Modeling Habitat Selection for Southern White Rhino (*Ceratotherium Simum Simum*) in Matopos National Park.

by

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I am largely indebted to my parents for their unwavering moral and financial support.

Abstract

In this study we modeled wet and dry season habitat selection of the Southern white rhinoceros (*Ceratotherium Simum Simum)* in Matopos National Park. We tested whether wet and dry season habitat selection was influenced by factors such as sex. We also tested whether home range size significantly differed between male and female rhinos. Habitat selection analysis was based on road survey data collected for the period 2009-2015. We determined rhino habitats using NDVI thresholded maps. Landsat TM images which corresponded temporally with the data were used to determine the habitats found in Matopos National park using a quantitative approach of thresholding NDVI to classify the landcover types . To model habitat selection, proportion of use and availability were calculated and the selection ratio which is given by use/availability was calculated. In the models, selection ratio was the dependent variable while sex and type of landcover were the independent variables. Of the models generated models generated to model habitat selection, the one with the lowest value for the Akaike Information Criterion (AIC) was used as it fit our data better. We observed that on average, females had higher home ranges than males for both seasons and that home range sizes were larger in the dry season than in the wet season for both males and females. Our model for the wet season suggested the areas classified as bare or rock were selected while grassland was neither selected nor avoided and the other habitats were avoided. The dry season model shows how the grassland and moderate woodland habitats were used as much as they were available while the other habitat types were avoided. We also conclude that the white rhinos prefer habitats that encompass short grasses which are available even in bare areas during the wet season and during the dry season, moderate woodland is utilized in addition to the grassland. We also conclude that our predictor variable, sex, was not really a significant factor in explaining the seasonal variation of white rhino habitat selection at Matopos National Park.

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CHAPTER ONE: INTRODUCTION

1.1. Background of Study

The Southern White Rhinoceros *Ceratotherium Simum Simum* is an endangered megaherbivore accorded the Near Threatened status by the International Union for Conservation of Nature (White et. al., 2007). Its current numbers may seem viable as it is the success story of the conservation of all the rhino species with approximately 21 000 individuals (World Wildlife Fund, 2016), however the illegal demand for its precious horn remains unabated as poaching is the greatest threat to its existence (Patton et.al,1999). An estimated 1300 African rhinos were poached in Africa in the year 2015 (World Wildlife Fund, 2016). Besides poaching, habitat loss and habitat encroachment (Patton et.al,1999) are also key threats to its existence. In light of that, understanding its habitat selection is of importance. A species survival is often tied to its habitat thus an alteration or loss of habitat significantly affects species populations. Thus understanding habitats that are critical for maintaining stable populations is important for it species conservation.

Several factors have been identified that can influence the distribution of animals and these mainly encompass biotic and abiotic factors which then determine the resources available to an individual (Boyce and McDonald, 1999). Resource selection is an important component of species ecology (Rosenzweig, 1981). Where resources are used disproportionately to their availability, use is said to be selective (Manly et al., 2007). Understanding how a species selects its habitat, that is to understand how a species interacts with its environment is key to successfully conserving it. Examining habitat selection is one way to assess the importance of habitat to species conservation, but making such assessments is not straight forward, even for well studied species (Mayor et al., 2009).

The purpose of investigating habitat selection of animals is to find out the preferred and avoided habitat types and also to identify the covariates influencing the choice of certain habitat types (Kneib et.al, 2007). Several factors may influence the variation in resource selection and understanding these factors is important in understanding the behavior and distribution of animals. The main aim of such analyses is an improvement of the conservation of animals. In most cases, large mammals are radiotracked or observed directly and the resulting locations are then used to analyse their habitat selection (Manly et al. 2002). For most studies, the available data is for presence only which is data for where the species was observed (Phillips and Elith, 2011). The temporal dimension of the data is however key in habitat selection data, with most studies being limited by the amount of data collected. In this study we use long term data to determine habitat selection of white Rhino an improvement over previous studies that have used short term data (Borthwick, 1986), (Van de goot, 2009) in order to provide improved insights into Rhino distribution.

Individual animals may be of the same species and even belong to the same population but the way they will utilize the resources availed to them will always differ (Arlettaz, 1999). When concerned with conservation of a species, it is important to attempt to understand this individual variability. Models that are able to incorporate individual variability have been developed in order to improve habitat selection models. One such model is the Linear Mixed Effects model which has the ability to incorporate fixed effects as well as the random effects which account for individual variability within species. Linear mixed effects models differ from the normal linear models in that they contain additional random effects and are used to analyse data that shows dependence and usually collected from the same individuals over a period of time (Fox, 2002). Fixed effects are those factors which are constant across individuals and cannot change while random effects are those which can vary (Starkweather, 2010). Thus models that account for individual availability are valuable for habitat selection studies as they improve

1.2: Objectives

The objectives of this study are:

- To test whether home range size varies according to sex.
- To determine whether seasonal variation in habitat selection is influenced by the factors such as sex.

1.3 Problem Statement

Understanding of a species habitat preferences and requirements is important for its conservation (Ferrar and Walker, 1974), (Putman, 1996). Thus it is important to have long term data on the distribution of the species in order to identify critical habitats important for their survival. Most studies have often used short term data particularly aerial survey data, thus by using long term data it may improve habitat modeling and provide improved insights into wildlife distribution. Use of methods that account for individual variability is also important in improving habitat selection models. Incorporating the robust and modern techniques of Remote Sensing and Geographic Information Science technology into habitat selection models will likely improve such models.

1.4 Justification of study

Understanding distribution of species is key in protection of endangered animals. The southern white rhino is a conservation dependent species thus identifying habitats critical for its survival will enhance strategies aimed at its successful conservation.

CHAPTER 2 : METHODOLOGY

2.1 Study Area

Matopos National Park is located in the south western Zimbabwe at 20.5500° S, 28.5080° E (Figure 1). It is relatively one of the smallest national parks with a total area of about 424km^2 . The western side of the national of the park is a fenced area named Whovi Game park which has an approximate area of about 105 km^2, of which 20% of this area is called Intensive Rhino Protection Zone mainly for the protection of black and white rhinos. Rhinos are generally confined to the Whovhi Game Park and the northern side of the park which is named Hazelside, various wildlife is found elsewhere in the park .

2.1.1 Climate

Matopos National Park is characterized as a semi arid region which falls under agro ecological zone III of Zimbabwe (Hyland and Umenne, 2005). Rainfall is mainly received between the months of October to April. Rainfall received in the area averages 601.7 mm per year (Lunt et al., 1997). However, the rainfall patterns tend to be unevenly distributed as the majority of the rain falls between November and March. Due to the significant granite landforms, a substantial amount of water is stored in the rocks which is then received as runoff even in the dry season hence water is normally available in the reservoirs all year round with the exception of drought years (Hyland and Umenne, 2005).

Average daily temperatures for the national park are generally high while the nights tend to be cool. The highest temperature are experienced during the dry season specifically from the months of September to December, with October being the hottest month with a mean monthly temperature of about 26.3^0 C and June the coldest with mean monthly temperature of 20.4^0 C (Tredgold, 1956).

2.1.2 Geology and Soils

Matopos has an outstanding geology because a variety of granitic landforms are found within such a small area, the most distinct landforms that are found there include dwalas, caves, inselbergs, kopjes and whalebacks. These landforms came about due to the erosion and weathering processes that were occurring to the hills from about 2.5 billion years ago (Garson and Mtsvanga, 1995). The Matopos area comprises an exposed granite batholith dissected by deep drainage systems carved down into NNW to NW trending joints and faults (Lightfoot, 1981). The area is almost entirely on granite rock hence the soils found there are resultant from granite hence they are coarse and sandy .

2.1.3 Vegetation

The area lies within the savanna biome and is typically a grassland ecosystem where grasses tend to be the dominant plant life with shrub and trees that are spaced. Regardless of the fact that there is little diversity in terms of soils available in the park, there is a great range in terms of vegetation. Vegetation formations range from types that are suited for extreme arid conditions all the way to mesic woodland (Hyland and Umenne, 2005).

