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DISTURBANCE AND HABITAT FACTORS IN A SMALL RESERVE: HOME RANGE ESTABLISHMENT BY BLACK RHINOCEROUS (*DICEROS BICORNIS MINOR*).

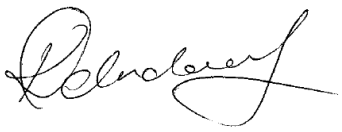
Karen Odendaal

A research report submitted to the Faculty of Science, University of the Witwatersrand, in partial fulfilment of the requirements for the degree of Master of Science.

Johannesburg, 2011

DECLARATION

I declare that this dissertation is my own, unaided work. It is being submitted for the Degree of Masters of Science in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.



_____

16th July 2011

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Abstract

Black rhinos are being moved to small protected areas in an attempt to expand their range; and factors commonly found within these small protected areas could influence black rhino ecology. From the literature we understand how biological factors affect rhino resource selection but not in the context of small reserves. This study investigates the home range establishment of black rhinos and those factors commonly associated with small reserves that affect rhino habitat-use as well as weigh the relative importance of each of them. The factors considered were human disturbances such as residences, lodges, roads and fences, slope, elevation, perennial water, burnt areas and vegetation type. Minimum convex polygon, 50% core and 95% local convex hull (LoCoH) was used to generate home ranges from sightings data collected for 17 individuals. The mean 95% LoCoH home range was 3.77 km² (95% CI: 2.92- 4.63, *n*=17), and is comparatively small in relation to the adaptive kernel home ranges of previous studies. A use-availability resource selection function showed that black rhinos avoided areas close to residences, lodges, camps, and perennial water, and these variables played a bigger role than their selection for thicket vegetation. These factors have a highly significant effect on rhino resource selection, and this effect is magnified due to the density of human disturbances and water points commonly found in small reserves. It is essential that this knowledge be applied in the management of reserves protecting black rhinos.

Dedication

I DO!

Acknowledgements

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1. INTRODUCTION

Black rhinos historically had an extensive range over eastern, central and southern Africa, with an estimated population of 100 000 in 1960 (Emslie and Brooks, 1999). Now black rhinos are classified as critically endangered under the IUCN Red list. Wild populations had been reduced by 97% in the 25 years leading up to 1994 (Berger, 1997) to only 2450 individuals that were protected in a small number of reserves in Africa. The decline was due to habitat loss, hunting and poaching for horn (Amin et al., 2006; Ferguson, 2009). Black rhinos have been translocated to vacant reserves since 1947 to expand the range of the meta-population and to stabilize and increase black rhino populations on the African continent (Linklater, 2007). The result has been a slow recovery bringing the population up to 3610 black rhinoceros (Emslie, 2004). The Black Rhino Range Expansion Project (BRREP) was established to expand meta-populations, implement genetic management and stimulate population growth in existing protected areas (Emslie, 2004). The BRREP is a partnership between Ezemvelo KwaZulu-Natal Wildlife (EKZNW) and World Wildlife Fund (WWF), where founder black rhinos are taken from protected areas containing healthy populations and translocated to private or community reserves.

The first BRREP project was implemented in 2004, where a founder population of 15 black rhino were translocated to Munyawana Private Game Reserve in Northern KwaZulu-Natal (Linklater *et al.*, 2006). The second BRREP project was the translocation of 21 individuals to the Zululand Rhino Reserve (ZRR) in 2005. Although these actions are expected to benefit black rhino conservation overall, the reserves are relatively small (approximately 130 km^2 and 142 km^2, respectively), and factors commonly found within these small protected areas could influence black rhino ecology. It is essential that we understand the factors that affect habitat use and home range establishment of black rhinos. Part of that understanding includes ranging behaviour, factors that affect resource selection, and the extent those behaviours are altered in a small

protected area. With that information more informed decisions can be made with regard to suitability and management of protected areas for black rhino conservation. Factors such as habitat heterogeneity, slope, rockiness, and distances to water, roads and fences play a role in black rhino habitat selection (van der Heiden, 2005). Specifically, I consider vegetation, slope, elevation, perennial water points, burnt areas as well as disturbance variables such as residences, lodges, camps, busy roads, fences, and competition between black rhino males. Eco-tourism is a rapidly growing industry in developing countries (Gössling, 1999) and as a result the majority of small protected areas in South Africa have a high density of lodges and residences. The disturbances associated with these lodges and residences within a small reserve could influence black rhino home range establishment and habitat use (Goddard, 1967; Mukinya, 1973; Conway and Goodman, 1989, Berger and Cunningham, 1994; Buk, 2004). Berger & Cunningham (1995) found that rhinos moved up to 40 km away after detecting human presence. Stress caused by human disturbances might be the cause of the high calf mortality in north-western Namibia (Hearn, 2001; Shaw, 2002) and possibly caused breeding problems in captive Sumatran rhinos (Foose and Strien, 1998). There are numerous residences and lodges within the ZRR. Rhinos are expected to avoid these areas and this behaviour could result in fragmentation of the home ranges with gaps being associated with houses, camps , lodges and human-induced disturbances.

Land owners promote the establishment of artificial waterpoints because animal concentrations around waterpoints are a tourist attraction and many landowners believe that abundant water will alleviate animal mortality during droughts (Owen-Smith, 1996). Consequently abundant perennial waterpoints are a common occurrence in many small reserves. The ZRR is no exception with a waterpoint density of 1 per 2.63 km². Herbivores impact on vegetation in close proximity to waterpoints, therefore abundant waterpoints result in the degradation of the vegetation around waterpoints which become more widespread (Owne-Smith, 1996) creating a piosphere affect (Andrews, 1988).

This degradation could result in reduced browse availability and quality for rhinos and might not be utilized by rhinos. Water in the ZRR is a readily available resource, therefore it is unlikely that water as a resource will strongly affect rhino home range establishment but rather affect the way in which rhinos utilize the habitat as a result of the impact of abundant water on forage quality.

Black rhinos are selective browsers (Muya and Oguge, 2000), and can utilize a large variety of plants. Goddard (1968) recorded black rhinos utilizing 191 species of plants in Ngorongoro. Rhinos select areas with high quality rather than high quantity of forage plants (Muya and Oguge, 2000; Ganqa *et al*., 2005; Morgan *et al.,* 2008), they generally do not exclude other rhinos as a strategy to maintain exclusive access to those resources (Buk, 2004). The home ranges of black rhinos in Sweetwaters Rhinoceros Sanctuary included more *Euclea* bush and less grassland and *Acacia* bush that expected (Tatman *et al*., 2000). *Euclea* sp. are considered to be less palatable browse plants (Adcock, 2001), but rhinos also make use of these dense *Euclea* thickets for bedding sites (Tatman *et al*., 2000). In addition to forage, burnt areas are a sought after resource. Other large herbivores such as Bison show a preference for grazing on burnt areas (Coppedge and Shaw, 1998; Biondini *et al*., 1999) and white rhinoceros (Shrader and Owen-Smith, 2006) and elephant also show preference for green flushes of grass in previously burnt areas (Sukumar, 1986). Black rhinos prefer eating burnt plants to lush green plants, (Adcock, 2001), and because of this preference, burnt areas could have a significant effect on area selection by black rhinos.

Literature on black rhinos is dominated by studies on habitat selection, forage, browse availability, browse quality and home range dynamics (Conway and Goodman, 1989; Muya and Oguge, 2000; Tatman *et al*., 2000; Buk, 2004; Ganqa *et al*., 2005; Morgan *et al*., 2008) but very few studies look at several variables simultaneously and weigh the relative importance of each variable. The variables I considered in this study are human disturbances such residences and lodges, water, vegetation, burnt areas, and social organization.

Given the lack of information on black rhinos in small protected areas, my objective was to determine the home range of each black rhino, whether there was an overlap, and the possible cause for overlap. Black rhinos are generally thought to be solitary (Mukinya, 1973; Frame, 1980; Owen-Smith 1988) however they recent studies have identified distinct social interactions amongst individuals and groups consisting of one male, females and calves and sub-adults (Conway and Goodman, 1989; Tatman *et al*., 2000; Lent and Fike, 2003). Adcock (1994) found that black rhinos in Pilansberg only developed territories at the age 10 years which are defended by chasing other conspecifics away and also marked territories through spray urination and scrapping and defecating on middens. The territorial boundaries are uncertain and are defined by a core area within a larger home range (Adcock, 1994). Because of the strongly territorial nature of adult males, I expected territories (core areas) of territorial males not to overlap. I expected greater overlap between sub-adult and adult males, and between males and females. A resource selection function was used to assess the effect of the different habitat and disturbance variables on rhino home range establishment. Black rhinos are considered water-independent species because they can utilize areas at distances far greater than 15 km from permanent water (Adcock, 2001) and even going year-round without drinking (Goddard, 1968). In the ZRR rhinos will drink daily due to the fact that water is readily available. I expected that rhinos will avoid areas in close proximity to waterpoints because of the poor quality browse available in these areas. Because of the importance of browse as a forage resource, I expected black rhinos to show preference for thickets and dense bush over more open vegetation types. Burnt areas are sought after by black rhinos and therefore I expected black rhinos will move out of their home range to a burnt area to browse on burnt shrubs and trees. Finally I expect black rhinos avoid areas with high human disturbance.

2. MATERIALS AND METHODS

2.1 Study area

The Zululand Rhino Reserve is approximately 142 km^2, is situated in northern Zululand, KwaZulu-Natal, South Africa (27°33 S to 27°50' S, 31°08'E to 31°57 E') (Fig 2.1) with altitudinal variation of 130-437 meters above sea level (m.a.s.l.). The climate is subtropical, with hot and humid summers and cool dry winters. The minimum and maximum temperatures are 16 ºC to 33 ºC respectively and the mean annual rainfall is 635 mm with 534 mm mean wet season rainfall extending from October to March and 101 mm mean dry season rainfall extending from April to September (Odendaal, 2011).

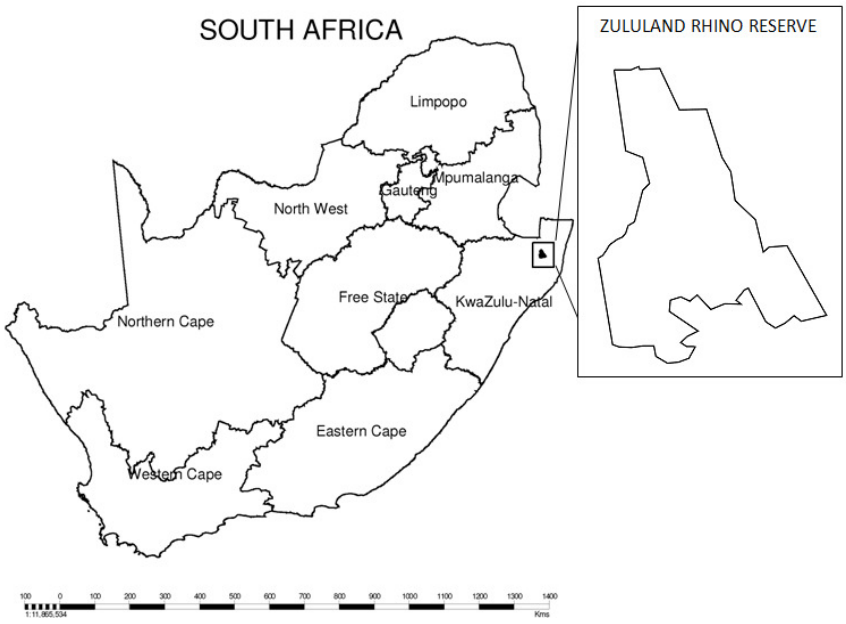


Figure 2.1 Map of South Africa indicating the location of the study site, Zululand Rhino Reserve.

