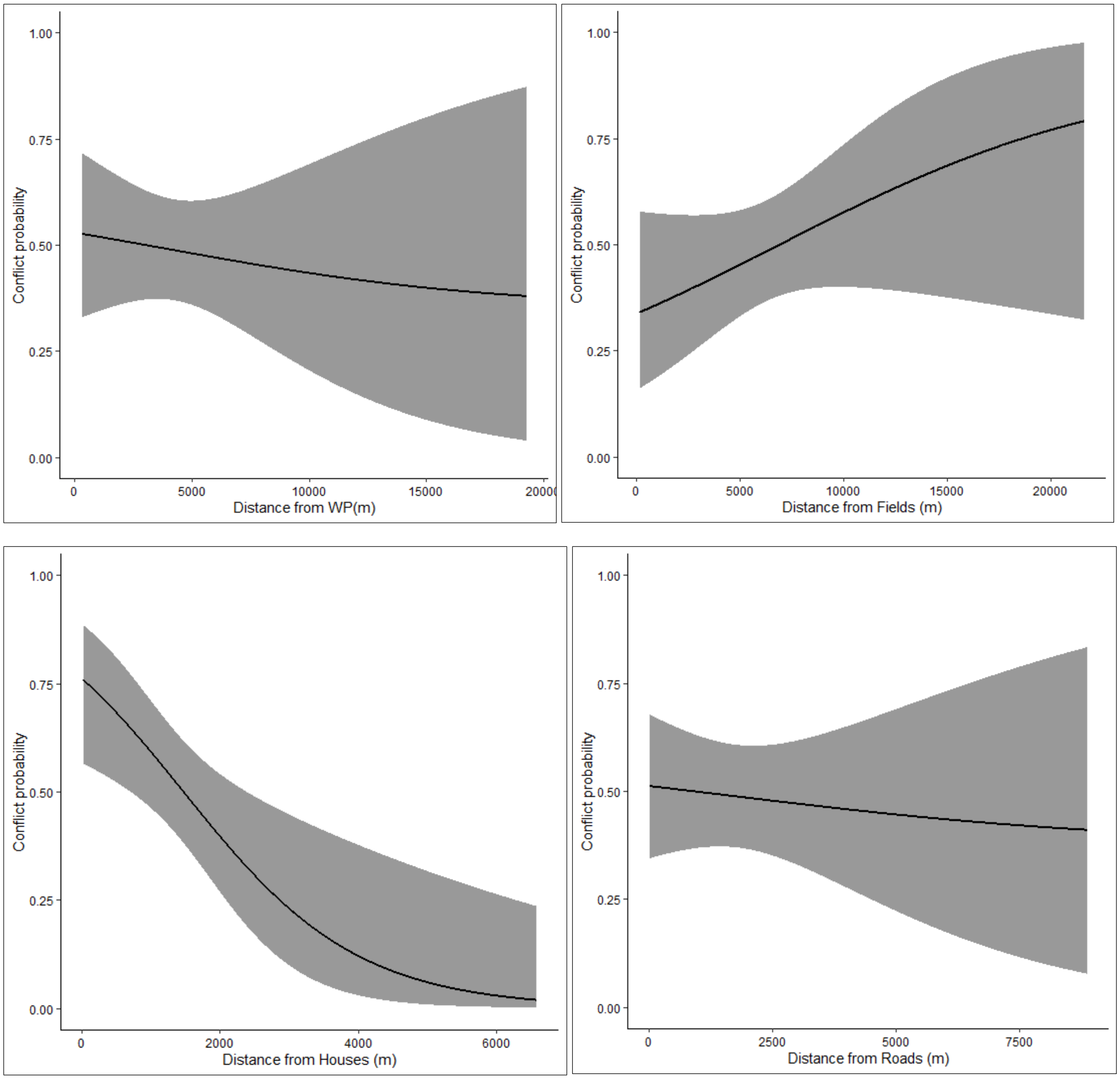


Figure 18. Epupa Conservancy anthropogenic variables averaged models predicted probability of livestock-predation occurrence. Marked in grey is the 95% confidence interval.

Comparing Okanguati Conservancy anthropogenic variables to Epupa Conservancy, distance from crop fields is similarly identified as an important predictor of conflict. Contrary to Epupa, distance from water points is highly important in determining the occurrence of conflict with an importance 100% as it occurred in all the top selected models. Distance from houses and roads occurred in one and three models respectively hence ranking the least important variables as presented in *Table 7.*

Table 7. Top-ranking averaged model's AICc, mode intercept, variable importance and AUC for predicting livestock-predation occurrence by anthropogenic predictors for Okanguati Conservancy.

Models and variables	Model OA6	Model OA4	Model OA2	Model - averaged variable intercept	Model - averaged variable Importance (%)	AUC (%)
	Wi=0.294	Wi= 0.284	Wi= 0.277			Training = 77
Intercept	1.387	1.760	1.760	1.631771		
D. houses (m)	N/A	N/A	2.026e-05	0.0000065	0.32	
D. roads (m)	N/A	-8.311e-05	-7.916e-05	-0.000053	0.33	Test = 73
D. WP (m)	-0.00037	-0.0003091	-0.0003047	-0.00033	1	
D. fields (m)	N/A	-0.0003799	N/A	0.0000096	0.66	
Model AICc	162.7	162.7	162.8			
ΔAICc	0	0	0.1			

*WP waterpoints, *D distance

The relationship between the predictor variables and the predicted probability of conflict occurrence vary. As predicted, the probability of conflict occurrence is associated with increased distance from houses (see positive intercept in *Table 7*). Distance from roads, and waterpoints are inversely related. The variables predicted responses are presented in *Figure 19*.

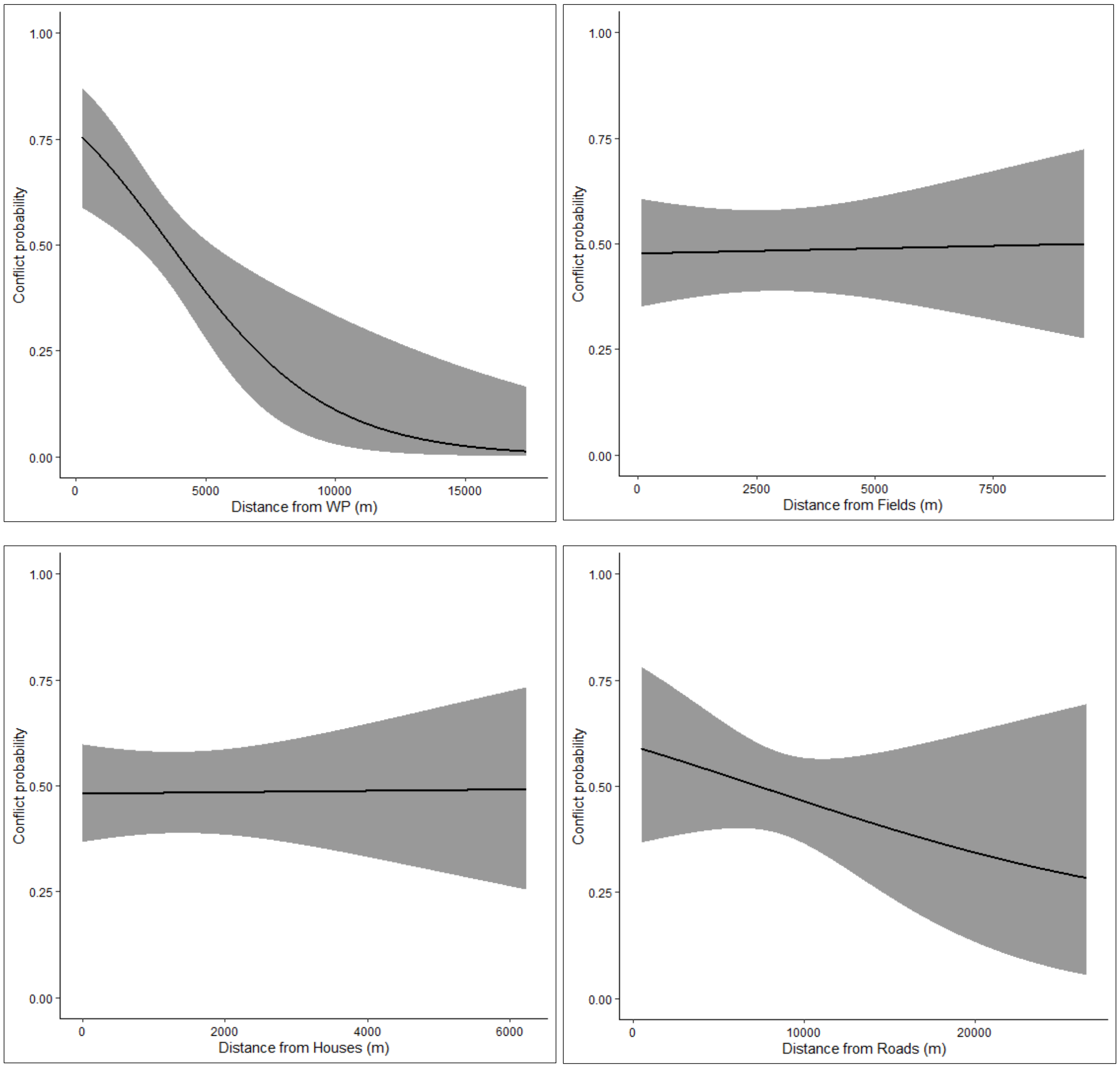


Figure 19. Okanguati Conservancy anthropogenic variables averaged models predicted probability of conflict occurrence. Marked in grey is the 95% confidence interval.

The probability of livestock predation is predicted at high risk (probability >50%) at an average of 8218m from field which is higher than the actual average distance of 6230m (EC). Livestock predation occurred in proximity to house, average distance 910 (EC). This is because some incidents occurred from within the house. Epupa conservancy experience more livestock incidences closes to houses in comparison to Okanguati conservancy were livestock was attacked at an average distance of more than 1080m see *Table 8* bellow.

Table 8. A comparison of averaged actual predictor variables values and prediction result - anthropogenic variables.

Variables	Actual values Epupa Conservancy		Predicted Epupa Conservancy		Actual Values Okanguati Conservancy		Predicted Okanguati Conservancy	
	Livestock predation	No livestock predation	Conflict probability <50	Conflict probability >50	Livestock predation	No livestock predation	Conflict probability <50	Conflict Probability >50
D. roads (m)	1105	2390	3557	1524	7057	10084	6059	2023
D. WP (m)	2727	5984	7372	5104	2547	5109	8365	2678
D. houses (m)	910	2290	3212	842	1083	1465	15373	13843
D. fields (m)	6230	7263	8218	7771	2334	3346	4349	2544

*WP – distance from water points, *D - distance.

Further for each conservancy, the combined effect of variables was measured by modelling all variables as a single set (environmental and anthropogenic variables merged). The outcome did not differ in terms of the selected important variables and the predicted response of conflict.

Table 9. Combined variables averaged top models AICc, model intercept, variable importance and AUC for predicting livestock predation occurrence for Epupa Conservancy.

Models and variables	Model EAV11	Model EAV9	Model - averaged variable intercept	Model - averaged variable importance (%)	AUC (%)
	Wi = 0.81	*Wi = 0.106*			*Training = 80* *Test = 72*
Intercept	*1.38*	*1.3480178*	*1.38388*		
Elevation (m)	N/A	N/A	N/A	-	
D. WP (m)	N/A	-0.00015	-0.000018	0.12	
Slope (d)	N/A	-0.00825	-0.000949	0.12	

NDVI	N/A	N/A	N/A	-	
D. streams (m)	N/A	N/A	N/A	-	
D. fields (m)	N/A	0.00012	0.0000138	0.12	
d. houses (m)	-0.0009	-0.00070	-0.00088	1	
D. roads (m)	N/A	-0.00021	-0.000024	0.12	
Model AICc	104.2	108.3			
Δ AICc	0	4.1			

*WP – distance from water points, * NDVI – normalized difference vegetation index, *D – distance.

Out of the 12 trained models *Appendix 11*, three top models (cumulative weights >95) were selected for model averaging. Our models for EC indicate as predicted, livestock predation probability is increased at a close distance to roads, houses, waterpoints and increased distance from fields. Distance from house occurred as an important variable appearing in all the models. The remaining variables (Distance from roads, fields, waterpoints and slope appeared in only two models hence the low variable importance score (*Table 9* and *Figure 20*). These combined variables predicted response outputs are similar to the separate variables' predictions however, the models AUC was higher in combined variables with exclusion of certain variables (NDVI, elevation and distance from streams) see *Table 3, Table 6* and *Table 9* outputs.

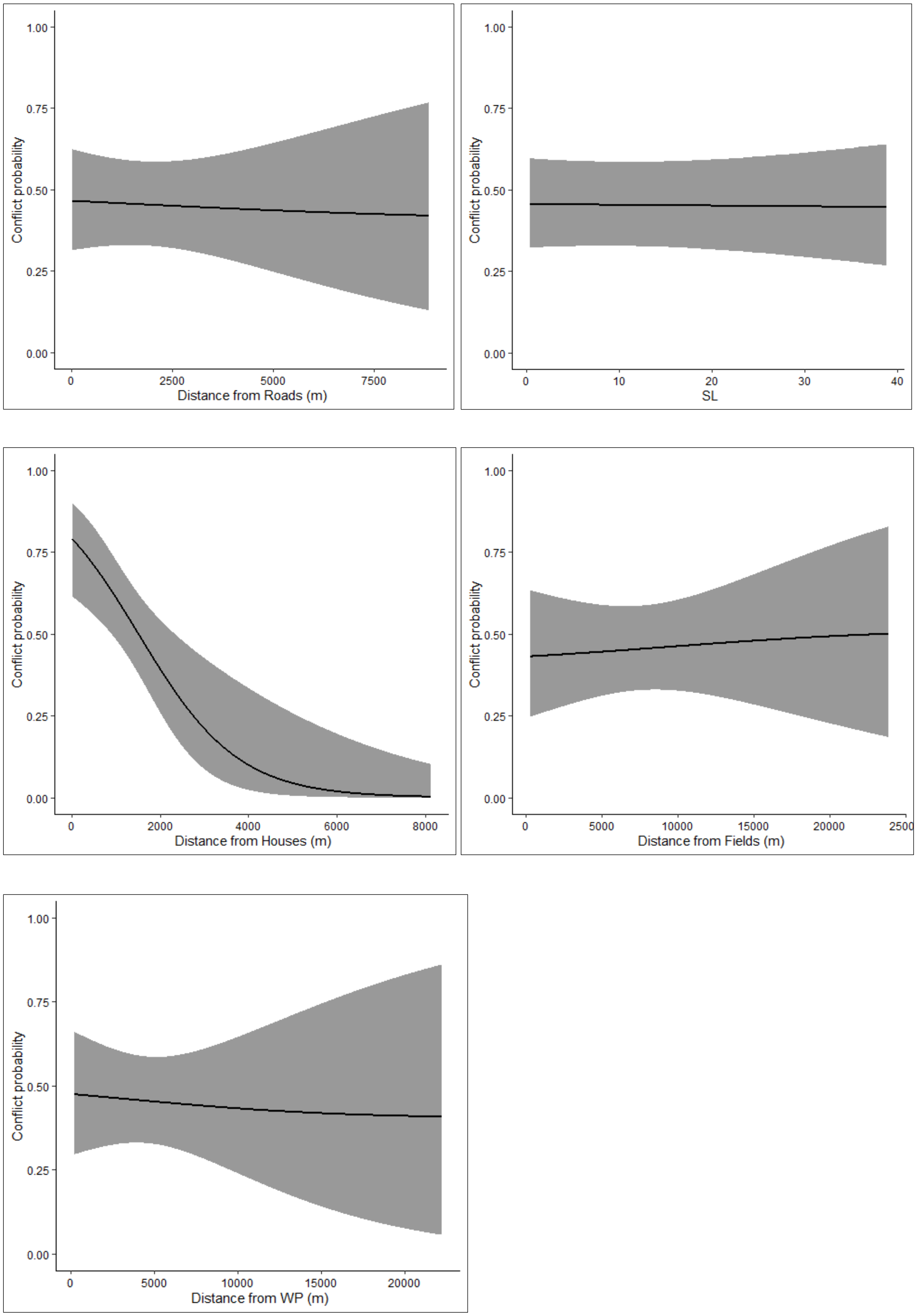


Figure 20. Epupa Conservancy combined variables averaged models predicted probability of livestock-predation. Marked in grey is the 95% confidence interval.

Table 10. Combined variables averaged top models AICc, model intercept, variable importance and AUC for predicting livestock predation occurrence for Okanguati Conservancy.

Models and variables	Model OAV12	Model OAV11	Model OAV13	Model - averaged variable intercept	Model - averaged variable importance (%)	AUC (%)
	Wi - 0.526	*Wi = 0.221*	*Wi = 0.191*	*1.47*		*Training* = 73 *Test = 79*
intercept	*1.567*	*1.564*	*1.1240*	*N/A*		
Elevation (m)	N/A	N/A	N/A	N/A		
D. WP (m)	-0.000240	-0.00026	-0.00030	-0.00026	1.00	
Slope (d)	N/A	N/A	N/A	N/A	-	
NDVI	N/A	N/A	N/A	N/A	-	
D. streams (m)	N/A	N/A	N/A	N/A	-	
D. fields (m)	N/A	0.0000641	N/A	0.000015	0.24	
D. houses (m)	N/A	N/A	N/A	N/A	-	
D. roads (m)	-0.000076	-0.000085	NA/S	-0.000062	0.80	
Model AICc	179.4	181.2	181.5			
Δ AICc	0	1.8	2.1			

*WP – distance from water points, * NDVI – normalized difference vegetation index

A total of the 14 models trained (*Appendix 13*), three top models (cumulative weight > 95) were selected for model averaging (*Table 10*). Among these models and selected variables, distance from waterpoints and distance from roads are associated with decreased livestock predation whereas livestock predation probability is expected to increase with increasing distance from fields (see negative and positive intercepts in *Table 10*). These results are similar to separate variable models except that elevation, slope, NDVI, stream, and distance from houses are not part of the composition of the best selected models (see *Table 4 Table 7* and *Table 10* for comparison).