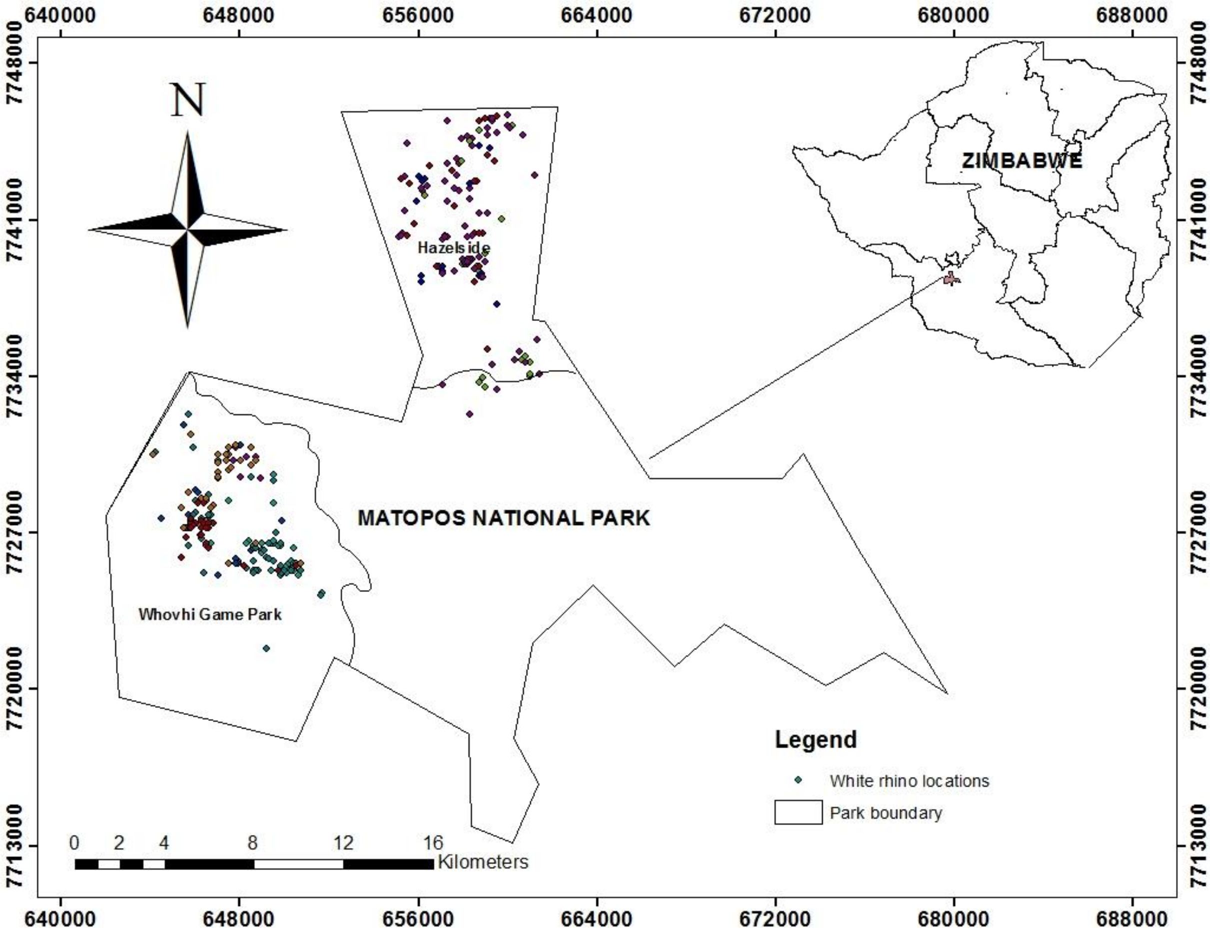


Figure 1: **Location of Matopos National Park in South Western Zimbabwe. Zones mainly for the protection of black and white rhinos are the Whovhi Game Park on the western side of the park and Hazelside on the northern side of the park**

2.2 Data Collection

2.2.1 Animal Data

The techniques used to collect the location data on white rhino sightings at Matopos National Park are usually road counts and foot patrols since it is a small park. When conducting road counts, rangers would traverse the park in an open vehicle along ‘transect ‘roads within the Park to count the rhinos (Wildlife ACT,2014). During patrols, the observer would be using a GPS receiver and a range finder. Information collected includes the location of the rhino, sex , date and estimate of the age and is recorded down on a sheet. The rhinos have ear notches that make them easy to identify.

Data was collected by rangers on a monthly basis for a period of about five years, 2009, 2011, 2012, 2014 and 2015. However, in some years data was incomplete, so for the purpose of this study, we had selected rhinos with sufficient data for further analyses. For the selected rhinos, data for the years had to be aggregated because unlike telemetry data, data collected by direct observation has a low temporal resolution. Rhinos are assigned four digit name codes beginning with the number 5 for males and 6 for the females

2.2.2 Landcover Classification

In order to determine the habitats found in Matopos National park we used a quantitative approach of thresholding NDVI to classify the landcover types herein referred to as habitats. We thus downloaded Landsat images from the years 2012, 2013, 2014 and 2015 from the www.usgs.glovis website.

Vegetation cover was estimated from the Normalised Difference Vegetation Index (NDVI) which was generated from Landsat 5 and Landsat 8 images for the area which correspond temporally with the white rhino location data. Prior to calculating NDVI we performed image preprocessing which entailed correction for the sun angle, calculation of image reflectance and projecting the images from WGS 84 to UTM Zone 35S which is the projection system that was being used in the study.

NDVI is given by the formula:

$$NDVI = \frac{NIR - R}{NIR + R}$$

Where :

NIR is near infra red band of Landsat Thermatic Mapper.

R is red band of Landsat Thermatic Mapper.

The classification was done as according to NDVI thresholds shown in Table1 defined by (Gandhi et al., 2015), (Arulbalaji & Gurugnanam, 2014). Table 2 shows the NDVI values used to classify images to show various landcover classes at Matopos.

Table 1**: NDVI Thresholds**

NDVI value	**Landcover Type**
0.1 or below	Barren areas of rock or sand or snow
0.2 -0.3	shrub and grassland
0.6-0.8	tropical rainforests
negative values	water bodies

Table 2**: NDVI values used for classification in this study.**

NDVI Value Range	**Land Cover Type**
-0.348 - (-0.098)	Water
-0.098 - 0.0980	Bare/Rock
0.098 - 0.194	Grassland
0.194– 0.294	Shrubland
0.294 - 0.392	Sparse Woodland
0.392 - 0.490	Moderate Woodland

2.2.3 Environmental Factors

Water sources were estimated in ILWIS GIS using an Aster 30x30m Digital Elevation Model. Firstly the Fill Sinks Function is used to remove local depressions from the DEM, then the flow direction of water is established using the Flow Direction function which determines where water in a central pixel will flow amongst its neighbouring cells, after that, the Flow Accumulation Function is used which counts the number of pixels that naturally drain into water outlets. Finally, the Drainage Network Extraction function is used which generates a basic drainage network, showing the streams and rivers. Distance of GPS points from the rivers was computed using Near Function in ArcGIS.

2.3 Data Analysis

White rhino locations were separated in terms of sex as well as season. The wet season in this study is defined as the period from the onset of the rainy season in Zimbabwe which is the period from November to April while the dry season is from May to October (GoZ, 2009). To construct Linear Mixed Effect Models, a minimum number of 12 individuals are required, hence 12 white rhinos were used for both seasons in the study. In terms of gender, there were 7 male and 5 female for both seasons. There was a need to aggregate the data for the years because the data were few and inconsistent for most of the rhinos hence could only select 12 from about 30 white rhinos.

2.3.1 Home range estimation

To model habitat selection, there is a need to come up with the ratio of use which can then be compared in relation to the availability (Mayor et.al, 2003). Shapefiles of the locations of the individual white rhinos were created in a GIS for the purpose of analysis. To determine availability, home ranges were estimated. A home range is defined as an area traversed by an animal on a regular basis which contains all the resources an animal requires to survive and reproduce which may overlap with that of other animals or other members of the same species (W.Koenig,2015).

The non parametric density kernel density estimation method was employed to calculate the home ranges for the wet season in the software Geospatial Modelling Environment. It has the following formula:

$$\hat{f}(x)= \frac{1}{n} \sum_{i=1}^{n} K(\frac{x-x(i)}{h})$$

where :

x is the variable

n is the number of observations

K is the Kernel function

h is the bandwidth

The Least Squares Cross Validation bandwidth was used for smoothing as it was appropriate for the sample size which was n≥50 locations per individual which concurs with (Seamen et.al, 1999). After getting the kernel density estimate, the 95% isopleths in GME were calculated to get the actual home ranges which were then clipped out in a GIS.

For the dry season data, home ranges were estimated using the Minimum Convex Polygon method in QGIS because it requires sample size of n≥ 10 locations per individual (Conway and Goodman, 1989) and for the dry season the rhinos had n ≥30 locations. Its merits are that it is non parametric and easy to construct while the shortcomings are that it is sensitive to outliers and that it tends to ignore boundaries that exclude animal movement within the home range (Mohr,1947).

2.3.2 Estimation of Selection Ratio

The home ranges were then used to extract landcover classes from the habitat maps using the Cross function in ILWIS. The home range polygons were rasterised so as to Cross them with the habitat map which was in raster format. Data were copied from the output ILWIS tables to excel where pivot tables summarized the area under a particular landcover type for individual rhinos.

To determine Proportion of Availability, the following formula was used:

$$\text{Proportion of Availability} = \frac{\textit{Area Under a Landcover Type}}{\textit{Total Area Of Home Range}}$$

To determine use, the number of GPS locations in each habitat were counted using the Point in Polygon function in QGIS. We then determined the proportion of use as a ratio of number of points in habitat over the total GPS locations in all habitats. To estimate the Selection Ratio, the following formula was used:

$$\text{Selection Ratio} = \frac{\textit{Proportion of Use}}{\textit{Proportion of Availability}}$$

2.3.3 Linear Mixed Effect Model

The Linear Mixed Effect Model is an extension of the linear model as it includes additional random effects (West et. al, 2007). The model takes the form:

$$Y=X\beta+Z\gamma+\varepsilon$$

Where:

β= Fixed Effects parameter estimates

X=fixed effects

Z=Random effects parameter estimates

γ = random effects

ε=Errors

We modeled habitat selection using the Linear mixed model in R Studio software using the ‘lme4’ package. The package fits linear mixed effects models and generalized linear mixed effects models using S4 methods (Bates et.al, 2016). The ‘lmer’ function was used to create the linear mixed effect model for this study.

Model evaluation was based on the Akaike Information Criteria (AIC) (Boyce et.al,2002). The best performing model was the one with the least AIC value. To show selection or avoidance the model calculates confidence intervals and if both the upper bound and the lower bound values are positive, it shows selection, while negative values for both the upper and lower bound mean avoidance. If the upper bound and the lower bound values have different signs, one being positive and another being negative there is neither selection nor avoidance. The estimates and confidence intervals generated by the model are then plotted to visually show habitat selection.

CHAPTER 3: RESULTS

Available Habitats

The landcover types that were obtained from the NDVI classification are shown on the habitat map (Figure 2). Six classes were generated, namely water, bare/rock, grassland, shrubland, sparse woodland and moderate woodland.