The vegetation type in the uplands (>300m.a.s.l) is characterized by *Aloe marlothii and Combretum sp* on rocky hilltops. Mid-slope vegetation (200-300m.a.s.l) is characterized by *Acacia nigresence, Dichrostachys cinerea, Sclerocarya birrea* in open savanna. The valley bottoms and lowland vegetation (<200m.a.s.l) is dominated by *Acacia tortillis, Acacianilotica*, *Spirostachys africanus, Berchemia zeyheri* in closed savanna as well as *Acacia luederitzii, Euclea sp* in thickets. The riverine vegetation along the Msunduze River is dominated by tall *Ficus sycomorus* and *Acacia xanthophloea.* This ephemeral river forms part of the southern boundary providing perennial surface water in many places. There are 50 perennial water points supplied by borehole water along with numerous ephemeral pans and mud wallows. The Segan and the Manyoni are ephemeral rivers that have been dry for past ten years. There are 30 human dwellings within the reserve, comprising lodges, residences and camps.

The ZRR is a protected area including 15 landowners who have dropped their internal fences to allow game movement across a larger landscape and to make the space available for the conservation of black rhinoceros. Each individual property was managed by the landowner prior to the establishment of the reserve in 2004. Since then the reserve has been managed as a whole. The central management body consists of a reserve management team and the board of directors that are elected every year by the landowners. The perimeter of the reserve consists of an electrified game fence.

2.2 Data collection

WWF-Ezemvelo KZN Wildlife BRREP captured a total of 21 black rhinos, four rhinos from Ithala Game Reserve, two rhinos from Mkuze Game Reserve and fifteen from Hluhluwe Umfolozi Park (HIP) mid August 2005 to early September 2005 for re-introduction into the Zululand Rhino Reserve. The rhinos were kept in the HIP holding enclosures for 40-50 days. During capture the rhinos were ear-notched for field identification, and horn implant transmitters (MOD-80 or MOD-125 transmitters, Telonics) were fitted into the anterior horn (Linklater *et al*., 2006). The rhinos were loaded into crates and transported to the ZRR to a predetermined release site in October 2005 where the rhinos were released within a five-day period. The rhinos were tracked by vehicle and located on foot using a Telonics receiver and antennae. For the first three months after release (October 2005 to December 2005), only triangulated locations were recorded, to reduce disturbance in the period after reintroduction.

Thereafter, the rhinos were monitored on a daily basis with an average of 4 sightings per rhino a month. Transmitter batteries lasted approximately 18 to 24 months. I used the data collected from January 2006 to December 2006. Because the rhinos had not yet established natural ranging patterns, the data collected during the first three months after release was not included. Data collected with each sighting was location, time, date and observer. No data were collected on the nocturnal movements of black rhinos. In this study I assessed the data for 17 rhinos consisting of 6 adult females, 2 sub-adult females, 5 adult males and 4 sub-adult males (Table 2.1) and each rhino was treated as an independent sample unit. Home range and resource selection comparisons were made between the various sex and age classes within this population (Table 2.1).

Table 2.1 Rhino details from Zululand Rhino Reserve.

Rhino ID	Sex	Age Class (Jan 2006)	No of observations (Jan- Dec 2006)
000	F	F	54
130	M	F	51
240	M	E	51
030	F	E	50
590	F	E	50
820	F	F	50
300	M	E	49
400	M	E	49
550	F	F	49
020	F	F	47
960	F	F	47
110	M	F	46
630	M	E	45
990	M	F	43
250	M	F	42
070	F	F	39
950	M	F	38

Age Class (Hitchins, 1978)

E: 3 ½ - 6,9 years

F: >7 years

2.3 Analysis

I estimated home ranges for each individual to make comparisons with other studies and to determine how home ranges are altered by the habitat and human disturbances.

The GPS locations for all the rhinos were logged onto a handheld Garmin Etrex GPS using the World Geodetic System (WGS) 1984 map datum. The data were uploaded from the GPS onto Map Source 3.02 Garmin computerized program. The rhino location data were exported as a text (tab delimited) file. The text file was opened in Microsoft Office Excel, the rhino ID, date, time and notes related to each sighting was captured in Microsoft Excel and sorted according to rhino ID. A separate file was created for each rhino with that rhino location data.

The files were then imported into Environmental Systems Research Institute (ESRI) Geographic Information Systems (GIS) ArcGis and projected to Universal Transverse Mercator (UTM) zone 36S for calculating distances using the Projections and Transformations tool in the Data Management toolbox.

2.3.1 Home Range

GPS radio-telemetry data are often auto-correlated in both space and time (Boyce, 2006). In order to reduce temporal auto-correlation of the data, only data with a minimum of one day between observations was used. RSF' in mountainous areas with substantial topographic relief (as in the ZRR) can vary among different scales (Bailey *et al*., 1996; Boyce, 2006) thus reducing auto-correlation of the data.

I constructed an annual adaptive Local Convex Hull (LoCoH) home range for each individual rhino even though Minimum convex polygon (MCP) and kernel methods currently make up the majority of literature on home range construction (Getz and Wilmers, 2004). Minimum convex polygon home ranges are plotted using only the peripheral data points unlike kernel methods that use location and density of internal data points to generate a home range (Lent & Fike, 2003). MCP overestimates the area size or home range (Barg *et al*., 2005; Borger *et al*., 2006; Nilsen *et al*., 2008) and kernel methods do not perform well in landscapes with distinct boundaries or where the gaps within the home range are of interest (Getz *et al*., 2007). To accommodate distinct boundaries, home range fragmentation and avoidance of human disturbances I used LoCoH to calculate 50% core and 95% home ranges, for animals having >35 observations per rhino as recommended by Lent and Fike (2003). Unlike MCP, LoCoH indicates high and low density use areas by calculating density contours (isopleths) around all locations (Elwen *et al*., 2006), maintaining holes or fragmentation in the home range. For the adaptive LoCoH the value of *k* was fixed at 3, which is the minimum number of points required to construct a polygon. The value of *a* was fixed at 1 meter which is the distance from the root

point. I then plotted the estimated home range for each individual increasing the *a* values to find the point where the area began to level off which is the minimum spurious hole covering (MSHC) value (Getz *et al*., 2007). With *a* fixed at the MSCH value, *k* was then varied to find the MSCH value. The MSCH values of *a* and *k* was used to construct the home ranges.

Recent studies have identified distinct social interactions amongst individuals (Conway and Goodman, 1989; Tatman *et al*., 2000; Lent and Fike, 2003). These associations or social interactions are referred to as "clans" or "clusters" (Joubert and Eloff, 1971; Morgan *et al.*, 2008; Kim, 2009). I measured the LoCoH home range overlaps amongst individuals. I calculated the overlaps based on Kernohan *et al*. (2001):

$$HR_{ij} = A_{i,j} / A_i$$

where HR_{ij} is the proportion of animal i's home range that overlaps with animal j's home range, A_i is the area of animal i's home range, and A_{ij} is the area of overlap between the two animals' home ranges. The results were then expressed as a percentage overlap for every individual.

Most other studies on black rhinos use Minimum Convex Polygon (MCP) to calculate home range, and in order for me to make comparisons with these studies I also used MCP to calculate home range. I used the ESRI ArcGis and its Analysis tools extension program to create the MCP (Minimum Convex Polygon) as well as Spatial Analysis Tools, LoCoH Adaptive kernel to generate a MCP home range for each rhino.

2.3.2 Resource selection analysis

Use-availability RSF compares used habitat characteristics to those potentially available (Manly *et al,.* 2002). I used resource selection functions (RSF) (Manley *et al*., 2002) to test the effect habitat and human disturbance have on black rhino home range establishment within a small reserve. In this RSF, use was defined by the location data for each rhino and availability was defined by a number of

random points 10 times that of the observed locations within an MCP home range for each rhino. The habitat characteristics in this RSF are perennial water points, burnt areas, vegetation type, slope and elevation. The human disturbances variables are, all human dwellings (lodges and residences and camps), boundary fence, district roads (high intensity-use) and central roads (low intensity-use). Using the location data of the different variables, a vector layer was created in ESRI ArcGis for each variable in the RSF. I used the Euclidean distance tool to create a raster "distance to" layer for each habitat variable. This Euclidean distance tool calculates for each cell within the raster layer a straight line distance to the nearest source, which ultimately allows us to determine the proximity of rhino observations to various resources and then determine whether there is a significant relationship between rhino observation and proximity to resources. The distance-to-perennial-water layer was created to test for selection or avoidance of areas in close proximity of water (Fig 2.2).

The vegetation layer was created using an existing ZRR vegetation map. The vegetation types are Thickets dominated by *Euclea divinorum* and *Euclea racemosa* and *Acacia luderitzii*. The vegetation structure can be described as multi-stemmed shrubs up to 2m in height on clay soil in the bottomlands. The rocky hills vegetation in the uplands to the west of the park is characterized by medium to sparsely scattered *Aloe melothii and Combretum sp* on Arrenite and mudstone. This rocky terrain has shallow soils with steep slopes with high runoff. There are also old agricultural lands that have become severely encroached by *Dichrostachys cineria* thickets, which are <2m in height occurring on fertile clay soils in the bottomlands. Closed Savanna is densely wooded grassland dominated by *Acacia sp*, *Berchemia zeyheri,* and *Ziziphus mucronata*. The woody component is >2m in height and occurs mainly along drainage lines and mid-slopes on Basalt. Open savanna is characterized by scattered trees and shrubs such as *Sclerocarya birrea, Acacia nigresence* and *Acacia nilotica* occurring on clay soil in the bottomlands and basalt midslopes. The riparian vegetation along the Segan and Msunduze River is dominated by *Ficus sycomorus and Acacia xanthophloea.* The

vegetation structure is tall trees along the river bank with dense *Spirostachys africana* forest between the riverbank and the adjacent savanna vegetation.

The polygons of the different vegetation units were imported into ArcGis as vector layers, these layers were then merged into a single vector layer with the different vegetation units. This vector layer was then converted into a raster layer (Fig 2.3).

I created a burnt-unburnt areas layer using the polygons of the areas that burnt during 2006. I used the Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM) for the northern KwaZulu-Natal area and masked out all areas outside the reserve boundary (Fig 2.4). I generated a slope raster layer (Fig 2.5) with the SRTM DEM, using ArcGis Surface Analysis Tool in the Spatial Analyst Toolbox.

I created a total of four distance-to-human-disturbance raster layers in ESRI ArcGis with the Euclidean Distance Tool using (1) the location data of the boundary fence, (2) all human dwellings (residences lodges, camps)(Fig. 2.6) to determine if rhinos avoid residences, lodges. For the roads variable, I created a (3) distance-to-district-roads (high intensity use) layer (Fig. 2.7) and (4) a distance-to-central-roads (low intensity use) layer (Fig. 2.8).

I used the Intercept Point Tool in the Analysis extension toolbox for ArcGis to extract the value for the all the variables (layers) for each location and random point for each rhino. The attribute tables for all the rhinos' observed locations (use) and random points (availability) were exported to Microsoft Office Excel, observed locations were labeled "1" and random locations were labeled "0".

