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Temporal and Spatial Distribution of Impala (*Aepyceros Melampus*) and Kudu (*Tragelaphus Strepsiceros*) In Tuli Safari Area

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A dissertation submitted in partial fulfillment of the requirements for a Bachelor of Science Honors Degree in Wildlife Ecology and Management Degree.

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DECLARATION

I Christopher Jani, {B192311B} do hereby declare that this dissertation titled temporal and spatial distribution of Impala (*Aepyceros melampus*) and Kudu (*Tragelaphus strepsiceros*) in Tuli safari area is my original work and all sources cited and or quoted are indicated by a list of references. This work has not been submitted to any university or submitted for acquiring any other qualification.

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DEDICATION

I dedicate this research to my father and my sisters.

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ABSTRACT

In adaptive management activities in diverse ecosystems stretching across national borders, such as the Greater Mapungubwe Trans Conservation area, an understanding of the distribution patterns and population structure of charismatic species is crucial. The timing of game viewing programs and ecotourism planning both rely heavily on this information. The following hypotheses were examined in Tuli safari area, Zimbabwe; (1) the spatial distribution of kudu and impala fluctuates with seasons in relation to environmental factors, (2) the population structure of kudu and impala across habitat in the Tuli Safari Area. Maximum Entropy modeling was used to simulate the geographical distribution of sable between the wet and dry seasons in the Tuli Safari Area, Zimbabwe. Predictor environmental factors were distance from roads and distance from rivers (MaxEnt).

Although the habitat area favoured during the rainy season was more than during the dry season, the distribution of impala did not change much between the wet and dry seasons. For both the wet and dry seasons, the likelihood of occurrence of Kudu were greatly influenced by the distance from roads. Kudu population structure did not vary across layers of habitat, indicating that the environment in the Tuli Safari Area had little bearing on kudu population structure. Similarly, population structure of impala was not different among habitats, and this indicated that the environment had no major influence on the population structure of impala in the protected area .Hence, population monitoring should be carried out to manage species like Kudu and Impala, as well as effective distribution monitoring for operational management and habitat conservation through additional information on the areas of occurrence /habitat selection. Long term monitoring of population numbers and offtakes are further essential for the implementation of an adaptive quota system based on population trends.

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LIST OF ACRONYMS

GTFCA	GREATER MAPUNGUBWE TRANSFRONTIER CONSERVATIONAL AREA
MAXENT	MAXIMUM ENTROPY
TFCA	TRANNSFRONTIER CONSERVATIONAL AREA
TSA	TULI SAFARI AREA
UTM	UNIVERSAL TRANSVERSE MERCATOR
ZIMPARKS	ZIMBABWE NATIONAL PARKS AND WILDLIFE AUTHORITY

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

The Tuli Safari Area is located in Zimbabwe's south-western region. The safari reserve's 16kilometer semi-circular perimeter was established when the initial inhabitants, known as the "pioneers," shot cannon balls over Zimbabwe into Botswana (Capesa 2010). Concession holders, managers and rangers of national parks, customers (hunters), and the local community are important stakeholders who make up the population (Darkey & Alexander, 2014). Prior to that date of 1958, when the Tuli safari area was declared, it was a restricted hunting area.

According to a signed memorandum, Zimbabwe's contribution to the Limpopo-Shashe Transfrontier Conservation Region consists mostly of the Tuli safari area. South-western Zimbabwe's Tuli Safari Area is a protected area that sits in the center of a ten-mile circular. The historical repercussion of this is that the Shashe River, or Tuli circle as it became called, became the international boundary between Zimbabwe and Botswana for the stretch where it runs through the circle. It is a protected area that is run primarily to offer hunting concessions and promote longterm conservation. It has been and continues to be dominated by an abundance and diversity of flora and faunal species. In the protected area, antelopes (including Impalas and Kudus) are the most prevalent and prominent species.

Globally, antelope species are experiencing diminishing populations. Disease outbreaks, irregular weather patterns, temperature rises, illicit hunting, human encroachment into important wildlife habitats, and frequent droughts are all contributing factors. Understanding how populations change and a population's behaviour considerably aids in determining conservation decisions regarding policy planning, restoration strategy, and management triggers susceptible to these aspects, especially when management activities are hazardous or expensive (Tsindi & Kupika, 2016). The International Union for Conservation1of Nature and Natural Resources (IUCN) has designated the Greater Kudu (*Tragelaphus strepsceros)* and Impala (*Aepyceros melampus)* as species of Least Concern. In most protected savannah habitats, the common impala *(Aepyceros melampus*) is ubiquitous, frequent, and plentiful. In other areas of its distribution, like as Burundi, it has been eradicated. Therefore, it is crucial to carefully monitor local impala populations to prevent more local extinctions like that of the species' near cousin, the Black-faced Impala (*Aepyceros melampus petersii),* which is currently fragile and restricted to Uganda (IUCN, 2013). Similarly, because local decreases have been seen elsewhere, the greater kudu need to be properly watched (Tsindi and Kupika, 2016).

The majority of the larger antelope species have seen a noticeable increase in their distribution and population even in commercial farming areas, (Zengeya et al, 2015). This expansion of the private sector wildlife industry has coincided with this trend. The majority of antelope species' populations are supported by private game ranches, including the Sable, Greater kudu, Eland, Tsessebe, and Wildebeest, which are the subject of much of the trophy hunting (Price Waterhouse 1996; Basel et al., 2018; Fritz et al., 2004; Tarakini et al., 2017).

The availability, quantity, and quality of food for large herbivores in semi-arid savannahs are impacted by irregular water availability, which also impacts the age and sex composition of herbivores with varying nutritional needs throughout the year (De & Pienaar, 1974; Joly et al., 2021; Lynch, 1974; Muposhi et al., 2016) .Effective conservation requires constant observation of the dynamics of herbivore populations. In both protected and unprotected regions throughout much of Africa, the majority of animal species have plummeted (Tarakini et al., 2017; Young, 1972).

1.2 PROBLEM STATEMENT

Although Tuli Safari Area conducts yearly wildlife counts, little is known about the kudu and impala's temporal and spatial distribution. The distribution, population structure and condition of the herbivores in Tuli Safari Area may have changed as a result of drought, rising temperatures, and other environmental stresses inside the Tuli circle. Spatial heterogeneity in the availability of resources like, rainfall, temperature, vegetation food and cover, is a major factor in population change and distribution of antelope species. Although many explanations have been put forth, there is a dearth of information and proof regarding the effects of habitat and environmental factors on the spatial distribution of kudus and impalas and population structure in the Tuli safari area, respectively. This information is crucial for the conservation of wildlife species.

1.3 RESEARCH OBJECTIVES

- To study seasonal distribution of Impalas and Kudus in the Tuli safari area between the year 2020 to 2022

- To determine the population structure of Impalas and kudus in the Tuli Safari area between 2020 to 2022

1.4 RESEARCH HYPOTHESIS

H_1 -There are differences in the temporal and spatial distribution of Kudus in the Tuli Safari Area

H_0 -There are no differences in the temporal and spatial distribution of Kudus in the Tuli Safari Area

H_1 – There are differences in the temporal and spatial distribution of Impala in the Tuli Safari Area

H_0 - There are no differences in the temporal and spatial distribution of Impala in the Tuli Safari Area

H_1 – There are differences in Kudu population structure in the Tuli Safari Area

H_0 - There are no differences in Kudu population structure in the Tuli Safari Area

H_1 – There are differences in Impala population structure in the Tuli Safari Area

H_0 - There are no differences in Impala population structure in the Tuli Safari Area

1.5 SIGNIFICANCE OF STUDY

Understanding the distribution of kudus and impalas is crucial for assessing the survivability of the two species. Planning, forming policies, and creating recovery programs all benefit greatly from knowing the state of a species at a given moment. Additionally, this study is anticipated to offer data on seasonal variations in the abundance of the two species as well as baseline data on population structure and sex ratio for subsequent research on these species.

CHAPTER 2

LITERATURE REVIEW

2.0 ANTELOPES DISTRIBUTION

All antelope species avoid hazardous areas, and the majority of them prefer safer ones, which reduce their risk of predation. In contrast to the bigger species (Wildebeest, Zebra, and Giraffe), which typically avoid places where predator space utilization is considerable, small species of prey (impala, warthog, waterbuck, and kudu) escape habitats used by predators (Thaker et al, 2011).

The conservation status of antelopes may improve or deteriorate due to anthropogenic effects, topdown restrictions brought on by the risk of predation, access to water, the amount or quality of food, and other factors. Understanding ecological patterns and processes, which are influenced by both naturally occurring and human-induced factors, requires an understanding of animal distribution and abundance (Williams et al 2001; Krebs 2009). When animal survival is at risk and management interventions have emerged, understanding these aspects becomes even more crucial.

Antelopes inhabit a variety of environments. They are mostly found in Africa's savannahs. There are more species of antelope in Africa than any other continent, and they are almost exclusively found in savannahs, with 25–40 species coexisting over most of East Africa(World and Union, 1998).

Previous studies have demonstrated that environmental variables including the accessibility of surface water, plant cover, and human-induced disturbances like roads and hunting activities have an influence on species distribution. In order to escape human disturbances, antelopes have been seen to avoid areas with heavy pressure from hunting in favour of regions with less exposure to hunting (Muposhi et al., 2016).

The most prevalent and numerous herbivore in Gonarezhou National Park is the impala (*Aepyceros melampus)*(Gandiwa, 2014). Little is known about the impala's seasonal patterns of habitat selection and usage within the very varied and dynamic ecosystems, despite their huge population and widespread range (Tsindi , 2016). Impala exhibit unique habitat usage patterns and seasonality in habitat choice. Due to the wide variety of microhabitats, impala exploit mixed open wooded areas to a great extent (Bonyongo, 2005).

Animals and their habitats have a dynamic connection. The fundamental environmental elements of an ecosystem determine a species' general pattern of distribution, and its individuals can adapt to changes in their local environment by moving about within their local range (Norton-Griffiths 1978). As opposed to medium or smaller herbivore species, big herbivores have a more generalized niche, which allows them to choose from a variety of habitat types. As a result, they may exploit a greater amount of the landscape. Wild herbivores like the Kudu however, may choose poor habitat patches in specific protected areas where trophy hunting (selective hunting) is practised permitted under controlled offtake levels in order to minimize human disruptions or exposure to hunting danger (Muposhi et al., 2016).Dekker (1996) proposed that knowledge of kudu and impalas' habitat preferences and geographical distribution is essential for managing protected areas.

Habitat quality, availability of surface water, competition, perceived threat from hunting or predation, and disruptions are all factors that influence habitat appropriateness and selection in the majority of ecosystems. In human-mediated ecosystems, issues including habitat loss and fragmentation, illegal logging, unsustainable use of animal resources, fires, and droughts have an indirect impact on how wild herbivores are dispersed. Fire has been seen to change plant cover in most savanna ecosystems, which affects the appropriateness of habitat areas exposed to frequent, accidental fires (Chamaillé-Jammes et al., 2016; Muposhi et al., 2016; Tarakini et al., 2017; Nicholson et al., 2020)

According to Peignier et al. (2019); Young (1972), the level of management interventions in specific ecosystems, such as the provision of artificial surface water, may reduce habitat diversity and alter the usual patterns of the movement of herbivore species. It has additionally been suggested that in some areas, vast networks of paths and roadways may have an impact on distribution trends for wild herbivores. The primary variables impacting the suitability of the habitat for big and medium-sized herbivores during the dry season are access to surface water, proximity to riverine ecosystems, and human interference due to roads... Because these factors are highly variable and dynamic, they can change from one year to the next. Due to water's homogenizing action supplies and accompanying human perturbations on the ecosystem, big herbivores may not always have greater range possibilities than medium-sized herbivores (Muposhi et al., 2016).