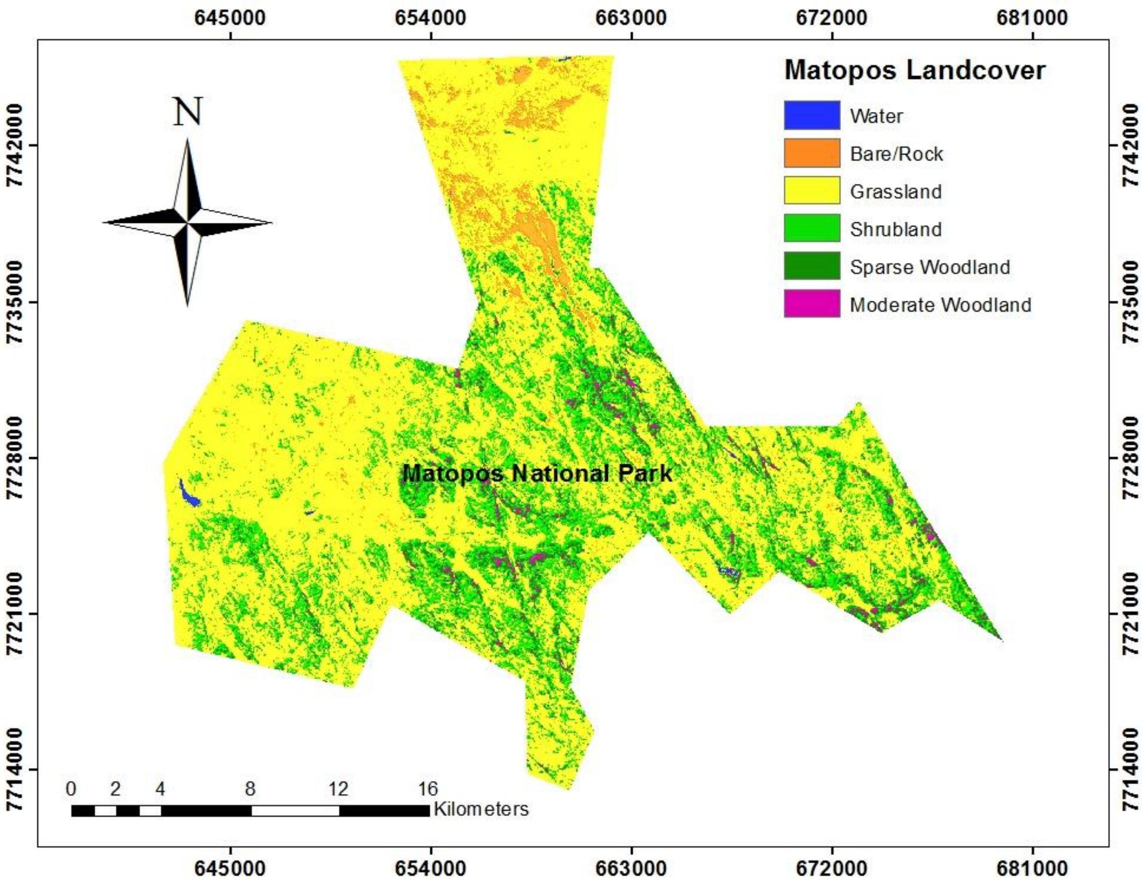


Figure 2**: Habitat types in Matopos National Park**

The distribution of the home ranges for the female white rhinos (n=5), during the wet season is illustrated by (Figure 3). Of the five females, one (6039) has its home ranges confined to western side of the park during the wet season, which is Whovhi Game Park while (6134) has its home range confined to the northern side of the park called

Hazelside. The other three (6107, 6044 & 6069) have their home ranges distributed between Whovhi Game Park and Hazelside.

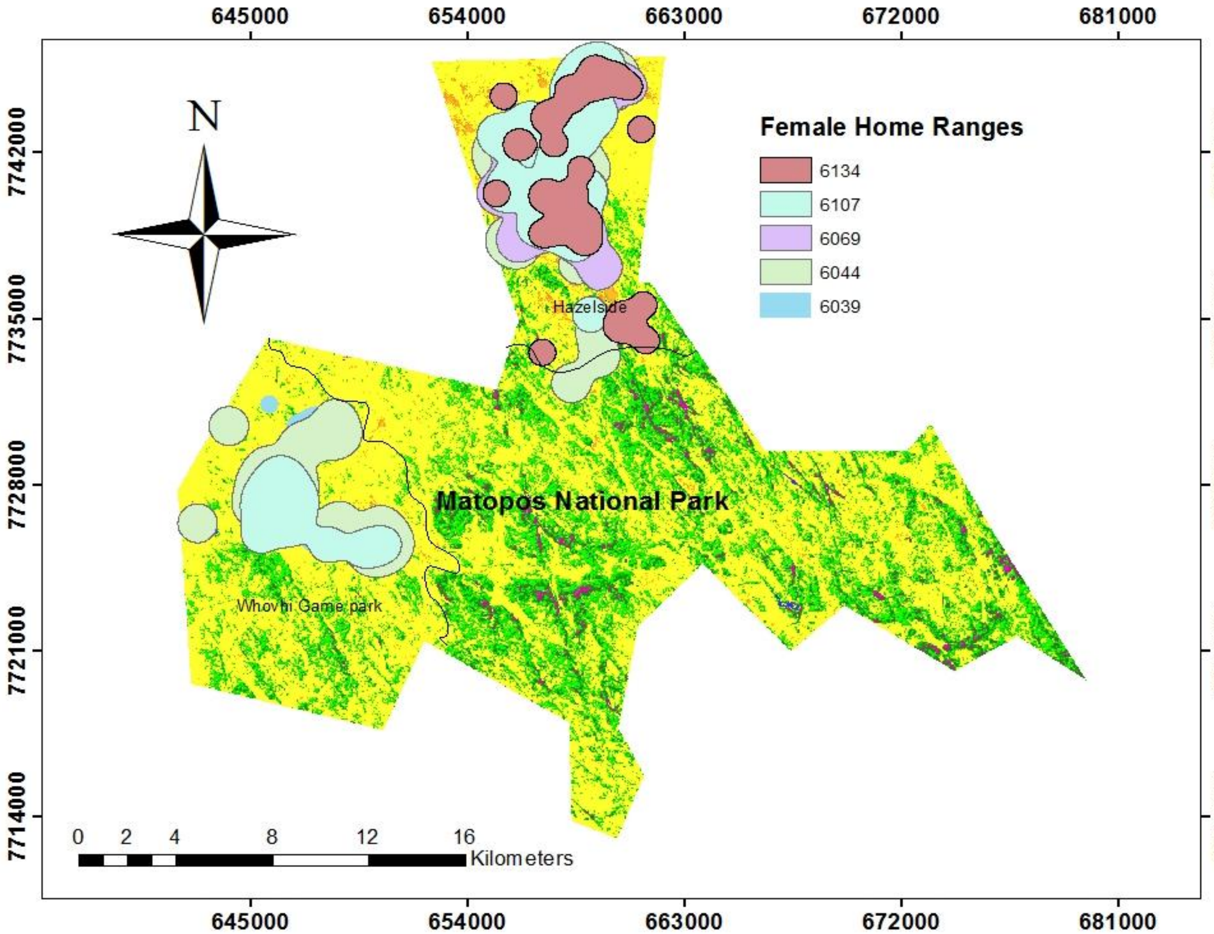


Figure 3: Home ranges for the female rhinos in the wet season

The distribution of the male home ranges (n=7) during the wet season is illustrated in . Figure 4. Males exhibit an even distribution between Whovhi game park and the Hazelside area as three males (5117, 5028 & 5024) have their home ranges confined to the Whovhi Game Park while (5152 & 5161) have their home ranges at the Hazelside area and the other two (5114 & 5106) have their home ranges within Whovhi Game Park and Hazelside areas.

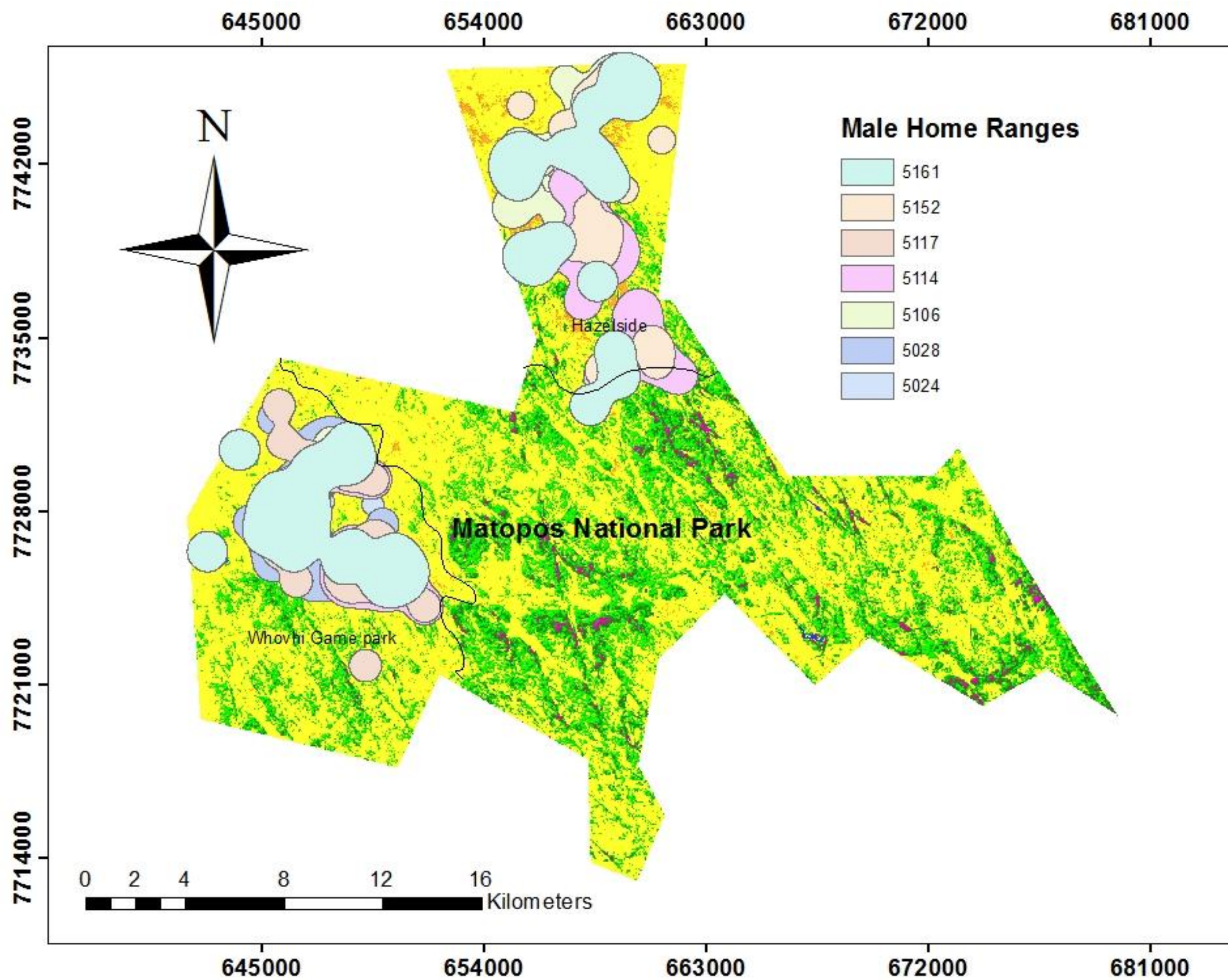


Figure 4: Distribution of male home ranges during the wet season

The average home range sizes for both the males and females during the wet season are shown in (Figure 5). The males have an average of approximately 34.1km^2 while the females have their average home range size at about 44.4km^2. The females have a higher average in terms of the size of their home ranges as compared to the males.