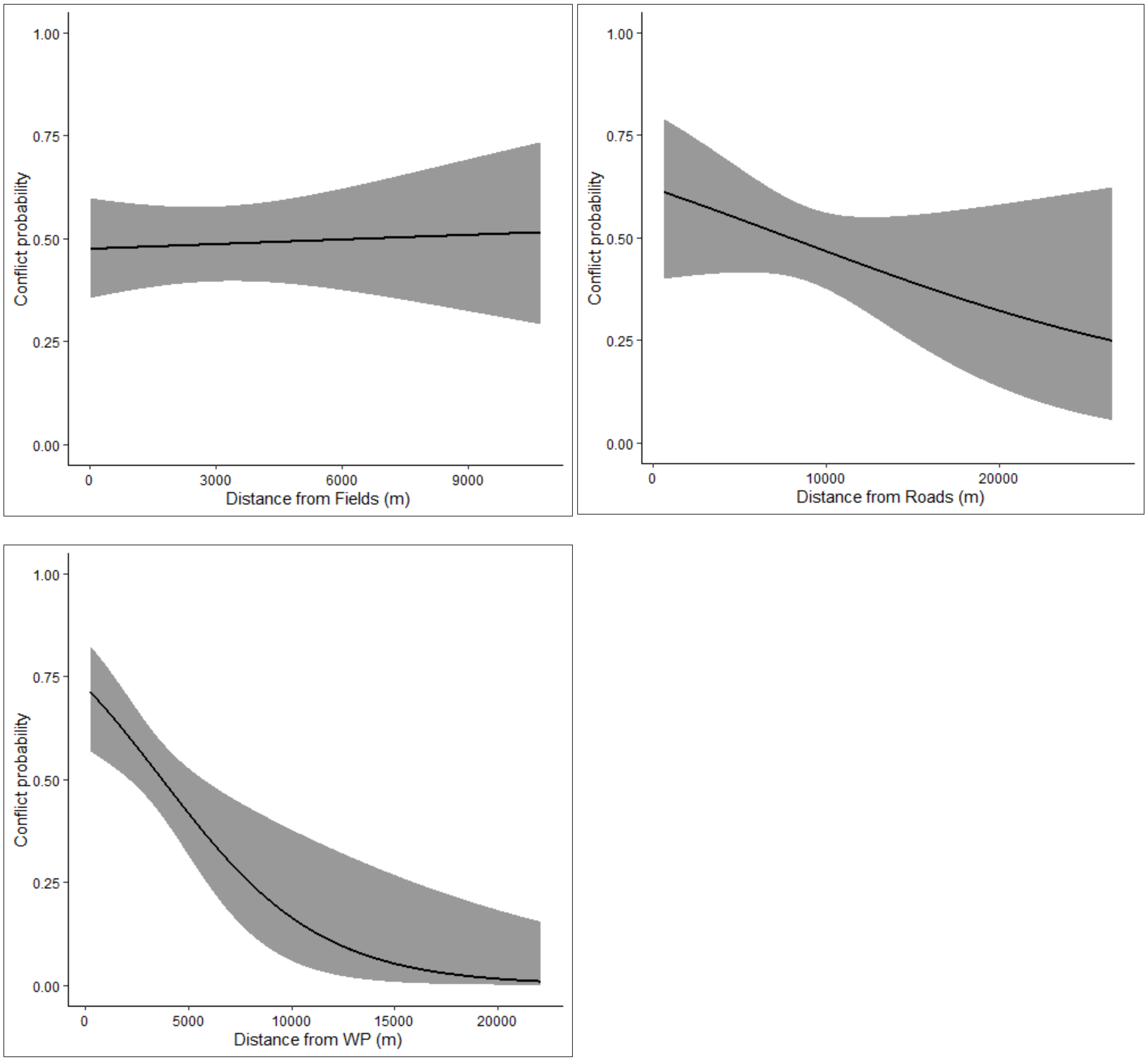


Figure 21. Okanguati Conservancy combined variables averaged models predicted probability of conflict occurrence. Marked in grey is the 95% confidence interval.

4.3.4. Livestock predation predicted hotspots

We mapped the probability of livestock predation around Epupa and Okanguati conservancies (*Figure 22* and *Figure 23*). A sum of 24 7322 points for Epupa Conservancy and 98 583 for Okanguati Conservancy was randomly selected at a resolution of 0.10km² to predict conflict hotspots using the selected top averaged models.

The risk of livestock predation in Epupa Conservancy as an influence of AVs is within the range of 0.004-0.91 with an average risk at 0.40. The distribution pattern of hotspots between the two variables is similar however the risk of livestock predation as a factor of EVs has a lower range between 0.004-0.78 with a high average risk of 0.41. Meaning that throughout Epupa Conservancy, the likelihood of livestock predation is 40% and 41% respectively.

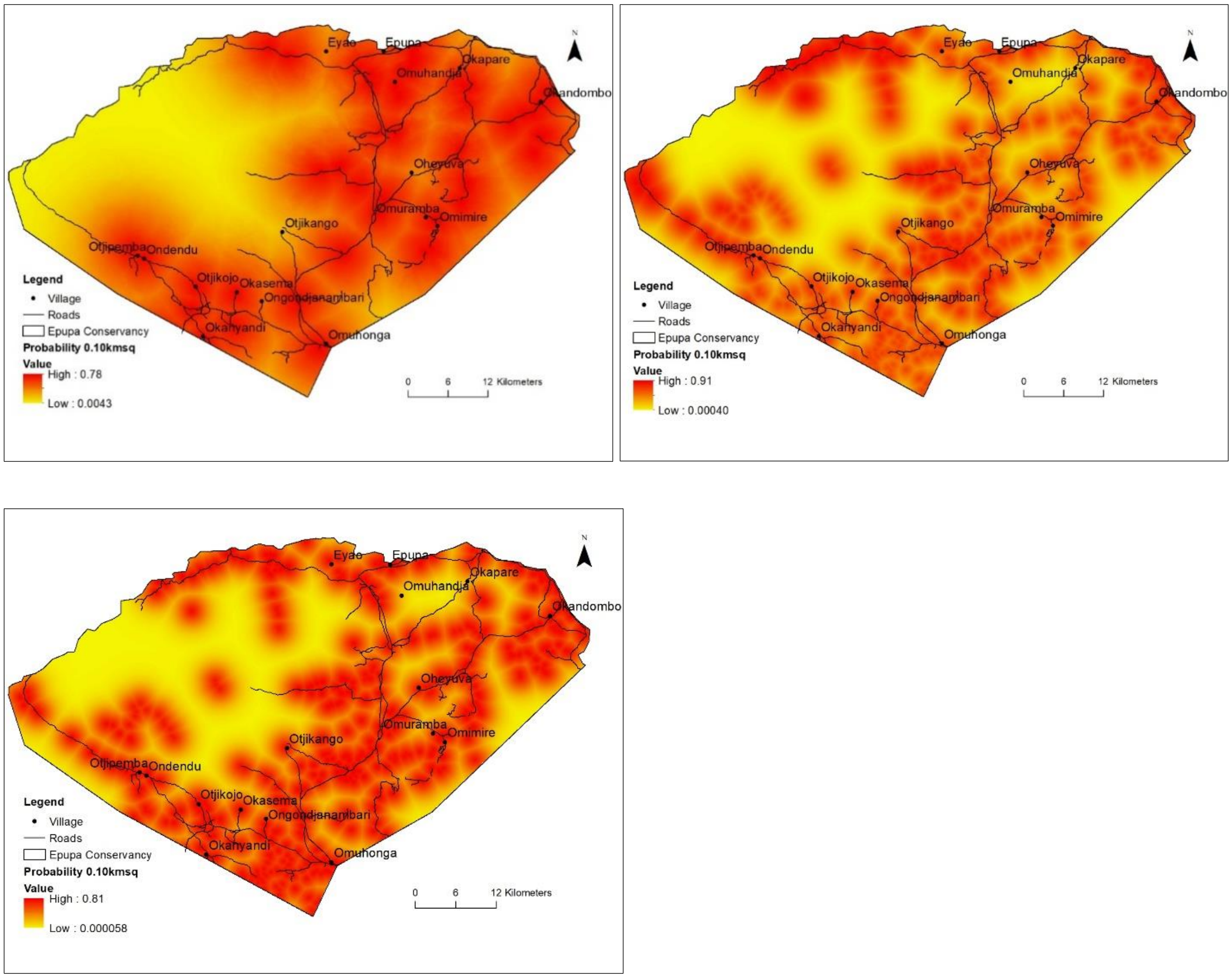


Figure 22. A comparison of predicted probability of livestock predation for Epupa Conservancy (a) Environmental variables, (b) anthropogenic variables and (c) predicted probability from combined variables.

Comparingly between the combined and non-combined variables for Epupa conservancy, the predicted conflict hotspots distribution does not differ. However noticeable is, the predicted probability range of conflict occurrence decreased and changed from 0.004 - 0.91 and 0.004 - 0.78 to between 0.000058 - 0.81. The average probability is 0.40 which translated that in Epupa conservancy the chances of livestock attack by a predator is 40%.

Under the environmental variable models, the average predicted probability of livestock predation in Okanguati Conservancy is 0.42 ranging between 0.003 - 0.81. Whereas for the anthropogenic variable models, the average risk is 0.52 ranging between 0.002- 0.85 probability. This is translated as the risk of livestock predation in Okanguati Conservancy is 42% and 52% for environmental and anthropogenic variables, respectively.

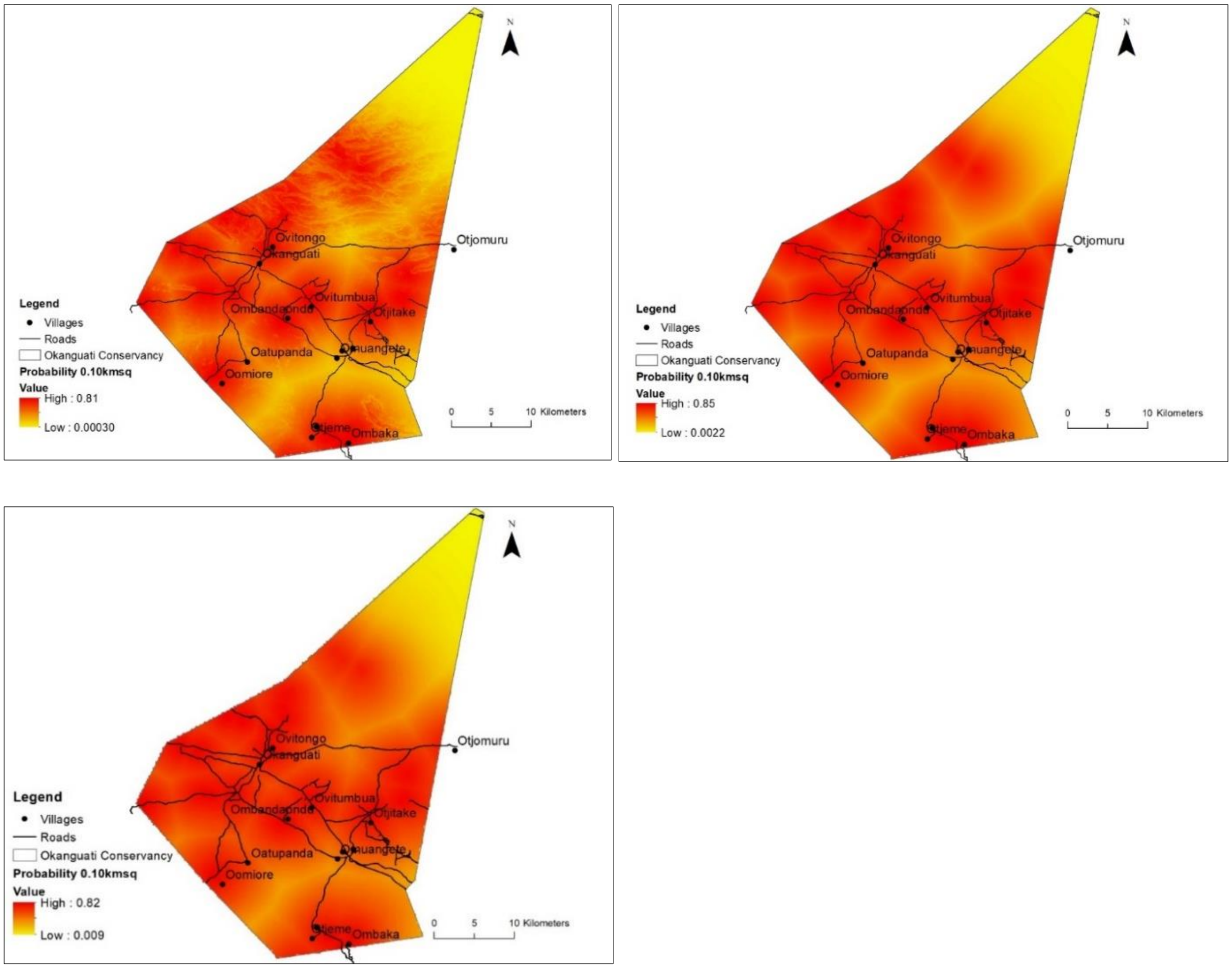


Figure 23. Predicted probabilities of livestock predation in Okanguati Conservancy, (a) Environmental variables (b) anthropogenic variables and (c) predicted probability from combined variables.

Similarly, the merged and single variable sets predicted probability distribution of livestock predation (*Figure 23*) do not contrast significantly. Nonetheless, the range of predicted probability slightly decreased from 0.003 - 0.81 and 0.002 - 0.85 to between 0.009 - 0.82. The average probability remains at 52%. This concludes that the risk of livestock attacks by predators is higher in Okanguati conservancy comparative to the neighboring Epupa conservancy.

Our modelling predict that livestock predation was higher in many parts of the conservancies, most of these are around villages. Exception of decreased livestock predation are predicted in areas of little to no human activities (north western parts of Epupa conservancy and northern parts of Okanguati conservancy). Considered the minimal change in predation probability and distribution in both scenarios, the results are equally useful and can be used for intended purposes.

4.4. Kraal structure and mitigation measures

A sum of 55 households were interviewed in Epupa Conservancy and 63 households in Okanguati Conservancy. Out of these, six households of Epupa Conservancy and four of Okanguati conservancy experienced kraal livestock attacks.

In total, the structures of 20 kraals were assessed (ten case kraals and ten control kraals), these attacks are attributed to four carnivores excluding leopard. They are respectively: jackal (2), hyena (4), caracal (1) and cheetah (3). Of the 20 kraals examined five were constructed from thorn branches, ten from poles and five were a mixture of poles and branches.

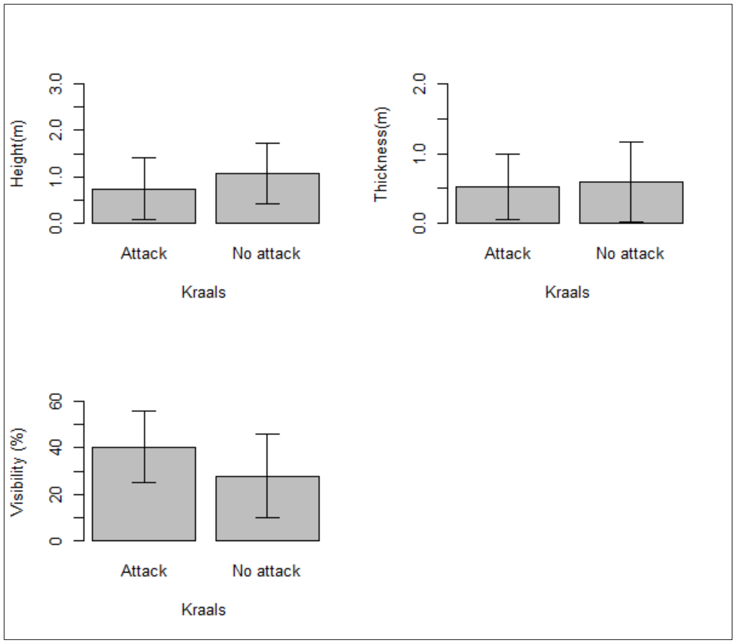


Figure 24. Kraal structure summary standard deviation boxplots. Comparison between kraals with and without livestock attacks, Epupa and Okanguati Conservancies data combined.

Kraals that experienced attacks did not significantly differ from those with no attacks in terms of kraal height (W = 36.5, p-value = 0.31), kraal thickness (W = 46, p-value = 0.78) and kraal visibility (W = 70.5, p-value = 0.12) Although not significantly different, kraals with attacks observably had a higher mean visibility, lower kraal thickness and height.

Out of the interviewed households, 39% of incidents occurred from around the house vicinity in Okanguati Conservancy when livestock was not kraaled at night, 7% from the kraal whereas 52% of the households did not experience livestock losses from the kraal or around the house. Incidents from the kraal and around the house in Epupa Conservancy were equally distributed (14% each) whereas 75% of households did not experience conflict from the kraal or around the house (*Figure 25*).

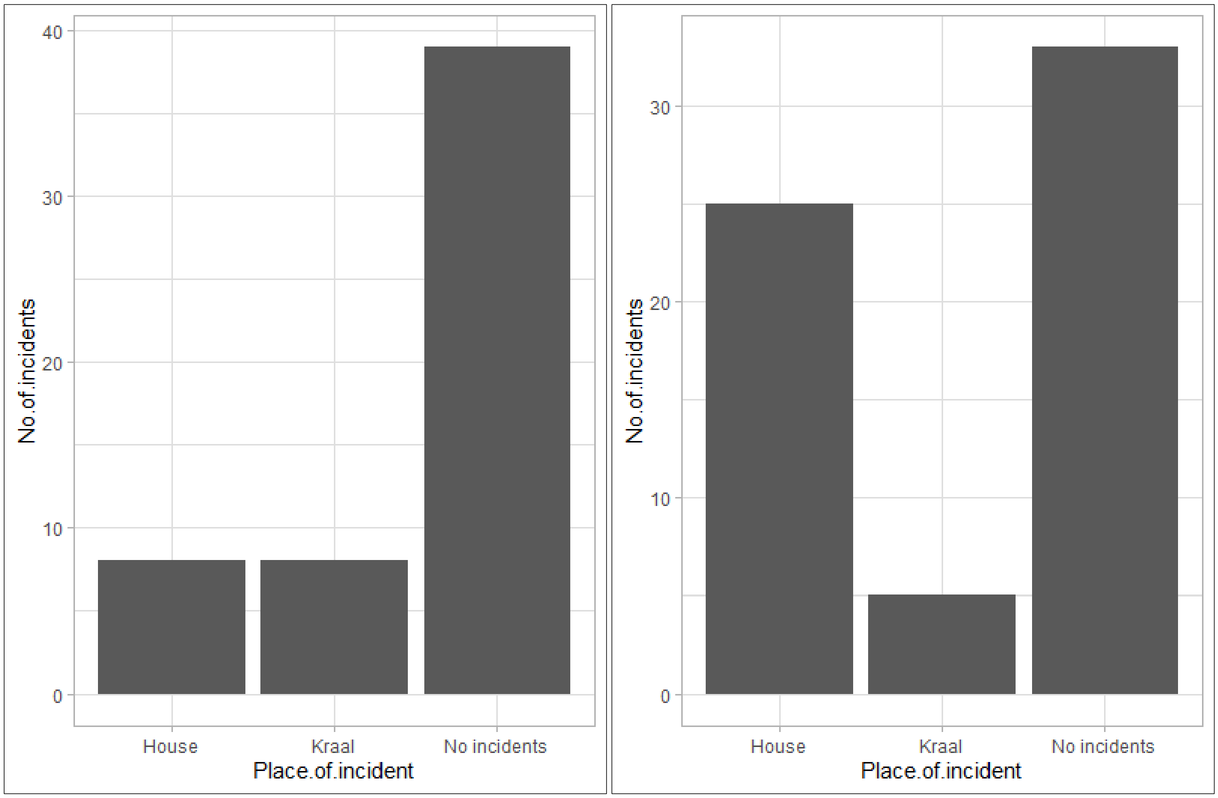


Figure 25. Comparison of household incidents between (a) Epupa Conservancy and (b) Okanguati Conservancy for the period 2019-2020.

Only 10% of the households that experienced kraal attacks did not implement conflict preventative measures. About 50% of the households practiced more than one conflict preventative measure such as fire and placed scarecrows around the house. 30% of the households only employed fire whereas 10% of the households regarded the presence of people alone as a predator deterrent. These measures are similar to kraals with no incidents. Domestic dogs were present at 10% of the households, 20% of the households practiced fire and scarecrows, 30% did not have measures in place whereas 40% used fire alone (see *Figure 26*).