The stability of distribution of individuals has effects that go beyond basic ecology. When a distribution remains stable over time, it should be easier and more reliable to forecast the effects of management decisions (Chamaillé-Jammes et al., 2016)

Animal abundance varies throughout space because environmental circumstances are heterogeneous (Brown 1984). Narrow niche requirements prevent a species from reaching high abundance. The majority of herbivores often live in less disturbed regions and like grasses over forbs and browse for food (Bista, 2011).Species like Kudu and Impalas are key causes of landscape variability that age-selectively and are not just impacted by vegetation and landscape structure. Due to these characteristics, Kudus and Impala geographic distribution and population ecology are crucial issues in animal management, environmental preservation, and landscape conservation (Anderson et al., 2016; Schweiger et al., 2015).

In a study by Tsindi and Kupika (2016), Impala group sizes changed seasonally with harem herds becoming larger in the hot wet season and smaller in the cold dry season. Impala and kudu populations are on the rise. The two chosen species have a female-biased population structures and group makeup. The kudu populations' high proportions of females and relatively large juvenile population indicated that they had the viability to grow. Additionally, there are usually more females in Impala than males. However, the ratio of juveniles to adults is incredibly low.

2.1 KUDU

2.1.1 DISTRIBUTION

The eastern, central, and southern regions of Africa's grasslands, woodlands, and shrublands are home to the Greater Kudu subspecies of antelopes(Tsindi , 2016). Kudu may be found in Zambia, Angola, Namibia, Botswana, Zimbabwe, and South Africa. It can also be found from the east in Ethiopia, Sudan, Somalia, Eritrea, Tanzania, and Kenya; and from the north, where it is found in Central Africa, where it is found in Chad (Tilahum, 2019).

In a study by Muposhi et al, (2016) the probability of occurrence of Greater Kudu declined with increasing vegetation density estimated by NDVI, distance from artificial water points and distance from rivers, While the Greater Kudu probability of occurrence distribution increased with increasing distance from the roads

According to current trends, the kudu population in Nech Sarr Park appears to be recovering as a result of the implementation of rigorous wildlife conservation regulations, such as the exclusion of kudu from the staff ration and training quota as well as routine monitoring of the kudu populations (Fetene and Mengesha, 2016). A healthy and expanding population status of kudu is indicated by the current female-biased sex ratio (1:1.43), a high ratio of sub-adults compared to other age groups (1:0.89), and the relatively high proportion of juveniles (10.53%) in the population (Joly et al., 2021; Tsindi & Kupika, 2016).

2.2 FACTORS AFFECTING THE DISTRIBUTION OF KUDU

2.2.1 Habitat selection

The range of Kudu is vast, and they are not territorial. A strong bull's typical home range is 10 km^2 (Kingdon, 1997). They like riverine areas and may be found everywhere from sea level to 2450 metres above sea level. Despite the higher probability of susceptibility among isolated groups in East Africa, the kudu is not threatened (Kingdon, 1997). Greater Kudu exploit a variety of habitat area and are frequently seen in wetlands, the kudu (*Tragelaphus strepsiceros)* can be found in open woodland, grasslands, and forested grasslands. Greater Kudu less frequently and seldom utilize the closed forest and woodland thickets, respectively, as evidenced by Bakele, Mangesha, and Girma, (2008), who recorded the least frequent records of the species in closed woods and a riverine forests at 1.7% and 1.03% respectively. The extensive forested grasslands of the Nech Sar Plain were found to be commonly frequented by the larger kudu. This can be due to the wide forest plains' greater forage availability. (Stirling, 2000; Bakele, Mangesha, and Girma, 2008; Girma, Mantene, and Fatene, 2011).

The Greater Kudu distribution ranges from the east; Ethiopia, Sudan, Somalia, Eritrea, Tanzania, from the south, Namibia, Angola, Zimbabwe, and Botswana in South Africa; from the north, Chad; from the south, Zambia; and from the east, Kenya. They live anywhere there is a steady supply of water, including densely forested areas, rocky slopes, dry riverbeds, and other locations (Worku, 2018). Greater Kudus are primarily found in environments like forests and bushes. (Fritz, Gordon and Illius, 2004).

2.2.2 Water supply and food

Due to their dependence on surface water, kudu are only found in a few areas of suitable forests in southern and eastern Africa. According to Estes (1997), this may be explained by the abundance of favored food plants in these areas and the animal's capacity to consume a higher diversity of species of hardwood plants that serve as browse and provide shelter and safety. They inhabit regions with a lot of flora, rocky slopes, riverbeds, and other locations with a continuous/constant water supply. They feed on the foliage and shoots of many different kinds of plants. During dry seasons, they feed different kinds of forage, including wild watermelons. Greater Kudu is more dependent on water supplies than Lesser Kudu (Fateme et al, 2011).

Greater Kudus have been known to occasionally go on midnight trips to plantations and vegetable fields when agriculture has developed near to their habitat (Tilahum, 2019). A significant portion of the diet of Greater Kudus appears to consist of forbs, particularly creepers, which is likely due to both the comparatively high nutritional content of the foliage and the less fibrous structure of their plant stem material in compared to that of trees and shrubs. When forbs are scarce at specific times of the year and woody browsing is most wanted in the early development season when its new shoots are softest, fruits and pods serve as a vital nutrient-rich supplement (Tilahum, 2019).

2.2.3 Predation

A negative correlation between risk of predation and density of Kudu would suggest that ungulates are effective in reducing the limiting impact of predation through their extensive dispersal patterns (Matandiko, 2016). A higher correlation between Kudu density and closeness to water implies increased exposure to predation danger since constant water will be connected to a significant risk of predation (high carnivore consumption density) (Crosmary et al. 2012).

2.2.4 Human influence

The Kudu population abundance and distribution are expected to gradually fall over time due to a number of causes. They are frequently pursued for both sport and bushmeat (wild animal meat). Although their cautious nature and preferred deep scrub habitat offer some protection from hunters. The Kudu cannot survive in large fields or farming, therefore overgrazing and farming interference affect the Kudu's environment. (Tilahum, 2019).

Low ungulate populations and distribution can be seen, for example, around park edges, along roadways, and in areas where there are indications of human access or use. The proximity of visitor camps, on the other hand, may provide protection from poaching, which would increase density.

(Matandiko, 2016).

In addition to these dangers, studies done in Kafue National Park show the species facing risks of human encroachment on park boundaries, which might result in a reduction in animal ranges, increased poaching, and increased burning (World and Union, 1998). Baseline information on the distribution and abundance of this group is needed in order to properly conserve and manage the vast herbivore population in Kafue National Park in the face of these threats (Gaynor, 2019).. One theory holds that enormous herbivore concentrations may now be constrained by poaching (Matandiko, 2016; Muposhi et al., 2016) .

2.3 IMPALAS

2.3.0 DISTRIBUTION

The subspecies is believed to be quite common throughout the assessment region and is present in almost all of the protected areas despite the lack of precise estimates. The Common Impala's current distribution range is largely unchanged from its past range. The nations where the species naturally exists include Angola, Tanzania, Kenya, Malawi, Mozambique, Namibia, Rwanda, South Africa, Swaziland, Botswana, Zambia, and Zimbabwe (Selier et al, 2016). The Common Impala is a generalist and adapts well to many plant types. Savannah areas make up the majority of its native range (Gaidet et al, 2013).

2.3.1 FACTORS AFFECTING DISTRIBUTION OF IMPALA (*Aepyceros melampus*)

2.3.1.1 Habitat selection

Impala avoid open grassland and favour open forest (Pienaar, 1974); yet, they frequently inhabit the ecotone between the two, where Acacia and Mopane woodlands are widely exploited. Limiting considerations also include access to surface water for drinking and protection from the elements and predators (Mason 1976, Pettifer & Stumpf 1981).

Impala prefer year-round browsing areas over grasslands, likely as a result of competition for pasture with other grazing animals like Wildebeest. Wildebeest and impala were drawn to grass flushes during the dry season. Grazers may be impacted differently from mixed-feeders by rainfall, competition, and fire regimes (Styles et al., 2014). Due to its desire for shade, the impala lives in forests. It can additionally be found in the ecotone, or transitional area, between savannahs and woods. The best locations are those close to water sources. Populations frequently coexist in *Colophospermum mopane* and *Acacia* woods in southern Africa. Seasonal differences in habitat preferences lead to a preference for *Acacia Senegal* forests in the rainy season and *A. drepanolobium* savannahs in the dry (Rutina et al, 2005). Predator vulnerability is another element that could affect habitat selection; Impala typically avoid regions with long grass since prey may be hidden there.

2.3.1.2 Water supply and food availability

Due of their dependence on water, impala prefer semi-arid regions that are near to rivers (Young 1972; Stewart & Stewart 1963). Young's (1972) findings show that in more than half of the cases, herds remained within 1,6km from the river. Where water is available, Impala will drink often, but during the dry season they rely more on it.). However, they often drink when it is openly accessible (Tello & van Gelder 1971). Impalas were observed drinking throughout the day at the Mkuzi Game Reserve, but primarily around noon (Villet & Woodiwiss 1986).

In pursuit of fodder and water during the dry season, Impalas have been shown by Gaidet and Lecomte (2013) to venture outside of their typical home areas. Other species have a similar pattern in their seasonal animal migrations depending the availability of food and water scarcity (Parker, Barboza, & Gillingham, 2009; Gaylard, Owen Smith, & Redfern, 2003). In pursuit of fodder and water during the dry season, impalas have been shown by Gaidet and Lecomte (2013) to venture outside of their typical home range areas.

Like most wild ungulates, the Impala's behaviour is primarily centered on foraging and reproduction .During the hottest period of the day, when temperatures reach their peak, impala prefer to relax in the shade. In some instances, Impalas have been observed foraging through the night. During the wet season, impalas often assemble in big groups, but during the dry season, impala herds search for food together (Setsaas et al, 2018). During the dry season, impalas are believed to be extremely reliant on water and are forced to make daily sorties in quest of it.

Since Impalas are frequently located within three kilometres of a water source and permanent water sources were similarly accessible in both the north and south ranges, it seems that access to drinking water had little effect on migratory behaviour. Impalas start to recolonize towards the conclusion of the dry season, according to observation of marked impalas near water sources over a period of several days. Impalas were now only visiting water sources every two to three days rather than everyday (Van Bommel et al, 2006). Ungulate density will decrease as distance from water increases; this effect will be exacerbated for species with a low tolerance for water scarcity (Matandiko, 2016).

According to Muposhi (2016), their natural eating and drinking habits and requirements, as well as many environmental conditions, greatly determine how they are distributed within a given region. Therefore, the quantity and distribution of surface water in the Kruger National Park has a big impact on how impala are distributed generally and how they use the food that is available there. The floristic cover and composition adjacent to watering holes may be significantly impacted by the impala's tendency for selective feeding and habit of congregating there (Young, 1997). Impalas and other wild herbivores like drinking from waterholes found inside of protected areas. This could be accounted for by a perception that such waterholes exhibit fewer signs of human interference. (Zvidzai et al, 2013).

Impalas aren't typically thought of as migratory animals, however seasonal movements between nearby areas have been seen. Small seasonal shifts (0.5 km) in the middle of the normal home range (Sengwa Wildlife Research Area, Zimbabwe), regular separation of a typical home range (with movements of up to 10 km) during times of extreme food scarcity (Serengeti National Park, Tanzania), or larger excursions (5-50 km) leading to distant dry and wet season ranges (Southern low-veld and Mana Pools National Park, Zimbabwe) were the patterns of movement (Gaidet et al., 2013).

Nevertheless as predicted by the "food hypothesis," populations experience a density-related reduction in fecundity and an increase in mortality among juveniles when food is in short supply (Gaillard et al. 1998; Gaillard et al. 2000; Sinclair et al. 1985). Water and soil nutrients have an impact on food availability in a broader sense because of their restrictions on plant development (Bell 1982). (Augustine et al 2003; Frank et al 1998; McNaughton 1985). Therefore, ungulate distributions are expected to be impacted by pasture quality, water availability, and nutrient availability. For impala, availability to permanent rivers and other alternate water sources, vegetation structure, and anthropogenic effects all influence herd size, whereas density and distribution are predominantly determined by anthropogenic activity (Matandiko, 2016).