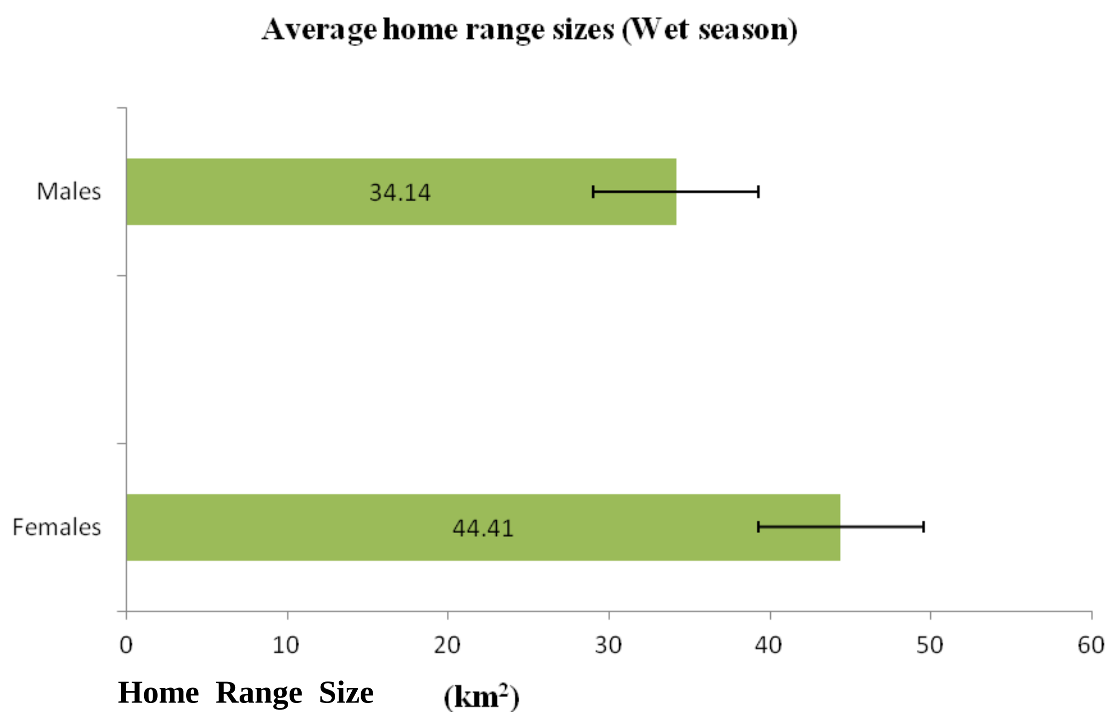


Figure 5: Average home range sizes for both sexes in the wet season

3.1 Dry season

The distribution of the male home ranges (n=7), in the park during the dry season is illustrated by (Figure 6). It is notable that all males had part of their home ranges within the Hazelside area, however two of them (5114 &5029) also had part of their home ranges in the Whovhi Game park. The home ranges of (5161 & 5152) can be observed to be extending to the central areas of the park which is different from the wet season distribution.

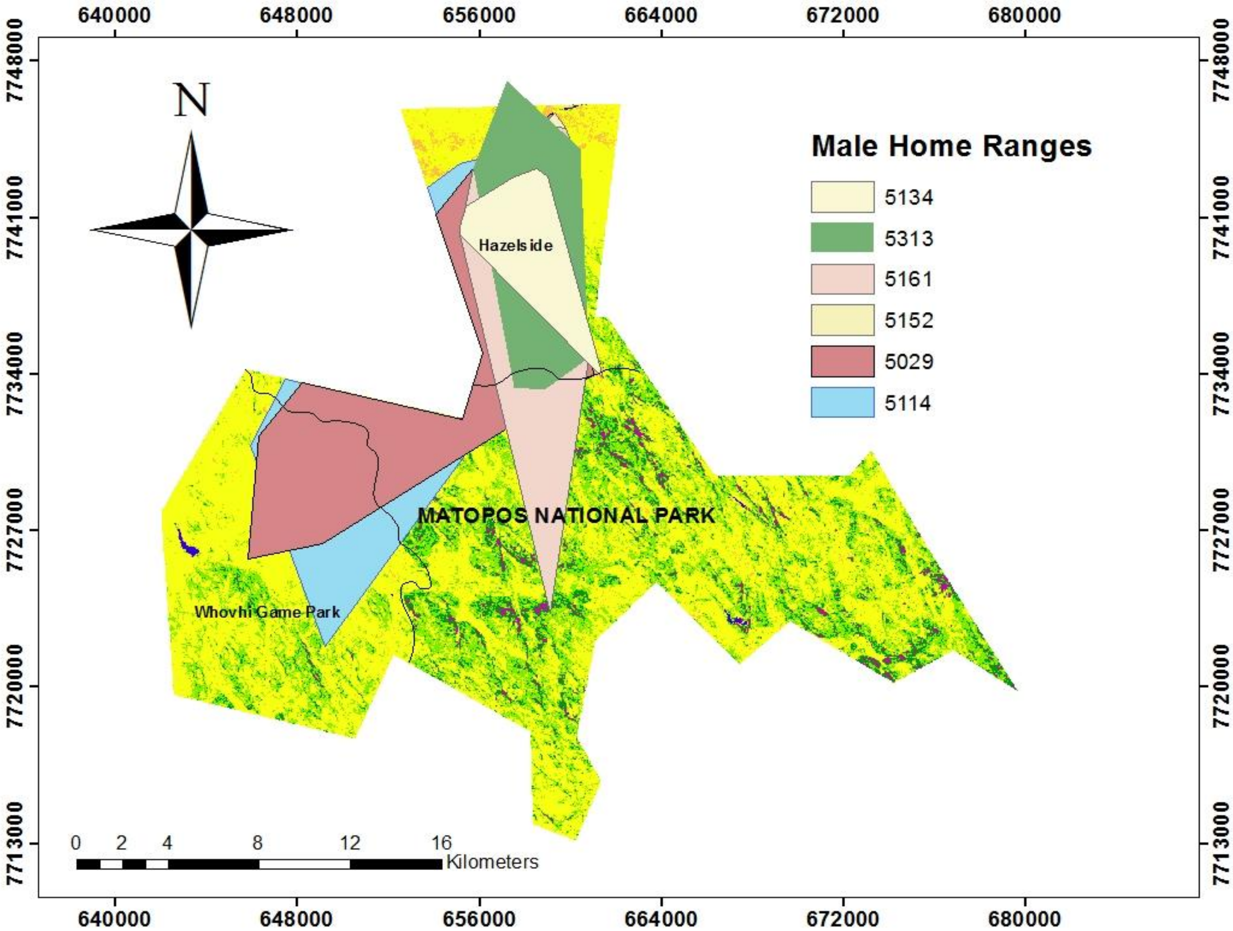


Figure 6: Distribution of male home ranges during the dry season.

The distribution of female home ranges (n=5) in the dry season is illustrated by (Figure 7). Of the five females, two (6044 & 6175) had their home ranges extending to Hazelside and Whovhi Game Park. Another two (6069 & 6175) had their home ranges extending to the central area of the park while one (6107) had its home range confined to the Hazelside area.