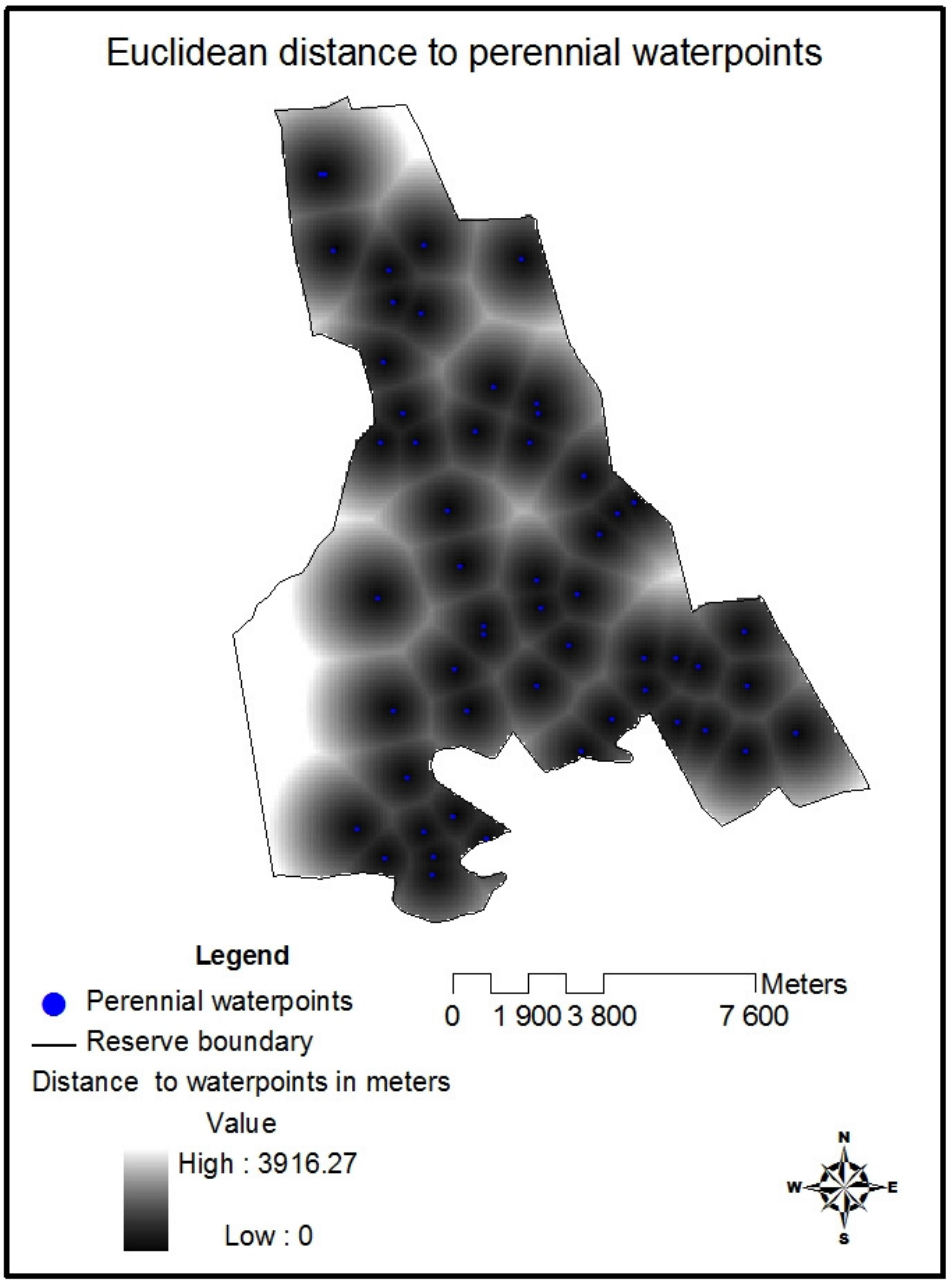


Figure 2.2 GIS layer showing the euclidean distance to all perennial water points in the Zululand Rhino Reserve. The black areas indicate close proximity to water.

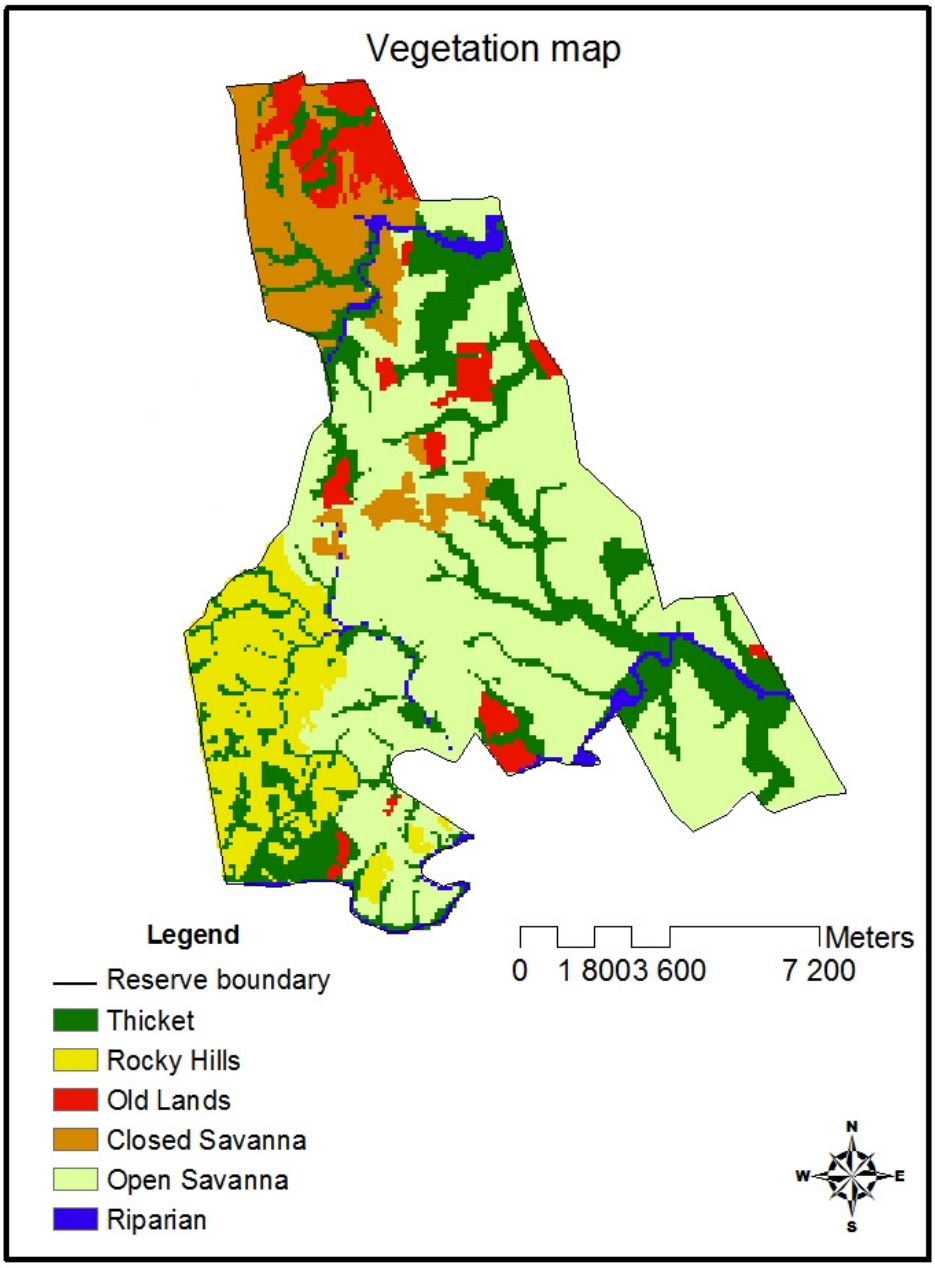


Figure 2.3 GIS layer showing the different vegetation types within the Zululand Rhino Reserve.

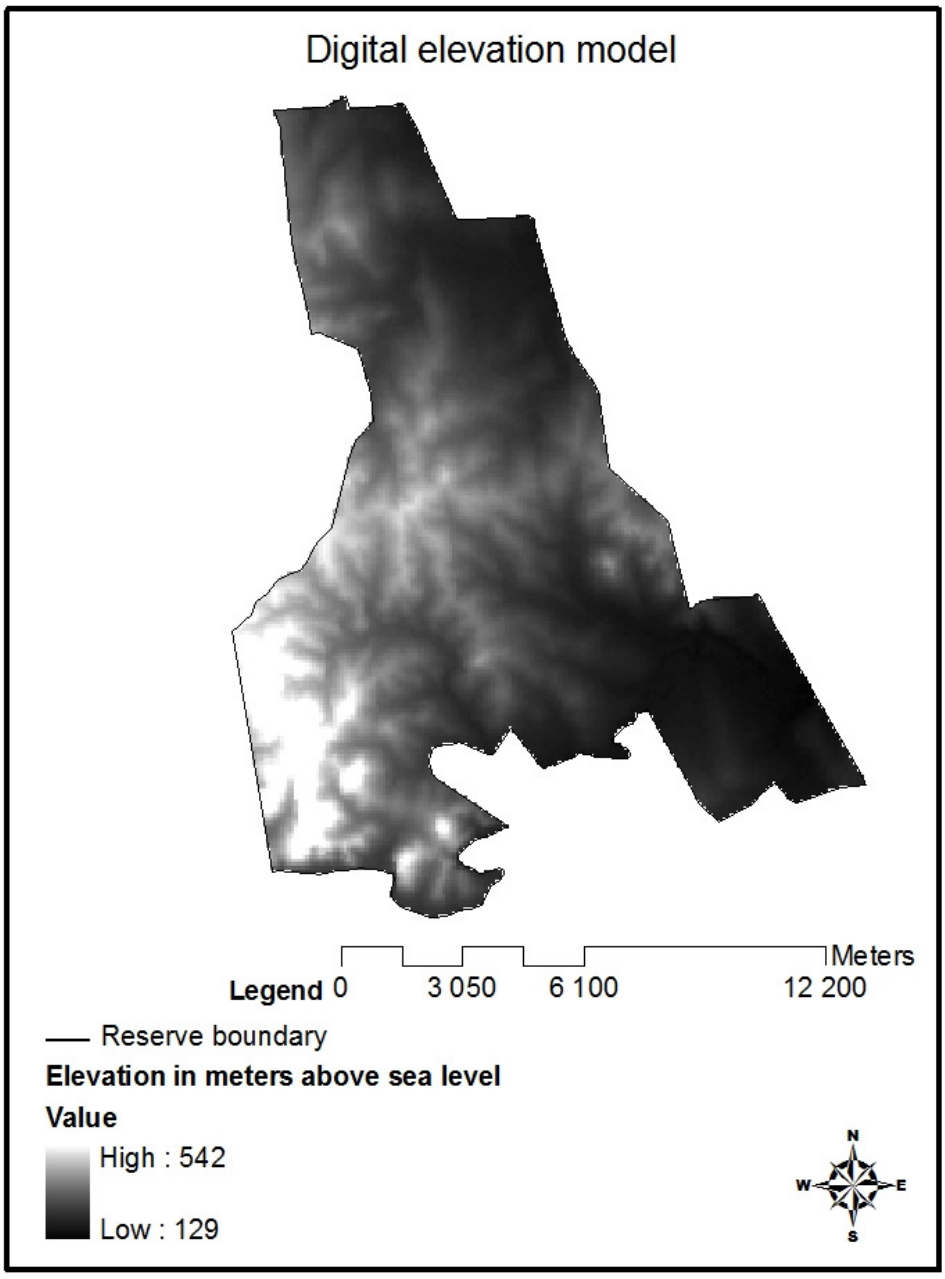


Figure 2.4 Shuttle Radar Topography Mission (SRTM) digital elevation model showing the altitudinal variation within the landscape.