The majority of grazer species were found to be linked to man-made waterholes, as browsers and mixed feeders are unconcerned with waterholes and were linked to the major rivers. Therefore, even in locations with availability to natural water, man-made waterholes are landscape features that have the power to affect how herbivores are distributed, influencing how humans utilise the land (Smit et al, 2007). The spatial organisation of the community explained the majority of the difference in the census data. Typically, certain waterholes had higher herbivore abundance than others. The Park-scale Migration, which is reliant on yearly rainfall, may have caused some temporal variability (Chammaile –James et al, 2016).

2.3.1.2 Predation

Predators have significant influence on prey species, impacting their number, distribution, and a variety of behavioural traits including the amount of time they spend guarding and foraging or travels between foraging regions (Favreau, 2013). All ungulate species avoid hazardous areas, and the majority opted for safer ones, which reduced their risk of passing away. Contrary to the bigger species (Wildebeest, Zebra, and Giraffe), that generally avoid regions where lion and leopard space use was high, the majority of the smaller predatory species (Impala, Warthog, Waterbuck, and Kudu) escape the space use of all predators (Thaker et al., 2011).

2.3.1.3 Human influence

Animals may avoid particular places in favour of inferior habitat patches as a result of human disruptions. Ecological traps are created as a result of this avoidance strategy, which implies that animals may favour "less suited environments" to maximise survival when doing so would be costly to their fitness (Muposhi et al., 2016). Findings are consistent with the theory that human activity via the road network may have an impact on the regional distribution of Impalas. Previous reseaerch3show that gregarious impala1species, which are frequently2 hunted5in this area, may alter their behaviour in response to an increase in hunting threat or exposure to mankind. Researchers argue that since human actions (such as hunting) have been seen to modify the environment because of fear of these herbivores, roads may diminish the sense of security and refuge from anticipated hunting risk (Peignier et al., 2019).

Native herbivore distribution has reportedly been impacted by human presence and disturbances. For instance, in other comparable ecosystems, big wild herbivores avoid livestock regions with heavy human disturbance (Ogutu et al. 2010; Stephens et al. 2001; Wallgren et al. 2009). The majority of homes in the northern Gonarezhou National Park maintain domestic dogs (*Canis familiaris*) to guard livestock from predators. The distribution of small to medium native herbivores in the park may have also been impacted by poorly fed and unruly dogs (Gandiwa 2011).

2.4.0 METHODS FOR ASSESSING DISTRIBUTION OF KUDUS AND IMPALAS

Although wildlife monitoring is a crucial conservation technique, African savannah authorities with limited funding and resources place it low on their list of priorities (Caro, 2016). Drive counts are suggested in forests where species concentrations are generally high, but they are predicted to be less accurate in places where species densities are low. The minimum density required to employ drive counts is determined by the desired level of precision (Borkowski, Palmer and Borowski, 2011).

2.4.1 DRIVE COUNTS

It has been demonstrated that Impala movements and other behaviours may be accurately tracked over an extended length of time without the need for expensive radio-telemetric game tracking apparatus. The use of such tools can facilitate studies of game movement, but ongoing, firsthand observation of the study herds can yield invaluable additional knowledge on the ecology of the species and their ethology. (Young, 1972).

The drive count is one variety of direct count. This is applicable to animals that are not found in open areas. Drive counts are easy if the terrain is not difficult. These counts were frequently carried out by the old authorities. In essence, the method requires confining the area while also "driving" the animals in a single direction. The appropriate distance between the people operating the drive is decided by experiments or past experience, because the animals that have been flushed out from their cover are free to travel in any direction, "stops" are installed on the sides to force the animals to only proceed in the direction of the enumerators. Stops are usually persons seated on hides at significant sites (Borkowski, Palmer and Borowski, 2011).

Drive count is a kind of direct count. Drive counts are straightforward when the terrain is not difficult. These counts were commonly done by the previous monarchs. The method requires essentially "driving" the animals in a single direction while also confining the area. The optimal separation between the people operating the drive is established by experiments or previous experience. The animals are free to travel in any direction once they have been flushed out from their cover, so 'stops' are set up on the sides to force them to only proceed in the direction of the enumerators. Typically, stops are individuals placed atop hides at significant points. Four vehicle transects were routinely travelled at a speed of around 10 km/h to conduct animal ground surveys in Katavi National Park. With the exception of one year when certain transects were driven just once, and another year when some were driven three times, transects were normally driven twice a year, early in the morning, throughout the dry season. A total of 112 transects covering 2,165 km were driven (Caro, 2016).

The outcomes of population assessment for the two woodland antelope species, Greater Kudu *(Tragelaphus strepsiceros)* and Impala (*Aepyceros melampus)*, were reported. Occasionally, direct observation recordings were made as well (Seydack et al, 1998). Drive counts were helpful for calculating density and locating sites of the species (Koster et al, 1988). In the Kruger National Park, radio-telemetric game tracking equipment was initially a possibility. But because the crucial supplies took longer than expected to arrive, a Landrover was deployed to follow and monitor the herd's activity. This method involved tracking the movements of Impala herds, with an average of 400 animals in the summer and 70 in the winter, over the length of 21 24-hour periods (Young, 1972).

Using a handheld GPS, the transect lines that were followed and the location where a specific animal or group of animals was sighted were both recorded. For every sighting, the GPS coordinates, estimated sighting distance, and compass orientation offset northward were noted. (Van Bommel et al, 2006). Drive counts were performed to calculate the distribution and winter populations (February–March) of small antelopes like Red and Roe Deer. Each region travelled was a block of one to many nearby woodland compartments (on average ca. 60 ha). The number of beaters and observers participating in the counts was typically between 15 and 20. The foresters or hunters who observed the deer have the necessary knowledge to identify the species, sex, and category (young/adult/sub-adult) of the Deer. On an observation form, each observer noted the species, number of people in each group, and, if possible, the makeup of the group as they left (or entered) the driven block to his right. The same data on the creatures observed by the beaters was gathered by a coordinator. To reduce the possibility of duplicate counting and incorrect group sizes, the coordinator gathered information from all observers after each block was completed and promptly corrected any potential discrepancies. Most of the time, the same blocks were defeated year after year (Borkowski, Palmer and Borowski, 2011; Caro, 2016).

During the census, the two species were separated into groups based on age and sex. The categories used were mature male and female, sub-adult male and female, juvenile male and female, and unidentified individual following Boyer and Hillman's methodology. Juveniles' sexes couldn't be confirmed in the field, thus information on them was combined. Using physical traits such horn length and form, body size, pelage (fur), external genitalia, and mammary glands, age and sex were determined. Sex ratios for the groups were determined by Doku, Yirga, and Regassa's direct census of the animals (Tsindi & Kupika, 2016).

Based on their own ground counts, some writers claimed that impala travel toward the water bodies of Lake Mburo National Park during the dry season while dispersing on the ranch land around the park during the rainy season (Averbeck, 2001). Wildlife managers commonly employ direct counts of species to gauge population size. Just educated assumptions regarding the number of each species are being made using these low data (Geese, 2001). Since drive counts had previously been used to gauge antelope distribution in the protected area, they were also utilised in the Tuli Safari Area.

2.4.2 Maximum Entropy Modelling

Given its reliance on just presence locations, maximum entropy (Maxent) modelling has enormous potential for identifying wildlife distributions and habitat preferences. Recent research shows that Maxent outperforms other presence-only modelling techniques, requires fewer locations to build useful models, and is comparatively unaffected by spatial mistakes in geographic information. To more accurately define model thresholds, assess model significance, and handle model selection, more developments are required. In order to evaluate habitat selection using repeated sampling of known people, modelling tools must also be developed. These developments would increase Maxent's usefulness for wildlife study and management (Baldwin, 2009).

Using actual data, the Maximum Entropy Model (Max ENT) forecasts the possibility of discovering anything given a collection of distributed circumstances using machine learning techniques (Dudik et al, .2007). It clarifies discretion in choosing which sorts of data to use and guarantees the originality and consistency of probability assignments generated by diverse techniques, particularly statistical mechanics and logical inference.It describes how to utilise presence-only data and the maximum entropy method (Maxent) to simulate species geographical distributions.

The Rule of Maximum Entropy the MEP (Jaynes, 1957) is a potent inference rule that allows one to identify the probability distribution that defines a system using the information at hand, typically in the in the form of observable averages (random variables) of relevance for the system. In this work, the geographic distributions of suitable habitats are mapped using Maxent, a species distribution model approach that employs a maximum entropy machine learning technique (Ngarega et al., 2021).

The geographical distribution of wild herbivores in Matetsi Safari Area in response to environmental conditions was modelled using the maximum entropy (MaxEnt) technique. Maximum Entropy modelling was chosen because it is believed to be a trustworthy and efficient model for predicting distributions of species from presence-only species data and because it can manage complex interactions between responder and predictor factors while remaining sensitive to small sample sizes. Max ENT is reliable because it may offer helpful data for predicting appropriate habitats even with limited samples (such as those from traffic counts) (Muposhi et al., 2016)

In a study by Muposhi et al, (2016), Maximum entropy was successfully used to predict the distribution of African Elephant, Cape buffalo, Greater Kudu and Sable in Matetsi Safari area using presence data and environmental predictor variables

CHAPTER 3

METHODOLOGY

3.0 STUDY AREA

The research was conducted at Tuli Safari Area located between Beitbridge and Gwanda districts and in Matebeleland South province of Zimbabwe (Fig 3.1).Tuli Safari Area lies between latitudes and longitudes $21^{\circ}55'44.88''$S $29^{\circ}11'25.51''$E and covers an area of $416km^2$. It is located along the Shashe River in the relatively low lying savannah of south western Zimbabwe (Darkey and Alexander, 2014). It shares a border with Botswana's Northern Tuli Game Reserve. It encompasses the whole west bank of the Shashe River in the Tuli Circle and consists of four reserves within the Zimbabwe Parks and Wildlife Estate. The protected area's flat topography transitions to rocky, steep terrain close to the Shashe River. Jurassic basalt makes up the foundation. The Safari region's eastern edge contains riverine vegetation, such as Ficus species that border the Shashe River, while the majority of the Tuli region is scrub land with Mopane and Combretum bush (Styles, 1993).Tuli Safari Area hosts a variety of wild animals, including elephants, giraffe, eland, zebra, impalas, kudus, jackal, waterbuck, hyena, cheetah, leopard, and lions (https://zimfieldguide.com/matabeleland-south/thuli-safari-area).

The Greater Mapungubwe Trans Frontier Conservation Area, which spans over 6,000km2 (600,000 hectares), is also anchored by the Tuli Safari Area. Bulbous baobabs and angular rocks are the dominant features. With over 350 species identified, Tuli provides a wide variety of fascinating birding experiences. While Kori bustards, Botswana's national bird, navigate the grasslands and Lanner falcons soar across steep valleys, Pel's fishing owls are hidden by the enormous riverine trees. Elephant numbers in Tuli are among the highest in Southern Africa, according to Styles (1993), and the population has enough room to thrive. Although buffalo and rhinos are not found in the protected region, it is home to robust populations of all three big cat species, as well as vast populations of crocodiles and pods of hippos that live in the deep pools of the rivers. An unusual encounter are the recently arrived painted dogs (Lycon pictus).

(https://africageographic.com/stories/tuli/).