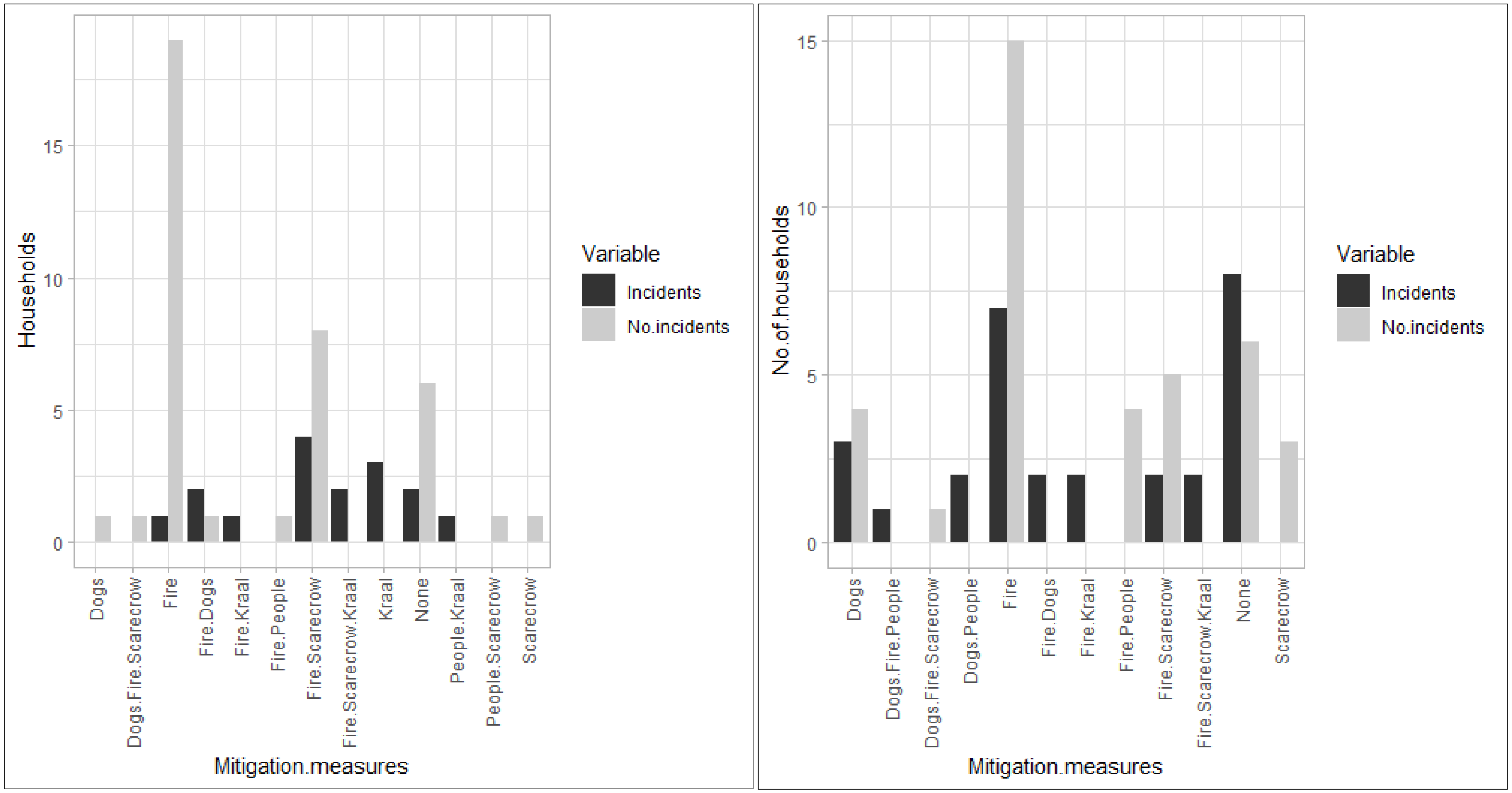


Figure 26. (a) Epupa Conservancy and (b) Okanguati Conservancy households livestock predation preventative and mitigation measures for the period 2019-2020.

A total of 105 incidents of livestock attacks from the field whilst grazing was reported for Okanguati Conservancy and 68 for Epupa Conservancy. For this descriptive analysis, events similar in time and space were treated as one event considering the matching livestock husbandry measures hence the 52 field incidents for Okanguati Conservancy and 41 for Epupa Conservancy. Out of these, 73% of Epupa Conservancy and 55% of Okanguati Conservancy field incidents occurred in the presence of a herder (*Figure 27*).

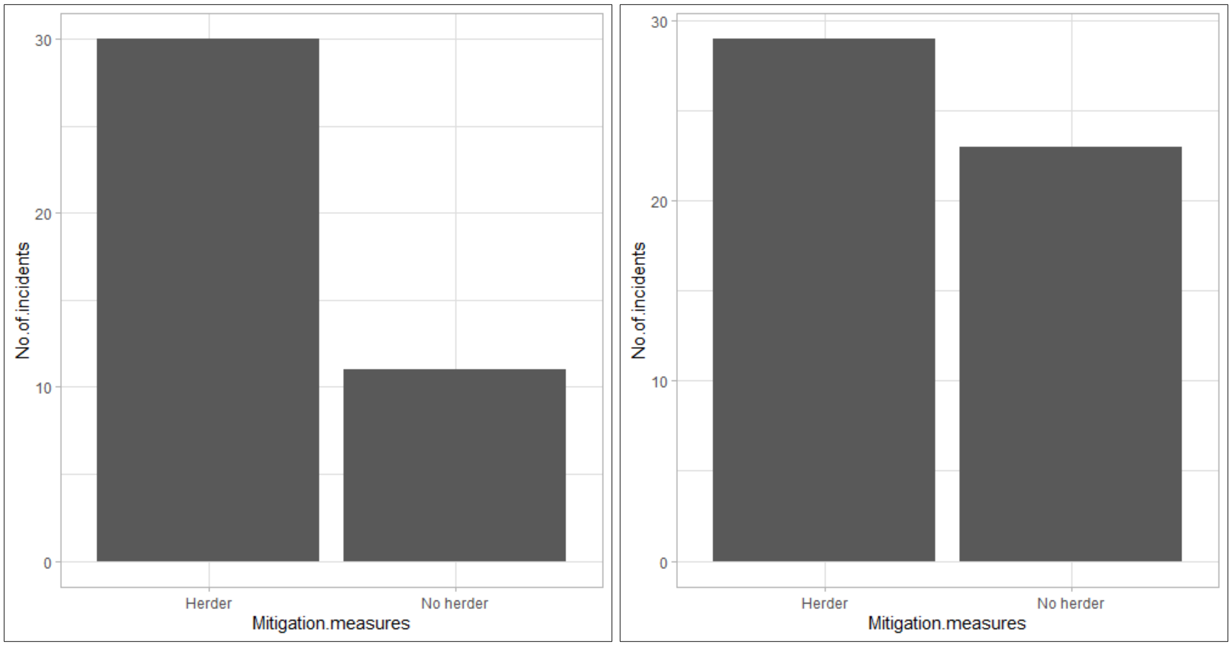


Figure 27. Mitigation measures of Epupa Conservancy and Okanguati Conservancy field incidents for the period 2019-2020.

Chapter 5: Discussion

5.1. Spatial and temporal distribution of livestock predation

This study investigated the temporal and spatial variation of livestock predation, the potential effect of vegetation structure on livestock predation by the different carnivores, the role of selected variables and their influence on livestock predation occurrence. While some studies reveal that livestock predation occurs predominantly either in dry or wet seasons Kuiper *et al.* (2015), and Sogbohossou *et al.* (2011), our results confirm that livestock predation in both conservancies is temporally changing but with no significant variation in the number of livestock attacks between seasons. Although not statistically significant, the highest numbers of incidents were recorded during the wet season.

During the wet seasons, the activities of farmers are partially shifted to crop farming hence the possibility of lack of livestock herding jeopardising livestock to predation. Further, the latter is arguable because during the wet seasons the grass is readily available close to homesteads as compared to the dry seasons when livestock is herded at a far distance from households increasing its susceptibility to predation. According to Epupa and Okanguati conservancies game guards (personal communication, 10 February 2020) the increasing trend of conflict in the early years of the conservancies might have been encouraged by farmers reporting incidents motivated by offsets and overtime as offsets are delayed, farmers lost interest in reporting incidents hence the decline in records. In addition, the migration of wild herbivores contributes to livestock predation. (Kissui *et al.* 2019) identified that livestock attacks from a boma by spotted hyena are linked to the seasonal migration of wildlife prey during the wet seasons shifting the movement of spotted hyena close to community areas increasing encounters with people and livestock.

Further and according to Aryal *et al.* (2014) seasons influence the movement, distribution of livestock and wildlife, carnivore-livestock interaction and conflict occurrence. Wild prey in dry seasons is weaker as a result of seasonal nutrient deficiency in grazing fodder resulting in prey susceptibility to carnivores. Whilst in wet seasons wild prey is widely dispersed and in better conditions hence the shift to and or increased livestock predation (Thorn *et al.* 2012, Mbiba *et al.* 2018). On the contrary, the indication of no major difference in the occurrence of conflict between seasons in Epupa and Okangauti conservancies could be as a result of almost uniform seasons throughout the year with exception of short and variable rainfall seasons during January to March. According to Thorn *et al.* (2012) and Kuiper *et al.* (2015) increased cases of livestock predation in both seasons are expected in times of wild prey scarcity.

This study identified caracal as the highest problem causing species in Epupa Conservancy and cheetah in Okanguati Conservancy. These findings correspond with NACSO's conservancy audit reports for the years 2014-2019 (NACSO Epupa Conservancy 2021, NACSO Okanguati Conservancy 2021). Considering the landscape of Epupa Conservancy, the rocky and mountain terrains forms rock crevices a suitable habitat for caracal however the findings for Okanguati Conservancy are debatable although the few valleys could potentially support cheetah populations. And additionally, data deficit on carnivores' populations in the area and game counts does not permit inferences on the linkage between conflict occurrence, abundance and distribution of carnivores in the conservancies. According to Broekhuis *et al.* (2017), the displaced feeding of carnivores to livestock is an indication of low wild herbivore populations in the area.

The occurrence of conflict correlates with above and below-average rainfall events (Thorn *et al.* 2012). Relating to this study, in 2016 Epupa Conservancy received 300mm NACSO Epupa Conservancy (2021) following a decline in conflict incidents for two consecutive years (2017 and 2018). The above average rainfall event might have contributed to abundant wild prey availability reducing predation pressure on livestock. The trend is similar for Okanguati Conservancy, the area received 90mm in 2014 and 140mm in 2015 NACSO Okanguati Conservancy (2021) followed by a declining number of conflict the following years (2016, 2017 and 2019). However, the cases increased again during 2019 as Namibia experienced the third-worst drought in history following the 2012/2013 drought (Shikangalah 2020). In that year, both conservancies experienced a spike increase in livestock-predator conflict. This could be attributed to the lack of food availability for carnivores as Stoldt *et al.* (2020) confirms that carnivores prefer wild prey in abundance.

Goats were the most frequently preyed livestock species in comparison to cattle and sheep. We suspect the wide distribution and high abundance of goats compared to other livestock species in both conservancies could be the underlying factor to the high predation susceptibility. A drought report by FAO (2016) references that cattle and sheep succumbed to the re-occurring droughts compared to goats. As cited by Stoldt *et al.* (2020) a decline in wild prey numbers can shift carnivore diet to livestock. The high number of livestock losses and very little evidence on presence and the number of wildlife prey in Epupa and Okanguati confirms the latter. Epupa and Okanguati communities dominantly farm with small stock therefore it can be deduced that the number of livestock is higher than wild prey jeopardising livestock to carnivores as the available prey.

As stated by Stoldt *et al.* (2020) the movement of wildlife is not restricted to human-defined ranges, this corresponds with our findings. The western part of Epupa Conservancy reserved as a wildlife exclusive zone (see *Figure 11*) borders settlements of Otjipemba, Ondendu and Otjikoyo. According to the density maps, the occurrence of conflict in the latter mentioned areas is intense (see results in *Figure 10*). Villages mark the presence of livestock and its proximity to wildlife areas could potentially encourage the in-movement of carnivores for easy prey and water availability.

Additionally, the movement is not restricted to wildlife only but parts of the wildlife exclusive zone are occasionally utilized for grazing during dry seasons. Lack of grazing fodder for livestock or climate-related factors can influence land-use decisions and strategies to improve livelihoods (Stoldt *et al.* 2020). The presence of water points in Epupa Conservancy's wildlife priority area is unknown nonetheless the sparse distribution of houses (see *Appendix 18* and *Appendix 19*) indicate minimal human activities in the area. Villages such as Omimire, Oheyuva and Okandombo that are at a distance from the wildlife area have a low intensity of conflict occurrence.

Comparably, the absence of Okanguati Conservancy management zones information could not permit accurate construction of inferences around the current conflict distribution and its relations to land-use zones in the conservancy. Nonetheless, the stretch of Okanguati Conservancy to the north is considered a wildlife area with very limited human activities and water points distribution hence the low conflict intensity (*Figure 12*). Similar to Epupa, conflict in Okanguati Conservancy is concentrated along villages (Ovitingo, Ombandaondu, Oomiore, Otjeme, and Otjitake) following the distribution of livestock. Refer to *Appendix 21* and *Appendix 22* for the distribution of houses and waters points in the conservancy.

The similarity in the distribution pattern of livestock predation between the event book data and GPS collected data for Epupa Conservancy addresses remarks on the accuracy and legibility of the event book coordinate system. This concludes the importance of using the event book system at the community level as a cost-effective and accurate tool for monitoring and decision making.

The occurrence of conflict in both conservancies along the Kunene River is not directly addressed in this study. The common type of conflict reported along the Kunene River is livestock predation by crocodiles which was not the focus of this study.

5.2. Vegetation structure

This study found no differences in the shrub vegetation structure between the different carnivores kill sites. Reflecting on these findings and the vegetation structure of the area, the similarity is potentially a result of; firstly, the vegetation structure is fairly homogenous in the study area, dominantly open trees and shrubs lands with patches of dense shrub lands and ephemeral rivers dense vegetation. Additionally, the landscape is similarly comprised of valleys, hills and mountains.

Despite these similarities in vegetation structure, the effect of visibility on the hunting preferences of different carnivores was contrasting. According to Michelle *et al.* (2013), heterogenous habitats of a mixture of settlements, grazing land and limited forests provide suitable hunting grounds for carnivores in particular leopards. As stated by Naha *et al.* (2020) carnivores repeatedly attack livestock in areas easily accessible and have similar features comprised of habitat type. These factors aid in prey detection, hunting success hence certain landscapes are hotspots. In our study, conflict hotspots are along villages, an indication of the presence of livestock and water availability which correlates with Naha *et al.* (2020) that prey density, human activities, the location of grazing area and water availability determine predation risks.

Visibility is crucial in the hunting success of different carnivores and/or carnivore-prey interaction (Gigliotti *et al.* 2020). In Epupa and Okanguati conservancies, hyena killed livestock in areas of high vegetation density (average tree density, 40trees/50m2 and average shrub density above 150/50m2 area) (*Figure 13, Figure 14* and *Figure 15*) hence the low visibility. Although contrary to the known hunting strategy of hyenas being cursorial predators Holekamp *et al.* (1997), the findings correspond with similar research work that hyena killed its prey in densely vegetated areas (Naha *et al.* 2020, Mbiba *et al.* 2018). Furthermore, a study in Kenya reveals hyena predation events occurred almost in every habitat type with a high correlation of increased vegetation cover (Abade *et al.* 2014).

Tree density was generally lower at majority of the kill sites in comparison to shrub density indicating the dominance of shrubs in the area, see *Figure 13* and *Figure 14*. Large carnivores' hunting is reported to elevate with dense vegetation, as such cover reduces the visibility of hunting carnivores by livestock consequently increasing the hunting success (Thorn *et al.* 2012). Furthermore, for ambush predators such as leopards, increased livestock predation risks are associated with decreased visibility and increased vegetation cover (Michelle *et al.* 2013, Miller, Jhala, Jena, *et al.* 2015). According to our results, the hunting preference of caracal and cheetah is dense areas that contrasted with the unexpected high visibility (*Figure 15*). Shrubs obstruct the line of sight, our results further detailed for caracal, density was higher in shrubs of a height less than 0.5m which is below and or equal to the visibility level of a caracal whereas for cheetah, shrub density was higher between 1-2m heights which is higher than the visibility level of a cheetah hence the high visibility (see Table 2 and *Appendix 17*). Vegetation structure affects the hunting ability of cheetah as opposed to ambush carnivores; cheetah requires space to chase prey although hunting in densely vegetated areas is possible, a cheetah's probability of success is increased in open habitats (Gigliotti *et al.* 2020).

According to Naha *et al.* (2020), leopard hunting behaviour preferring moderate vegetation cover differs from that of other carnivores such as hyenas, lions and tigers that depend on protective vegetation cover for hunting. Our study concludes that leopards hunt at low shrub density with low average visibility this is as a result of 62% of leopard kill sites were obstructed by boulder rocks and steep hills harboring ideal hunting grounds for leopard as an ambush predator hence the low visibility and shrub density. However, Woodroffe, Thirgood, *et al.* (2005) argues that leopard attacks occurred when herds entered dense bush and as ambush carnivores, leopards rely on adequate vegetation for camouflage but not too dense to interfere with prey visibility and catchability (Abade *et al.* 2014).

The mesopredators; caracal and black-backed jackal are perceived as the dominant predators of livestock in southern Africa. Caracal and jackal are natural opportunistic feeders with a diverse prey range from small mammals, medium-sized ungulates to reptiles (Neils 2018, Minnie *et al.* 2018). In Epupa and Okanguati conservancies, the presence of livestock presents such an opportunity. Concerning this study, jackal hunting preference was in areas of lower vegetation density (trees and shrubs) and higher visibility whereas caracal preyed livestock in densely vegetated areas with lower visibility (as presented in *Figure 13, Figure 14,* and *Figure 15*). The habitat selection of jackals varies from open grassland to avoiding densely vegetated areas and dominantly depended on food, shelter and security. Conversely, like ambush carnivores, caracals prefer dense areas for cover(Minnie *et al.* 2018).

Vegetation structure results from this study must be treated with caution as it reflects a small sample size of the different carnivores, an unequal number of samples between carnivores and results from different vegetation zones might differ.

5.3. Environmental and anthropogenic variables

This study identified the four major environmental and anthropogenic factors associated with livestock predation and predicted risk areas in Epupa conservancy and Okanguati conservancy. The variables are the presence of water points, elevation, distance from fields, and distance from houses. The predicted probability of conflict by EV and AV for both conservancies was higher around settlements or livestock priority areas.

Water is a significant resource affecting both the temporal and spatial distribution of wildlife. In arid African savanna, the availability of water has been identified as a contributing driver of human-carnivore conflict. Similar to our study, distance to water emerged as an important negative predictor of livestock predation by a leopard in non-forest areas and was associated with increased livestock losses (Karanth *et al.* 2012, Kuiper *et al.* 2015, Naha *et al.* 2020). Although our study was not species-specific the probability of conflict occurrence decreased with increased distance from water points. Livestock predation is higher within the 5000m radius from waterpoints *(Figure 16, Figure 17, Figure 18 and Figure 19*) and waterpoints are distributed along human settlements and livestock present areas.

Elevated and or mountainous areas and habitats thereof are regarded as suitable habitats for carnivores such as caracals (Minnie *et al.* 2018). Given the possible presence of carnivores in such areas, the probability of livestock predation whilst grazing is increased. Generally, both Epupa and Okanguati are mountainous landscapes and livestock grazing occurs throughout the different landscapes of the conservancies. Although not an important variable for predicting livestock predation in Epupa conservancy, livestock predation with a probability above 50% is predicted to occur at an average elevation of 976m whereas as an important predictor in Okanguati conservancy, high risk livestock predation is predicted at an average elevation above 1000m (*Table 5*). Livestock predation at slope level was coherent to elevation. Comparing our findings to North Bengal (leopard specific study), livestock predation occurred between 270m and 1200m in Pauri Garhwal as cited by (Naha et al. 2020). Livestock predation at slope level is coherent with elevation.

In the mountainous areas north of Okanguati and west of Epupa, livestock losses were rarely recorded and predicted probabilities in those areas were lower however OC livestock losses are directly correlated with elevation and scored as the second most important factor in determining livestock predation occurrence. The findings for Epupa Conservancy are contrary to conclusions from South Africas' by Michelle *et al.* (2013) that probabilities of livestock losses are higher on farms with high elevation. The two conservancies have contagious landscapes and similar land use therefore importance and conflict response to elevation is expected to be similar however it is not the case and the underlying factors are not known.