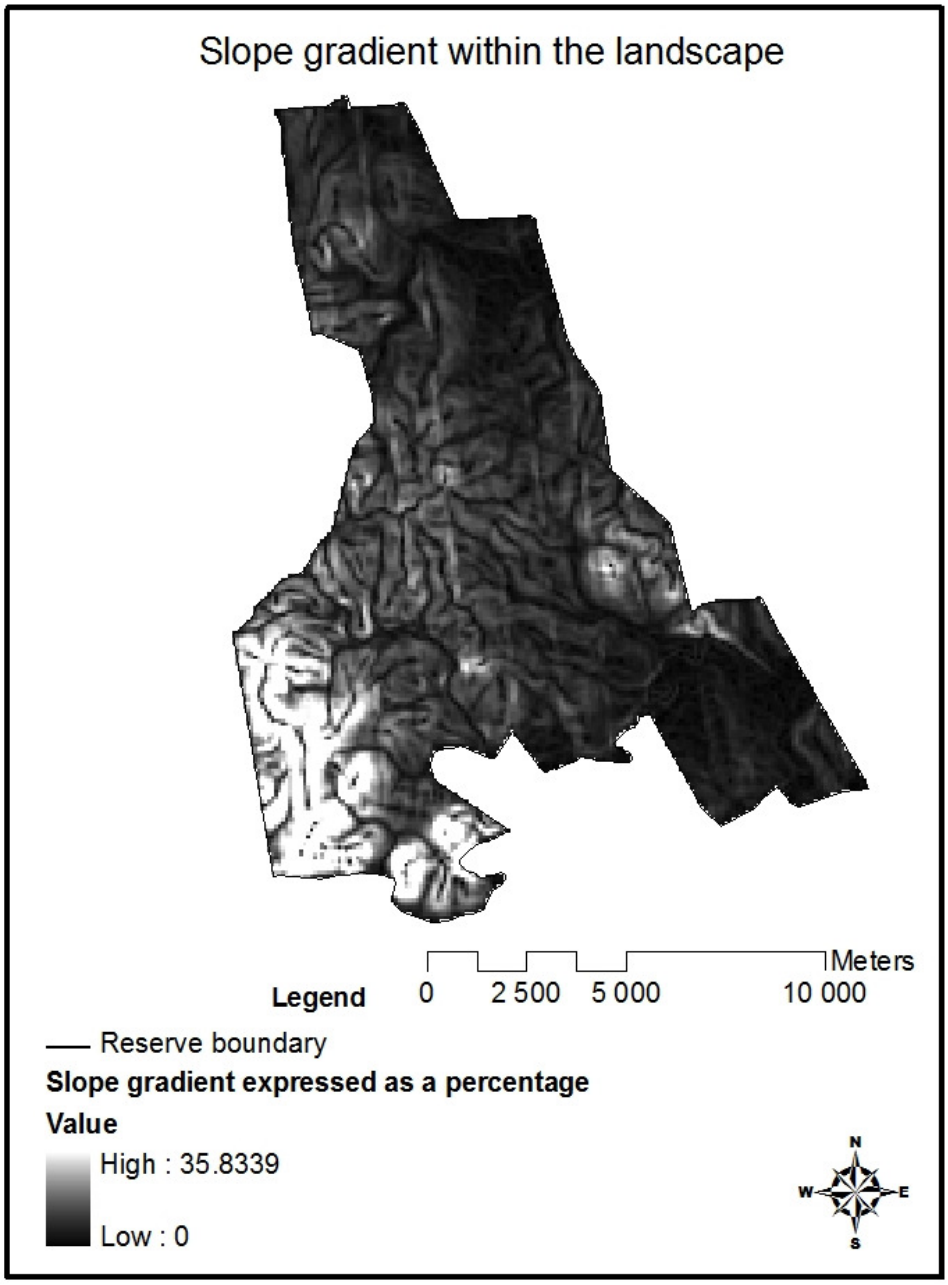


Figure 2.5 GIS slope layer showing the slope gradient within the landscape, this slope layer was generated from the SRT digital elevation model.

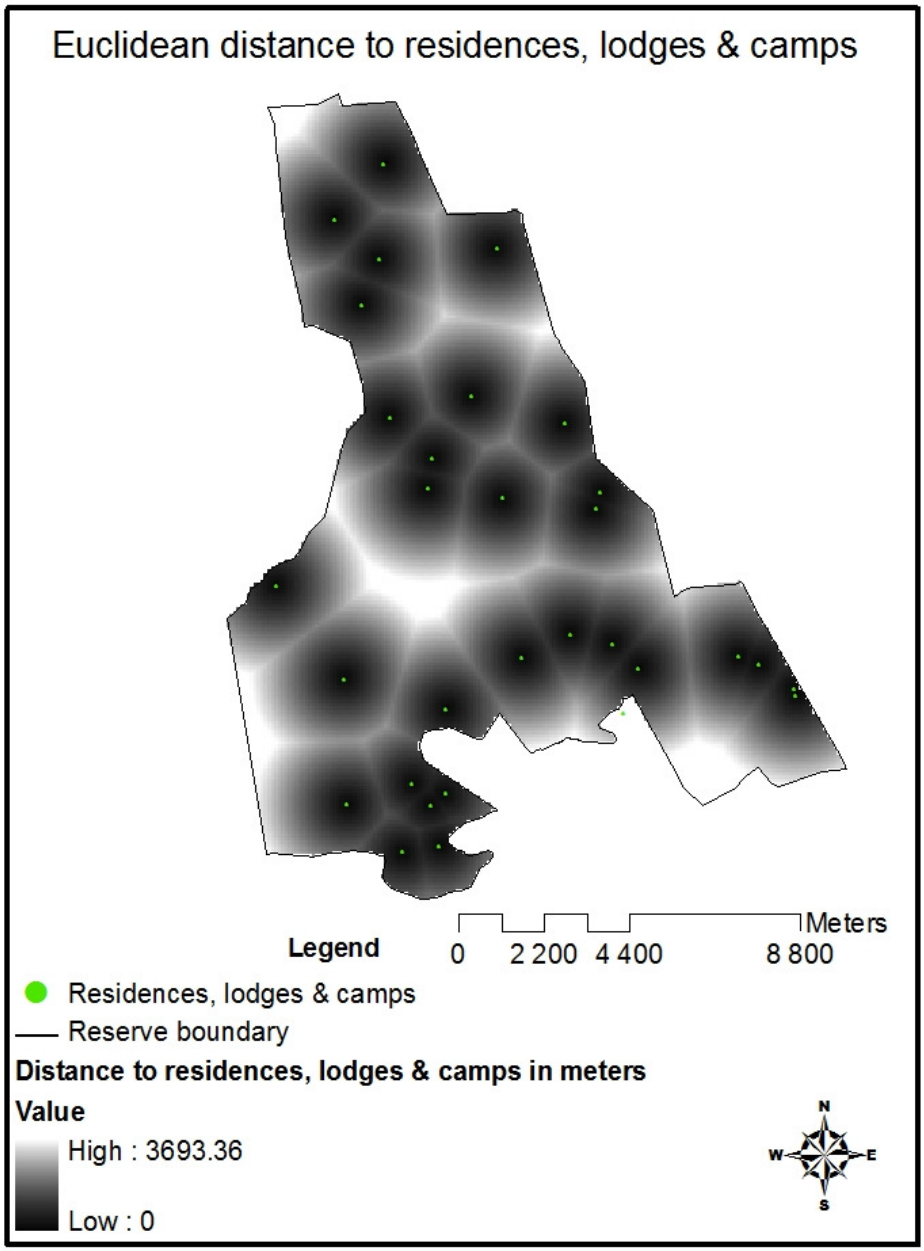


Figure 2.6 GIS layer showing the euclidean distance to residences, lodges and camps in the Zululand Rhino Reserve. The black areas indicate close proximity residences, lodges and camps.

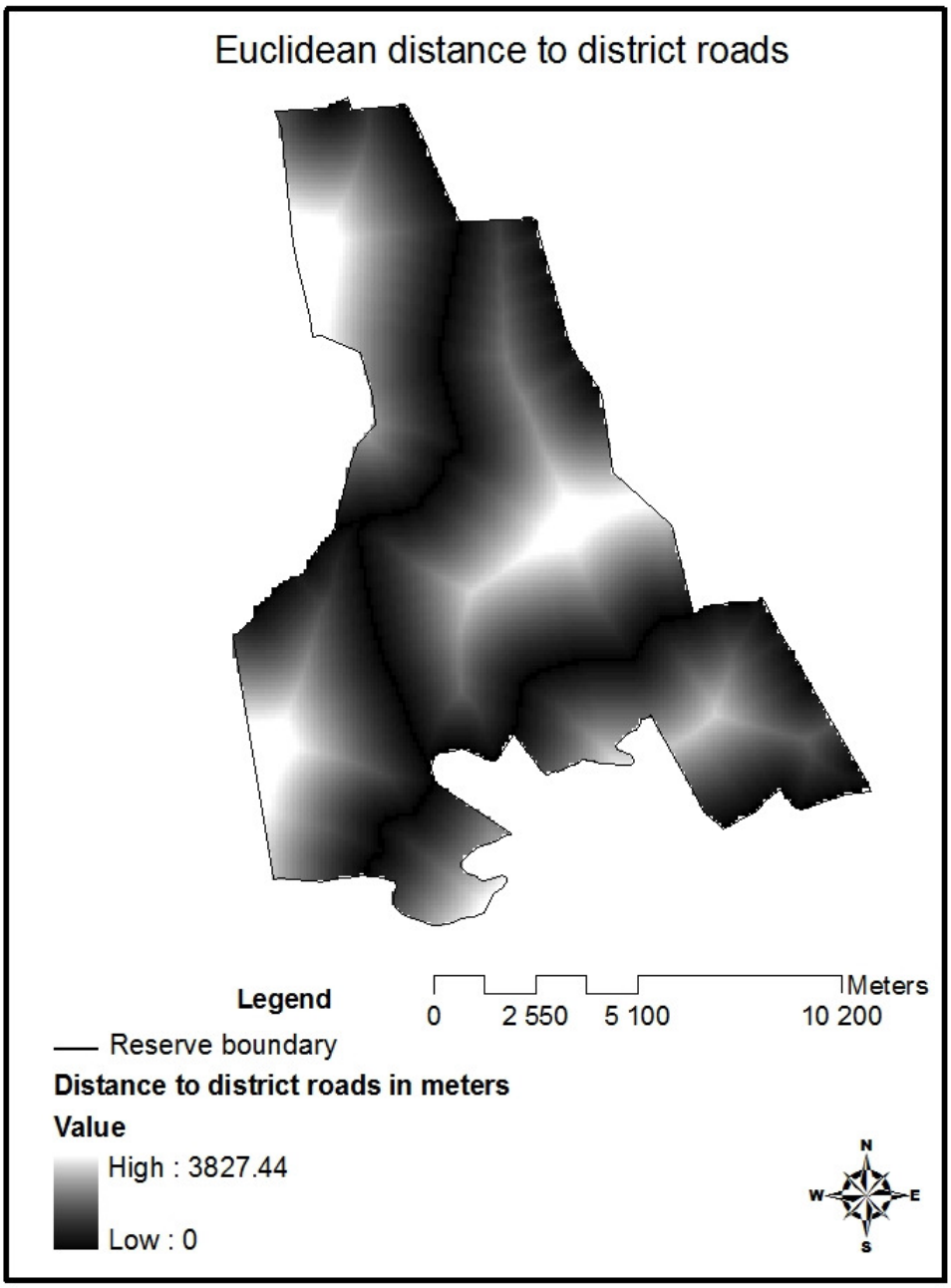


Figure 2.7 GIS layer showing the euclidean distance to district roads in the Zululand Rhino Reserve. The black areas indicate close proximity district roads.