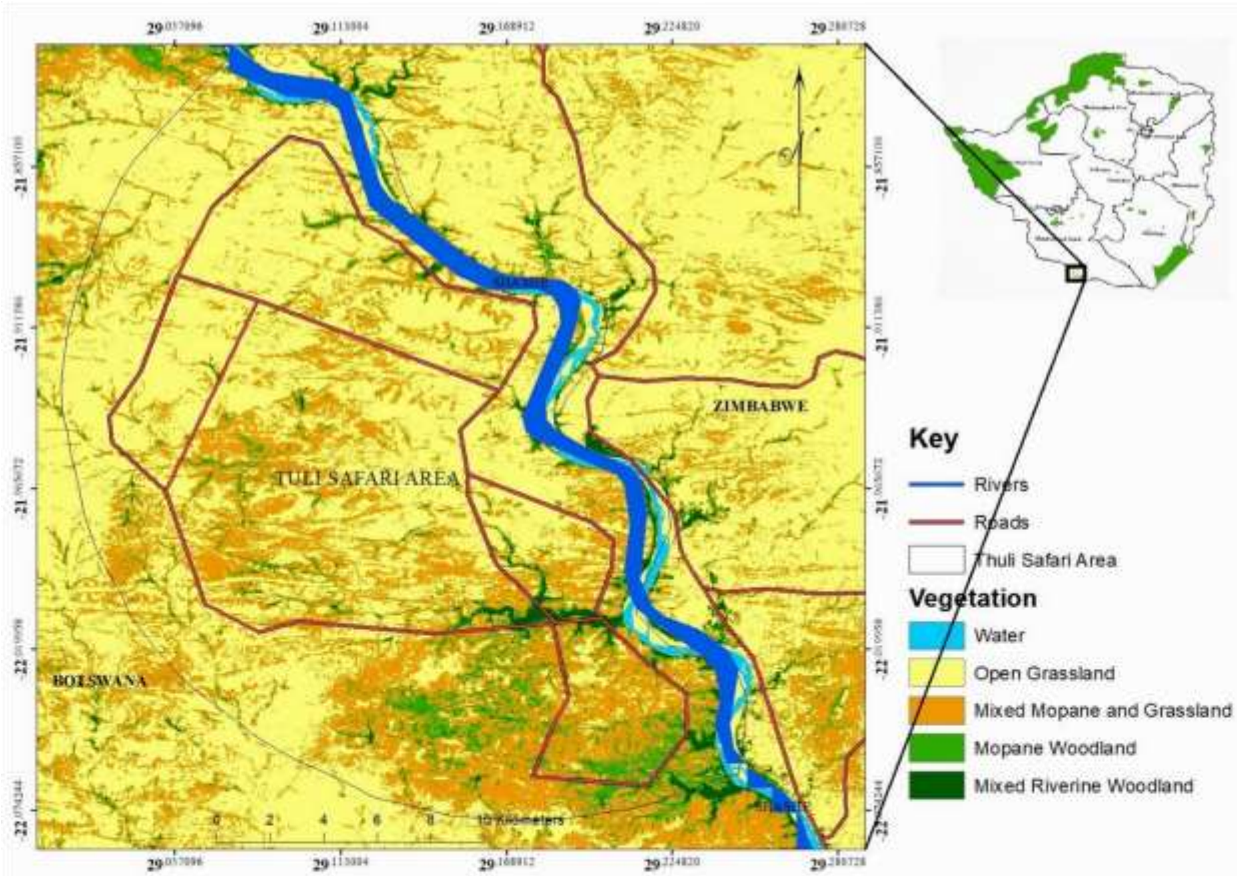


Figure 3.1 Map of Tuli Safari Area

3.1 Data collection methods

A total of 102 road transect counts were conducted between the year 2020 and June 2022. Counts in TSA were done at a of 416km^2 radius (total size of the Tuli Circle) of the protected area.

Data collection on Impala (*Aepyceros melampus*) and Kudus (*Tragelaphus strepsiceros)* distribution was done using road transects counts along all accessible roads in Tuli Safari Area

(TSA) which are used for wildlife monitoring purposes. When a herd of Kudu or Impala was sighted all individuals in the herd were counted and broken down into three categories , thus juvenile , sub-adult , and adult, and the sexes of the species with aid of Binoculars (Nikon Monarch). The GPS coordinates were recorded using the GPS receiver (Garmin Etrex 10) in Universal Transverse Mercator (UTM) format .Incidental sightings were also recorded where the herd , dual , or solitary species were seen.

Species were counted from a hide as they visit waterholes thus at rivers, windmills, pools, and springs. Results of animal presence were obtained. A large population in the locality will have more animals drinking than a small population (Smit et al, 2007). If populations increase in size, then the number of animals seen drinking will increase. Once a year, during the hot, dry season, data on the quantity of herbivore at water points were gathered at the few surviving natural waterholes as well as the manmade (windmill) waterholes. Every full moon, counts were made starting in the early morning, midday, and late afternoon, and the number of kudus and impalas coming to drink was noted. Binoculars and good waterhole views made it possible to count both the number of individuals and group size.

To complement the collected primary data on sightings, secondary data on Impala and Kudu presence for previous two years was collected from the Zimbabwe Parks and Wildlife Management Authority (ZPWMA) database.

3.2 DATA ANALYSIS

3.2.1 MAXIMUM ENTROPY MODELLING

First Kudu and Impala presence-only location data was obtained from road transect counts and locations of kudu and impala for the year 2020-2022 and supplementary data was obtained from the ZIMPARKS database. The data was grouped into two seasons (dry and wet) for different analysis. Distance of locations from environmental factors, the nearest road (dist_roads), and nearest river (dist_rivers) were then calculated using Euclidian distance algorithm in ArcMap version 10.2.2 (Environmental Systems Research Institute: Redlands, California, USA). Study area data (shape-files) on roads and rivers were made available by ZIMPARKS from their database. The shape-files were converted to ASCII format in preparation for MaxEnt modelling.

Default variable response conditions were used to run the model in MaxEnt and the response of Kudus and Impalas to each of the two predictor variables was assessed using the response curves. For interpretation of the response curves, the logistic threshold of equal training sensitivity and specificity was used (Phillips et al. 2006) whereas Area Under Curve (AUC) of the Receiver Operating Characteristic (ROC) curve was used to evaluate the predictive ability of the models (Elith et al. 2006). A total of six models were built in Maxent, namely Kudu overall ,Kudu hot wet season, Kudu cold dry season , Impala overall , Impala hot wet season, and Impala cold dry season in MaxEnt in which environmental factors (dist_rivers), and (dist_roads) were tested to predict the spatial distribution of kudu and impala respectively.

3.2.2 POPULATION STRUCTURE

Data from the field was tabulated into three groups namely adults, sub-adults, and juveniles, and into two sexes, thus male and female. The data were grouped in Microsoft Excel 2010 windows software. Excel files for occurance points of both Kudus and Impalas were converted to csv files.

The IBMM SPSS version 21 was used to analyse the population structure of the two species.

CHAPTER 4

RESULTS

4.1 KUDU OVERALL DISTRIBUTION

Maximum Entropy model (MaxEnt) using distance from rivers (dist_rivers), and distance from roads (dist_roads), as environmental variables successfully explained the variation of probability of occurrence of Kudu (*Tragelaphus strepsciceros*) in the Tuli Safari Area for three years (AUC = 0.642) (Figure 4.1). This showed that environmental variables used in the model accounted for the distribution.

Table 4.1.1 Relative contribution of the environmental variables used in Maximum Entropy modelling of habitat selection of Kudu.

Variable	Percentage contribution %	Permutation importance
dist-roads	79.4	71.5
dist-rivers	20.6	28.5

The variable importance analysis showed that distance from roads was the best predictor (79, 4%) and most important for the prediction of the potential distribution of Kudus in 3 consecutive years (Table 4.1.1 and figure 4.1.2).

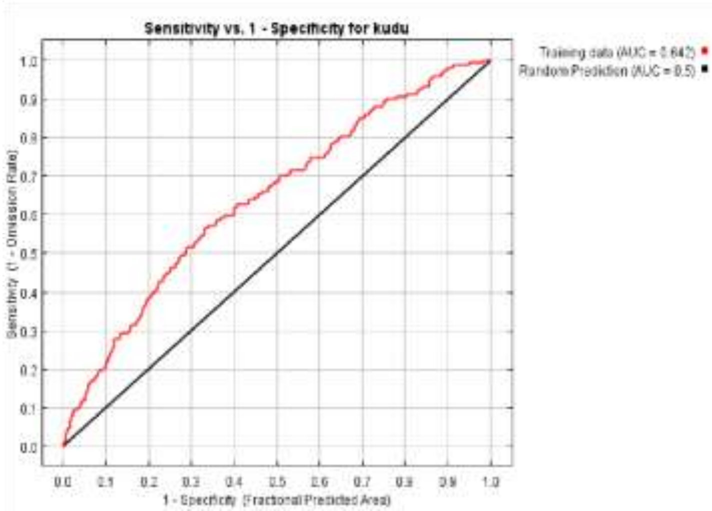


Figure 4.1.1 Area under curve (AUC) of the Receiver Operating Characteristic (ROC) curves for the MaxEnt habitat models based on Kudu presence only.

Figure 4.1.2 MaxEnt model showing the Jackknife test of the importance of variables used in training the distribution model of Kudu. Notes: dist_rivers – Distance from rivers, dist_roads – distance from roads.

The probability of occurrence of Kudu increased with increasing distance from rivers (Figure 4.1.3a) and probability of occurrence of Kudu decreased with increasing distance from roads (Figure 4.1.3b).

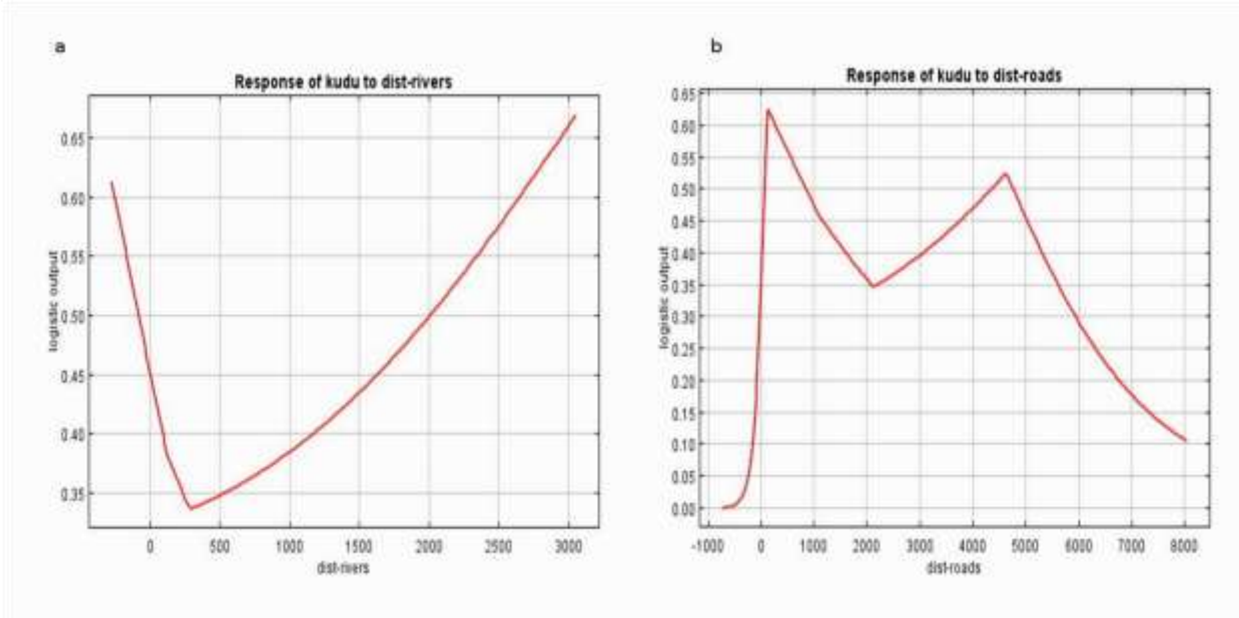


Figure 4.1.3 Probability of occurrence response curves of Kudu in response to environmental factors derived from MaxEnt model. Notes; (a) dist-rivers- distance from rivers, (b)dist-roads – distance from roads.

The overall distribution of Kudu for the three years showed that the most suitable habitat was close to the rivers and roads (Figure 4.1.4).