According to Epupa and Okanguati Conservancy game guards (personal communication, 10 February 2020), the lack of grazing fodder near household land is the primary cause of livestock grazing in mountains, distant from villages and unattended predisposing livestock to predation. This observation by game guards correlates with Naha *et al.* (2020) discovery that poor livestock protection practices, the location of grazing area also contributes to the extent of livestock predation. Livestock predation probability is estimated higher on farms of mixed farming (Michelle *et al.* 2013). The livestock and wildlife management structure of Epupa and Okanguati conservancies is not entirely distinct from the mixed farming approach so as the likelihood of potential issues such as conflict arising thereof.

Streams are associated with dense vegetation increasing cover for carnivores (Thorn *et al.* 2012). Contrary and according to this study, the distance from streams in both conservancies was not a major determinant of conflict occurrence despite the herding practice of livestock feeding on *Faidherbia albida* (Anna boom) pods along streams and rivers. During the study, very few livestock losses were reported from dry streams. These findings correlate with a spotted hyena specific study in Nyamandi communal area Zimbabwe, livestock was killed at a further distance (less than 4148m) from the stream (Mbiba *et al.* 2018). Comparing to our mixed predator study, conflict occurred within an average distance range of 604m in Epupa conservancy and 700m in Okanguati conservancy. Specific to the Kunene river as a water source with densely vegetated banks, carnivore livestock predation was rarely reported except predation by crocodile, with evidence of risk spots along the river demarcated off by thorn branches. During the study, the livestock predation sites visited were at least three kilometers from the Kunene river.

Wild prey availability and abundance is a major determinant of carnivore-livestock predation (Naha *et al.* 2020). However, conservancy data on prey abundance was not available for an informed analysis confirming such a relationship. Nonetheless, we suspect, the immerging and rarely experienced types of livestock losses by rarely recorded species such as python, honey badgers, birds of prey, baboons and wild cat is an indication of limited food and/or wildlife prey availability.

According to Mbiba *et al.* (2018) distance from the homestead is an important variable in predicting livestock depredation in communal landscapes. In India, livestock tiger conflict occurred at 1100m from villages (Miller, Jhala, Jena, *et al.* 2015). Similarly, in Epupa and Okanguati conservancies livestock predation occurred at an average 910m and 1083m from houses respectively (*Table 5*). Further, distance from houses and fields (average 6230m) in Epupa Conservancy has been identified as influential in predicting conflict occurrence as well as the distance from fields (average 2334m) in Okanguati Conservancy. Houses and fields represent the presence of people, a carnivore deterrent as indicated by some respondents in this study (*Figure 27*). We predict the outcomes are linked to the time of the day in relation to place (fields and houses). As predicted conflict increases with increasing distance from the fields (*Figure 18* and *Figure 19*) supposedly because and especially in ploughing and harvesting seasons farmers spent days at the crops field.

The proximity to houses and the predicted decrease of livestock predation with increasing distance from houses is a result of conflict incidents occurring from the house at night with limited human activities in addition to the presence of livestock as prey at homesteads. According to a lion specific study by Kuiper *et al.* (2015), cattle are killed within the home enclosure only at night and day incidents occurred more than 500m further from homesteads. In addition to the presence of people, hunting time preference play a role. Large carnivores are reported to nocturnally prey on livestock, although carnivores such as leopards preferred diurnal hunting for maximized visibility and prey catchability whereas cheetahs are known to avoid human activity areas in fear of prosecution (Minnie *et al.* 2018, Naha *et al.* 2020).

Roads are amongst the man-made landscape features affecting the distribution and activity patterns of carnivores (Kissui *et al.* 2019). In India, livestock attacks were prominent at 1200m from the road (Miller, Jhala, Jena, *et al.* 2015). In this study conflict for OC is prominent at an average 7057m from the road and at an average of 1105m for EC (*Table 5*). The occurrence of incidences in Okanguati conservancy in areas inaccessible by road could have influence the increased distance from roads.

The distribution of roads as a proxy for human presence and its effect on predation risks increases at a further distance from roads (Miller, Jhala, Jena, *et al.* 2015, Mbiba *et al.* 2018). The latter is contrary to our prediction probability, predation in both conservancies is predicted to decrease with increasing distance from roads. This could be as a result of roads dominantly along villages and/or livestock distribution areas despite the notion that roads present human presence avoided by predators (see the distribution of roads in relation to house, (*Appendix 18* and *Appendix 21*). NDVI as a proxy for vegetation cover did not emerge as an important predictor of conflict in both conservancies.

5.4. Kraal structure and mitigation measures

The risk of livestock predation by night is lowered when livestock is kept in the kraal with thick walls and additionally with the presence of men and domestic dogs (Woodroffe *et al.* 2007). In Epupa and Okanguati Conservancy, assessing the impacts and importance of kraaling livestock as a protective measure is difficult with the situation on the ground in the two conservancies. Culturally, the Ovahimba community do not kraal small stock (goats and sheep) but large stock (cattle) (Tjiposa, personal communication, 11 September 2019).

Certain households have kraals within the homestead and livestock is not enclosed at night. This reveals that livestock kraaling is not firmly practised hence it is poorly effective. In some houses, kraals are only constructed for kids and livestock overnight around the house thus predation within the house surroundings. Again, some households' livestock overnight both around the house and in the kraal whereas in some cases the house yard acts as a kraal hence the uncertainty to positively conclude whether livestock kraaling is effectively implemented in the area.

As it is with our study, according to Woodroffe *et al.* (2007) hyena killed more livestock enclosed in bomas. There is no definite conclusion about the kraaling of livestock. We can however empirically conclude that livestock kraaling is not strictly enforced. Nonetheless and leaning onto similar studies, densely build kraals provide effective overnight livestock protection against predation (Woodroffe *et al.* 2007). Similar studies found that kraals with weak structures are likely to experience livestock attacks (Broekhuis *et al.* 2017). According to the few confirmed positive kraals assessed in our study, there was no difference in kraal structure between kraals with and with no attacks, however, kraals with attacks had lower height, thickness and high visibility resulting in limited livestock protection. Many of the kraals from this study were repaired more than a year ago. In addition, there are five commonly practised non-lethal carnivore deterrent measures in both conservancies; scarecrows, fires, peoples, and dogs used to scare or discourage the movement and passage of carnivores close to homesteads and herding.

Livestock husbandry measures can influence the odds of livestock attack from the kraal (Broekhuis *et al.* 2017). Nearly all sampled positive attack kraals in Epupa and Okanguati Conservancy had mitigation measures in place except 10%. Despite these efforts, attacks from the kraal still occurred. It is however imperative to note that the employed measures were similar for control kraals. What then could cause livestock predation from the kraals especially given the no variance in structure between test and control kraals? To answer the question, Broekhuis *et al.* (2017) continue that the success of the carnivore deterrent is depended on the measure taken. Measures such as scarecrows give a false sense of security which carnivores consequently habituate to with time. Poorly maintained kraals with openings, poor quality and overhanging material provide little to no barrier for night hunting and climbing predators such as hyena and leopards.

Unexpectedly we found that even in the presence of a herder or guarded livestock, predation still occurred contrary to Woodroffe *et al.* (2007) who found that the risk of predation risk is lowered amongst small livestock grazing groups accompanied by a shepherd dog and a herder. However, regarding the experience and effectiveness of livestock husbandry, the probability of livestock attack was higher in herds accompanied by child herders (Woodroffe *et al.* 2007). The Ministry of Environment Forestry and Tourism has established and made provisions to offset farmers for livestock losses through the HWCSRS (MET 2018). This provision however has requirements such as, livestock should have been under guarding measures or reasonable precautions put in place during the time of the attack. The offset requirements might have encouraged farmers to falsely report the presence of herder when contrary livestock was not guarded. Lastly, the use of physical structures such as bomas has been identified as effective in lowering livestock losses by (Karanth *et al.* 2012) however in Epupa and Okanguati conservancies kraaling strictly enforced.

Chapter 6: Conclusions and Recommendations

The successful management of carnivores requires an understanding of the ecology and biology of the target carnivores (Minnie *et al.* 2018). This has not been fully addressed in our study. Further, the spatial and temporal movement of carnivores in the area remains unknown and apart from livestock carnivore conflict, livestock crocodile conflict and human primate conflict are some of the problem's experiences by these communities in need of research interventions. Livestock predation is driven by a variety of interconnected social, economic and environmental factors that differ spatially (Michelle *et al.* 2013). Most of these were not covered in our study. Hence the conclusions and recommendations arising herein are only applicable given the investigated parameters.

Livestock predation has important consequences for local populations in terms of foods security, safety and wellbeing, for the micro and macro economy, and also for wildlife conservation. There is an urgent need to re-orient the management of our wildlife reserves to pass on economic benefits to local communities and to conserve biodiversity. Information on spatial and temporal patterns on farmer's property losses in the highly affected areas contribute to designing and implementing effective mitigation measures (Lamichhane *et al.* 2018).

The lack of variety in the conflict between seasons is an indication of conflict throughout and conveys the lack of wild prey availability in the area. Livestock predation at households could not be effectively prevented as the structure of kraaling livestock is not properly enforced and carnivores are habituated to measures such as scarecrows and fires.

There are several livestock protecting methods recommended for cheetah, caracal, jackal, hyena and leopard (Williams and Wonder Nyoni 2008). Considering the primary predator management stage of Okanguati and Epupa conservancies, this study recommends, active game guards community awareness on livestock predator conflict and preventative management techniques, strengthened livestock kraaling at night, improved kraal maintenance and implementation of predator-secured kraals and/or visual barrier designed kraals implemented simultaneously with existing control methods could reduce the likelihoods of livestock predation from the kraals. Predator-secured kraals have improved livestock protection south of Kunene south (Gargallo 2021). Visual barriers around kraals prevent predators from seeing livestock and have reduce livestock predation in Kenya farming communities by 80% (Williams and Wonder Nyoni 2008).

Human carnivore conflict in Epupa and Okanguati conservancies t is influenced more by the presence of waterpoints, elevation (OC), distance from houses and fields (EC), and fields (EC). To guide the selection and successful implementation of suitable mitigation actions, it would be appropriate to align mitigation measures within and or prioritizing the identified risk areas. The placement of water points in wildlife areas at the moment is unknown and likely none given the little human activities in the area. The current placement of waterpoints has the potential to drive carnivore's concentration near water sources where it is probably easier to prey on livestock. Experimenting with the introduction of water points in wildlife areas could discourage the movement of carnivores into cropping, livestock and settlements zones to meet water needs. However, the effectuality of such recommendation is depended on factors such as the availability of wild prey in the area.

Retaliation against carnivores by farmers has not been documented in the two conservancies and the possibilities are not overlooked. Continued livestock predation in the absence of mitigation interventions and community support could tense local resistance towards living with carnivores. Aryal *et al.* (2014) suggest four mitigation measures to assist reduce and prevent the latter consequences; generate alternative local income sources, engagement and inclusion of communities in conservation education opportunities at the local level, the development of a livestock insurance policy, or the adoption and development of predator-proof livestock kraals. Epupa conservancies has an existing zonation plan (*Figure 11,* a source of NACSO) however none was available for Okanguati conservancy. It is therefore important to recognize wildlife areas, harmonise zonation plans between conservancies to prevent trans-conservancy conflict.

Wildlife activities play an important role in income generation which can potentially reduce the felt impacts of human-carnivore conflict on community livelihoods. In addition, income must be streamlined to the community either through employments creation and equitable benefit distribution can ease community tolerance towards living with carnivores. This is at least the case for Epupa Conservancy however no income-generating activities are known in Okanguati Conservancy except trophy hunting therefore very few benefits trickle down to the community level.

Despite conservancy reports on the community's willingness to have increased wildlife numbers, none of the conservancy reports indicates reintroduction to foster wild herbivore population in the area. The reintroduction of wildlife holds potential for regrowth of local wildlife population, and possibly redirect carnivore-prey focus and promote wildlife tourism. In addition, the introduction of wild prey in the area could aid in livestock-predation conflict resolution.

The similarity in the distribution of conflict between GPS collected data and event book data of Epupa Conservancy is an indication of the event book accuracy. This implies that event book data is liable and useful for decision making thus Okanguati Conservancy should consider recording spatial data as Epupa Conservancy. The outcomes of this study; risk maps, conflict trends, distribution of roads, houses and waterpoints and recommendation have been shared with Epupa and Okanguati conservancies and support organisations in a poster translated to the local language.

Considering previous local research work, their focus, and the outcome of this study, we recommend species-specific studies as the biology and ecology of different species differ and a monopoly of conflict preventative measures and risk factors may not apply to all species. Further a collar based spatial based study is required to determine home ranges and the seasonal movement and pattern of carnivores in the areas. Importance livestock husbandry factors such as livestock preventative and mitigation measures must be included in the anthropogenic variable modelling and additionally, the inclusion and segregation of age demography to test the influence and effectiveness of herding per age group. Furthermore, the primary understanding of the dynamics of carnivore livestock conflict requires awareness on prey and predator population sizes hence records of the population of carnivores and herbivores in the conservancies should be maintained.

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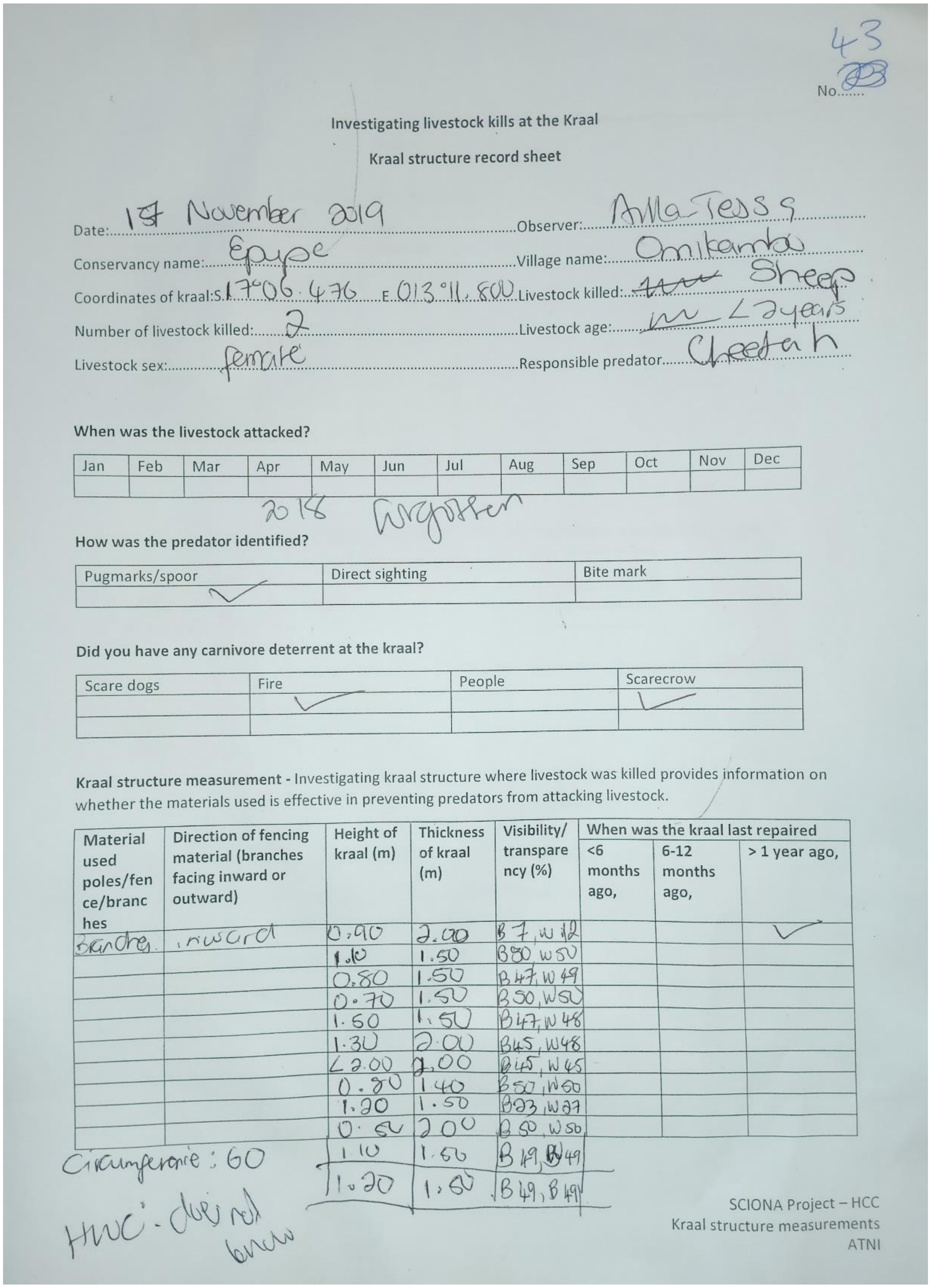
Appendices

Appendix 1. Kraal structure data collection completed sheet.



No. ~~23~~ 43

Investigating livestock kills at the Kraal

Kraal structure record sheet

Date: 1st November 2019

Observer: Anna-Tess S

Conservancy name: Epupe

Village name: Omikanda

Coordinates of kraal: S. 17°06.476 E. 013°11.800

Livestock killed: Sheep

Number of livestock killed: 2

Livestock age: < 2 years

Livestock sex: female

Responsible predator: Cheetah

When was the livestock attacked?

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

2018 forgotten

How was the predator identified?

Pugmarks/spoor	Direct sighting	Bite mark
✓		

Did you have any carnivore deterrent at the kraal?

Scare dogs	Fire	People	Scarecrow
	✓		✓

Kraal structure measurement - Investigating kraal structure where livestock was killed provides information on whether the materials used is effective in preventing predators from attacking livestock.