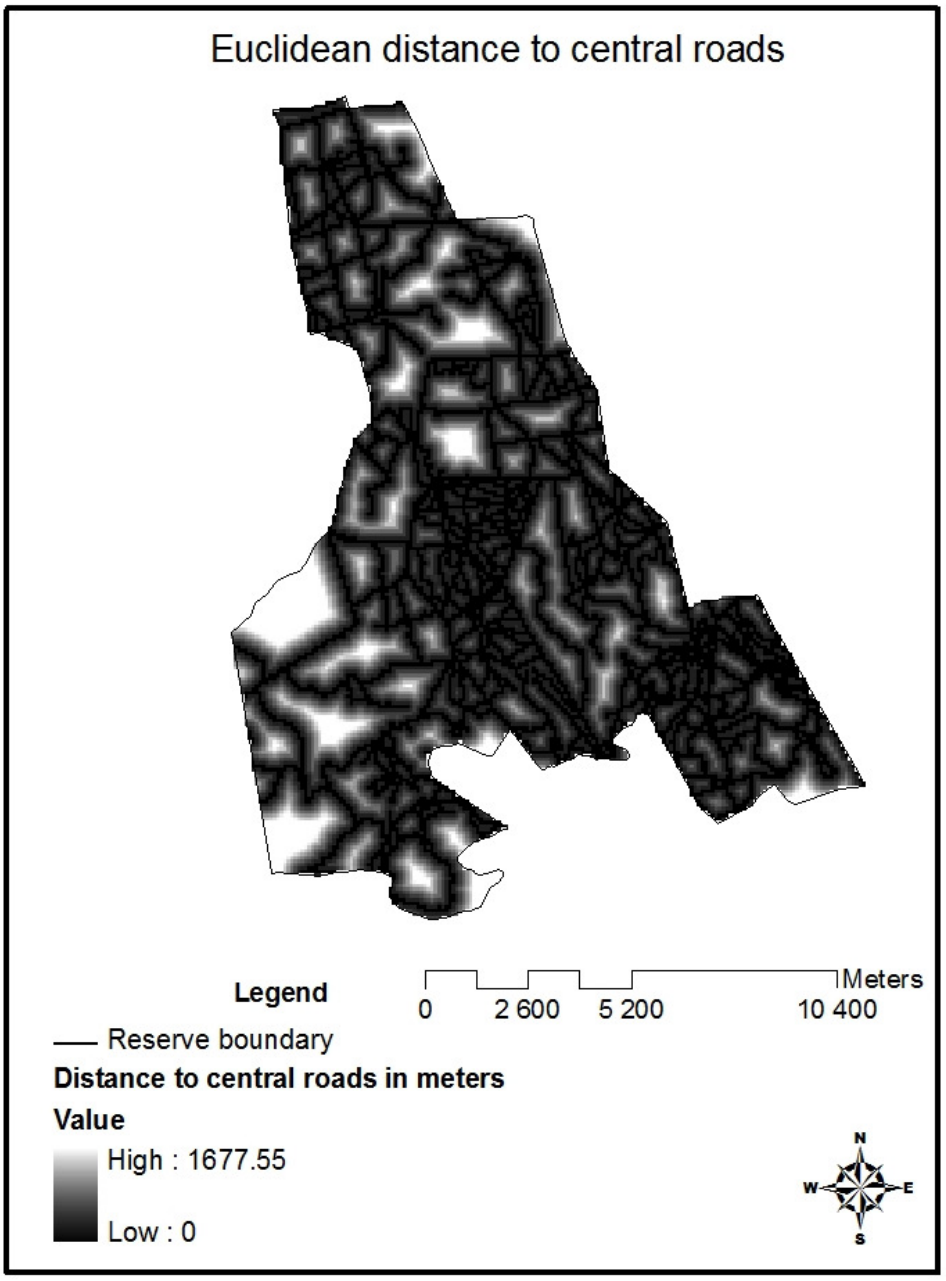


Figure 2.8 GIS layer showing the euclidean distance to central roads in the Zululand Rhino Reserve. The black areas indicate close proximity central roads.

2.3.3 Resource Selection Function

RSF are employed to obtain the relative degree of use of a resource unit, which is done by taking the used and unused or available units in a population of resource units and fitting a logistic regression function (Manley et al., 2002). I used RSF by fitting a linear mixed-effect logistic regression (lmer) model to my data. The lmer was adapted from the fixed-effect exponential RSF (Manly *et al,.* 2002) with the random effect as proposed by Gillies *et al*. (2006):

$$w(x) = (\beta_0 + \beta_1 x_{1ij} + \beta_2 x_{2ij} + \ldots + \beta_n x_{nij} + y_{nj} x_{nj} + y_{0j})$$

The β_0 in this equation is the mean intercept, y_{0j} is the random intercept, which is the difference between the mean intercept β_0 for all groups and the intercept for group j, and x_n are covariates with fixed regression coefficients β_n (Skrondal and Rabe-Hesketh, 2004; Gillies *et al*., 2006). The y_{nj} is the random coefficient of covariate x_n of group j, the inclusion of random effects in RSF models present more robust inference of grouped data structures (Gillies *et al*., 2006). Assumptions from mixed effect models permit researchers to make group-specific inferences which can be applied individual variation (Gillies *et al*., 2006). I treated the individual rhino as the grouping variable to for multiple observations on the same sample unit.

I used R (R Development Core Team, 2008) to develop the linear mixed-effect model using function "lmer" in library lme4. The response variables are the observed black rhino locations and random locations. The data set used in the regression analysis consists of the values for all the explanatory variables: perennial water points, burnt areas, vegetation units, slope, elevation, human dwellings, district roads, central roads, and boundary fence). Rhino locations (used resource units) were labeled "1" and the random points (unused resource units) were labeled "0".

The continuous data set consisted of integer numbers for the various variables, which represented the distance from the rhino locations and random points to the different variables. The continuous data was re-coded to categorical data due to problems with false convergence. This occurs when the fitting algorithm for the model does not converge on a maximum likelihood estimate and is frequently caused by major divisions in the frequency distribution of an explanatory variable (Allison, 2004). Variables were categorized into five levels with equal-sized intervals. I categorized the data into these five levels which are, very close, close, medium, far and very far from the variables. This is the best classification for the data, too few classes would result in the loss of information and too many classes would result in yet another convergence error.

I ran the linear mixed-effect model in R with all the variables. I excluded the variables with $P > 0.05$ one at a time from the model until all the variables had a $P< 0.05$. I carried out the likelihood ratio test to determine if the simpler models explains the variation in the data equally as well as the full model. The Chi-squared test on deviances (Manley *et al*., 2002) or the likelihood ratio test or drop in deviance test (Ramsey and Schafer, 2002) was done by calculating the difference in the deviances of the full model and the reduced model giving a Chi-squared statistic. The difference in the degrees of freedom of the full model and the reduced model is calculated and the Chi-squared statistic is compared to the critical value from the chi-squared distributions (Ramsey and Schafer, 2002).

3. RESULTS

3.1 Home range size

I generated MCP and LoCoH home range estimates for each rhino. The mean MCP home range was 12.3 km² (95% CI: 7.7-16.8, *n*=17) and the mean LoCoH home range was 3.77 km² (95% CI: 2.91-4.63, *n*=17) (Table 3.1). The mean 50% core LoCoH to 95% LoCoH ratio was 0.23 (95% CI: 0.18-0.28, *n*=17) indicating that their core use area is 23% of their total home range area. There were no significant differences between the home range sizes of adult males and adult females, or sub-adult males and sub-adult females, or adults and sub-adults (Table 3.1) for the 95% LoCoH home range estimates (Mann-Whitney U-test, $P > 0.05$ in all cases).

Table 3.1 The mean 95% LoCoH and mean 50% core LoCoH home range estimates and mean MCP home range estimates for the rhinos in the Zululand Rhino Reserve for the period of January 2006 to December 2006. Standard error in brackets.

		Home range (km^2)		
	Number of data points	95% LoCoH	50% Core LoCoH	Minimum convex polygon
All rhinos	47.06	3.77	0.90	12.30
n = 17	(1.07)	(0.44)	(0.17)	(2.31)
Adult males	44.00	5.18	1.17	16.03
n = 5	(2.17)	(0.72)	(0.31)	(6.29)
Adult females	47.67	2.69	0.73	9.70
n = 6	(2.03)	(0.65)	(0.36)	(2.17)
Sub-adult males	48.50	2.83	0.58	11.46
n = 4	(1.26)	(0.93)	(0.22)	(0.48)
Sub-adult females	50.00	5.43	1.35	12.46
n = 2	(0.00)	(2.50)	(0.82)	(1.18)

3.2 Home range overlap

The mean overlap for the 95% LoCoH home range for all rhinos is 31.68% (ranging from 0.07%- 98.05%; 24 overlaps). I identified five clusters. These clusters are groups of animals with overlapping home ranges. The clusters consisted of an adult male, adult females, and sub-adults males and females. The females and sub-adults home ranges overlapped with one or two adult males. There is one overlap between the core area of a territorial male rhino and a sub-adult male rhino whose 50% core LoCoH home ranges overlapped by 0.46km², 50.37% overlap for the adult male and 55.61% for the sub-adult male. The 95% LoCoH home ranges of two territorial adult males (>10 years) at ZRR overlapped by 1.37 km² (39.51% and 17.82% for each animal). There are substantial overlaps between all the various sex and age classes with the lowest mean percentage overlap between adult females and sub-adult males.

Table 3.2 The mean 95% LoCoH home range overlap according to different sex and age groups (n= number of overlaps). Standard error in brackets.

Sex and Age Group	Mean 95% LoCoH Home Range Overlap
All rhinos	31.68%
n =48	(4.08%)
Adult females and Adult males	35.57%
n = 16	(7.27%)
Adult females and Adult females	22.38%
n = 4	(14.58%)
Adult females and Sub-adult males	8.15%
n = 8	(5.26%)
Adult females and Sub-adult females	60.69%
n = 4	(14.13%)
Adult males and Adult males	28.67%
n = 2	(10.85%)
Adult males and Sub-adult males	28.33%
n = 4	(13.64%)

3.3 Home range fragmentation

Three different home range patterns were identified based on fragmentation of the home ranges: type 1 - a single area with unimodal core (one core range); type 2 - the range is split into spatially separate areas with a unimodal core; and type 3 - range is split into spatially separate areas with a multimodal core (more than one core range) (Fig 3.1). The majority (71%) of rhinos had a type 1 home range pattern, 24% (4 rhinos) had type 2 and only 1 adult male (6%) had a type 3 home range pattern with a multimodal home range and core area.