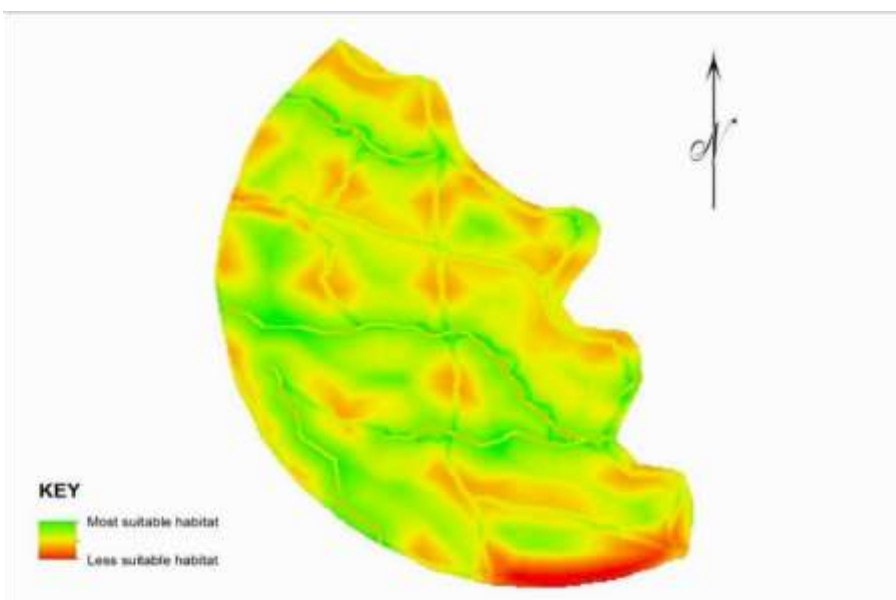


Figure 4.1.4 Probability distribution model of Kudus in the Tuli Safari Area, derived from MaxEnt modelling. The most suitable and preferred habitat for kudus

4.2 KUDU HOT WET SEASON AND COLD DRY SEASON

Maximum Entropy model (MaxEnt) using distance from rivers (dist_rivers), distance from roads (dist_roads), as environmental variables successfully explained the variation of probability of occurrence of Kudu (*Tragelaphus strepsciceros)* in the Tuli safari area for both dry (AUC = 0.707) and wet (AUC = 0.748) seasons (Figure 4.2.1). This showed that environmental variables used in the model accounted for the distribution

Table 4.2.1 .Relative contribution of the environmental variables used in Maximum Entropy modelling of habitat selection of Kudu for wet and dry seasons.

VARIABLE	Percentage contribution %		Permutation importance	
	wet season	dry season	wet season	dry season
Distance from rivers (m)	4.9	16.6	10.3	7.3
Distance from roads (m)	95.1	83.4	89.7	92.7

The variable importance analysis showed that distance from roads was the best predictor during the wet season(95.1%) and dry season (83.4%)and most important for the prediction of the potential distribution for wet (89.7%) and (92.7%) dry seasons for Kudus in 3 consecutive years (Table 4.2.1) .

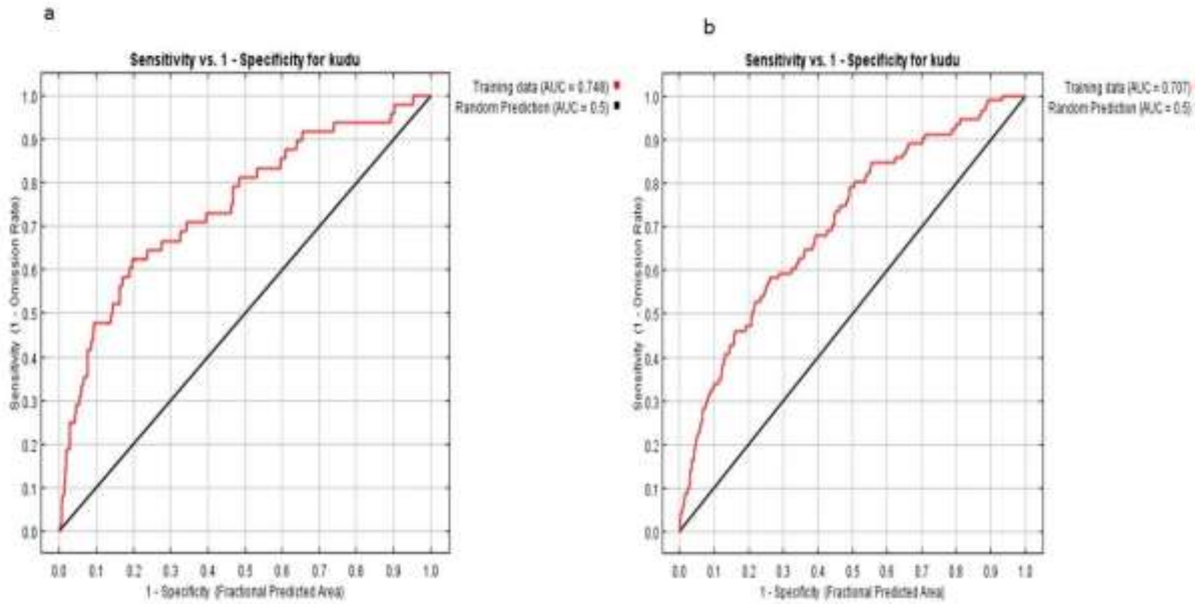


Figure 4.2.1 Area under curve (AUC) of the Receiver Operating Characteristic (ROC) curves for the MaxEnt habitat models based on Kudu presence only data for (a) hot wet season (b) cold dry season respectively.

Figure 4.2.3 MaxEnt model showing the Jackknife test of the importance of variables used in training the distribution model of Kudu (a) hot wet season (b) cold dry season. Notes: Dist_rivers – Distance from rivers, dist_roads – distance from roads

The probability of occurrence of Kudu decreased with increasing distance from rivers in the hot wet season up to about 1000m (Figure 4.2.4.a). The probability of occurrence of Kudu increased with increasing distance from rivers the cold dry season, from about 400m to about 3200m in the cold dry season (Figure 4.2.4.b).

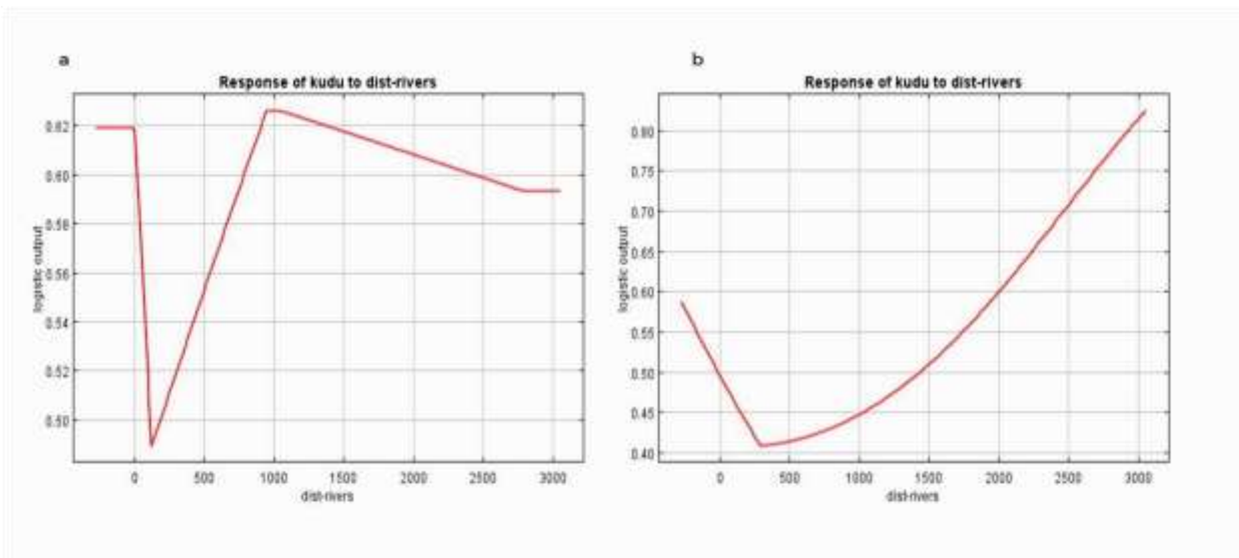


Figure 4.2.4 Probability of occurrence response curves of Kudu in response to environmental factors (distance) in hot wet season and cold dry season derived from MaxEnt model from rivers

The probability of occurrence of Kudu increased with increasing distance from roads from about 1000- 4500m in the hot wet season (Figure 4.2.5.a). The probability of occurrence of Kudu decreased with increasing distance from rivers (100-8000m) in the cold dry season (Figure 4.2.5.b).

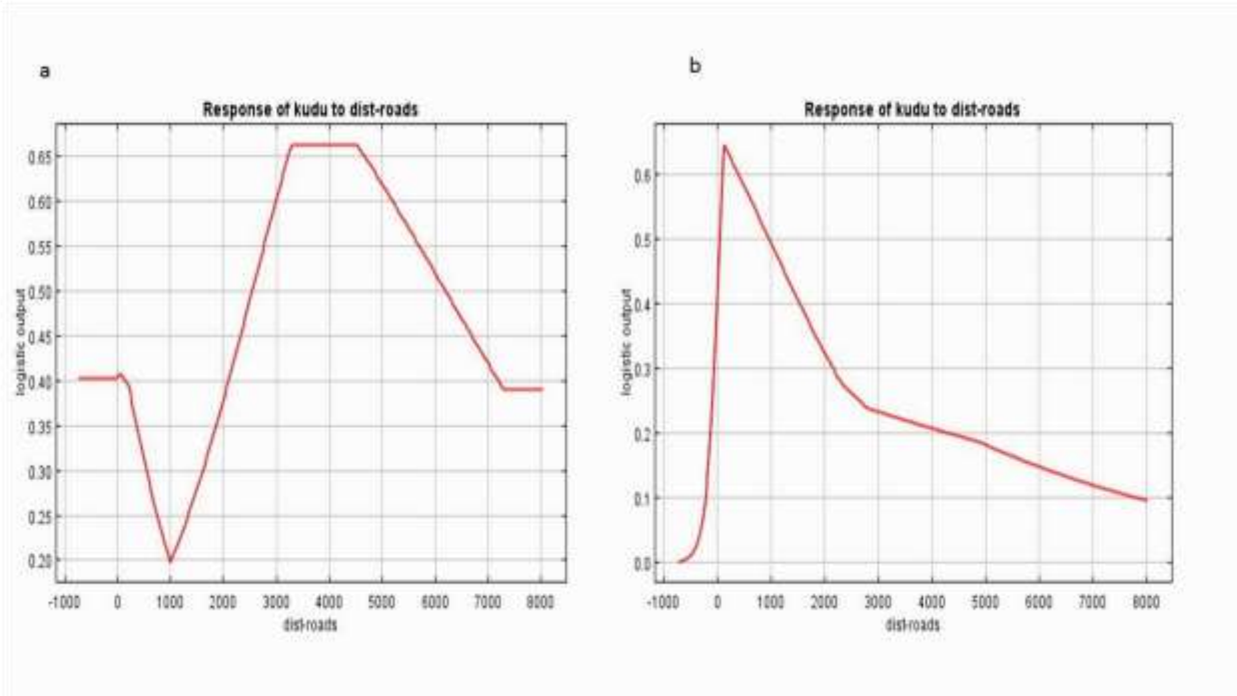


Figure 4.2.5 Probability of occurrence response curves of Kudu in response to environmental factors (distance from roads) in hot wet season and cold dry season derived from MaxEnt model.

There was a spatial variability in habitat suitability of Kudu between hot wet season and cold dry season .In the hot wet season (Figure 4.2.6a), Kudus area of occurrence was along river banks and in the cold dry season (Figure 4.2.6b), Kudus most suitable habitat was close to roads .