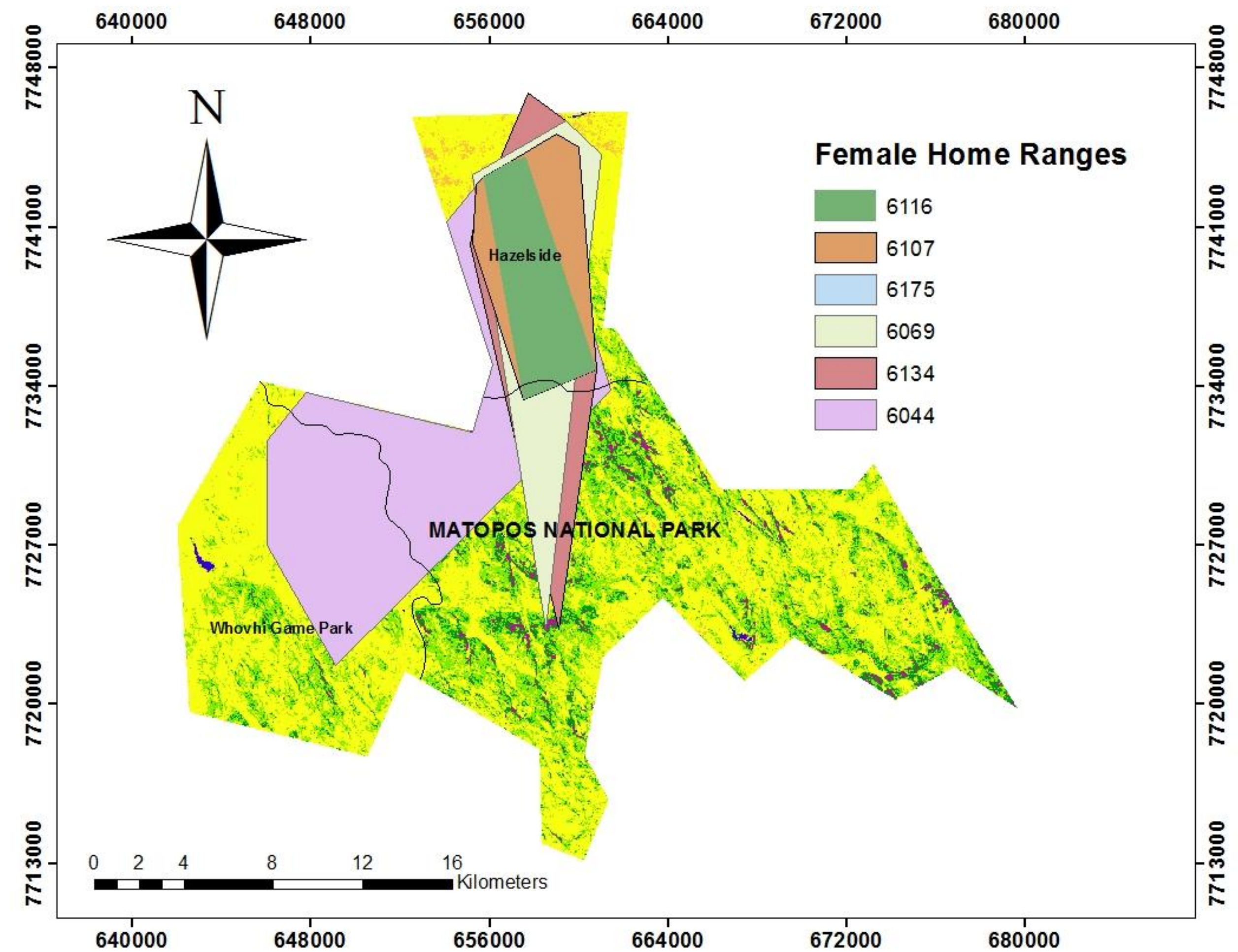


Figure7: Distribution of female home ranges during the dry season.

The average home range sizes for both males and females in the dry season are shown by (Figure 8). Males have an average home range size of about 45.97km^2 while females have an average of 51.86km^2. Females have larger home ranges on average as compared to the males during the dry season.

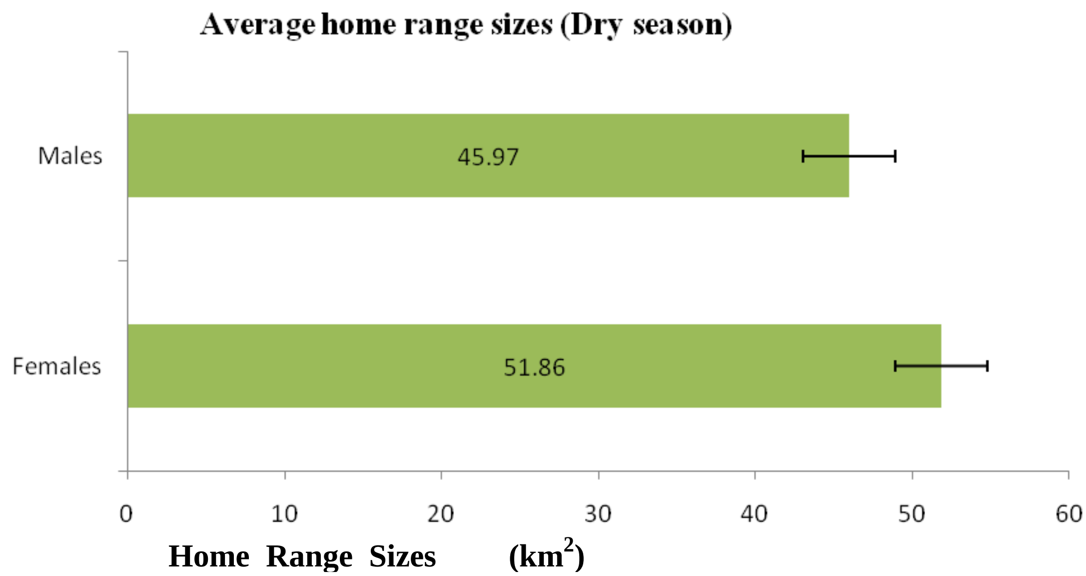


Figure 8: Average home range sizes for both sexes in the dry season

3.2 Selection of Habitats

For the wet season, the model with the least AIC is the model with landcover/habitat only as the covariate (Table 3). Based on this model bare areas were selected (), while sparse woodland were avoided. (Figure 13).

Table 3: Model evaluation for Model 1 and Model 2 in the wet season

	Model 1	Model 2
AIC	208.8	210.8
BIC	223.5	227.5
Loglik	-97.4	-97.4
Deviance	194.8	194.8
df residuals	52	52
F-Value	2.075	Landcover 2.0750 Sex 0.0588

Model 1: Formula: Selection.Ratio ~ Landcover + (1 | Subject)

Model 2: Formula: Selection.Ratio ~ Landcover + Sex+ (1 | Subject)

Table 3 : Random Effects for Model 1

Groups	Name	Variance	St .dev
Subject	Intercept	0.3267	0.5716
Residual		1.2765	1.1298

Table 4: Confidence intervals for Model 1

	2.5%	97.5%
.sig01	0.0000000	1.10099771
.sigma	0.9366241	1.39987306
Bare/rock	1.5184041	0.05789249
Grassland	-0.1372869	1.70756999
Moderate Woodland	-0.1724062	1.67245071
Shrubland	-0.4333358	1.41152107
Sparse Woodland	-1.1982897	0.64656718

The selection or avoidance of different habitat types by the white rhinos during the wet season is illustrated in Figure 9. In Figure 9 we noted that the Bare/Rock Habitat lies above 0, hence is in the positive region which means it is being selected for. The Grassland habitat type falls both above and below 0 meaning its use is equal to availability its neither being selected nor being avoided. The Moderate Woodland habitat type falls just above and just below -1 meaning that it is being avoided. The Shrubland habitat type lies almost below -3 which implies that it is completely being avoided. The Sparse Woodland habitat type lies between -1 and -2, which is well within the negative region of (Figure 9) hence it is being avoided.

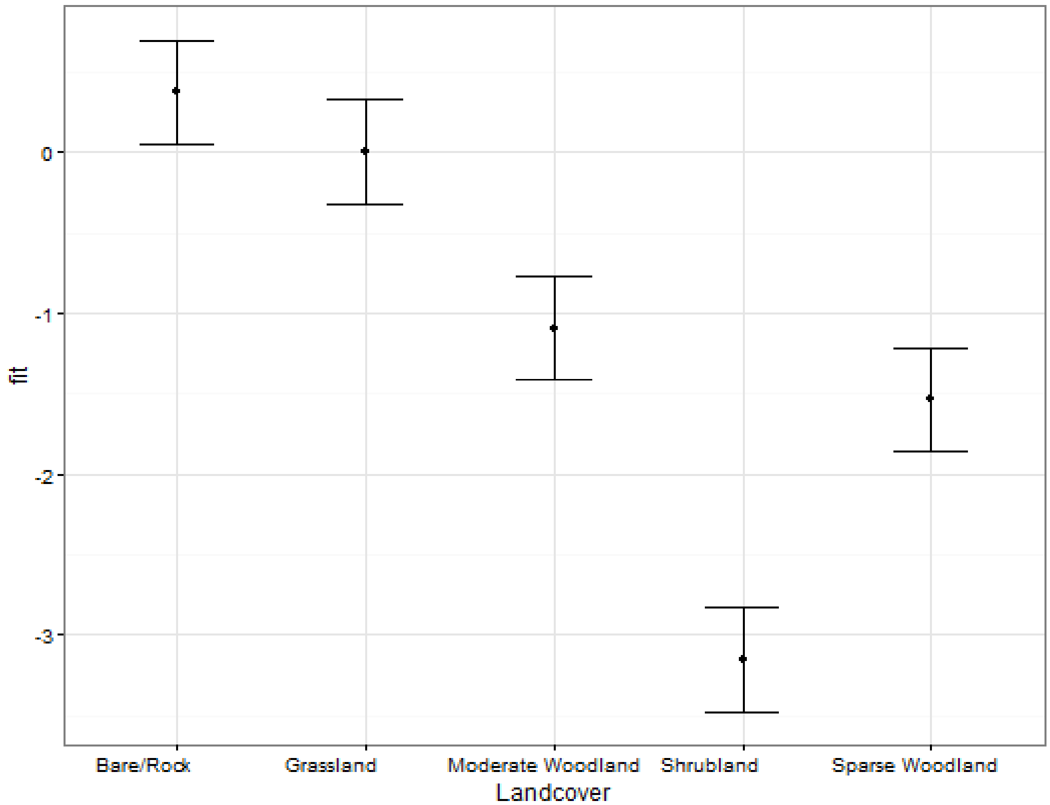


Figure 9: Habitat selection and of white rhinos in the wet season

3.3 Linear Mixed Models For the Dry Season

For the wet season the model with the least AIC is the model with landcover only as the covariate (Table 7). Based on this model bare areas were selected (), while sparse woodland was avoided. (Figure 9).

Table 5 :Evaluation for Model 3 and model 4 in the dry season

	Model 3	Model 4
AIC	193.8	194.6
BIC	210.0	209.3
Loglik	-88.6	-90.3
deviance	177.2	180.6
df residual	52	53

F value	Landcover 20.8338 Sex 3.8513	20.701

Model 3: Selection.Ratio ~ Landcover + Sex + (1 | Subject)

Model 4: Selection Ratio~ Landcover +(1|Subject)

The model chosen to model our dry season data is the Model 3 because it had a lower Akaike Information Criterion compared to Model 4

Table 6: Random Effects of Model 3

Groups	Name	Variance	St .dev
Subject	Intercept	4.410e-15	6.64e-08
Residual		1.123e+00	1.06e+00

Table 7: Confidence intervals for Model 3

	2.5%	97.5%
.sig01	0.00000000	0.5772759
.sigma	0.87966884	1.2816733
Bare/rock	-0.63337525	0.7457120
Grassland	-1.23268764	0.4905289
Moderate Woodland	-2.32737531	-0.6041588
Shrubland	-4.38986059	-2.6666440
Sparse Woodland	-2.77150514	-1.0482886

The selection or avoidance of different habitat types by the white rhinos during the dry season is illustrated by (Figure 10). Interpretation of Figure 10 is the same as that of Figure 9, selected habitat types fall within the positive region while the avoided habitat types fall in the negative region. The habitat type Bare/Rock lies well below -0.5 and -1 which means that it is being avoided. The Grassland habitat falls partly above 0 and below 0 meaning that its use is equal to availability hence its neither being selected or avoided. The Moderate Woodland habitat falls within the same region as the Grassland implying that its neither being selected nor avoided. The Shrubland habitat falls mostly below 0 meaning mostly being avoided. The Sparse Woodland habitat falls below -0.5 to -1.5 which implies that it is completely avoided.