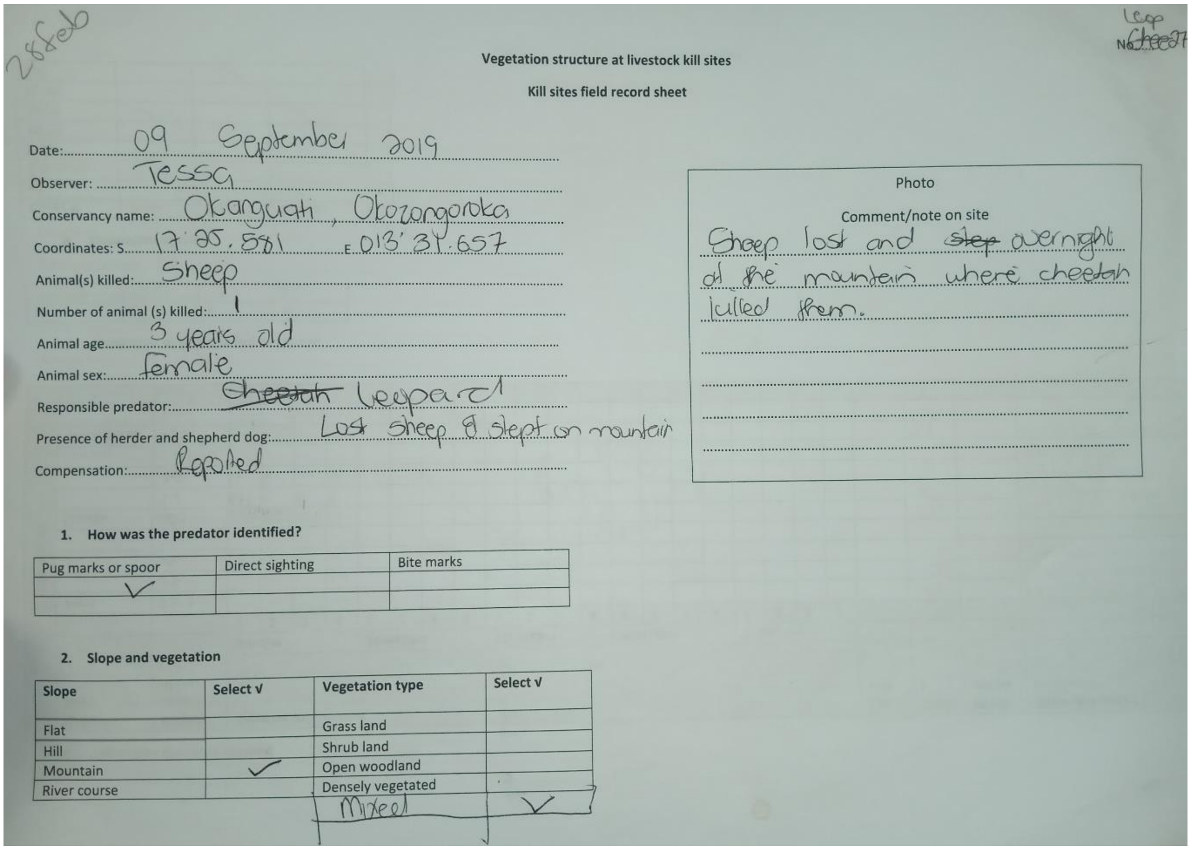
Material used poles/fence/branches	Direction of fencing material (branches facing inward or outward)	Height of kraal (m)	Thickness of kraal (m)	Visibility/transparency (%)	When was the kraal last repaired		
					<6 months ago,	6-12 months ago,	> 1 year ago,
Branches.	inward	0.90	2.00	B 7, W 12			✓
		1.10	1.50	B 80, W 50			
		0.80	1.50	B 47, W 49			
		0.70	1.50	B 50, W 50			
		1.50	1.50	B 47, W 48			
		1.30	2.00	B 45, W 48			
		< 2.00	2.00	B 45, W 45			
		0.80	1.40	B 50, W 50			
		1.20	1.50	B 23, W 27			
		0.50	2.00	B 50, W 50			
		1.10	1.50	B 49, B 49			
		1.20	1.50	B 49, B 49			

Circumference: 60

HWC - does not know

SCIONA Project – HCC
Kraal structure measurements
ATNI

Appendix 2. Vegetation structure data collection completed sheet.



28feb

Leop

No ~~Chee~~27

Vegetation structure at livestock kill sites

Kill sites field record sheet

Date: 09 September 2019

Observer: Tessa

Conservancy name: Okanguati , Otozongoroka

Coordinates: S 17°25.581 E 013°34.657

Animal(s) killed: Sheep

Number of animal (s) killed: 1

Animal age 3 years old

Animal sex: female

Responsible predator: ~~Cheetah~~ Leopard

Presence of herder and shepherd dog: Lost sheep & slept on mountain

Compensation: Reported

Photo

Comment/note on site

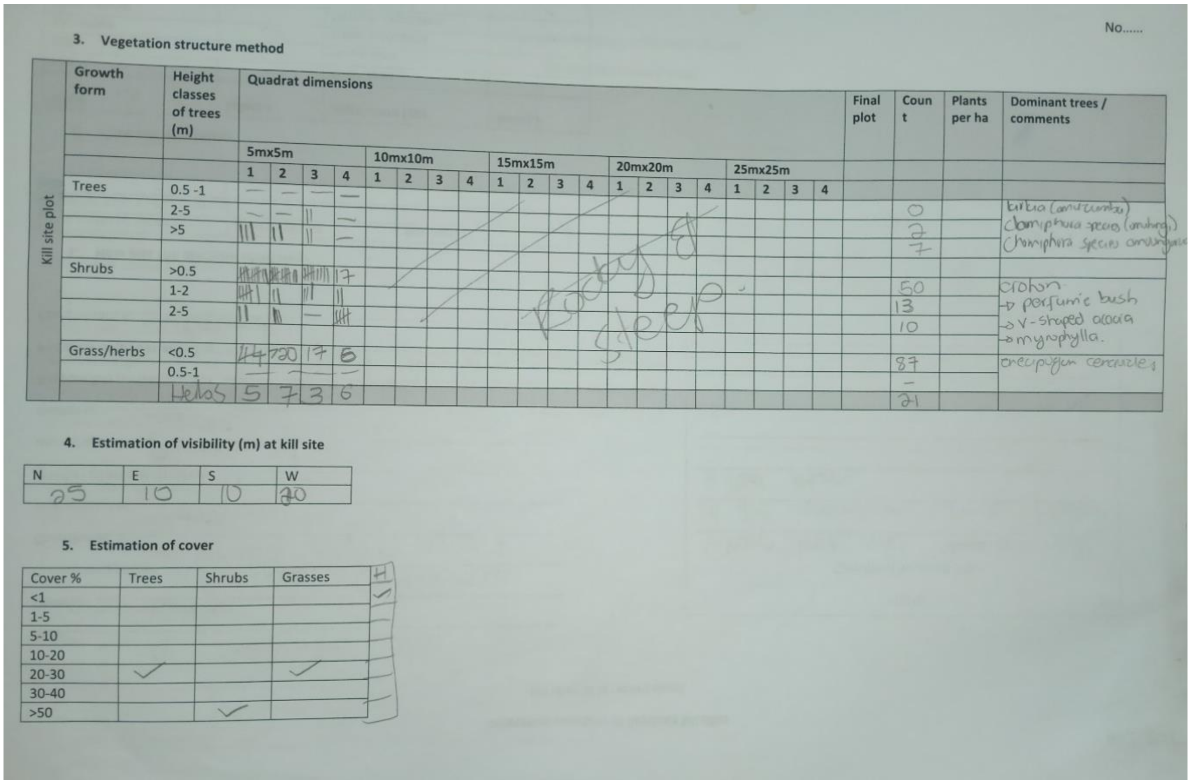
Sheep lost and ~~slep~~ overnight at the mountain where cheetah killed them.

1. How was the predator identified?

Pug marks or spoor	Direct sighting	Bite marks
✓		

2. Slope and vegetation

Slope	**Select √**	**Vegetation type**	**Select √**
Flat		Grass land	
Hill		Shrub land	
Mountain	✓	Open woodland	
River course		Densely vegetated	
		Mixed	✓



No......

3. Vegetation structure method

	Growth form	**Height classes of trees (m)**	**Quadrat dimensions**																				**Final plot**	**Count**	**Plants per ha**	**Dominant trees / comments**
			5mx5m				**10mx10m**				**15mx15m**				**20mx20m**				**25mx25m**							
			1	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**				
Kill site plot	Trees	0.5 -1	—	—	—	—																		0		kirkia (omuzumba)
		2-5	—	—	||	—																		2		Clamiphura species (omuhongi)
		>5	|||	||	||	—																		7		Chmiphora species omun
	Shrubs	>0.5	[illegible]	[illegible]	[illegible]	17																		50		croton
		1-2	[illegible]	||	|||	||																		13		→ perfume bush
		2-5	||	|||	—	[illegible]																		10		→ V-shaped acacia
																										→ mynophylla.
	Grass/herbs	<0.5	44	720	17	5																		87		oneapugon cencrizles
		0.5-1	—	—	—	—																		—		
		Herbs	5	7	3	6																		21		

Rocky & steep

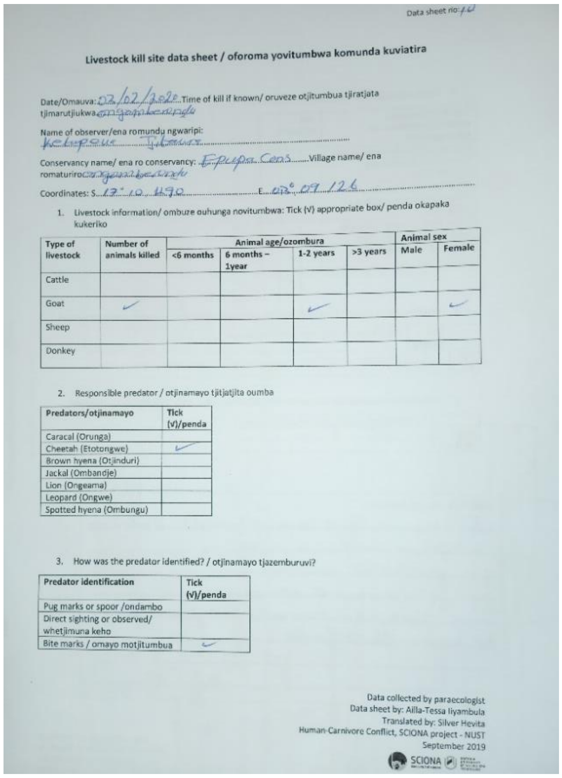
4. Estimation of visibility (m) at kill site

N	E	S	W
25	10	10	20

5. Estimation of cover

Cover %	Trees	Shrubs	Grasses	H
<1				✓
1-5				
5-10				
10-20				
20-30	✓		✓	
30-40				
>50		✓		

Appendix 3. Para-ecologist data collection completed sheet.



Data sheet no: 10

Livestock kill site data sheet / oforoma yovitumbwa komunda kuviatira

Date/Omauva: 02/02/2020 Time of kill if known/ oruveze otjitumbua tjiratjata tjimarutjiukwa [illegible]

Name of observer/ena romundu ngwaripi: [illegible]

Conservancy name/ ena ro conservancy: Epupa Cons Village name/ ena romaturiro [illegible]

Coordinates: S 17° 10. 490 E 013° 09.126

1. Livestock information/ ombuze ouhunga novitumbwa: Tick (√) appropriate box/ penda okapaka kukeriko

Type of livestock	Number of animals killed	Animal age/ozombura				Animal sex	
		<6 months	6 months – 1year	1-2 years	>3 years	Male	Female
Cattle							
Goat	✓			✓			✓
Sheep							
Donkey							

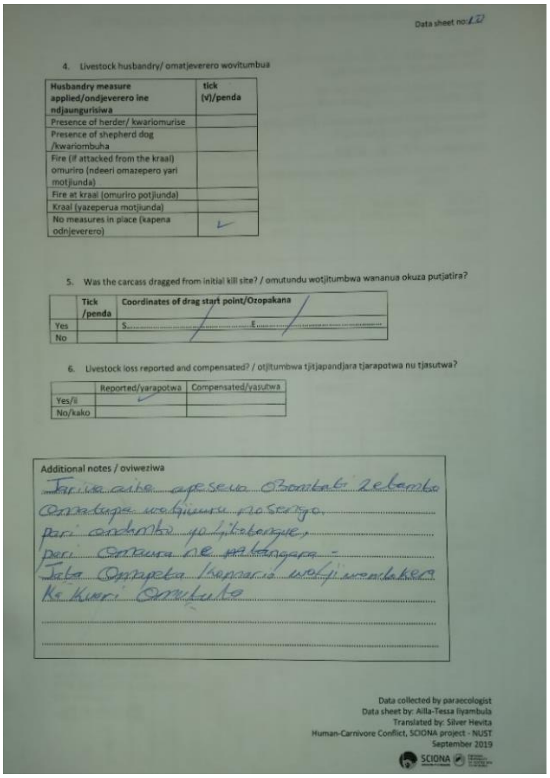
2. Responsible predator / otjinamayo tjitjatjita oumba

Predators/otjinamayo	Tick (√)/penda
Caracal (Orunga)	
Cheetah (Etotongwe)	✓
Brown hyena (Otjinduri)	
Jackal (Ombandje)	
Lion (Ongeama)	
Leopard (Ongwe)	
Spotted hyena (Ombungu)	

3. How was the predator identified? / otjinamayo tjazemburuvi?

Predator identification	Tick (√)/penda
Pug marks or spoor /ondambo	
Direct sighting or observed/ whetjimuna keho	
Bite marks / omayo motjitumbua	✓

Data collected by paraecologist
Data sheet by: Ailla-Tessa Iiyambula
Translated by: Silver Hevita
Human-Carnivore Conflict, SCIONA project - NUST
September 2019



Data sheet no: 10

4. Livestock husbandry/ omatjeverero wovitumbua

Husbandry measure applied/ondjeverero ine ndjaungurisiwa	tick (√)/penda
Presence of herder/ kwariomurise	
Presence of shepherd dog /kwariombuha	
Fire (if attacked from the kraal) omuriro (ndeeri omazepero yari motjiunda)	
Fire at kraal (omuriro potjiunda)	
Kraal (yazeperua motjiunda)	
No measures in place (kapena odnjeverero)	✓

5. Was the carcass dragged from initial kill site? / omutundu wotjitumbwa wananua okuza putjatira?

	Tick /penda	Coordinates of drag start point/Ozopakana
Yes		S. E.
No		

6. Livestock loss reported and compensated? / otjitumbwa tjitjapandjara tjarapotwa nu tjasutwa?

	Reported/yarapotwa	Compensated/yasutwa
Yes/ii	✓	
No/kako		

Additional notes / oviweziwa
Tariua aike apeseua Ozombabi 2ebambo
Omatupa wokuurusi nosengo,
pari ondmbo yo Tjitebengue,
peri Omaura ne [illegible] -
Jata Ompeta [illegible] [illegible]
Ke Kueri Omutute

Data collected by paraecologist
Data sheet by: Ailla-Tessa Iiyambula
Translated by: Silver Hevita
Human-Carnivore Conflict, SCIONA project - NUST
September 2019

Appendix 4. Epupa Conservancy variables Pearson's correlation matrix table.

Environmental variables							Anthropogenic variables				
	DEM	SL	WP	S	NDVI			F	WP	R	H
DEM	1										
SL	0.32	1					F	1			
WP	0.075	0.37	1				WP	0.68	1		
S	0.25	0.19	0.08	1			R	0.54	0.64	1	
NDVI	0.47	0.13	0.26	0.01	1		H	0.56	0.78	0.72	1

*SL – slope, *WP – waterpoints, * DEM – elevation, *S – streams, *D – distance, * F – fields, *R – roads, *H – houses, * NDVI – normalized vegetation index

Appendix 5. Okanguati Conservancy variables Pearson's correlation matrix table.

Environmental variables							Anthropogenic variables				
	DEM	SL	WP	S	NDVI			F	WP	R	H
DEM	1										
SL	0.30	1					F	1			
WP	0.12	0.24	1				WP	0.57	1		
S	0.29	0.32	0.23	1			R	0.43	0.33	1	
NDVI	0.02	0.22	0.39	0.16	1		H	0.59	0.41	0.18	1

*SL – slope, *WP – waterpoints, * DEM – elevation, *S – streams, *D – distance, * F – fields, *R – roads, *H – houses, * NDVI – normalized vegetation index.

Appendix 6. Okanguati Conservancy summary of environmental variables models build prior to model averaging.

Variables	Global model	Model O2	Model O3	Model 04	Model 05	Model O6	Model O7	Model O8
Intercept	-0.49	0.83	-0.81	-0.38	0.88	0.63	2.07	1.279
DEM	0.00 21	0.00072	0.0024	0.0017	0.00035	N/A	-0.0017	N/A
SL	-0.060	N/A	-0.055	-0.061	N/A	-0.058	N/A	N/A
S	0.000224	0.000054	N/A	0.00021	N/A	0.000075	N/A	N/A
NDVI	-1.97	-2.10	-1.97	N/A	N/A	-1.727	N/A	N/A
WP	-0.0004	-0.00038	-0.00039	-0.00038	-0.00036	N/A	N/A	-0.00036
Model AICc	174.41	176.43	172.59	173.22	173.42	194.38	196.72	171.37
AICc weights	0.08	0.03	0.21	0.15	0.14	0.00	0.00	0.39
P.values	Wp =0.00003 SL=0.050*	Wp = 0.00003	WP = 0.00003 SL= 0.059	WP = 0.00003 SL= 0.04	WP= 0.000028	SL = 0.0358		WP= 0.000013

*SL – slope, *WP – waterpoints, * DEM – elevation, *S – streams, *D – distance, * NDVI – normalized vegetation index

Appendix 7. Okanguati Conservancy summary of anthropogenic variables models build prior to model averaging.

Variables	Global model	Model OA2	Model OA3	Model OA4	Model OA5	Model OA6
Intercept	1.76	1.76	1.42	1.76	1.42	1.38
WP	-0.00030	-0.00030	-0.00038	-0.00030	N/A	-0.00037
F	0.000030	N/A	-0.000072	0.000028	-0.000090	N/A
R	-0.000083	-0.000079	N/A	-0.000083	-0.00011	N/A
H	-0.000005	0.000020	0.00013	N/A	-0.00016	N/A
Model AICc	164.90	162.79	166.34	162.74	173.29	162.67
AICc weights	0.10	0.28	0.05	0.28	0.00	0.29
P.value	WP= 0.005	Wp= 0.00504 R= 0.052	WP= 0.00035	WP= 0.0028	Roads= 0.004141	WP= 0.000024

*WP – waterpoints, *D – distance, * F – fields, *R – roads, *H – houses.

Appendix 8. Epupa Conservancy summary of environmental variables models build prior to model averaging.

Variables	Global model	Model E2	Model E3	Model E4	Model E5	Model E6	Model E7
Intercept	1.88	1.98	2.04	1.86	1.98	1.062	1.19
DEM	0.00011	N/A	-0.00014	-0.000088	-0.00045	0.0005	N/A
SL	-0.016	-0.015		-0.017	-0.012	-0.051	N/A
S	-0.00025	-0.00025	-0.00027	N/A	-0.00024	-0.00020	N/A
WP	-0.00025	-0.00025	-0.00026	-0.00024	-0.00027	N/A	-0.00027
NDVI	-2.79	-2.67	-2.57	-2.68	N/A	-5.12	N/A
Model AICc	115.34	113.05	113.38	113.68	114.07	125.33	109.00
AICc weights	0.03	0.09	0.08	0.07	0.05	0.00	0.68

p.values	WP= 0.0034	WP= 0.0032	WP= 0.00134	WP= 0.0035	WP= 0.0013	SL= 0.0466	WP= 0.00054

*SL – slope, *WP – waterpoints, * DEM – elevation, *S – streams, * NDVI – normalized vegetation index

Appendix 9. Epupa Conservancy summary of anthropogenic variable models build prior to model averaging.

Variables	Global model	Model AE2	Model AE3	Model AE4	Model AE5	Model AE6	Model AE7
Intercept	0.8.4	0.74	0.817	0.68	1.02	1.06	0.08
WP	-0.00012	N/A	-0.00014	N/A	-0.00010	N/A	N/A
R	-0.00020	-0.00024	N/A	N/A	-0.00033	N/A	N/A
H	-0.00060	-0.00073	-0.00073	-0.00091	N/A	-0.00073	N/A
F	0.00014	0.00011	0.00013	0.00010	N/A	N/A	-0.000009
Model AICc	109.17	108.25	107.83	107.48	114.16	108.87	124.69
AICc weights	0.12	0.19	0.24	0.29	0.01	0.14	0.00
p.value	F= 0.024 H=0.052	F= 0.04 H= 0.013	F= 0.029 H= 0.008	H= 0.0009	-	H= 0.0011	-

*WP – waterpoints, *D – distance, * F – fields, *R – roads, *H – houses,

Appendix 10. Epupa Conservancy combined variables Pearson's correlation matrix table.

	DEM	SL	WP	S	NDVI	F	H	R
DEM	1							
SL	0.32	1						
WP	0.075	0.37	1					
S	0.25	0.19	0.083	1				
NDVI	0.47	0.13	0.26	0.01	1			
F	-.0.06	0.34	0.68	0.03	0.15	1		
H	0.008	0.34	0.78	0.27	0.15	0.56	1	
R	0.11	0.43	0.64	0.26	0.15	0.54	0.72	1

*SL – slope, *WP – waterpoints, * DEM – elevation, *S – streams, *D – distance, * F – fields, *R – roads, *H – houses, * NDVI – normalized vegetation index

Appendix 11. Epupa Conservancy summary of combined variable models build prior to model averaging.