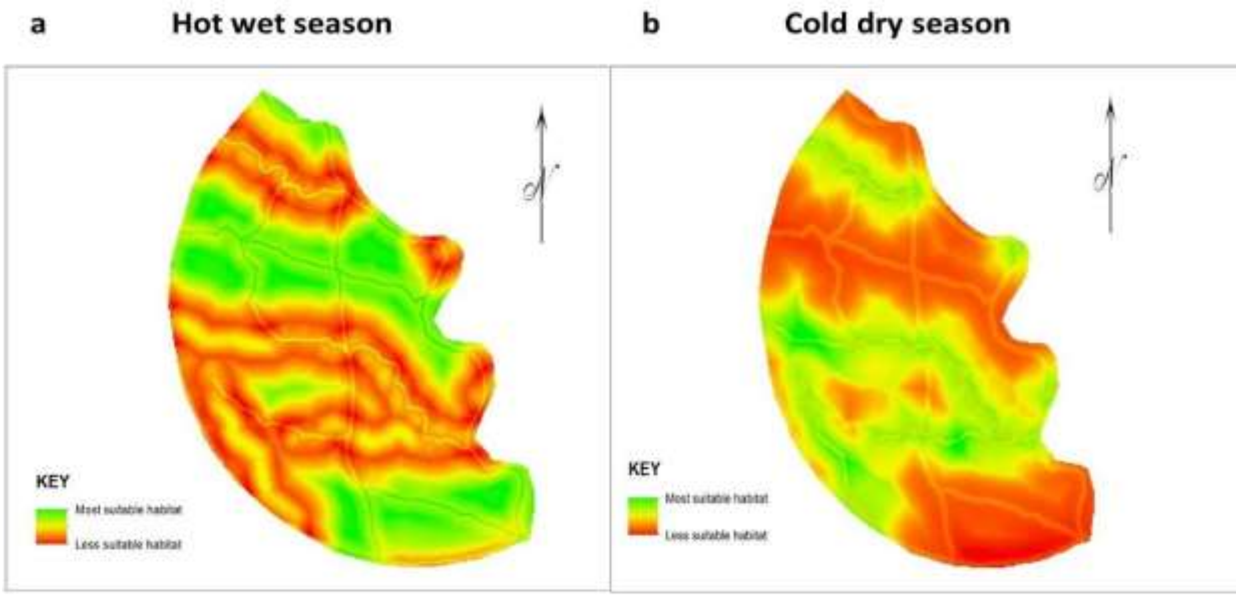


Figure 4.2.6.Most suitable habitat for Kudu in (a) hot wet season and (b) cold dry season

4.3 IMPALA OVERALL DISTRIBUTION

Maximum Entropy model (MaxEnt) using distance from rivers (dist_rivers), distance from roads (dist_roads), as environmental variables successfully explained the variation of probability of occurrence of Impala (*Aepyceros melampus)* in the Tuli safari area for three years (AUC = 0.625) seasons (Figure 4.3). This showed that environmental variables used in the model accounted for the distribution.

The variable importance analysis showed that distance from roads was the best predictor (61.3%) and distance from roads was the most important for the prediction of the potential distribution of Impalas in 3 consecutive years.

Table 4.3.1 Relative contribution of the environmental variables used in Maximum Entropy modelling of habitat selection of Impala.

Variable	Percentage contribution %	Permutation importance
dist-roads	61.3	43.1
Dist-rivers	38.7	56.9

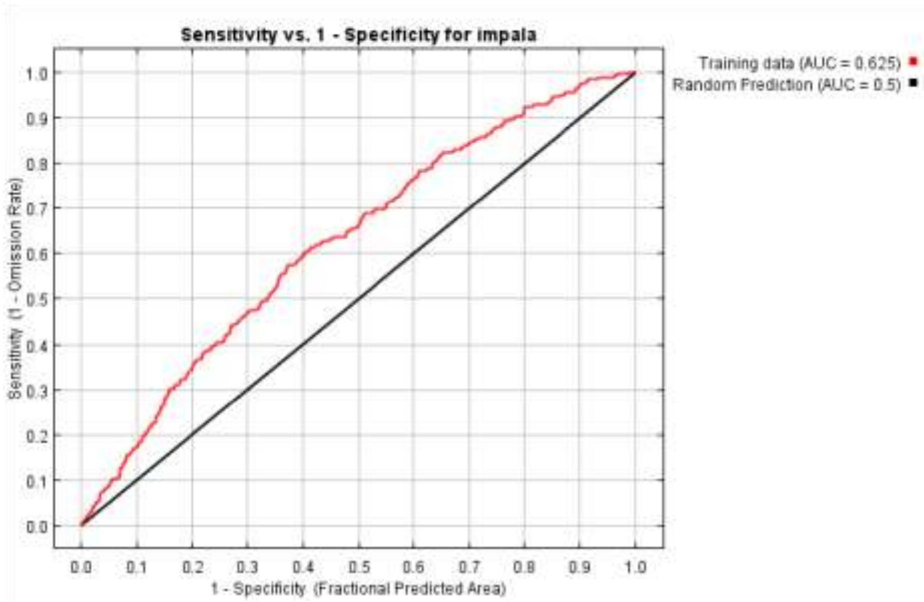


Figure 4.3.1 Area under curve (AUC) of the Receiver Operating Characteristic (ROC) curves for the MaxEnt habitat models based on Impala presence only.

Figure 4.3.2.MaxEnt model showing the Jackknife test of the importance of variables used in training the distribution model of Impalas. Notes: dist_rivers – Distance from rivers, dist_roads – distance from roads.

The overall probability of occurrence of Impalas increased with increasing distance from rivers from about 250m to 2500m (Figure 4.3.3a) and probability of occurrence of Impala decreased with increasing distance from roads .Impala occurred up to a distance of 8000m from roads In the three years (Figure 4.3.3b).

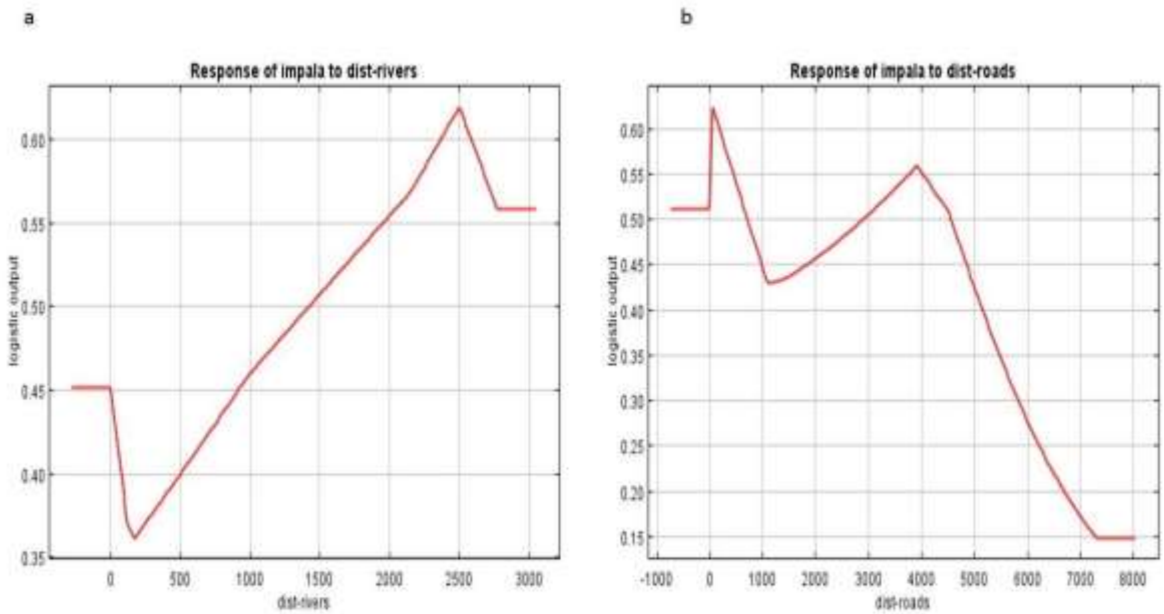


Figure 4.3.3.Probability of occurrence response curves of Kudu in response to environmental factors derived from MaxEnt model. Notes; (a) dist-rivers- distance from rivers, (b)dis-roads – distance from roads.

The overall distribution of Impala for the three years showed the most suitable habitat for Impalas is close to rivers, and less likely to occupy areas close to roads (Figure 4.3.4).

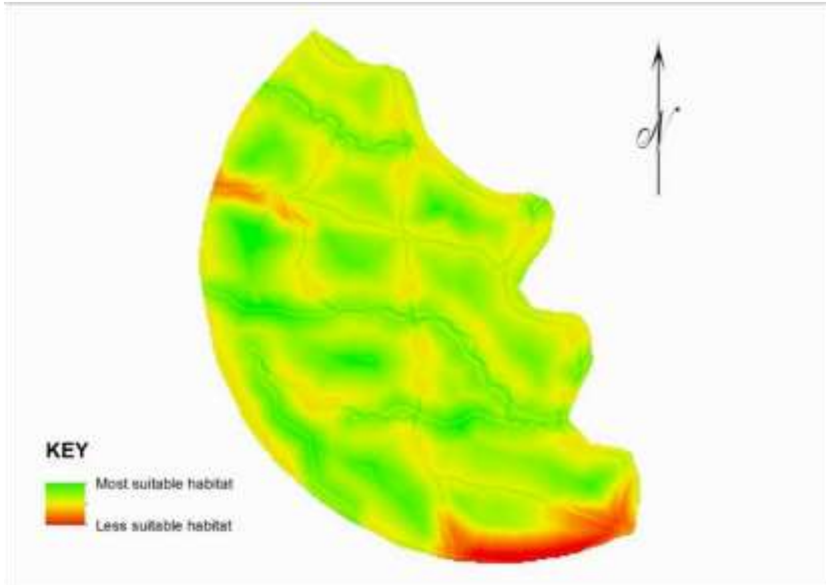


Figure 4.3.4 Probability distribution model of impalas in the Tuli Safari Area, derived from MaxEnt modelling.

4.4 IMPALA HOT WET SEASON AND COLD DRY SEASON

Maximum Entropy model (MaxEnt) using distance from rivers (dist_rivers), distance from roads (dist_roads), as environmental variables successfully explained the variation of probability of occurrence of impala (*Aepyceros melampus*) in the Tuli Safari Area for both dry (AUC = 0.665) and wet (AUC = 0.625) seasons (Figure 4.4.1). This showed that environmental variables used in the model accounted for the distribution

Table 4.4.1 Relative contribution of the environmental variables used in Maximum Entropy modelling of habitat selection of Impala for dry and wet seasons.

VARIABLE	Percentage contribution %		Permutation importance	
	wet season	dry season	wet season	dry season
Distance from rivers (m)	51.3	56.9	48.9	64
Distance from roads (m)	48.7	43.1	51.1	36

The variable importance analysis showed that distance from roads was the best predictor and most important for the prediction of the potential distribution of Kudus in 3 consecutive years (Table 4.4.1 and figure 4.4.2).