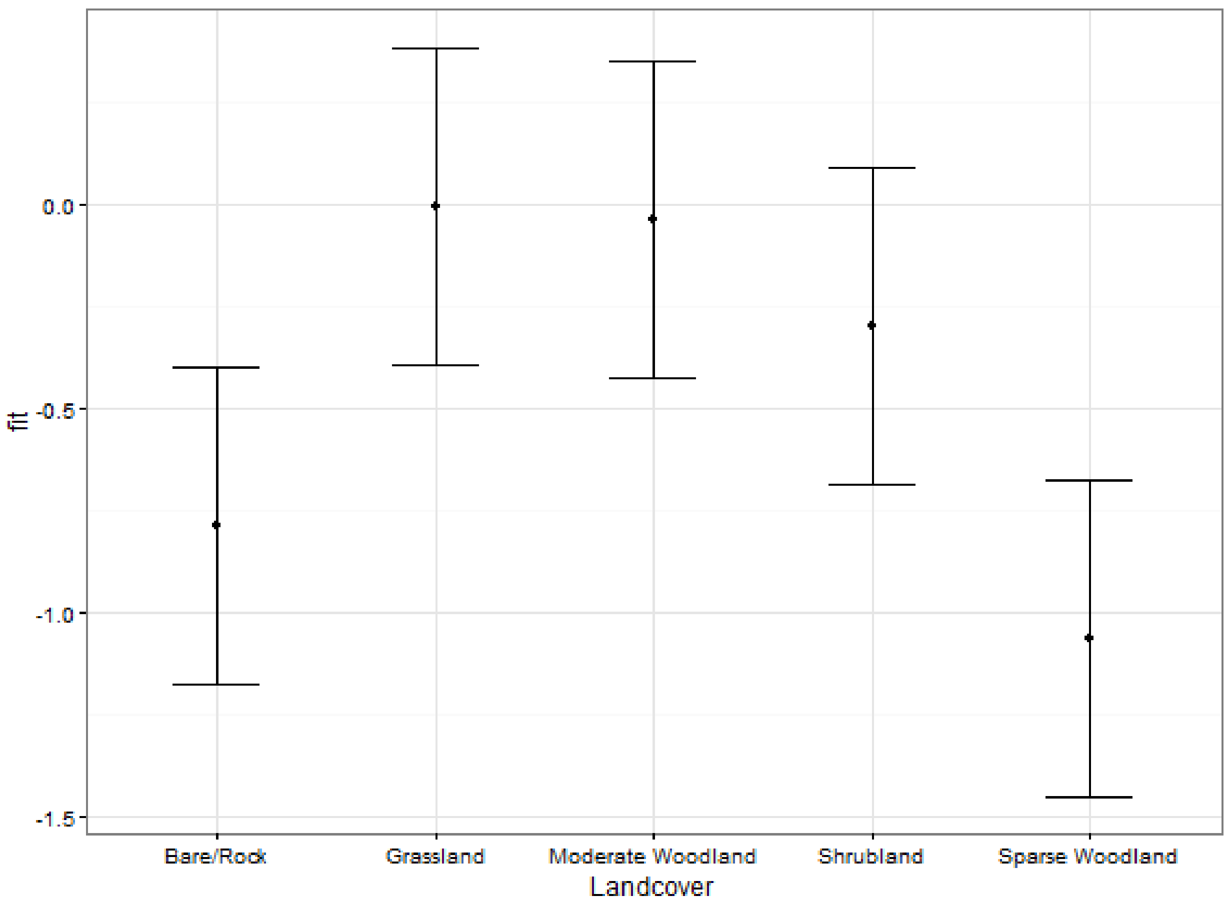


Figure 10 :Habitat selection of white rhinos in the dry season

3.4 Influence of water on habitat utilisation

It can be observed that grassland areas selected by rhino were closer to water during both wet (Figure 11a) and dry (Figure 11b) seasons. The highest frequencies of rhino points in grassland occur at distances of <50m from water. The mean distance of points from water sources is about 148m from rivers.

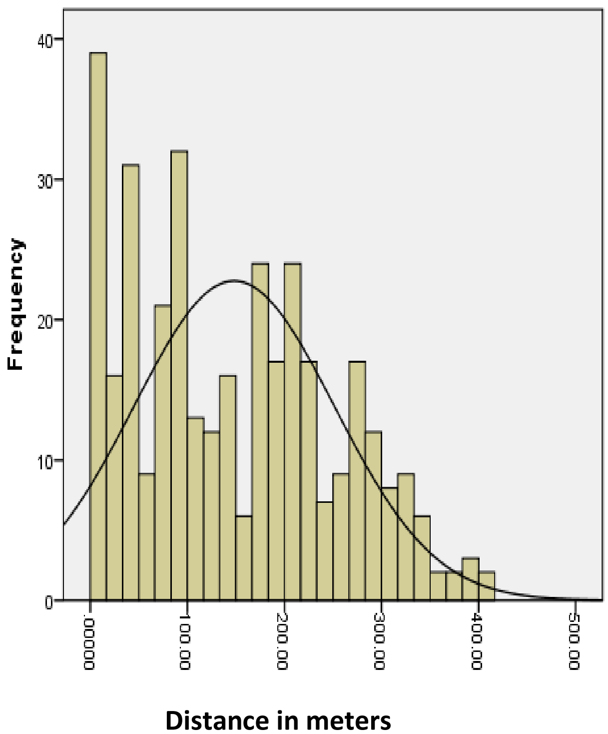


Figure 11a:Wet season

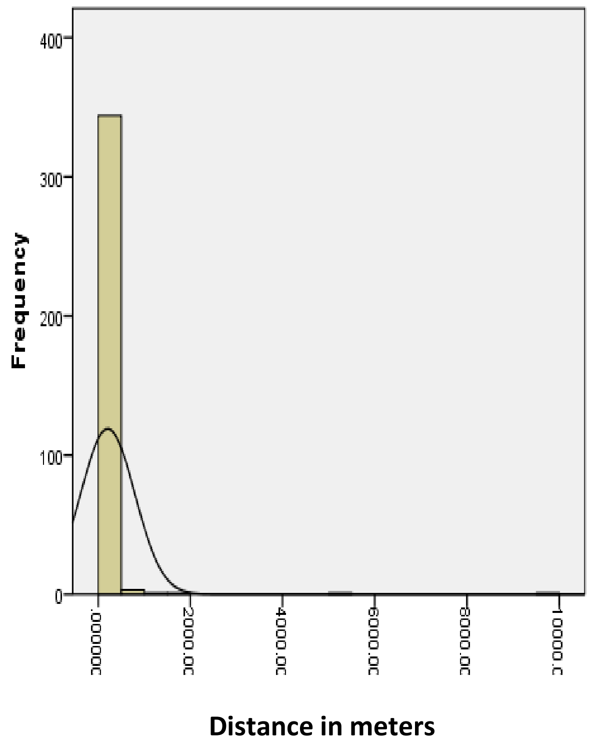
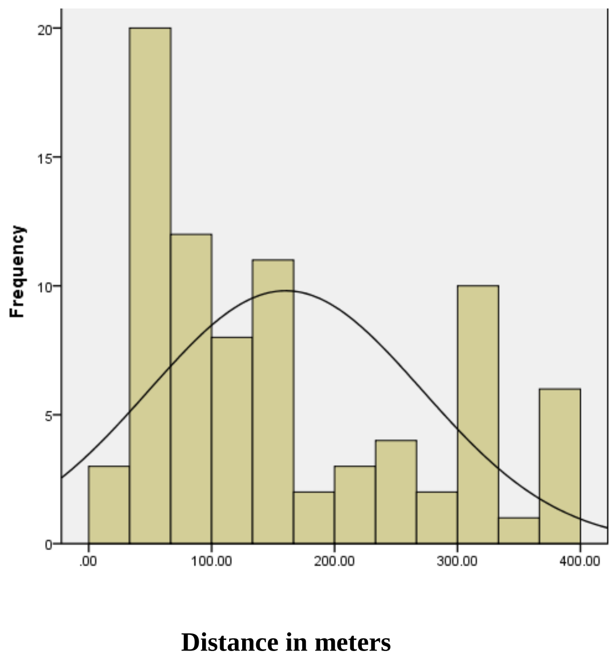


Figure 11b:Dry season

Figure 11: The influence of water on grassland habitat utilization in the wet season (Figure 11a) and the dry season(Figure 11b).

It can be observed that bare areas selected by rhino were closer to water during both wet (Figure 12a) and dry (Figure12b) seasons. The highest frequencies of rhino points in grassland occur at distances of 0-200m from water. The mean distance of points from water sources is about 160m from rivers



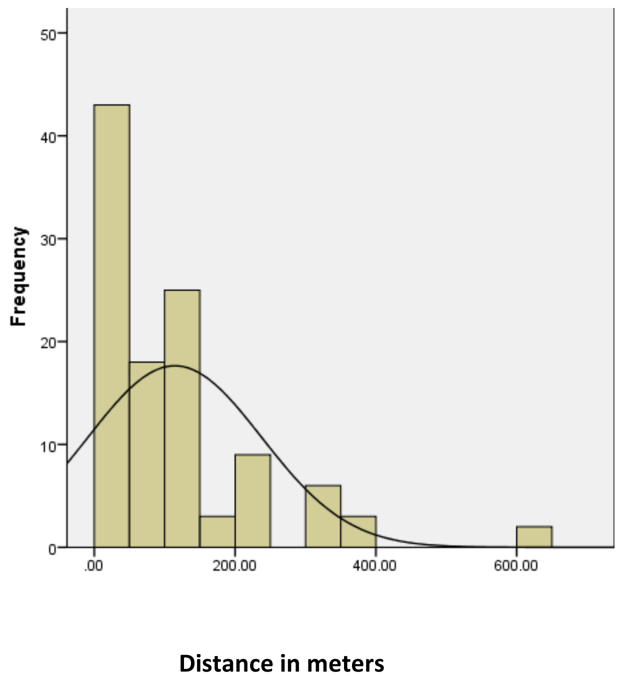


Figure 12a: Wet season

Figure 12b: Dry season

Figure 6 : The influence of water on bare or rock habitat utilisation in the wet (12a) and dry season (12b).