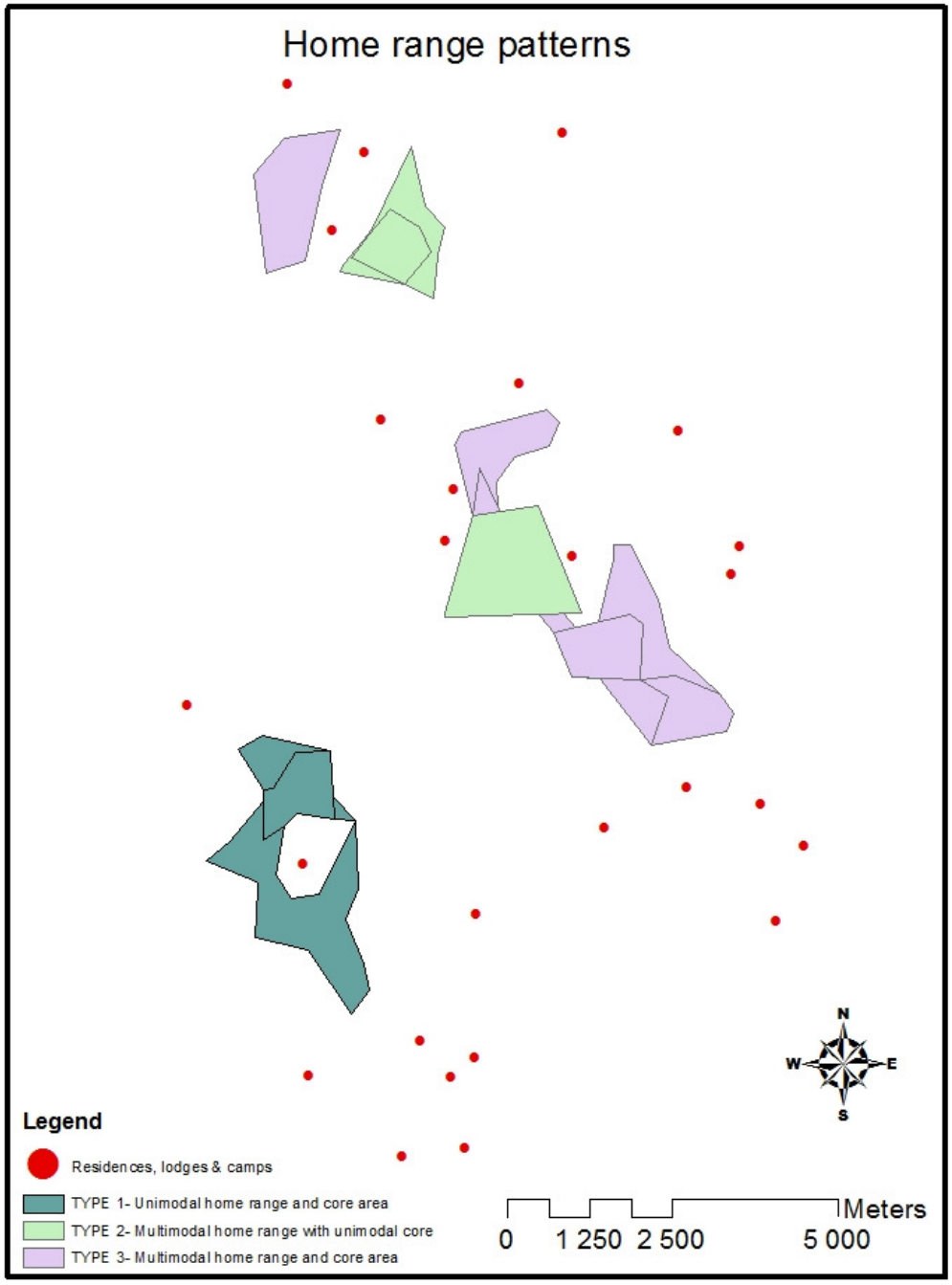


Figure 3.1 GIS layer showing the three examples of home range patterns of black rhinos in the Zululand Rhino Reserve.

3.4 Resource selection function model

I ran 5 models in R, the null model (the intercept without any variables) and models 1-4. The chi-squared test on the deviances between the null model and model 1 is x^2=303, which is significantly larger than the critical value of 42.56 at 29 degrees of freedom, P= 0.05, hence there a significant difference in between the null model and model 1. Therefore it is clear that the variables in model 1 explain the variation in the data better than the null model. I then excluded the variables central roads, boundary and district roads in model 4. The chi-squared test on the deviances between the model 1 and model 4 is x^2=14, which is not significantly larger than the critical value of 18.31 at 10 degrees of freedom, *P*=0.05, therefore indicating that there is no significant difference between model 1 and model 4. In summary, model 4 describes the variation in the data equally as well as the models 1, 2 and 3. I therefore excluded the variables, central roads, and boundary and district roads from the analysis.

Table 3.3 Likelihood ratio test (Chi-squared test on the deviances for the different models).

Chi-squared test on deviances				
Model	Deviance	Number of variables (df)	AIC	Description
Null Model	5341	2	5345.0	No Selection Model
Model 1	5038	31	5100.1	All variables
Model 2	5040	29	5098.0	Excluding : Central roads
Model 3	5045	25	5095.3	Excluding : Central roads and Boundary
Model 4	5052	21	5094.3	Excluding : Central roads and Boundary and District roads

Selection for perennial water indicated use of areas by rhinos increased with distance from water points, and use only occurred in areas >1097 m away from perennial water (Fig 3.2). The selection estimates (log-odds ratio ± 95% confidence interval) of the mixed-effects logistic regression model for predicting selection for vegetation type by black rhinoceros (Figure 3.3) indicated greater use of thicket 1.007 (95% CI: 0.429-1.584) (Appendix A) and closed savanna 0.8656 (95% CI: 0.250-1.480) than of the reference category (riparian fringe). The results do indicate that there is no significant difference in use by rhinos between thicket, open savanna, closed savanna and rocky hills due to the overlap in confidence intervals of these variable. Another variable that indicated significant use by rhinos was burnt areas, -0.63772 (95% CI: -0.08586 to -1.18958) (Appendix A). Rhinos used unburnt areas significantly more than the burnt areas. The selection estimates for the slope variable show that use by rhinos increased with decreasing slope (-0.09979; 95% CI: -0.04959 to -0.14999) indicating that rhinos prefer gentle slopes more than steep slopes. The selection estimates for predicting selection for areas at different elevation indicated that rhinos used upper-midslopes (314 – 376 m.a.s.l.) less than the reference category (lowlands 130-191m.a.s.l.) (Figure 3.4). For the human dwellings variable, rhinos used areas very far (2265-2830 m) and to a lesser extent areas at an intermediate distance from residences, lodges and camps more so than the reference category (very close) (Fig 3.5). One sub-adult female's and one adult female's home range (12%, 2 of 17 rhinos) overlapped with one residence and one lodge and camp (10%, 3 of 30 human dwellings) within the reserve.

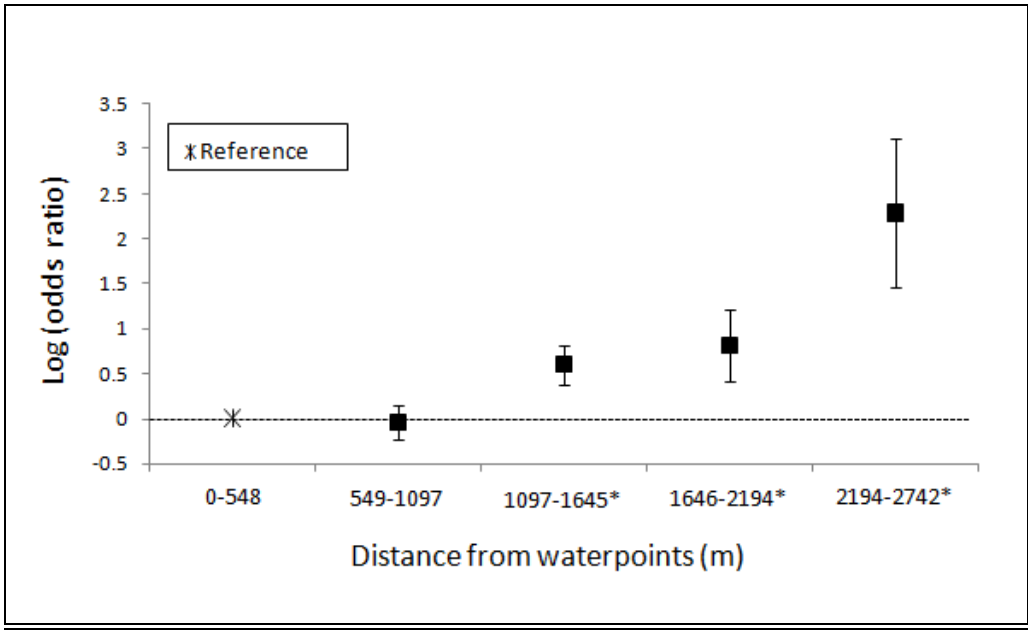


Figure 3.2. Space use estimates (log odds ratio ± 95% confidence intervals) for distance from all perennial water points by black rhinos in comparison with the reference category: very close 0-548 m. Confidence intervals > 0 indicate selection and, <0 indicate avoidance of distance classes compared with the reference category. *Indicates significant values $P < 0.05$

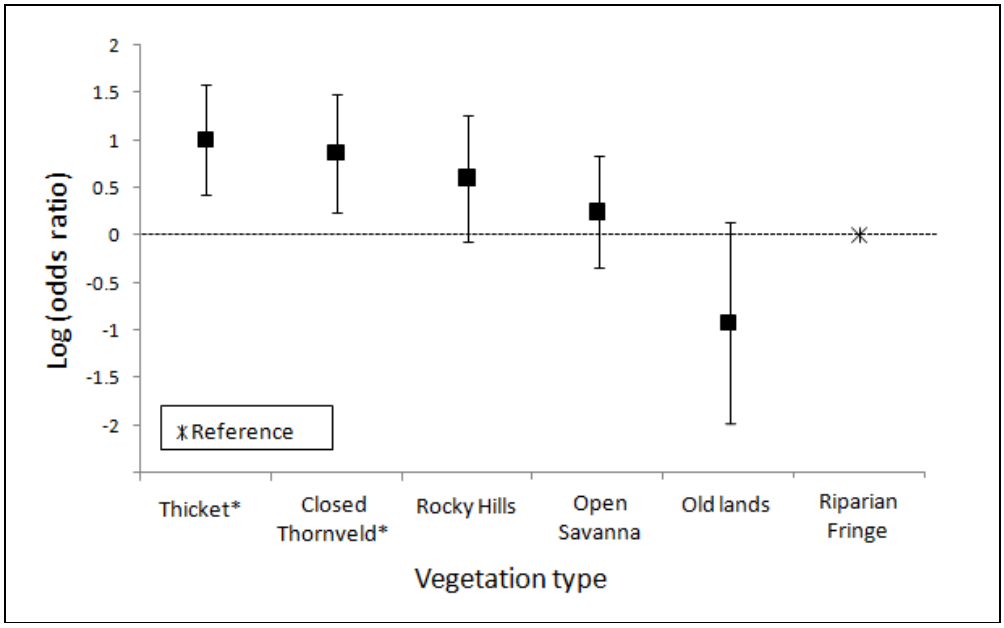


Figure 3.3. Selection estimates (log odds ratio ± 95% confidence intervals) for vegetation type by black rhinoceros in the Zululand Rhino Reserve in comparison with the reference category (riparian fringe). Confidence intervals >0 indicate selection and, <0 indicate avoidance of elevation classes compared with the reference category. *Indicates significant values $P < 0.05$

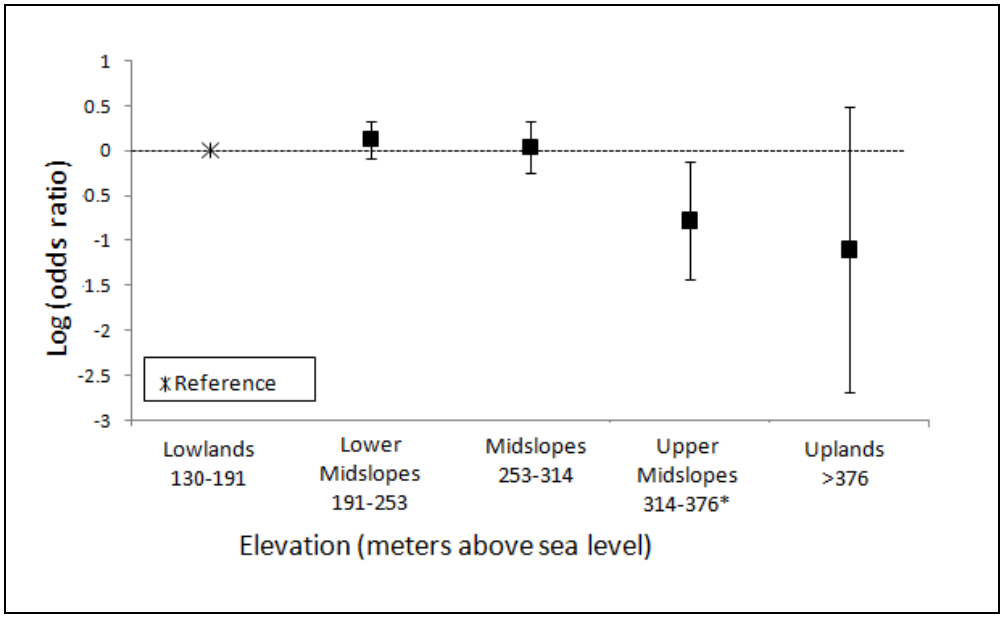


Figure 3.4. Space use estimates (log odds ratio ± 95% confidence intervals) for the different elevation classes by black rhinos in comparison with the reference category: 130-191 m.a.s.l. Confidence intervals > 0 indicate selection and, <0 indicate avoidance of distance classes compared with the reference category. *Indicates significant values $P < 0.05$