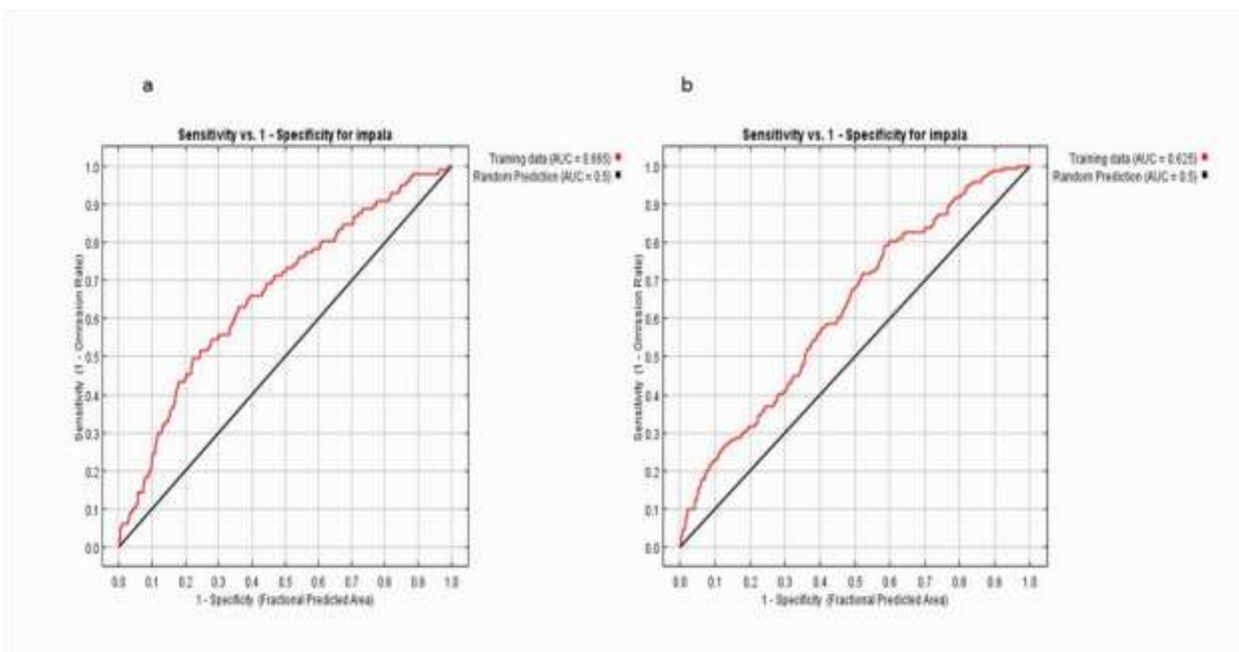


Figure 4.4.1 Area under curve (AUC) of the Receiver Operating Characteristic (ROC) curves for the MaxEnt habitat models based on Impala presence only data for (a) hot wet season and (b) cold dry seasons respectively.

Figure 4.4.2 MaxEnt model showing the Jackknife test of the importance of variables used in training the distribution model of Impala (a) hot wet season (b) cold dry season. Notes:

Dist_rivers – Distance from rivers, dist_roads – distance from roads.

The probability of occurrence of Impala decreased with increasing distance from rivers in the hot wet season (Figure 4.4.3.a). The probability of occurrence of Kudu increased with increasing distance from rivers in the cold dry season, from 0 to about 2500m in the cold dry season (Figure 4.4.3.b).

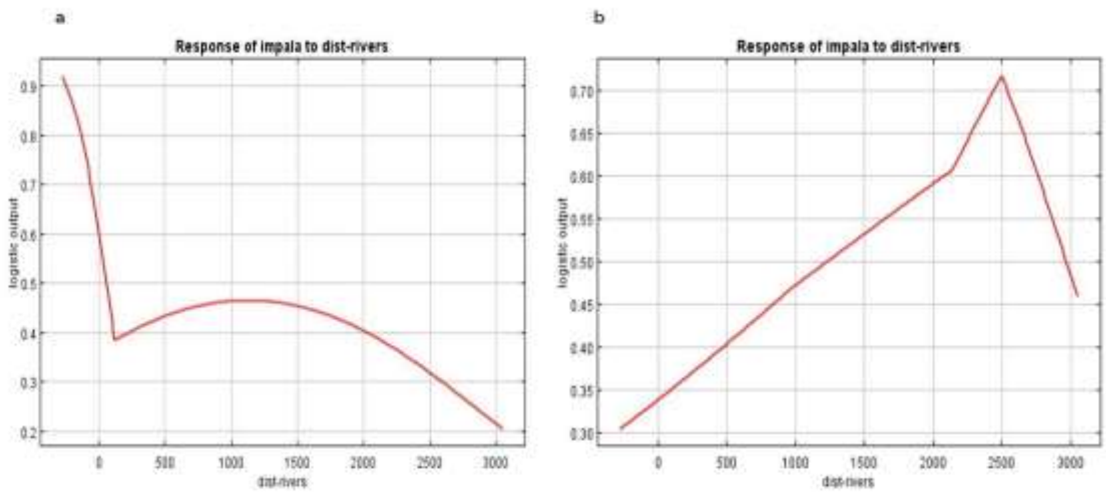
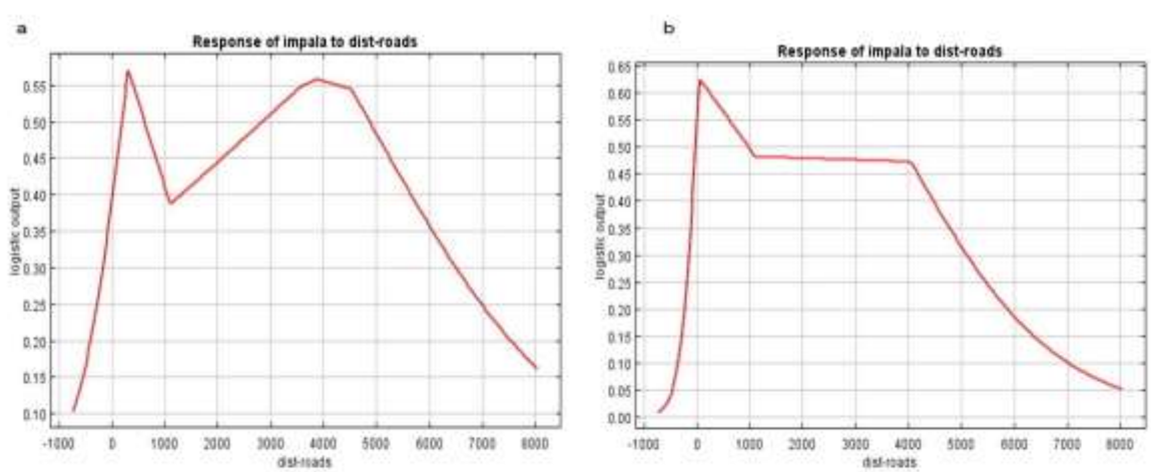


Figure 4.4.3 Probability of occurrence response curves of Impala in response to environmental factors (distance from rivers) in hot wet season (a) and cold dry (b) season derived from MaxEnt model.

The probability of occurrence of Impala decreased with increasing distance from roads in the hot wet season (Figure 4.4.4.a). Similarly, probability of occurrence of Kudu increased with increasing distance from rivers in the cold dry season (Figure 4.4.4.b).



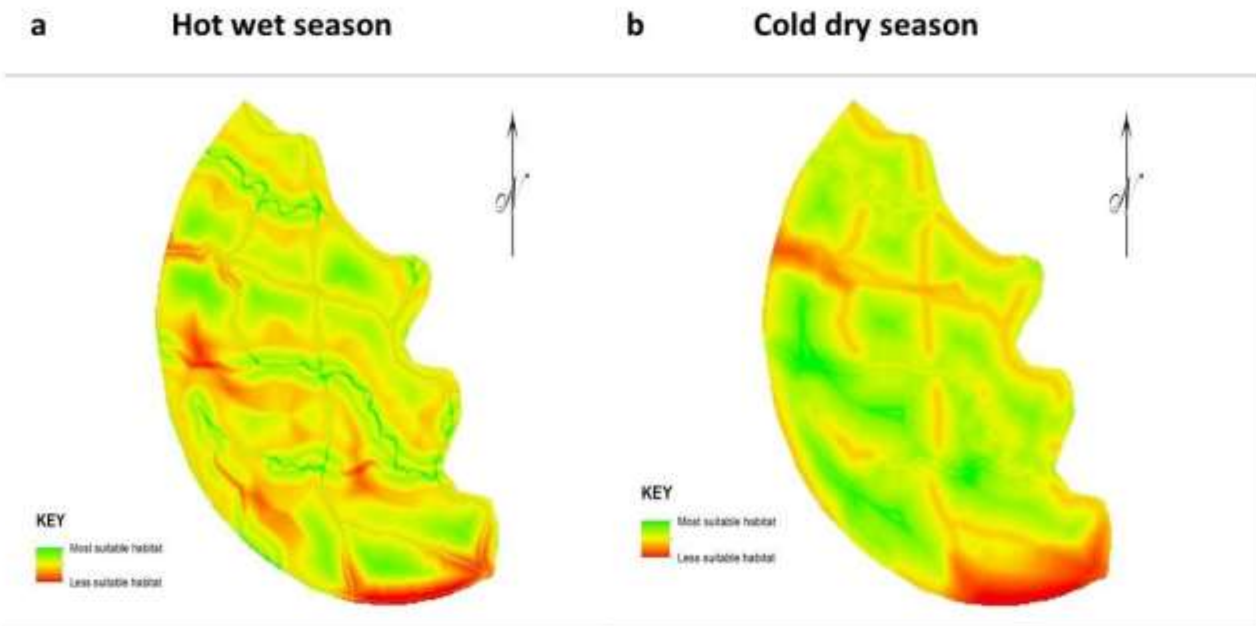


Figure 4.4.4 Probability of occurrence response curves of Impala in response to environmental factors (distance from roads) in hot wet season (a) and cold dry season (b) derived from MaxEnt model.

There was spatial variability in the habitat suitability of Impala between hot wet season and cold dry season .In the hot wet season (Figure 4.4.5a), Impalas area of occurrence was close to rivers and away from roads. In the cold dry season (Figure 4.4.5b), Impalas most suitable habitat was close to both roads and rivers.

Figure 4.4.5Most suitable habitat for Impala in (a) hot wet season and (b) cold dry season

4.5 POPULATION STRUCTURE

4.5.1 Kudu (*Tragelaphus strepciseros*) overall population structure

In 61 sightings for the three years, Kudus were observed mainly in distinctive herds dominated by female adult age class making up to 40% of the total population

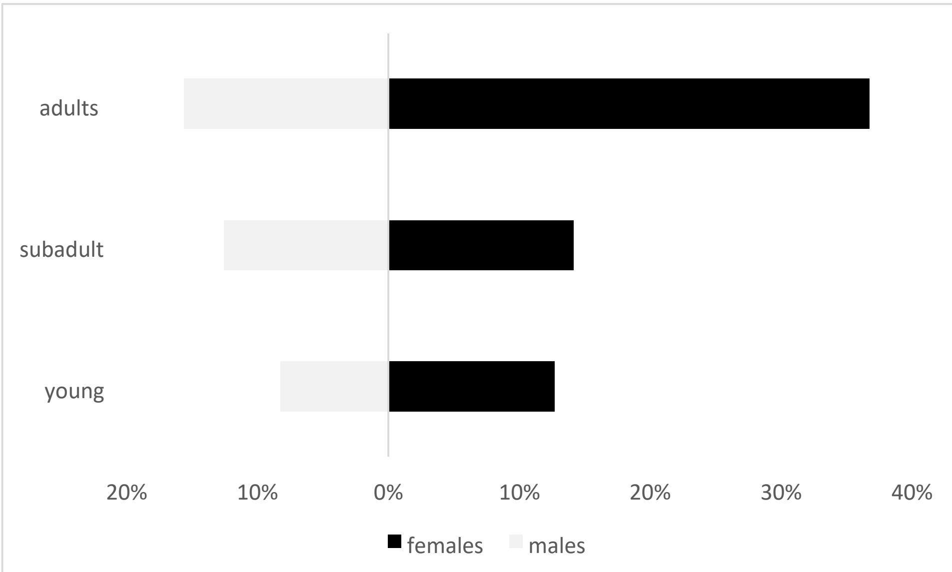


Figure 4.5.1: Overall population structure of Kudu in the Tuli Safari Area for three years