CHAPTER 4: DISCUSSION & CONCLUSION

4.1 Home Range Size

Our results indicate the female white rhinos generally exhibit larger home ranges on average for both seasons which is consistent with (WWF, 2016) who concluded that adult female white rhinos can have home ranges up to seven times larger than that of the males as well as a study conducted at Kruger National Park by (Piennar et.al,1993) who also obtained greater home range size estimates for female rhinos. Our home range size estimates concur with the estimates obtained by (Rachlow et al., 1999) who were carrying out a study on spatial patterns and territoriality of white rhinos at Matopos National Park. Thus sex is a significant factor explaining variation in HR size in white rhino and should be taken into account in understanding distribution of rhinos.

Morever the results show that rhinos found at the northern side of the park generally had larger home ranges as compared to the ones found in the western side of the park which was attributed to the fact that the western side of the park is a fenced area called Whovhi Game Park which was stocked with higher densities of white rhino (Rachlow et al., 1999) whereas the northern side has lower densities. High densities imply that there is more competition for resources among the white rhinos as they utilise the same resources from their environment hence that tends to limit the space that is available to an individual hence smaller home ranges when compared to rhinos in lower density areas. This has also been observed between Umfolozi Game Reserve and Kruger National Park, where smaller home ranges were observed for white rhinos at Kruger National Park because it had higher white rhino densities as compared to Umfolozi Game Reserve (Pienaar et al., 1993).

Our results generally show differences in the distribution of home ranges of individual rhinos in the wet and dry season. A more even distribution is observed in the designated areas of the park during the wet season, this may be attributed to the fact that during the wet season, resources are readily available almost everywhere in the park hence almost all accessible areas are utilised whereas in the dry season, resources tend to be scarce due to the dry conditions and high temperatures hence the much preferred grasses may be confined to certain areas not necessarily the whole park. The results are consistent with a study conducted by (Grobler, 1981) who observed that animal groups are at a maximum in the hot dry season when they concentrated on the limited resources available to them.

Results also indicated that generally for both males and females, home range sizes are greater in the dry season as compared to the wet season. This may be attributed to the fact that during the wet season, resources are abundant hence more readily available so the white rhinos may not need to go very far to get the resources they need to sustain themselves. Whereas in the dry season, resources tend to be scarce, the streams and the wallows may dry up due to the high temperatures and the fact that no rainfall is received at that time hence the rhinos may be forced to travel to other areas of the park where they can find these resources, for example, in the dry season, rhinos could be seen utilizing the central area of the park which deviated from the norm of being found either at the western side of the park or the northern side.

4.2 Habitat Selection

Contrary to our expectation that habitat selection would be influenced by sex, the best models explaining variation in habitat selection did not include the effects of sex. This is surprising considering the fact that home range size was found to significantly vary as a function of sex. During the wet season, results indicate that bare or rock habitat was selected. This could be explained by the fact that bare areas are closer to water and may contain grass during the wet season influencing selection of these areas. These findings are however contrary to the findings of (Pienaar, 1994) at Kruger National Park who observed that the white rhino generally selected grassland. This can be explained by the fact that white rhinos are mega herbivores which are predominantly grazers which prefer to graze on short grasses (Owen Smith,1988). However, in this study, the grasslands were neither selected nor avoided in this study, this result could have been influenced by the fact that Matopos being in the savanna ecosystem where grasses are the dominant plant species, they are likely to be more available than any other habitat type in the park hence grassland availability constituted over 60% of home ranges for all individuals (See tables in Appendix 4.

During the dry season results show that the bare or rock areas are avoided in the dry season, grassland is used as much as it is available because the white rhinos generally prefer to feed on grasses. The moderate woodland habitat is also used as much as it is available which is unlike in the wet season where it was avoided, this is because the white rhinos do prefer the grasses that grow under the shade provided by some extent of tree canopy which help to protect them from the direct heat of the sun on hot days (Joordan et.al, 2015). It was observed that during the dry season, when the much preferred short grasses in a grassland habitat have been depleted, they tend to move on to graze the taller grasses which are associated with a moderate woodland habitat (Piennar et. al,1994). Our results show that the rhinos use areas that are closer to water.

4.3 Distance from water sources

Our results show that the average distance from water sources for points found in the Grassland habitat in the wet season was smaller than the average distance of points in the Grassland habitat from water in the dry season. This is because in the wet season, water as well as grass are abundant in the park so distance to water tends to be shorter as compared to the dry season where the rhinos may have to travel longer distances as some local reservoirs may have dried up. These findings are consistent with the findings of (Owen-Smith, 1988) who also realized that white rhino distances to water in the dry season were slightly higher than those of the wet season as some water sources would have dried up at Umfolozi Game Reserve.

4.5 CONCLUSION

In this study we determined home range size and habitat selection for white rhino. Results suggest that habitat selection is not influenced by sex during dry and wet season. We conclude that white rhino prefer a habitat which comprises of short grasses, which can be readily available in the wet season, even in the bare areas. However in the dry season white rhino utilize grassland again as well the moderate woodlands because they also utilize the shade in times of high temperatures.

We also conclude that white rhinos prefer habitats that are close to water sources during both the wet and dry season as they need water for drinking and wallowing though they usually have to travel longer distances in the dry season for this resource, particularly in the dry season so there is a need to preserve these riverine ecosystems for the purpose of conserving this water dependent mega herbivore.

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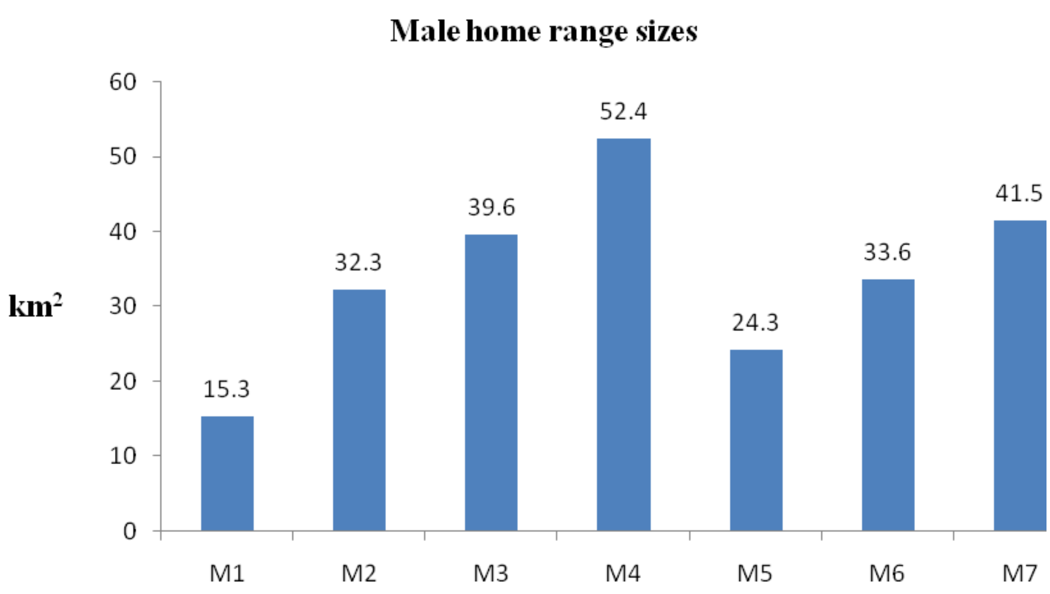
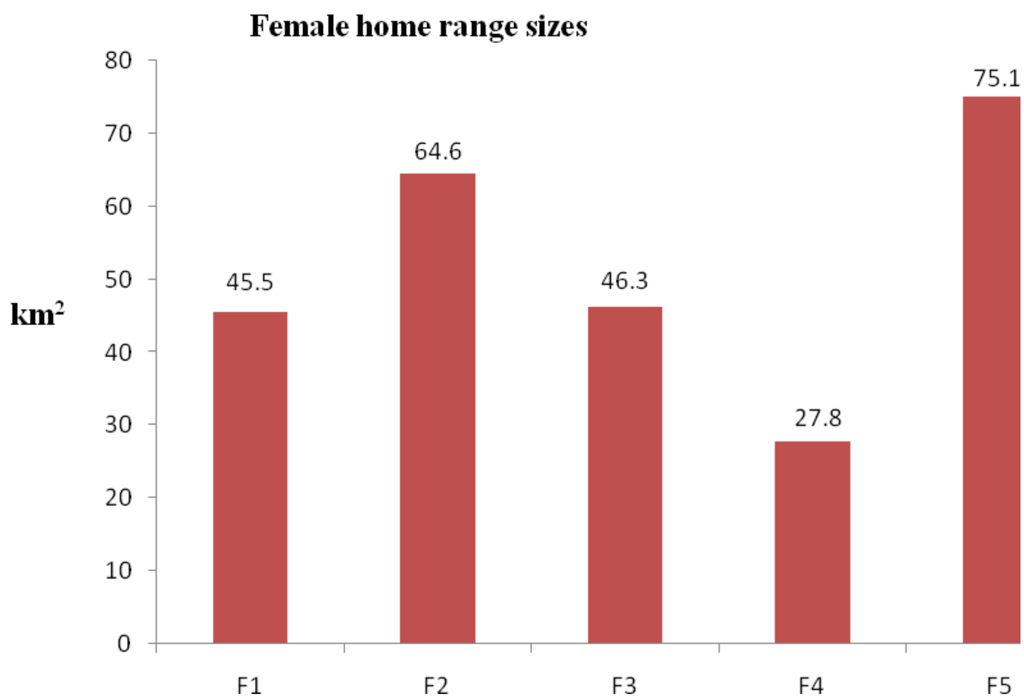
Appendices

Appendix 1 illustrates the male home range sizes for the wet season, generated using the kernel density estimation..The home range sizes range from a minimum area of 15.3km^2 to a maximum of 52.4km$^{2.}$ .Of the seven males,M1 had the least area with 15.3km^2, M2, M3& M6 had their home range areas in the thirties while M7 was not far off with an area of 41.5km^2 and M4 had the highest size in terms of area with 52.4km^2.The males confined to the western side of the park exhibited smaller home ranges(M1,M5) ,while the ones who had intermediate sizes were confined to the northern side of the park and the ones with larger sizes had home ranges extending to both the western and northern side of the park.