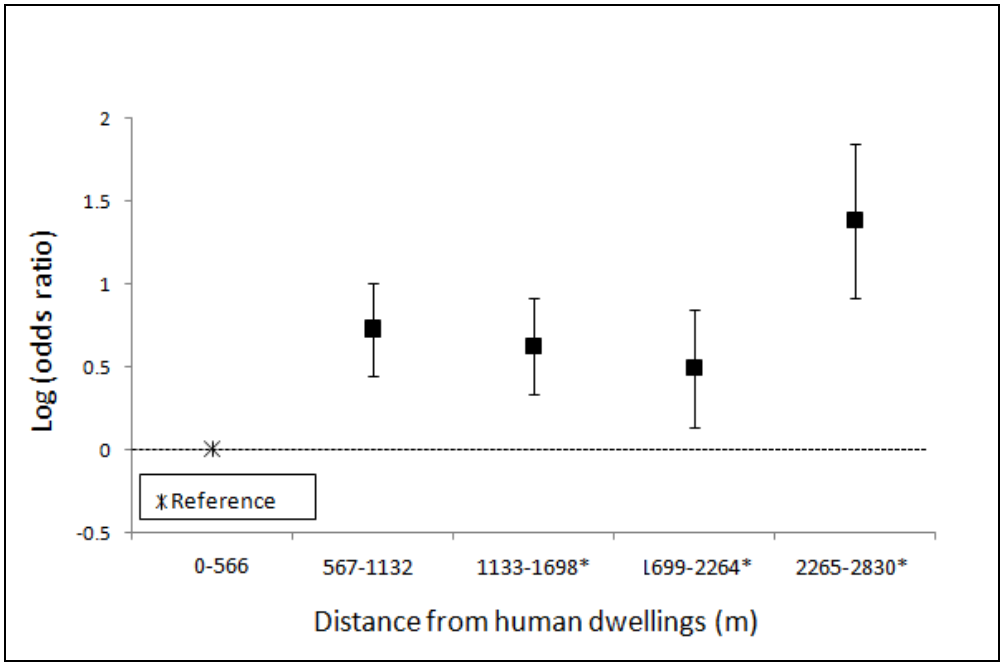


Figure 3.5. Space use estimates (log odds ratio ± 95% confidence intervals) for distance from human settlements by black rhinos in comparison with the reference category: 0-566 m. Confidence intervals > 0 indicate selection and, <0 indicate avoidance of distance classes compared with the reference category. *Indicates significant values P < 0.05

4. Discussion

Habitat-use is one of the most common research topics in rhinoceros ecology (Linklater, 2003) but there is a great need for this research to be applied to ecological management of relatively small reserves that make up the rhino metapopulation (Emslie and Brooks, 1999). From the literature we understand how biological factors affect rhino resource selection but not in the context of small reserves. This study investigates the factors commonly associated with small reserves and how these factors affect rhino habitat-use and weigh the relative importance of each variable.

4.1. Home range size

The home ranges of different black rhino populations vary to a certain degree due to biological differences amongst populations and habitats as well as methods used to construct home ranges. Even though LoCoH provides the best results for home range construction in this study, I constructed the MCP home ranges to allow for comparison with previous studies.

The mean MCP home range was 12.3 km² (2.46 km²-40.21 km²), which is similar to 11.7 km² (1.7 km² -18.3 km²) in the Great Fish River Reserve (Lent and Fike, 2003) but is larger than the 7.65 km² (2.25 km²-14.39 km²) found in a Sweetwaters Rhinoceros Sanctuary (Tatman *et al*., 2000). This variation is due to the fact that Taman *et al*. (2000) estimated the home ranges based on data for only three months, and therefore represent seasonal home ranges which would be smaller than annual home ranges. The mean 95% LoCoH home range was 3.77 km² (95% CI: 2.91 km²-4.63 km², *n*=17).The mean MCP home range was 69.6% larger than the mean 95% LoCoH home range. MCP overestimates the home range (Barg *et al*., 2005; Borger *et al*., 2006; Nilsen *et al.*, 2008), but should not be discarded altogether as it is a valuable tool in use-availability RSF studies such as this one.

The mean 95% LoCoH home range of 3.77 km² (1.08 km² -7.70 km²)for the black rhinos in ZRR was comparatively small in relation to the 95% adaptive kernel estimates of 32.3 km² in the Great Fish River Reserve (Lent and Fike, 2003), and the 23.03 km² (5.0 km²- 55.0 km²) in Hluhluwe-Umfolozi Park (Reid *et al*., 2007). It was similarly so for the mean 95% harmonic mean home range of 7.68 km² (2.17 km² -15.82 km²) in Sweetwaters Rhino Sanctuary (Tatman *et al.*, 2000). The mean 50% core LoCoH home range of 0.9 km² for the black rhinos in ZRR is comparatively small in relation to the 6.8 km² (Lent and Fike, 2003) and 2.95 km² (Reid *et al*., 2007) mean 50% core adaptive kernel home range for the black rhinos in the Great Fish River Reserve and Hluhluwe-Umfolozi Park respectively.

The degree of human disturbances in ZRR is substantially higher than that of the Great Fish River Reserve and HIP, this disturbance results in fragmentation of home ranges and thus results in smaller home range estimates. The very small home range estimates for the ZRR can also possibly be attributed to high habitat quality. Foodplants such as *Acacia* sp. (Adcock, 2001; Buk, 2004; Ganqa *et al*., 2005), *Spirostachys africana*, *Dicrostachys cinerea* (Adcock, 2001), *Euphorbia* sp. (Adcock, 2001; Buk, 2004; Ganqa *et al*., 2005) *Maytenus senegalensis* (Muya and Oguge, 2000; Adcock, 2001) are utilized by black rhinos (pers. obs.) and are common species occurring within the different habitat types within the ZRR.

Home range size has been related to habitat quality (Goddard, 1967; Hitchins, 1969, Mukinya, 1973, Tatman *et al.*, 2000) suggesting that home range size decreases with increased habitat quality. However Linklater *et al*. (2010) caution that home range size is not a reliable surrogate for habitat quality and it often arises through insufficient data. Another reason for the comparatively small home range size in the ZRR might be adaptive kernel home range estimates are larger than those of LoCoH, because unlike LoCoH, adaptive kernel methods might smooth across holes and corners depending on the smoothing parameter (Getz *et al*., 2007). This could result in slightly over-estimating the home range. Adaptive kernel home ranges can be generated for the rhinos in ZRR to for better

comparison with previous studies. Kiwia (1989) reported on much larger black rhino home ranges in the Great Fish River Reserve in 1982 than that reported on by Goddard (1967) and he attributed this to the fact that the population density declined by 80.6%. This negative correlation between home range size and population density suggest that the small rhino home ranges in the ZRR is as a result of high population density which is negated by the fact that the black rhinos in the ZRR occupy only 30.7% of the reserve.

Home ranges of black rhinos can be influenced by sex and age (Goddard, 1967; Mukinya, 1973; Adcock *et al*.,1998; Morgan *et al*., 2008). This differs from my results and that of Tatman *et al*. (2000), Lent and Fike (2003) and Reid *et al*. (2007), showing that black rhino home range sizes are independent of sex and age. The mean core area for all the rhinos in the ZRR amounts to 23% of their total home range size. These results are very similar to the 21% reported on by Lent and Fike (2003) using 50% and 95% adaptive kernel. Thus indicating that use of home ranges is not uniform and core areas are used much more intensively. Tatman *et al*. (2000) reported that rhinos show preference for certain habitats but more importantly they use certain habitats in different ways. Therefore the variation in use of different habitats such as certain habitats preferred for bedding sites and other habitats for forage could explain the variation is use of the home ranges versus the core area. More investigation of the core areas comparatively to the home range and the habitats contained within them would provide more clarity on the variation in use the home range.

4.2 Home range overlap

Recent studies have identified distinct social interactions amongst individuals. Lent and Fike, (2003), Joubert and Eloff (1971), Morgan *et al*., (2008), Kim (2009) referred to these associations or social interactions between rhinos as clans or clusters. At ZRR one of the clusters consisted of four rhinos sharing a 10.46 km². In this cluster the sub-adult males and females and adult female home ranges

overlapped with two adjacent territories. In Ndumo Game Reserve a group of seven rhinos shared 4.3 km² (Conway and Goodman, 1989). Many rhinos utilizing a small area indicate high habitat quality and suitability for black rhinos. The home range overlap for the ZRR rhino population ranges from 0.07%- 98.05% and is similar to that reported at Ndumo 12.4%– 79.5% (Conway and Goodman, 1989). Animals at ZRR were more social than initially anticipated, which is supported by the degree and number of home range overlaps seen in this population. There is opportunity for further analysis of the home range overlaps to determine which factors contribute to these overlaps. Logistic regression analysis could be done with the rhino locations within the overlaps as the response variable and the habitat and disturbance factors as the explanatory variable. The results should indicate which variables play the biggest role in rhino home range overlap and provide us with more insight into the social behaviour of black rhinos.

There are substantial overlaps between all the various sex and age classes with the lowest mean percentage overlap between adult females and sub-adult males. The mean overlap between adult males and adult females is 35.57% which is substantially higher than the 8.15% overlap between adult females and sub-adult males. Similarly Owen-Smith (1975) reported on white rhinoceros adult males accompanying adult females and sub-adult females in 38.8% of the sightings, whereas non-territorial males only associated with adult females in 8.1% of the sightings. Owen-Smith (1975) reported home ranges of white rhinoceros cows overlapped with 6-7 territories and that most cows spent 50% of their time in during the wet season in one or the other of two adjacent male territories. Therefore indicating that non-territorial male home ranges do not overlap substantially with that of females due the substantial overlaps between females and territorial males. The small percentage overlap between the adult females and sub-adult males in the ZRR can be attributed to the fact that adult females spend a substantial amount of time in adult male territories.

Even though adult males do tolerate sub-adult males within their territories they probably only allow this without the presence of females within their territory.

Adult males' home ranges generally don't overlap (Tatman *et al.*, 2000; Lent and Fike, 2003; Groves and Hillman-smith, 1994) due to territoriality. However a territory is not a home range but rather a core area within a home range which is defended more severely than the home range itself (Adcock, 1994). Contrary to previous studies the home ranges of two territorial adult males (>10 years) at ZRR overlapped by 1.37 km² (39.51% and 17.82% for each animal) but not their core areas indicating that the territorial males will tolerate one another within the home range but not within their core area. There is also one overlap between the core area of a territorial male rhino and a sub-adult male rhino whose 50% core LoCoH home ranges overlapped by 0.46 km², 50.37% overlap for the adult male and 55.61% for the sub-adult male. Territorial males tolerate sub-ordinate males within their home range and territory (Adcock, 1994, Groves and Hillman-smith, 1994). There is therefore evidence supporting my hypothesis that core areas of territorial males do not overlap.