Variables	EAV1	EAV2	EAV3	EAV4	EAV5	EAV6	EAV7	EAV 8	EAV9	EAV10	EAV11	EAV12
Intercept	0.847	0.804	0.300	0.568	0.360	1.127	0.3493	1.039	1.348	1.334	1.388	0.6284
WP	-0.0001	-0.0001	N/A	N/A	N/A	-0.00025	N/A	N/A	-0.0001	-0.0001	N/A	
F	0.00013	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.00012		N/A	-0.00007
R	-0.00025	-0.0002	N/A	N/A	N/A	N/A	N/A	-0.0005	-0.0002	-0.0003	N/A	
H	-0.0007	N/A	N/A	N/A	N/A	N/A	N/A	N/A	-0.0007	N/A	-0.0009	
DEM	0.0005	0.0005	-0.0002	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
S	0.0001	-0.0001	N/A	N/A	-0.0003	N/A	N/A	N/A	N/A	N/A	N/A	
SL	-0.015	-0.0102	N/A	-0.057	N/A	N/A	N/A	N/A	-0.0082	-0.0050	N/A	
NDVI	-1.185	0.6776	N/A	N/A	N/A	N/A	-1.5025	N/A	N/A	N/A	N/A	
Model AICc	114.88	118.32	128.77	123.2	127.23	110.27	128.39	111.90	108.27	111.90	104.18	124.26
AICc weights	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.02	0.11	0.02	0.82	0.00
P.values	H = 0.03 F = 0.05	-	-	SL = 0.02	-	WP = 0.001		R = 0.0005	H = 0.03		H = 0.0003	F = 0.04

*SL – slope, *WP – waterpoints, * DEM – elevation, *S – streams, *D – distance, * F – fields, *R – roads, *H – houses, * NDVI – normalized vegetation index.

Appendix 12. Okanguati Conservancy combined variables Pearson's correlation matrix table.

	DEM	SL	WP	S	NDVI	F	H	R
DEM	1							
SL	0.30	1						
WP	0.12	0.24	1					
S	0.29	0.32	0.23	1				
NDVI	0.027	0.27	0.39	0.16	1			
F	0.28	0.34	0.57	0.24	0.20	1		
H	0.46	0.29	0.41	0.30	0.05	0.59	1	
R	0.13	0.23	0.32	0.033	-0.02	0.43	0.18	1

*SL – slope, *WP – waterpoints, * DEM – elevation, *S – streams, *D – distance, * F – fields, *R – roads, *H – houses, * NDVI – normalized vegetation index

Appendix 13. Okanguati Conservancy summary of combined variable models build prior to model averaging.

Models and Variables	Model OAV1	Model OAV2	Model OAV3	Model OAV4	Model OAV5	Model OAV6	Model OAV7	Model OAV8	Model OAV9	Model OAV10	Model OAV11	Model OAV12	Model OAV13	Model OAV14
Intercept	-1.26	-1.05	-1.94	-1.609	-0.252	0.345	0.649	0.046	1.92	1.01	1.564	1.567	1.12	1.02
WP	-0.0002	N/A	N/A	N/A	N/A	N/A	N/A	N/A	-0.0002	N/A	-0.00026	-0.00024	-0.0003	N/A
F	0.00008	-0.00001	0.0001	-0.0002	N/A	N/A	-0.0002	N/A	0.00009	-0.0001	0.000064	N/A	N/A	N/A
R	-0.00008	-0.0001	N/A	-0.0001	N/A	N/A	N/A	N/A	-0.00009	N/A	-0.00008	-0.000076	N/A	-0.00011

H	−0.0001	-0.0002	-0.0001	N/A	N/A	-0.0002	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
DEM	0.0287	0.0025	0.0023	0.0019	0.0002	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
S	0.00025	0.0001	0.0002	0.00015	N/A	N/A	N/A	-0.00005	N/A	N/A	N/A	N/A	N/A	N/A
SL	-0.032	-0.023	-0.033	N/A	N/A	N/A	N/A	N/A	-0.019	-0.020	N/A	N/A	N/A	N/A
NDVI	-0.191	-0.284	N/A	N/A	N/A	N/A	N/A	N/A	-1.533	-1.7	N/A	N/A	N/A	N/A
Model AICc	188.18	195.53	200.81	200.23	205.07	200.90	195.59	205.06	183.99	197.02	181.17	179.43	181.47	192.45
AICc weights	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.22	0.53	0.19	0.00
P.values	WP = 0.008	R = 0.008 NDVI = 0.05		F = 0.0237		H = 0.048	F = 0.003		WP = 0.005 R =0.034	F = 0.03	WP = 0.002 R = 0.04	WP = 0.001 R = 0.047	WP = 0.00006	R = 0.00089

*SL – slope, *WP – waterpoints, * DEM – elevation, *S – streams, *D – distance, * F – fields, *R – roads, *H – houses, * NDVI – normalized vegetation index

Appendix 14. Epupa Conservancy event book conflict spatial data 2014-2020.

Date	Village	lat	long	Carnivore	Livestock	No
01/06/2014	Omuhonga	-17.3833	13.15	Cheetah	Sheep	1
03/06/2014	Okuu	-17.3167	12.96667	Leopard	Cattle	1
06/06/2014	Okuu	-17.3167	12.96667	Spotted hyena	Sheep	1
10/06/2014	Omukazakejao	-17.3167	12.96667	Leopard	Cattle	1
12/06/2014	Otjindigue	-17.3167	13.03333	Leopard	Cattle	2
13/07/2014	not known	-17.3167	12.96667	Caracal	Sheep	1
13/06/2014	Okuu	-17.3167	12.96667	Leopard	Goat	8
14/06/2014	Ongamberondu	-17.25	13.1	Spotted hyena	Sheep	9
02/08/2014	Ondimba	-17.1333	12.73333	Leopard	Cattle	3
03/08/2014	Ombaro	-17.1333	12.81667	Leopard	Sheep	19
22/08/2014	Otjisika	-17.3167	12.96667	Caracal	Goat	1
28/08/2014	Otjipemba	-17.3167	12.96667	Leopard	Cattle	1
18/09/2014	Omutatati	-17.3167	12.96667	Leopard	Sheep	25
07/10/2014	Otjitara	-17.1333	12.73333	Leopard	Sheep	8
11/10/2014	Otjindungue	-17.3167	13.03333	Spotted hyena	Goat	12
12/10/2014	Otjindingue	-17.3167	13.03333	Caracal	Goat	3
13/10/2014	Otjikango	-17.25	13.1	Cheetah	Goat	1
02/11/2014	Otjipemba	-17.3167	12.96667	Leopard	Goat	3
13/11/2014	Okomirenda	-17.3167	13.03333	Cheetah	Goat	3
13/11/2014	Otjipemba	-17.3167	12.96667	Caracal	Goat	4
26/11/2014	Okuu	-17.3167	12.91667	Leopard	Sheep	14
03/12/2014	Etutu	-17.3167	13.03333	Leopard	Goat	3
26/03/2014	Ondonga	-17.15	12.96667	Cheetah	Goat	3
26/03/2014	Ondogna	-17.15	12.96667	Cheetah	Goat	7
11/06/2014	Ovizorombuku	-17.0333	13.23333	Cheetah	Goat	2
25/06/2014	Orukoko	-17.0333	13.23333	Leopard	Goat	4
05/10/2014	Ovibibi	-17.0333	13.23333	Caracal	Goat	6
06/10/2014	Okapare	-17.0333	13.23333	Caracal	Goat	2
18/10/2014	Ovibibi	-17.0333	13.23333	Caracal	Goat	7
17/10/2014	Otjitongozeva	-17	13.2	Caracal	Goat	2
27/10/2014	Orukoko	-17	13.21667	Caracal	Goat	2
02/11/2014	Otjitinge	-17.3167	13.03333	Caracal	Goat	1
12/11/2014	not known	-17.0667	13.13333	Caracal	Goat	1
21/12/2014	Okaromuzu	-17.0333	13.23333	Caracal	Goat	1
25/12/2014	Ovizorobuku	-17.0333	13.23333	Leopard	Goat	1
26/12/2014	Otjomazeva	-17.1	13.23333	Caracal	Goat	1
27/12/2014	Ejao	-17.05	13.16667	Caracal	Sheep	1
28/05/2014	Eturo	-17.15	12.96667	Leopard	Cattle	2

28/05/2014	Ourundu	-17.15	12.96667	Leopard	Cattle	3
29/05/2014	Orokambuende	-17.3167	12.96667	Leopard	Cattle	1
07/06/2014	Okahituo	-17.3167	12.96667	Leopard	Cattle	1
11/06/2019	Omutati	-17.3167	12.96667	Leopard	Cattle	1
22/08/2014	Okazenga	-17.3167	12.96667	Spotted hyena	Goat	3
28/08/2014	Okazenga	-17.3167	12.96667	Caracal	Goat	1
29/08/2014	Okazenga	-17.3167	12.96667	Caracal	Goat	1
05/10/2014	Okuu	-17.2833	12.95	Leopard	Sheep	2
25/10/2014	Omaheke	-17.3167	12.96667	Spotted hyena	Sheep	2
27/10/2014	Omutati	-17.3167	12.96667	Caracal	Goat	5
30/10/2014	Omutati	-17.3167	12.96667	Spotted hyena	Cattle	1
31/10/2014	Omutati	-17.3167	12.96667	Caracal	Goat	2
31/10/2014	Omapa	-17.3167	12.96667	Leopard	Sheep	4
13/10/2014	Otjikango	-17.25	13.1	Cheetah	Cattle	1
21/10/2014	Onayuua	-17.0333	13.36667	Leopard	Goat	4
21/10/2014	Onayuua	-17.0333	13.36667	Caracal	Goat	2
07/06/2014	Omuna	-17.3333	13.2	Leopard	Cattle	1
07/01/2015	Okwava	-17.3333	13.2	Leopard	Cattle	1
19/02/2015	Otjikango	-17.1	13.06667	Caracal	Goat	1
16/06/2015	Ondova	-17.2333	13.2	Cheetah	Goat	1
09/11/2015	Omuramba	-17.1833	13.25	Caracal	Goat	1
25/01/2015	Orukoko	-17.0167	13.23333	Caracal	Goat	3
05/05/2015	Ovibibi	-17.3	13.05	Leopard	Goat	8
25/05/2015	Ovizorobuku	-17.0167	13.16667	Caracal	Goat	1
21/12/2015	Ohakaji	-17.1167	13.25	Caracal	Goat	1
04/02/2015	Orute	-17.35	13	Cheetah	Goat	1
13/05/2015	orute	-17.35	13	Cheetah	Goat	2
07/06/2015	Omuhonga	-17.3833	13.15	Brown hyena	Goat	1
11/10/2015	Otjiheke	-17.3667	13	Cheetah	Goat	4
07/11/2015	Ominjandi	-17.2833	13.06667	Leopard	Goat	4
03/01/2015	Otjipemba	-17.3167	12.96667	Leopard	Cattle	2
15/01/2015	Otjingoro	-17.15	12.96667	Leopard	Cattle	1
13/01/2015	Okuu	-17.35	12.96667	Spotted hyena	Goat	5
20/01/2015	Orotjiruiro	-17.1333	12.76667	Leopard	Goat	8
05/02/2015	Orotjiruiro	-17.3167	13.06667	Leopard	Cattle	1
07/02/2015	Ombaue	-17.3167	12.96667	Caracal	Goat	5
10/03/2015	Ombaue	-17.3167	12.96667	Caracal	Goat	3
11/03/2015	Ondendu	-17.3167	12.9	Spotted hyena	Goat	4
09/04/2015	Okombambi	-17.2333	12.81667	Leopard	Goat	6
12/04/2015	Orotjiue	-17.2167	12.81667	Leopard	Goat	2
13/05/2015	Etundu	-17.2333	12.81667	Leopard	Cattle	1

17/05/2015	Otjimbayo	-17.2667	12.81667	Leopard	Cattle	1
19/05/2015	Etunda	-17.2333	12.81667	Leopard	Cattle	1
27/06/2015	Okazenga	-17.2333	12.81667	Leopard	Goat	4
29/06/2015	Omutati	-17.3167	12.96667	Caracal	Goat	3
16/07/2015	Okanyandi	-17.35	13	Brown hyena	Sheep	2
18/07/2015	Omazikua	-17.35	13	Spotted hyena	Goat	15
14/09/2015	Okenyina	-17.3167	12.96667	Leopard	Cattle	3
15/09/2015	Omaheke	-17.2667	13.03333	Leopard	Cattle	2
16/09/2015	Otjindingue	-17.3667	13.05	Caracal	Goat	1
21/09/2015	Otjindingue	-17.3667	13.05	Brown hyena	Goat	2
27/12/2015	Ombuhazu	-17.3333	13.05	Leopard	Cattle	2
12/03/2015	Okaninga	-17.05	13.08333	Leopard	Cattle	1
26/03/2015	Otjouzauo	-17.0667	13.13333	Leopard	Goat	1
20/12/2015	Otjouva	-17.1167	13.23333	Caracal	Goat	1
23/02/2015	Ondova	-17.2667	13.18333	Caracal	Goat	1
27/02/2015	Ondova	-17.2667	13.18333	Caracal	Goat	2
11/04/2015	Ongomberondu	-17.1333	13.13333	Caracal	Goat	1
15/05/2015	Oheuva	-17.1667	13.13333	Caracal	Goat	1
19/05/2015	Okorumbo	-17.2	13.16667	Caracal	Sheep	1
01/06/2015	Okatjauri	-17.2167	13.16667	Spotted hyena	Sheep	3
06/07/2015	Ongongorondu	-17.0833	13.18333	Caracal	Sheep	1
11/10/2015	Otjouva	-17.1333	13.23333	Caracal	Sheep	1
15/10/2015	Otjouva	-17.1833	13.15	Caracal	Sheep	2
15/11/2015	Omimire	-17.2	13.35	Caracal	Goat	7
15/11/2015	Omimire	-17.2	13.35	Caracal	Goat	2
20/12/2015	Otjouva	-17.15	13.23333	Cheetah	Sheep	1
13/02/2016	Orute	-17.3833	13.03333	Caracal	Goat	2
27/10/2016	Okapekona	-17.3667	13	Caracal	Goat	1
03/10/2016	Orute	-17.3833	13.06667	Jackal	Goat	1
05/11/2016	Onakai	-17.0667	13.21667	Caracal	Goat	1
26/02/2016	Otjouva-outiti	-17.2833	13.23333	Caracal	Cattle	1
10/04/2016	Otjouva	-17.2833	13.23333	Caracal	Goat	1
01/06/2016	Okapare	-17.0333	13.23333	Leopard	Sheep	1
01/06/2016	Okapare	-17.0333	13.23333	Leopard	Goat	1
25/08/2016	Ohakai	-17.1333	13.23333	Caracal	Goat	2
29/10/2016	Oheuva	-17.1167	13.18333	Jackal	Goat	3
11/05/2016	Ondova	-17.2833	13.23333	Leopard	Goat	1
30/05/2016	Oheuva	-17.3	12.93333	Brown hyena	Goat	3
16/06/2016	Oheuva	-17.15	13.15	Cheetah	Goat	1
21/06/2016	Oheuva	-17.1667	13.16667	Spotted hyena	sheep	1
19/08/2016	Epupa	-17.1667	13.16667	Caracal	Goat	1

02/09/2016	Oheuva	-17.1667	13.16667	Jackal	Goat	1
26/09/2016	Oheuva	-17.1667	13.16667	Caracal	sheep	1
26/09/2016	Oheuva	-17.1667	13.16667	Cheetah	Goat	1
08/10/2016	Oheuva	-17.1667	13.16667	Jackal	Goat	1
08/10/2016	Otjouva	-17.1	13.18333	Caracal	Goat	1
20/10/2016	Otjindingue	-17.35	12.95	Caracal	Goat	1
05/11/2016	Oheuva	-17.1667	13.16667	Jackal	sheep	1
28/11/2016	Omuhonga	-17.4	13.1	Cheetah	Goat	2
07/12/2016	Ongomberondu	-17.1833	13.16667	Cheetah	Cattle	1
07/02/2016	Otjindingue	-17.35	13.03333	Leopard	Cattle	1
11/03/2016	Otjindingue	-17.35	13.03333	Leopard	Cattle	1
14/05/2016	Otjindingue	-17.35	13.03333	Cheetah	Goat	1
22/07/2016	Okongongotue	-17.3333	13	Cheetah	Goat	3
10/10/2016	omutati	-17.2667	12.96667	Leopard	Cattle	1
16/10/2016	Orondumbu	-17.1	12.88333	Spotted hyena	Goat	7
17/10/2016	Okazenga	-17.2	12.96667	Caracal	sheep	9
18/10/2016	Ohunguyovivera	-17.15	12.85	Spotted hyena	Goat	1
29/10/2016	Otjikoyo	-17.3167	13	Caracal	Goat	5
09/11/2016	Otjindingue	-17.35	13.03333	Jackal	Goat	3
11/11/2016	Orombungu	-17.2333	12.81667	Caracal	Goat	1
12/12/2016	Ongondjanambari	-17.3167	13.03333	Jackal	Goat	1
07/01/2016	Orongunga	-17.05	13.23333	Caracal	Goat	3
08/01/2016	Orongunga	-17.05	13.23333	Caracal	Goat	2
15/01/2016	Okapare	-17.05	13.28333	Caracal	Goat	2
27/01/2016	Orokatati	-17.05	13.28333	Leopard	Goat	11
24/03/2016	Orongunga	-17.05	13.28333	Caracal	Goat	1
10/06/2016	Orokatati	-17.05	13.28333	Caracal	Goat	1
26/08/2016	Orokawe	-17	12.93333	Caracal	Goat	1
05/10/2016	Ouakatiku	-17.0833	13.28333	Spotted hyena	Goat	1
08/10/2016	Eyao	-17	13.13333	Jackal	Goat	1
04/11/2016	Otjindingue	-17.35	13.03333	cheetah	Goat	1
15/11/2016	Oheuva	-17.1167	13.1	Jackal	Goat	1
20/11/2016	Oheuva	-17.1167	13.1	Jackal	Goat	1
07/01/2016	Orongunga	-17.05	13.23333	Caracal	Goat	3
08/01/2016	Orongunga	-17.05	13.23333	Caracal	Goat	2
15/01/2016	Okapare	-17.05	13.28333	Caracal	Goat	2
27/01/2016	Orokatati	-17.05	13.28333	Leopard	Goat	11
26/02/2016	Otjovoutiti	-17.2833	13.23333	Caracal	Goat	1
27/02/2016	Otjindingue	-17.35	13.03333	Leopard	Goat	1
13/02/2016	Orute	-17.3833	13.03333	Caracal	Goat	2
11/03/2016	Otjindingue	-17.35	13.03333	Leopard	Cattle	1