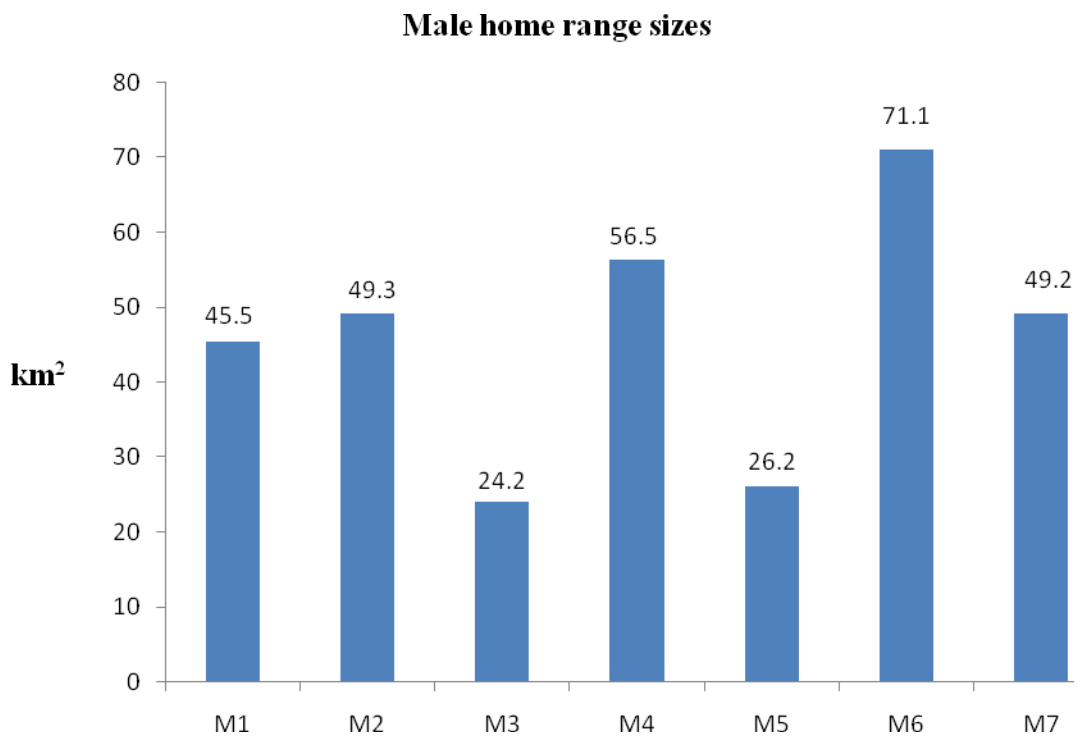
Appendix 1: Male home range area estimates in the wet season

Figure 11 illustrates the sizes of the female home ranges in the dry season in terms of area.F4 has the least area size at 27.8km^2 while F5 has the largest home range at 75.1km^2.F1 and F3 have intermediate home ranges while F2 has a larger home range at 64.6km^2.Home ranges are generally larger for the females in the dry season.



Appendix 2: Female home range area estimates in the dry season

Figure 9 illustrates the home range sizes for the males in dry season, the area sizes were obtained using the Minimum Convex polygon method.M3 has the least area size at 24.2km^2 while M6 had the largest at 71.5km^2.Three of the males have their home range sizes in the forties,M1,M2& M7 but M4 has 56.5km^2.Home ranges are generally larger for the males in the dry season as much as all the rhinos have their part of their home range in the northern side of the park ,they mostly extend either to the west and central areas of the park.



Appendix 3:Male home range area estimates in the dry season

Appendix 4:Calculation of Selection Ratio

Name_code	Landcover	Use	Availability	Selection Ratio	LN(Selection Ratio)	Sex
5029	Bare/Rock	0.319181818	0.108252187	2.948502257	1.081297332	Male
5029	Grassland	0.591909091	0.759787094	0.779045993	-0.249685194	Male
5029	Shrubland	0.023727273	0.108904109	0.217873071	-1.52384263	Male
5029	Sparse Woodland	0.001	0.018971778	0.052709874	-2.942952488	Male
5029	Moderate Woodland	0.001	0.003903284	0.256194514	-0.591430173	Male
5114	Bare/Rock	0.162290323	0.086139809	1.884033917	0.633415179	Male
5114	Grassland	0.839709677	0.791743817	1.060582552	0.058818334	Male
5114	Shrubland	0.001	0.101355159	0.009866296	-4.618630779	Male
5114	Sparse Woodland	0.001	0.016512366	0.060560672	-2.804109567	Male
5114	Moderate Woodland	0.001	0.003533253	0.283025317	-1.262218925	Male
5134	Bare/Rock	0.290473684	0.261195422	1.112093319	0.106244113	Male
5134	Grassland	0.606263158	0.665125468	0.911501946	-0.09266155	Male
5134	Shrubland	0.001	0.061076104	0.016373016	-4.112120689	Male
5134	Sparse Woodland	0.053631579	0.011186101	4.794483695	1.567466027	Male
5134	Moderate Woodland	0.001	0.001342331	0.744972943	-0.294407379	Male
5152	Bare/Rock	0.185210526	0.164748329	1.124202762	0.117074128	Male

5152	Grassland	0.737842105	0.689292955	1.07043326	0.068063482	Male
5152	Shrubland	0.053631579	0.118229275	0.453623513	-0.790487692	Male
5152	Sparse Woodland	0.027315789	0.023770373	1.149152726	0.139024911	Male
5152	Moderate Woodland	0.001	0.003831356	0.261004176	-1.343218871	Male
5160	Bare/Rock	0.231769231	0.269649791	0.859519414	-0.151381866	Male
5160	Grassland	0.770230769	0.67539609	1.140413426	0.131390851	Male
5160	Shrubland	0.001	0.04488435	0.02227948	-3.804089192	Male
5160	Sparse Woodland	0.001	0.008935631	0.111911519	-2.190046731	Male
5160	Moderate Woodland	0.001	0.001065401	0.938613527	-0.063351463	Male
5161	Bare/Rock	0.173413793	0.148582279	1.167122986	0.154541734	Male
5161	Grassland	0.794103448	0.672088608	1.181545764	0.166823551	Male
5161	Shrubland	0.018241379	0.147050633	0.124048289	-2.087084365	Male
5161	Sparse Woodland	0.018241379	0.028341772	0.643621702	-0.191369321	Male
5161	Moderate Woodland	0.001	0.003835443	0.260726061	-1.344284998	Male
5313	Bare/Rock	0.264157895	0.20103208	1.314008662	0.273082512	Male
5313	Grassland	0.658894737	0.701311524	0.93951791	-0.062388397	Male
5313	Shrubland	0.053631579	0.080200454	0.668719142	-0.402391125	Male
5313	Sparse Woodland	0.001	0.01514587	0.066024599	-2.717727901	Male

5313	Moderate Woodland	0.001	0.002105145	0.475026579	-0.744384521	Male
6044	Bare/Rock	0.156555556	0.076972145	2.033924804	0.709967327	Female
6044	Grassland	0.823222222	0.757936585	1.086136015	0.082626458	Female
6044	Shrubland	0.001	0.133518902	0.007489576	-4.894243052	Female
6044	Sparse Woodland	0.023222222	0.026495016	0.876475114	-0.131846968	Female
6044	Moderate Woodland	0.001	0.004561885	0.219207632	-1.517735907	Female
6069	Bare/Rock	0.283608696	0.120407251	2.35541209	0.856715697	Female
6069	Grassland	0.653173913	0.643757212	1.014627722	0.014521769	Female
6069	Shrubland	0.001	0.174198712	0.005740571	-5.160196672	Female
6069	Sparse Woodland	0.001	0.047779474	0.02092949	-3.86659613	Female
6069	Moderate Woodland	0.001	0.013010461	0.076861228	-2.565753715	Female
6107	Bare/Rock	0.182818182	0.198253844	0.922141928	-0.081056132	Female
6107	Grassland	0.728272727	0.719259838	1.012530784	0.012452923	Female
6107	Shrubland	0.001	0.065467813	0.015274682	-4.181558625	Female
6107	Sparse Woodland	0.001	0.014242898	0.070210429	-2.656258413	Female
6107	Moderate Woodland	0.001	0.002514986	0.397616601	-0.922267051	Female
6116	Bare/Rock	0.227415094	0.253890548	0.895720997	-0.110126302	Female

6116	Grassland	0.774584906	0.653319935	1.185613455	0.170260324	Female
6116	Shrubland	0.001	0.070840357	0.014116247	-4.260428851	Female
6116	Sparse Woodland	0.001	0.018771883	0.05327116	-2.932360188	Female
6116	Moderate Woodland	0.001	0.003144857	0.317979474	-1.145768445	Female
6134	Bare/Rock	0.376	0.15278249	2.461014996	0.900573865	Female
6134	Grassland	0.518857143	0.674826701	0.768874649	-0.262827328	Female
6134	Shrubland	0.018857143	0.141245334	0.133506307	-2.013606561	Female
6134	Sparse Woodland	0.036714286	0.027243201	1.347649477	0.298361946	Female
6134	Moderate Woodland	0.001	0.003684134	0.271434241	-1.304035377	Female