4.5.1.2 Kudu hot wet season and cold dry season

In 42 hot wet season sightings, Kudus were observed in herds which were composed of males and female adults, male and female sub-adults, and male and female young/juveniles. Adult females were the most commonly observed age class, followed by the male adults .Juvenile females also contributed the most compared to all the sub-adult classes (figure 4.5.2a). In 19 cold dry season sightings, Kudus were observed in herds which were composed of males and female adults, male and female sub-adults, and male and female young/juveniles. Sub-Adult females and adult females recorded the highest numbers in the overall population in the cold dry season (Figure 4.5.2b)

a b

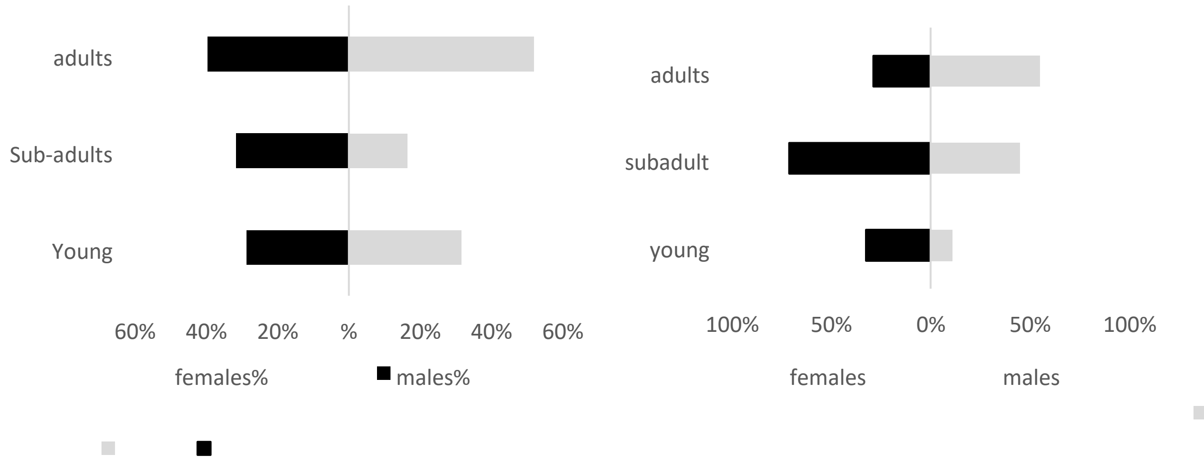


Figure 4.5.2 Population structure of Kudu in (a) hot wet season and (b) cold dry season

4.5.2 Impala *(Aepyyceros melampus*) overall population structure

In 100 total sightings for the three years, Impalas were observed mainly in distinctive herds dominated by female adult age class making up to 50% of the total population

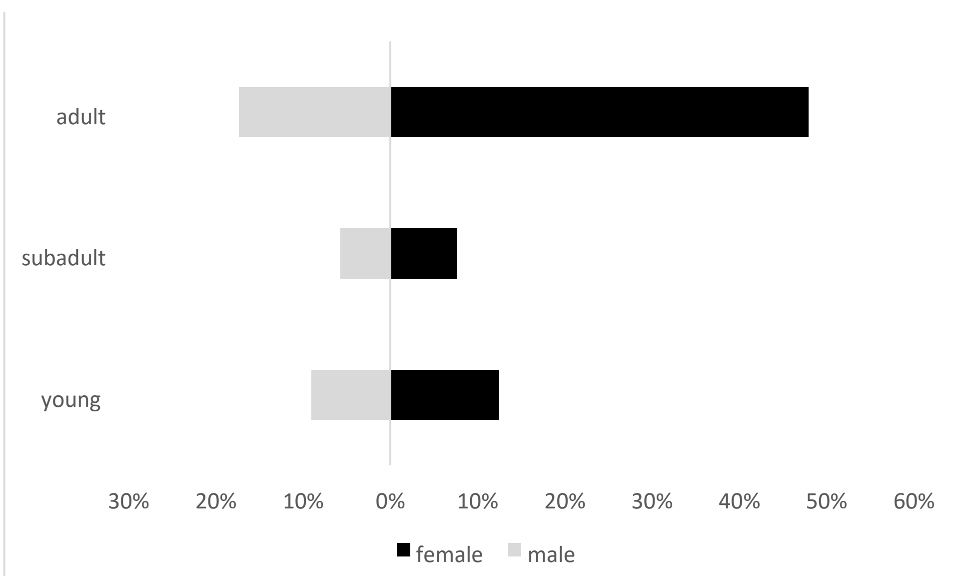


Figure 4.5.3 the overall population structure of Impalas in the Tuli Safari Area for three years.

4.5.2.2 Impala hot wet season and cold dry season

In 80 hot-wet season sightings, Impalas were observed in herds which were composed of males and female adults, male and female sub-adults, and male and female young/juveniles. Adult females were the most commonly observed age class, with 50% of the total observations. In 20 cold dry season sightings, Impalas were observed in herds which were composed of males and female adults, male and female sub-adults, and male and female young/juveniles. Adult females were the most commonly observed age class, followed by the population of sub-adult females and males of the total observations (thus, combining both wet and dry season), with juvenile male and female populations showing the least contribution to the population. (Figure 4.5b and c)

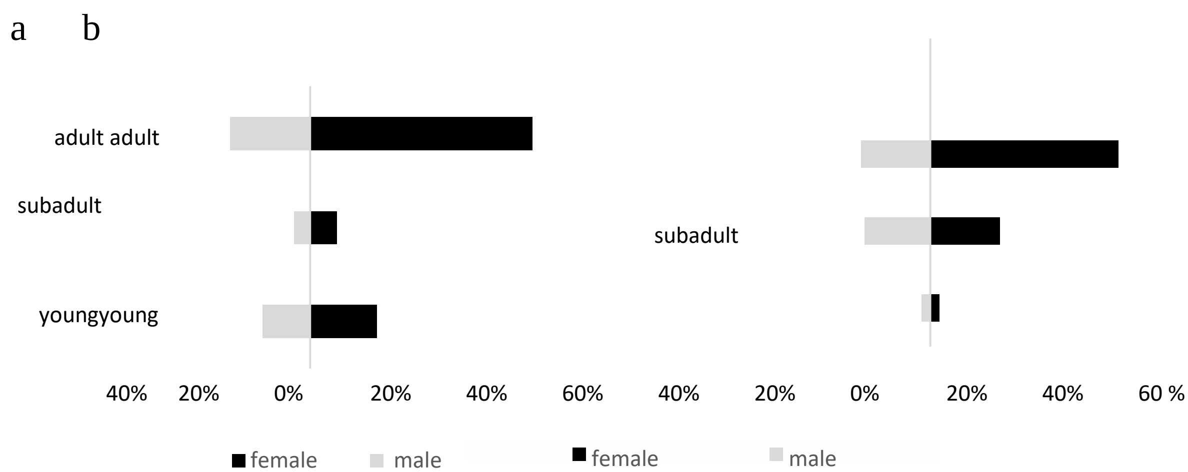


Figure 4.5.4 Population structure of Impala in (a) hot wet season and (b) cold dry season

CHAPTER 5

DISCUSSION

5.1 TEMPORAL AND SPATIAL DISTRIBUTION

5.1.1 KUDU (*Tragelaphus strepciseros)*

Kudu were observed to prefer habitats close to roads in the Tuli safari area. Roads in some cases may provide unique micro- habitats especially after fire episodes which are associated with resprouting leaves desirable for feed. This is possible because in most cases, road sides are burnt as fire guards as part of fire management plans in protected areas(Fritz, Gordon and Illius, 2004; Tarakini *et al.*, 2017). Distance from roads was the best predictor variable in the wet season as compared to the dry season based on the occurrence of Kudu.

Kudu, however, became more frequent the further away they were from rivers. These results, however, are consistent with those of earlier research by Muposhi et al, (2016) the1probability of occurrence of Greater Kudu declined with increasing vegetation density estimated by NDVI, distance from artificial water points and distance from rivers. Similarly, it has been found that having access to surface water during the dry season has an impact on the habitat choice by Kudus(Tarakini *et al.*, 2017). Western (1975) documented that herbivore distributions are influenced by the location of water sources, particularly during the dry season.

5.1.2 IMPALA (*Aepyyceros melampus)*

Findings support the hypothesis that the geographical distribution of the species may be influenced by human activity via road networks(Averbeck, 2001). Roads created by man for easy access into the Tuli Safari Area for conservation purposes and activities like hunting may modify their behaviour and distribution in response to increased harvesting risk or encounters with humans (Muposhi *et al.*, 2016;).Roads may lessen the sense of security and cover from perceived hunting risk and that human activities have been observed to change the landscape of fear of these species (Peignier et al., 2019).Such disturbances to the natural environment have impacts on the spatial distribution of the species.

In the dry season, results suggested that distance from rivers showed a major influence on the impala probability of occurrence than distance from roads. This is similar to findings by (Hensman et al. 2012; Muposhi et al. 2016) where access to surface water and artificial water points had influenced the probability of occurrence of species. Impalas are frequently located within three kilometres of the rivers it seems that access to drinking water had effect on the way they are distributed. Impalas start to recolonize towards the conclusion of the dry season, according to observation of marked impalas near water sources over a period of several days. (Van Bommel et al, 2006).

5.2 POPULATION STRUCTURE

5.2.1 KUDU (*Tragelaphus strepciseros)*

Predation and competition play a major role in the population structure of kudu in the cold dry season, as less juveniles were observed and more juveniles observed in the hot wet season. In addition population structure is highly inclined towards sub adults and adults, those age groups who have passed the infant mortality stage which is an indicator of external factor such as (Winterbach et al. 2013) in the composition of population structure in the cold dry season.

5.2.2 IMPALA (*Aepyyceros melampus)*

The size of the impala population was increasing from 2020 to 2022 and was highly dominated by the adult females making up most of the population. In the hot wet season, there was a notable increase in the juvenile population as compared to the cold dry season. This maybe because the breeding season has commenced and as a result more juveniles are sighted. This is in contrast to the cold dry season where the population of both sub-adult males and females are more than the juveniles because of ceasing of the breeding season. Therefore in accordance with the findings of this study suggest that the high off- take from predation , illegal hunting , staff quotas and hunting bags offered include mainly male species because of body size and for trophy ,compared to female counterparts in in Tuli Safari Area .

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The results of this study indicate that Impalas are most impacted by distance from rivers. Kudu distribution is primarily determined by distance from roads. Because surface water availability, proximity to riverine ecosystems, and human disturbances like roads are dynamic and highly variable, the habitat suitability of Kudus in the dry season can change from year to year. Additionally, in human-mediated ecosystems (like trophy hunting areas), Kudus may not always have larger ranging options than medium-sized antelopes. There were no major differences in the spatial distribution of Kudus and Impalas in the Tuli Safari Area between the two seasons.

This finding was showed as wet season of the study area is peak breeding season for both Impalas and Kudus. Rivers in Tuli Safari Area ecosystem may be under threat due to climate change thereby imposing constraints to the species distribution across the landscape. Additionally, this study revealed that there were more females Kudus and female Impalas than males of both species, which indicated that both species have viable population in the study site. Similarly, there were no major differences in the population structure of Kudus and Impalas in the Tuli Safari Area in the hot wet season and cold dry season in the three consecutive years.

6.2 Recommendations

Impalas are more water dependent (distance from rivers) than Kudus, and thus the water content of browse is higher than that of a grass, given climate change impacts, Impalas (grazers) will most suffer than Kudus (browsers). This implies that protected area management should take into consideration and maintain heterogeneity in surface water as a facilitative entity for maintaining herbivore distribution and diversity.

To improve interpretation of data and ensure accuracy of count data, it is important that counts are repeatable, the entire area is counted and that animals are counted accurately. This can only be achieved through proper planning, using experienced and preferably the same counters for biennial counts and counting the entire core area or at the very least use a similar counting method and counting at more or a less the same time to prevent double counting of species. Good recording keeping of offtakes including the sex and age class of the animals removed will further improve the quality of the data and is important for establishing sustainable offtake quotas and determining the impact of hunting and/or ecological factors on population structure and estimate.

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