24/03/2016	Orongunga	-17.05	13.28333	Caracal	Goat	1
20/04/2016	Otjouva	-17.2833	13.23333	Caracal	Goat	1
11/05/2016	Ondova	-17.2833	13.23333	Leopard	Goat	1
30/05/2016	Okuu	-17.3	12.93333	Spotted hyena	Goat	3
14/05/2016	Otjindingue	-17.35	13.03333	Cheetah	Goat	1
10/06/2016	Orokatati	-17.05	13.28333	Caracal	Goat	1
16/06/2016	Oheuva	-17.15	13.15	Cheetah	Goat	1
21/06/2016	Oheuva	-17.1667	13.16667	Spotted hyena	sheep	1
01/06/2016	Okapare	-17.0333	13.23333	Leopard	sheep	1
01/06/2016	Okapare	-17.0333	13.23333	Leopard	Goat	1
22/06/2016	Okongotue	-17.3333	13	Cheetah	Goat	3
26/08/2016	Orokawe	-17	12.93333	Caracal	Goat	1
19/08/2016	Oheuva	-17.1667	13.16667	Caracal	Goat	1
25/08/2016	Ohakai	-17.1333	13.23333	Caracal	Goat	2
02/09/2016	Oheuva	-17.1667	13.16667	Jackal	Goat	1
26/09/2016	Oheuva	-17.1667	13.16667	Caracal	sheep	1
26/09/2016	Oheuva	-17.1667	13.16667	Cheetah	Goat	1
08/10/2016	Oheuva	-17.1667	13.16667	Jackal	Goat	1
08/10/2016	Otjouva	-17.1	13.18333	Caracal	Goat	1
20/10/2016	Otjindingue	-17.35	12.95	Caracal	Goat	1
10/10/2016	Omutati	-17.2667	12.96667	Leopard	Cattle	1
16/10/2016	Orondumbu	-17.1	12.88333	Spotted hyena	Goat	7
17/10/2016	Okazenga	-17.2	12.96667	Caracal	sheep	9
18/10/2016	Ohungujovivera	-17.15	12.85	Spotted hyena	Goat	1
29/10/2016	Otjikoyo	-17.3167	13	Caracal	Goat	5
03/10/2016	Orute	-17.3833	13.06667	Jackal	Goat	2
05/10/2016	Ouakatiku	-17.0833	13.28333	Spotted hyena	Goat	1
08/10/2016	Eyao	-17	13.13333	Spotted hyena	Goat	2
29/10/2016	Oheuva	-17.1167	13.18333	Jackal	Goat	3
05/11/2016	Oheuva	-17.1667	13.16667	Jackal	sheep	1
09/11/2016	Otjindingue	-17.35	13.03333	Caracal	Goat	3
11/11/2016	Orombungu	-17.2333	12.81667	Caracal	Goat	1
04/11/2016	Ontjindingue	-17.35	13.03333	Cheetah	Goat	1
15/11/2016	Oheuva	-17.1167	13.1	Jackal	Goat	1
20/11/2016	Oheuva	-17.1167	13.1	Jackal	Goat	1
28/11/2016	Omuhonga	-17.4	13.1	Cheetah	Goat	2
12/12/2016	Ongondjanambari	-17.3167	13.03333	Jackal	Goat	1
07/12/2016	Ongomberondu	-17.1833	13.16667	Cheetah	Cattle	1
30/01/2017	Okanyandi	-17.2667	12.96667	Caracal	Sheep	1
06/08/2017	Okonyama	-17.2333	12.81667	Cheetah	Donkey	1
13/08/2017	Osemi	-17.25	12.8	Caracal	Goat	1

09/02/2017	Oheuva	-17.1833	13.25	Cheetah	Goat	1
25/02/2017	Orombepo	-17.0667	13.15	Caracal	Goat	1
09/11/2017	Oheuva	-17.15	13.18333	Caracal	Sheep	1
20/11/2017	Oheuva	-17.15	13.18333	Caracal	Sheep	1
23/11/2017	Oheuva	-17.15	13.16667	Cheetah	Goat	3
15/11/2017	Orokaue	-17	12.93333	Caracal	Goat	1
05/10/2017	omutati	-17.0167	13.46667	Cheetah	Sheep	3
06/02/2017	Omuramba	-17.2	13.26667	Cheetah	Goat	2
06/02/2017	Omuramba	-17.2	13.26667	Cheetah	Sheep	2
09/02/2017	Omuramba	-17.25	13.26667	Jackal	Goat	1
08/12/2017	Omuramba	-17.25	13.26667	Caracal	Goat	1
22/12/2017	Omuramba	-17.25	13.26667	Cheetah	Goat	1
24/04/2017	Oromina	-17.3667	13.03333	Leopard	Goat	1
29/05/2017	Orute	-17.3667	13.03333	Cheetah	Goat	1
25/11/2017	Orute	-17.3667	13.03333	Caracal	Goat	1
13/12/2017	Omuhonga	-17.3833	13.15	Caracal	Goat	1
10/11/2017	Ongukutu	-17.1167	12.98333	Leopard	Cattle	1
16/11/2017	Okozondjundju	-17	13.2	Leopard	Sheep	5
18/11/2017	Okozondjundju	-17	13.2	Leopard	Sheep	4
24/11/2017	Ondjindombondo	-17.05	13.08333	Leopard	Cattle	1
26/11/2017	Orukoko	-17	13.2	Leopard	Goat	2
26/11/2017	Orukoko	-17	13.2	Leopard	Sheep	4
30/11/2017	Okapare	-17.0333	13.16667	Cheetah	Sheep	1
30/11/2017	Okapare	-17.0333	13.16667	Cheetah	Goat	2
20/01/2017	Okuu	-17.3333	12.93333	Caracal	Goat	1
21/04/2017	Omuhonga	-17.3833	13.15	Cheetah	Goat	1
19/07/2017	Omao	-17.3	13	Spotted hyena	Goat	1
26/08/2017	Okavare	-17.1333	12.83333	Caracal	Cattle	2
20/09/2017	Okotayo	-17.3167	13.01667	Cheetah	Cattle	1
04/10/2017	Okongue	-17.25	12.95	Cheetah	Goat	4
31/10/2017	etunda	-17.2333	12.8	Leopard	Sheep	9
19/11/2017	Otjipemba	-17.3167	12.96667	Cheetah	Cattle	1
30/03/2018	Otjouva	-17.15	13.21667	Caracal	Goat	1
03/04/2018	Otjouva	-17.15	13.21667	Caracal	Goat	1
07/04/2018	Otjouva	-17.1833	13.18333	Cheetah	Goat	1
09/04/2018	Otjouva	-17.1833	13.18333	Cheetah	Goat	1
04/04/2018	Oheuva	-17.2333	13.16667	Jackal	Goat	1
20/06/2018	Oheuva	-17.1667	13.18333	Caracal	Goat	1
09/07/2018	Ohauatje	-17.3	13.05	Cheetah	Sheep	3
03/07/2018	Omuramba	-17.2167	13.23333	Cheetah	Sheep	2
03/07/2018	Omuramba	-17.2167	13.23333	Cheetah	Goat	2

03/09/2018	Omuramba	-17.2167	13.23333	Cheetah	Goat	2
10/09/2018	Okambanga	-17.2333	13.23333	Cheetah	Goat	1
11/12/2018	Erova	-17.2833	13.26667	Leopard	Goat	1
28/10/2018	Okandombo	-17.0667	13.46667	Jackal	Goat	1
03/11/2018	Oserundu	-17.1167	13.45	Jackal	Goat	1
23/10/2018	Eturo	-17.05	13.18333	Cheetah	Goat	1
28/10/2018	Oromupia	-17.0333	13.2	Caracal	Goat	1
18/02/2018	Otjipemba	-17.3167	12.96667	Cheetah	Goat	4
12/08/2018	Ongondjanambari	-17.3333	13	Jackal	Sheep	1
07/09/2018	omaheke	-17.1833	12.91667	Leopard	Cattle	1
16/09/2018	ondarua	-17.3	12.96667	Cheetah	Cattle	1
20/09/2018	Otjipemba	-17.2833	12.9	Cheetah	Sheep	1
28/09/2018	Orute	-17.2	13.08333	Cheetah	Sheep	1
10/10/2018	Otjipemba	-17.2667	12.88333	Cheetah	Sheep	2
15/11/2018	Otjomizo	-17.3833	13.1	Cheetah	Goat	12
07/12/2018	Okombambi	-17.2333	12.81667	Cheetah	Cattle	2
09/12/2018	Otjikoyo	-17.3167	13.03333	Caracal	Goat	1
18/12/2018	ouhotoue	-17.2833	12.85	Caracal	Sheep	2
30/12/2018	Otjikoyo	-17.3167	12.98333	Caracal	Goat	1
09/02/2018	Epupa	-17	13.23333	Caracal	Goat	2
21/02/2018	Epupa	-17	13.23333	Caracal	Sheep	1
11/03/2018	Orokatati	-17	13.21667	Caracal	Goat	1
14/04/2018	Ovizorobuku	-17	13.2	Brown hyena	Goat	1
14/06/2018	Ovizorobuku	-17	13.15	Caracal	Goat	1
25/08/2018	osemojozongo	-17	13.11667	Leopard	Sheep	2
23/09/2018	Orukoko	-17.0167	13.16667	Cheetah	Goat	1
22/11/2018	Onjokohe	-17.2	13.36667	Caracal	Goat	1
17/01/2018	Ombondo	-17.1667	13.35	Caracal	Goat	1
05/03/2018	Otjipemba	-17.2833	12.9	Caracal	Sheep	3
25/03/2018	Otjavininga	-17.2833	12.9	Caracal	Sheep	9
17/07/2018	orute	-17.35	13.1	Cheetah	Goat	1
25/10/2018	Okaokozondana	-17.35	13.05	Cheetah	Goat	1
13/11/2018	Otjipemba	-17.2667	12.93333	Caracal	Goat	1
03/06/2019	Omuramba	-17.2167	13.23333	Cheetah	Goat	4
27/07/2019	omikambo	-17.1167	13.16667	Cheetah	Sheep	5
09/09/2019	eyayona	-17.2667	13.3	Leopard	Cattle	1
28/11/2019	eyayona	-17.2667	13.3	Caracal	Goat	2
06/12/2019	omuramba	-17.2167	13.23333	Cheetah	Goat	4
17/12/2019	Omuramba	-17.2167	13.23333	Cheetah	Goat	2
21/12/2019	Omuramba	-17.2167	13.23333	Cheetah	Goat	1
20/06/2019	Okandombo	-17.0667	13.46667	Spotted hyena	Sheep	1

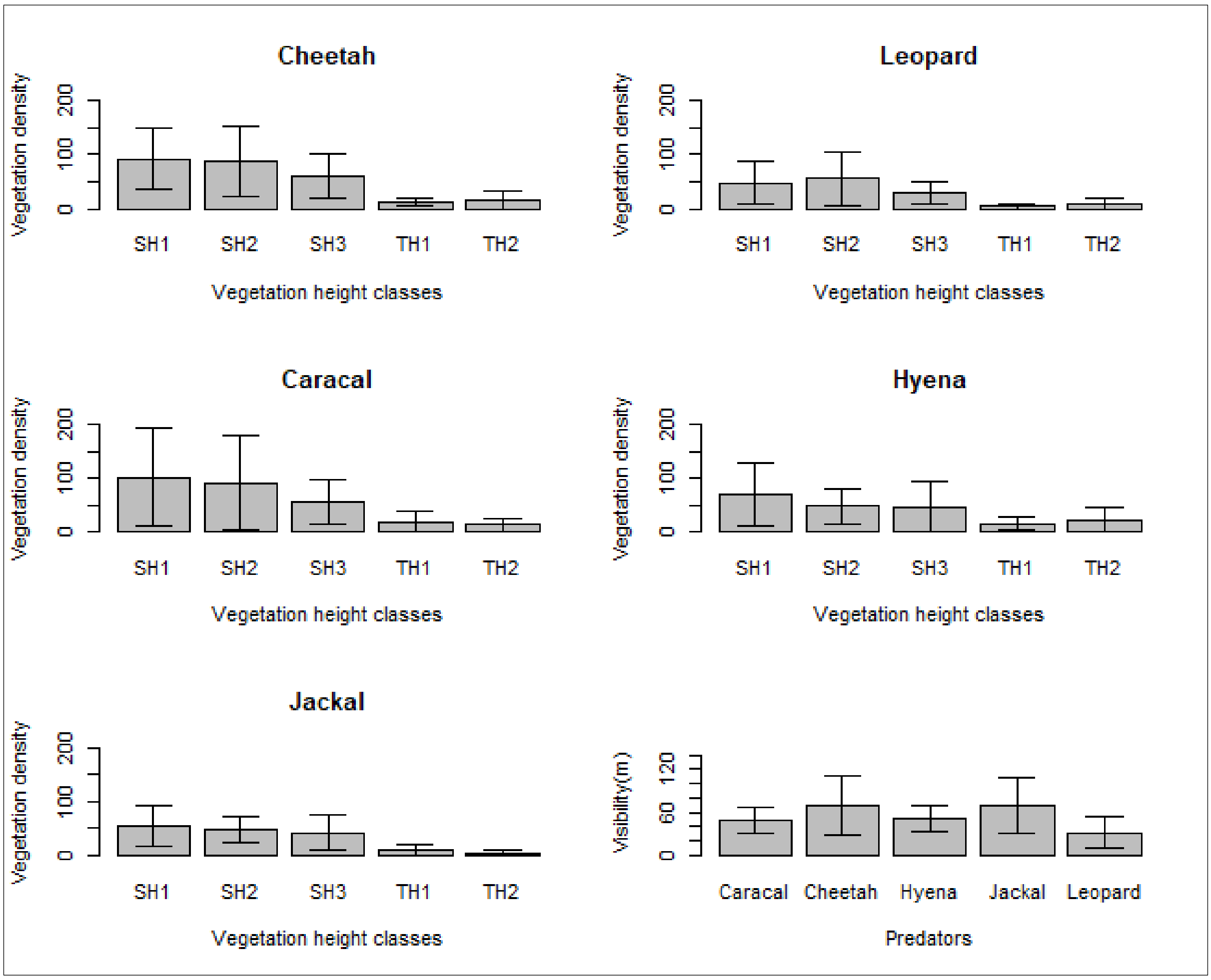
25/10/2019	Okandombo	-17.0667	13.46667	Caracal	Goat	1
18/12/2019	Otjouva-outiti	-17.15	13.21667	Cheetah	Goat	1
17/04/2019	Ominjandi	-17.3333	13.11667	Cheetah	Goat	4
10/01/2019	Ozongoko	-17.0667	13.35	Leopard	Cattle	1
13/01/2019	Ovipimbi	-17.0333	13.28333	Leopard	Cattle	1
16/01/2019	Okapare	-17	13.25	Caracal	Goat	2
16/01/2019	Okasemokoma	-17	13.25	Leopard	Goat	2
24/01/2019	Ongukutu	-17.0167	13.03333	Leopard	Cattle	1
13/02/2019	Eteyamgombo	-17.0167	13.16667	Caracal	Goat	2
07/04/2019	Omuhandja	-17.0167	13.2	Leopard	Goat	3
18/04/2019	ozongoko	-17.0667	13.35	Leopard	Sheep	3
20/04/2019	ovipimbi	-17	13.23333	Brown hyena	Goat	4
05/06/2019	Ejao	-16.9833	13.06667	Spotted hyena	Goat	3
27/08/2019	Ovizorobuku	-17.0167	13.16667	Leopard	Cattle	1
01/09/2019	okaobo	-17.0333	13.03333	Leopard	Sheep	4
07/09/2019	Ongongorondu	-17.0667	13.01667	Cheetah	Sheep	2
27/12/2019	Ondova	-17.2667	13.18333	Cheetah	Goat	5
27/12/2019	Ondova	-17.2667	13.18333	Cheetah	Sheep	1
04/01/2019	Otjpemba	-17.2833	12.9	Cheetah	Goat	2
09/04/2019	Otjipemba	-17.2833	12.91667	Cheetah	Goat	2
10/04/2019	Orovinguma	-17.3	12.9	Cheetah	Goat	3
18/04/2019	Otjikoyo	-17.3667	13.01667	Spotted hyena	Goat	1
13/05/2019	Otjozombinda	-17.3333	13.03333	Cheetah	Goat	3
13/05/2019	Otjozombinda	-17.3333	13.03333	Cheetah	Sheep	1
12/05/2019	Okombito	-17.3167	13.05	Spotted hyena	Goat	1
16/05/2019	Orotjizema	-17.25	13	Cheetah	Goat	1
20/05/2019	Ongotue	-17.35	13	Cheetah	Goat	1
08/06/2019	Ondimba	-17.1333	12.95	Leopard	Goat	1
14/06/2019	Otjipemba	-17.2833	12.9	Cheetah	Goat	2
07/09/2019	Omapa	-17.25	12.9	Cheetah	Sheep	2
07/09/2019	Omapa	-17.25	12.9	Cheetah	Goat	1
29/09/2019	Oratuwe	-17.2833	12.88333	Caracal	Goat	2
25/09/2019	Orongaka	-17.2333	13.05	Spotted hyena	Cattle	1
09/10/2019	Ondendu	-17.3333	12.93333	Caracal	Goat	3
21/10/2019	Ondova	-17.2667	13.26667	Leopard	Sheep	7
23/10/2019	Okasema	-17.3167	13.01667	Caracal	Goat	1
24/10/2019	Okasema	-17.3167	13.05	Spotted hyena	Goat	4
04/11/2019	Okanjandi	-17.35	12.9	Brown hyena	Goat	1
11/11/2019	Otjipemba	-17.2833	12.91667	Caracal	Goat	3
20/11/2019	Ovitemarundu	-17.2833	12.95	Caracal	Goat	1
21/11/2019	Otjipemba	-17.2833	12.95	Caracal	Goat	2

09/12/2019	Otjiparo	-17.25	12.95	Brown hyena	Goat	1
17/05/2019	Okanjandi	-16.9833	13.06667	Caracal	Goat	1
14/06/2019	Okapare	-17.0167	13.2	Jackal	Goat	1
07/08/2019	Omimire	-17.25	13.31667	Caracal	Goat	1
13/08/2019	Otukaravize	-16.9833	13.06667	Leopard	Sheep	2
22/08/2019	Omapa	-17.25	12.9	Caracal	Goat	5
13/10/2019	Okaruikozondu	-17	12.95	Caracal	Goat	4
16/10/2019	Otjiue	-17.0167	12.98333	Caracal	Goat	5
18/10/2019	Okomaere	-16.9833	13.05	Caracal	Goat	1
08/12/2019	Omuramba	-17.2167	13.23333	Cheetah	Goat	3
16/12/2019	Otjouva-outiti	-17.15	13.21667	Cheetah	Goat	1
12/03/2019	Otjouva	-17.1333	13.21667	Caracal	Goat	1
12/05/2019	Orukoko	-16.9833	13.18333	Brown hyena	Sheep	4
14/05/2019	Eyao	-16.9833	13.2	Brown hyena	Sheep	2
28/07/2019	Okotjikora	-17.0333	13.03333	Leopard	Cattle	1
30/10/2019	Otjikango	-17.2333	13.16667	Caracal	Goat	1
14/11/2019	Orotjivero	-17.2167	13	Spotted hyena	Cattle	1
16/11/2019	Orotjivero	-17.2167	13	Spotted hyena	Cattle	1
23/11/2019	engondo	-17.1333	13	Spotted hyena	Cattle	1
26/11/2019	Otjouva	-17.1167	13.21667	jackal	Goat	1
09/12/2019	Oheuva	-17.1833	13.18333	Cheetah	Goat	1
13/12/2019	ookatjunda	-17.2	13.16667	Cheetah	Goat	2
08/12/2019	Otjita	-17.1833	13.2	Cheetah	Goat	3
26/06/2019	Ombabazu	-17.3	13.05	Spotted hyena	Goat	1
04/11/2019	Onyanduuo	-17.3333	12.95	Brown hyena	Goat	5
05/11/2019	Okasema	-17.0333	13.2	Spotted hyena	Cattle	1
12/11/2019	Otjindingue	-17.35	13.01667	Caracal	Sheep	3
02/02/2020	Ongomberondu	-17.15	13.18333	cheetah	Goat	1
02/02/2020	Ongomberondu	-17.15	13.18333	cheetah	Goat	2
08/02/2020	Ongomberondu	-17.15	13.18333	cheetah	Goat	2
24/03/2020	Otjouva-outiti	-17.1333	13.16667	cheetah	Goat	1
28/03/2020	Ongomberondu	-17.1333	13.21667	cheetah	Goat	1
09/07/2020	Okovakaendu	-17.0667	13.18333	cheetah	Goat	5

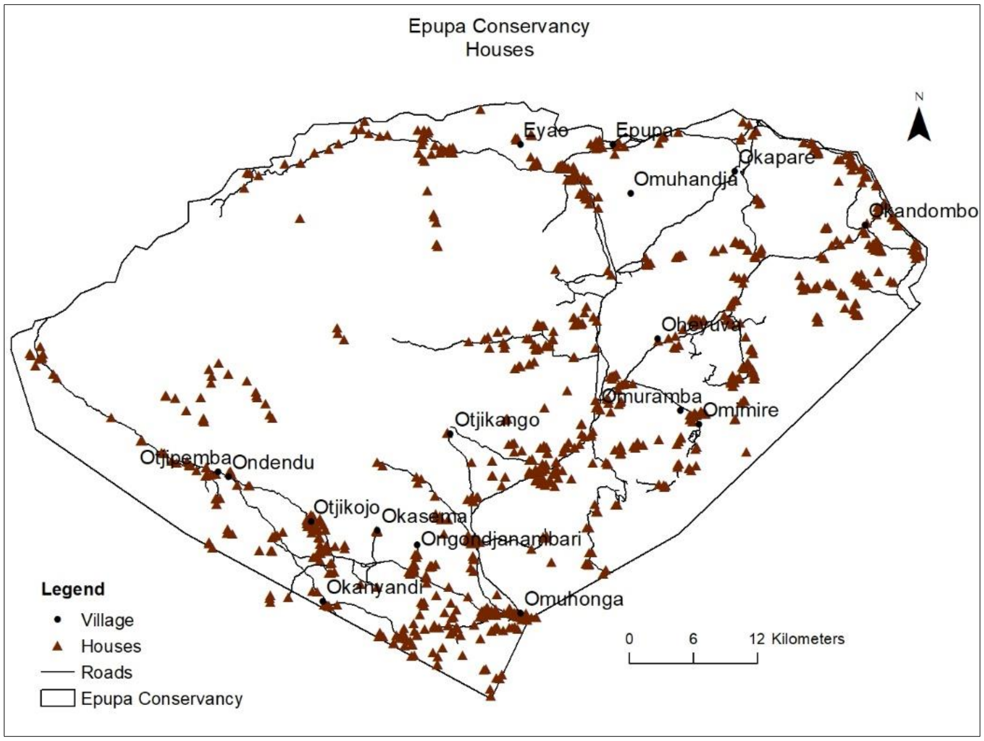
Appendix 15. Epupa Conservancy GPS collected data used for modelling.

Appendix 16. Okanguati Conservancy GPS collected data used for modelling.

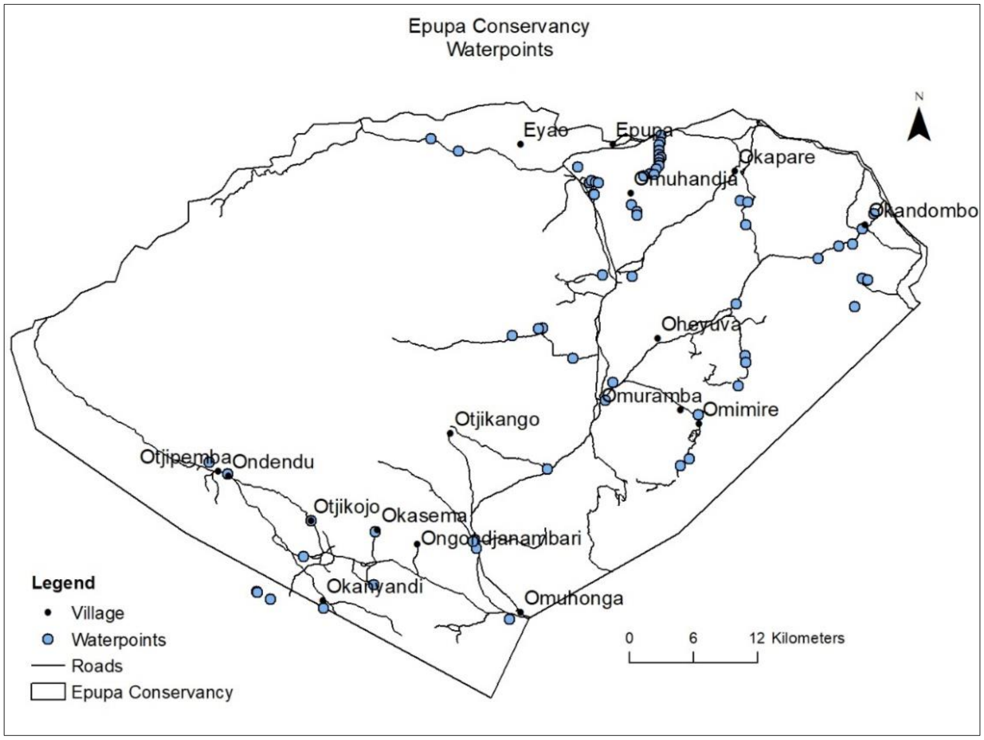
Appendix 17. Vegetation structure summary: shrub density, tree density and visibility. Shrubs heights classes are represented by SH and trees height classes are represented by TH. Standard deviation boxplots.



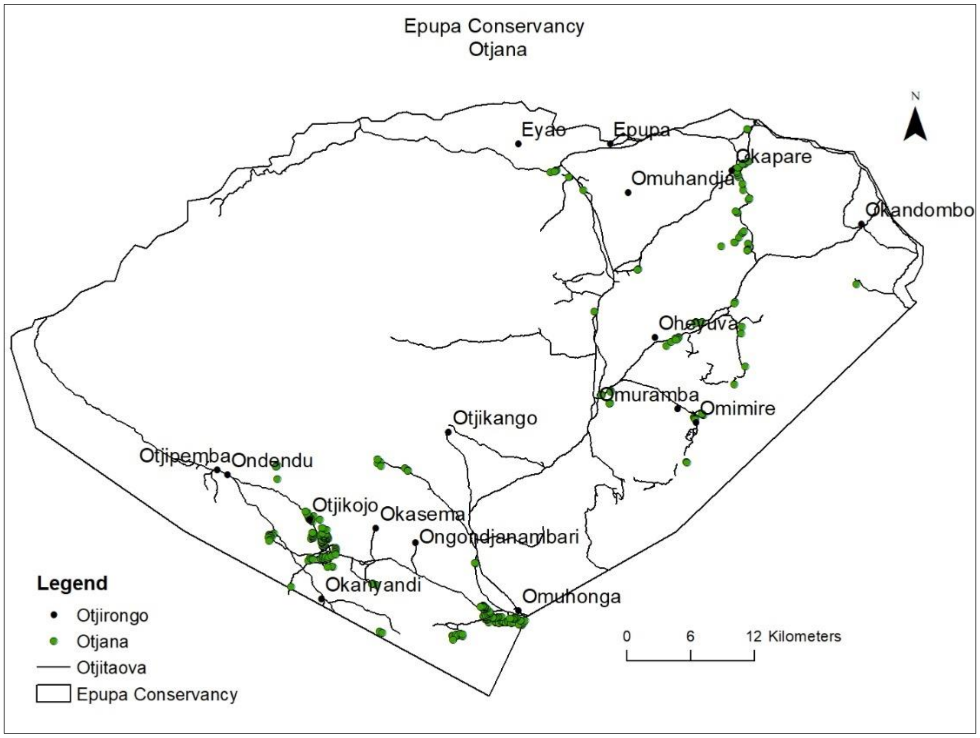
Appendix 18. Epupa Conservancy houses distribution.



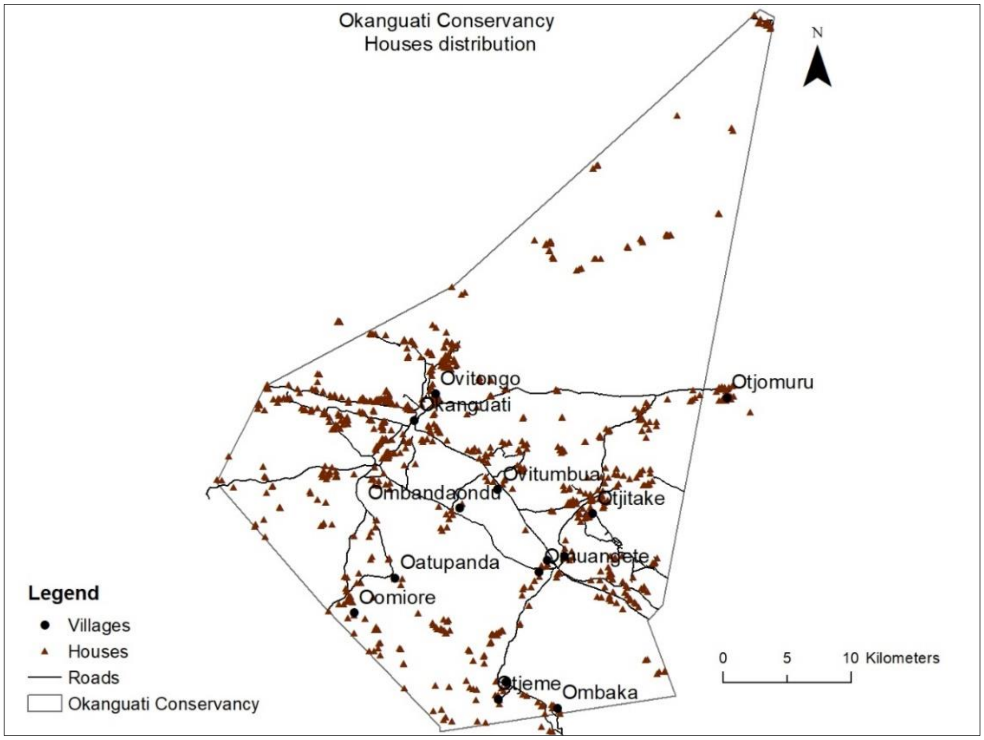
Appendix 19. Epupa Conservancy waterpoints distribution.



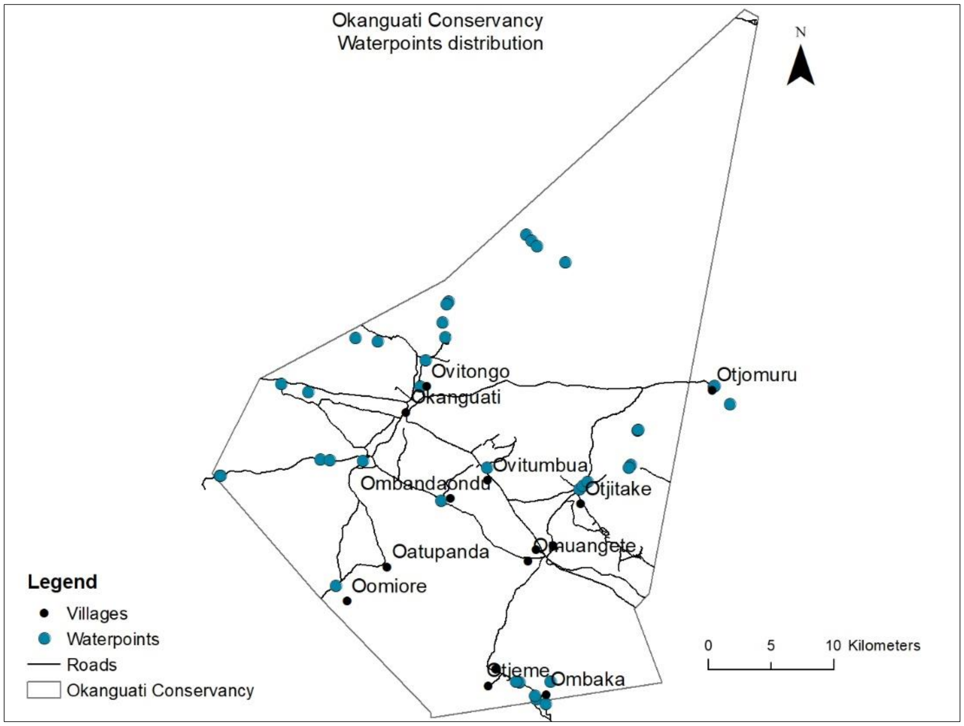
Appendix 20. Epupa Conservancy crop fields distribution.



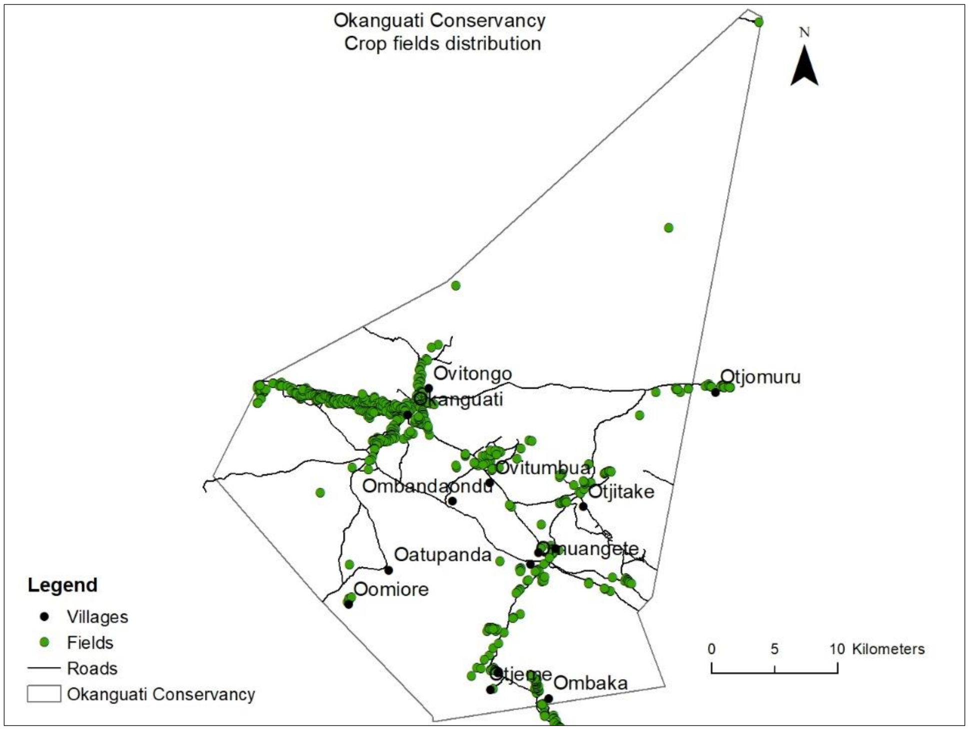
Appendix 21. Okanguati Conservancy houses distribution.



Appendix 22. Okanguati Conservancy waterpoints distribution.



Appendix 23. Okanguati Conservancy crop fields distribution.



Appendix 24. Vegetation structure at predator livestock killing site. Shrubs heights are represented by SH and tree heights by TH.

Predators	*SH1*	*SH2*	*SH3*	*TH1*	*TH2*	*N*	*E*	*S*	*W*
Cheetah	*50*	*13*	*10*	*2*	*7*	*25*	*10*	*10*	*20*
Leopard	*54*	*11*	*5*	*1*	*0*	*15*	*10*	*10*	*5*
Leopard	*54*	*121*	*71*	*11*	*4*	*43*	*34*	*38*	*50*
Caracal	*65*	*211*	*65*	*8*	*5*	*34*	*38*	*36*	*34*
Caracal	*80*	*219*	*76*	*1*	*0*	*45*	*38*	*105*	*50*
Cheetah	*25*	*13*	*17*	*5*	*3*	*42*	*40*	*15*	*35*
Cheetah	*11*	*14*	*28*	*0*	*5*	*15*	*12*	*40*	*30*
Cheetah	*73*	*91*	*45*	*12*	*28*	*60*	*35*	*30*	*62*
Cheetah	*123*	*204*	*34*	*4*	*4*	*22*	*40*	*70*	*48*
Caracal	*11*	*6*	*23*	*8*	*23*	*10*	*80*	*15*	*60*
Caracal	*170*	*78*	*73*	*9*	*7*	*25*	*70*	*86*	*58*
Caracal	*126*	*76*	*61*	*34*	*19*	*62*	*89*	*75*	*60*
Jackal	*96*	*66*	*70*	*23*	*11*	*71*	*56*	*58*	*49*
Caracal	*54*	*12*	*14*	*7*	*2*	*38*	*29*	*21*	*41*
Cheetah	*141*	*91*	*89*	*19*	*24*	*38*	*40*	*41*	*37*
Jackal	*12*	*10*	*6*	*3*	*0*	*10*	*25*	*18*	*10*
Jackal	*33*	*71*	*77*	*17*	*5*	*68*	*88*	*58*	*50*
Caracal	*65*	*86*	*115*	*11*	*9*	*22*	*30*	*33*	*37*
Brown hyena	*101*	*67*	*52*	*20*	*19*	*52*	*49*	*80*	*87*
Caracal	*61*	*29*	*7*	*8*	*3*	*39*	*52*	*35*	*44*
Spotted hyena	*24*	*28*	*1*	*4*	*5*	*10*	*15*	*15*	*35*
Cheetah	*121*	*81*	*97*	*6*	*9*	*82*	*63*	*55*	*68*
Cheetah	*110*	*112*	*117*	*13*	*8*	*68*	*70*	*64*	*78*
Cheetah	*80*	*72*	*118*	*12*	*4*	*59*	*70*	*75*	*68*
Cheetah	*135*	*145*	*61*	*4*	*2*	*48*	*54*	*110*	*82*

Jackal	*94*	*55*	*43*	*3*	*1*	*125*	*86*	*134*	*145*
Cheetah	*111*	*139*	*52*	*6*	*0*	*66*	*50*	*62*	*73*
Leopard	*1*	*7*	*24*	*1*	*1*	*10*	*15*	*5*	*10*
Leopard	*34*	*16*	*28*	*0*	*0*	*18*	*5*	*15*	*10*
Cheetah	*87*	*101*	*110*	*8*	*5*	*76*	*68*	*67*	*78*
Leopard	*50*	*86*	*27*	*3*	*1*	*69*	*68*	*128*	*41*
Jackal	*37*	*42*	*14*	*0*	*5*	*115*	*66*	*68*	*68*
Cheetah	*4*	*5*	*7*	*4*	*3*	*20*	*10*	*20*	*15*
Caracal	*171*	*112*	*87*	*23*	*3*	*33*	*38*	*21*	*34*
Cheetah	*18*	*65*	*90*	*12*	*24*	*50*	*64*	*90*	*54*
Cheetah	*23*	*17*	*13*	*5*	*8*	*72*	*78*	*38*	*74*
Cheetah	*160*	*0*	*0*	*27*	*1*	*100*	*200*	*200*	*200*
Cheetah	*56*	*1*	*0*	*9*	*2*	*200*	*110*	*95*	*100*
Spotted hyena	*134*	*79*	*104*	*15*	*9*	*63*	*46*	*72*	*64*
Cheetah	*60*	*81*	*114*	*12*	*2*	*78*	*72*	*92*	*73*
Caracal	*131*	*57*	*63*	*8*	*1*	*88*	*48*	*61*	*59*
Cheetah	*76*	*198*	*165*	*10*	*4*	*98*	*75*	*85*	*85*
Caracal	*10*	*50*	*98*	*47*	*0*	*150*	*80*	*90*	*110*
Cheetah	*69*	*66*	*54*	*17*	*0*	*180*	*200*	*200*	*180*
Caracal	*15*	*18*	*12*	*3*	*7*	*70*	*40*	*90*	*30*
Cheetah	*56*	*123*	*73*	*8*	*3*	*118*	*137*	*128*	*130*
Caracal	*1*	*9*	*23*	*0*	*15*	*30*	*55*	*40*	*50*