4.3 Home range fragmentation

Rhinos with multimodal home ranges had a human dwelling located in the gap or hole within the home range, suggesting that human disturbance might alter the home range establishment of black rhinos. Thus, there is evidence to support my sixth hypothesis that black rhino home range in the ZRR is fragmented due to the degree of human disturbance within this small reserve.

4.4 Resource selection function model

4.4.1 Water

The results from distance from water points indicated that use of areas by rhinos increased with distance from water points, greatest use occurred for areas very

far (2194-2742 m) away. This finding was consistent with my second hypothesis. Even though black rhinos drink water daily, this does not mean that they always have a water point within their home range, but they move out of their home range to drink water. This avoidance of areas close to water points played the second biggest role in rhino resource selection. This avoidance is related to poor habitat quality. Small, medium and large herbivore density increases with proximity to perennial water (Parker and Witkowski, 1999) as does habitat use by these herbivores resulting in degradation of these areas which leads to reduced browse availability for black rhinos. These results indicate that black rhinos avoid areas up to 1097 m from water indicating that a significant piosphere effect exist up to that distance around the waterpoints in the ZRR.

4.4.2 Vegetation type

The confidence intervals for thicket, closed savanna, rocky hills and open savanna overlap indicating that there is no significant difference in use of these vegetation types by rhinos. However the results do show that rhinos in ZRR selected thicket and to a lesser extent closed savanna, more than riparian vegetation. Thicket vegetation is dominated by *Euclea* spp. Rhino home ranges in the Sweetwaters Rhinoceros Sanctuary also contained more *Euclea* spp. than grassland and *Acacia* spp. (Tatman *et al*., 2000). However *Euclea* spp. are considered to be less palatable browse plants (Adcock, 2001), but these thickets also contain palatable species such as *Acacia* spp*., Ziziphus mucronata* and *Spirostachys africana.* Thickets also provide shelter for black rhinos, particularly to females with young. Suitable cover, palatable browse and water were identified as the main reasons for the high population density and high juvenile recruitment in Ndumo game reserve (Conway and Goodman, 1989). The evidence from ZRR thus supports my hypothesis that thickets and closed savanna are important to rhinos because of the browse and shelter they provide.

4.4.3 Burnt Areas

Large herbivores show a preference for utilizing burnt areas (Sukumar, 1986; Coppedge and Shaw, 1998; Biondini *et al*., 1999; Shrader and Owen-Smith, 2006) including black rhinos (Adcock, 2001). The selection estimates for burnt areas indicate that use by rhinos decrease as distance to burnt areas increase. The data do not support my forth hypothesis that black rhinos will move to a burnt area to browse on burnt shrubs and trees. Two blocks with a total area of 8.24 km² (5.7% of the total study area) in the southern part of the reserve burnt in August 2006 and thus was only burnt for four months of the study period, which would result in this negative association with burnt areas.

4.4.4 Slope and elevation

Use by rhinos decreased with increasing slope, confirming that rhinos prefer flatter areas and gentle slopes over steep slopes. It is also consistent with findings from the literature. Slope affects accessibility which affected utilization of woody plants by black rhinos in Western Ithala Game Reserve (Ganqa *et al*., 2005). Areas with >30º slope are considered inaccessible to black rhinos (Adcock, 2001). The selection estimates for elevation class by black rhinoceros indicate significant avoidance for upper-mid slopes (314 – 376m.a.s.l.) more so than the reference category (lowlands 130-191m.a.s.l.).Black rhinos avoid areas with a high percentage of rockiness (Buk, 2004; van der Heiden, 2005). At ZRR rockiness increases with elevation, being highest on upper- mid slopes and uplands. Rhinos due to their large body size utilize roads due to ease of access. And for the same reason avoid rocky areas due to the effort required to move within these area.

4.4.5 Human dwellings and disturbance

Rhinos avoid areas close to human dwellings due to the disturbance.

Many studies report on the absence of human disturbances as an important factor affecting habitat suitability for black rhinos (Goddard, 1967; Mukinya, 1973; Goodman and Conway, 1989; Berger and Cunningham, 1994; Tatman, *et al*., 2000; Buk, 2004) but this study is the first to investigate how human disturbances actually affect rhino ranging bahviour particularly within a small reserve. In North-western Namibia human-induced disturbances were linked to high calf mortality (Hearn, 2001; Shaw, 2002). At ZRR, human disturbances played the biggest role in resource selection by rhinos suggesting that black rhinos are very sensitive to human disturbance and might therefore avoid utilizing a preferred habitat patch close to human dwellings, in support of my fifth hypothesis.

5. Conclusion and management implications

The LoCoH home ranges in this study highlighted the holes and gaps within the home ranges which allowed me to identify the cause of these gaps and holes. Adcock (2001) indicated that the average home range size of adult black rhino males can be used as a surrogate for determining the carrying capacity of the reserve. It is therefore crucial to use LoCoH for home range estimation of black rhinos as it does not over-estimate the home range size and identifies unused areas within the home range ultimately allowing for a more accurate carrying capacity estimates. Areas within 500 m of all developments should be excluded from the total area size in black rhino carrying capacity models seeing that black rhinos do not use these areas.

Rhino resource selection is driven by many different variables and from this study we learnt that, certain factors play a larger role than others. Rhinos' avoidance for disturbance plays a bigger role than their selection of resources, and will therefore force individuals into sub-optimal habitats. The home ranges of this rhino population are also fragmented due to the location residences, lodges and camps within preferred black rhino habitat. It is therefore essential that we consider the habitat preferences of black rhinos in development plans for protected areas. Developments should be concentrated in one area rather than spread out over a large area, and these developments should not be placed within preferred black rhino habitat. The question arises as to whether this sensitivity for human disturbances affects reproduction, calf survival and intraspecific competition in black rhinos. More research needs to be done to determine the extent of the affect of human disturbance on black rhino ecology.

Rhino's avoidance for areas close to perennial water plays the second biggest role in rhino resource selection. Their avoidance of these areas is due to the habitat degradation that occurs from the high degree of utilization by herbivores around water points, resulting in reduced browse availability and quality for black rhinos. More research is required to determine the degree of

variation in the browse availability within areas surrounding waterholes and areas farther away from perennial water.Owen-Smith (1996) documented that abundant surface water favours common ungulate species at the expense of rarer species due to vegetation impacts. Abundance and proximity of perennial water points should be 15 km apart during the wet season and 10 km apart during the dry season as recommended by Owen-Smith (1996), but this model for water distribution is not always practical especially within small protected areas. However, it is essential that we do limit water point density and proximity, reducing habitat degradation which affects habitat quality for black rhinos. The metapopulation of black rhino consist of small protected areas such as this one and from this study we have learnt that the density of human disturbances and water points commonly found in small reserves do affect rhino home range establishment and habitat use. It is essential that this knowledge be applied in the management of reserves protecting black rhinos.

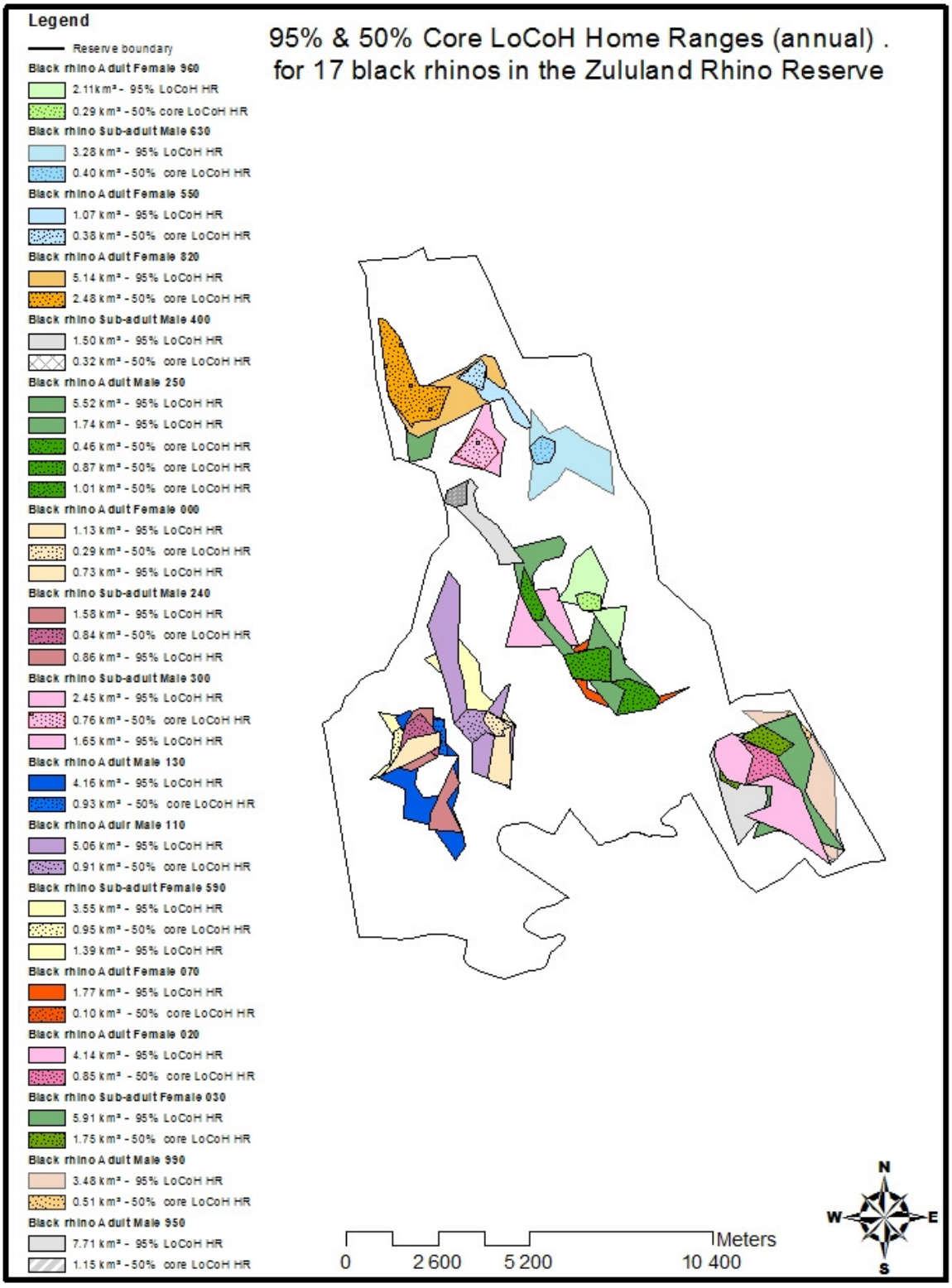
Appendix A

Variable	Category	Log odds	Std. Error	z value	Pr(>|z|)	UCL	LCL
Human dwellings	Very far 2264-2830	1.38312	0.23584	5.865	4.50E-09*	1.845366	0.920874
Perennial water	Very far 2194-2742	2.28587	0.42147	5.424	5.84E-08*	3.111951	1.459789
Perennial water	Medium 1097-1645	0.59599	0.11409	5.224	1.75E-07*	0.819606	0.372374
Human dwellings	Close 566-1132	0.7262	0.14182	5.12	3.05E-07*	1.004167	0.448233
Human dwellings	Medium 1132-1698	0.62339	0.14791	4.215	2.50E-05*	0.913294	0.333486
Perennial water	Far 1645-2194	0.80913	0.20574	3.933	8.40E-05*	1.21238	0.40588
Slope		-0.09979	0.02561	-3.896	9.76E-05*	-0.04959	-0.14999
Vegetation type	Thicket	1.00718	0.29479	3.417	0.000634*	1.584968	0.429392
Vegetation type	Closed savanna	0.8656	0.31395	2.757	0.005832*	1.480942	0.250258
Human dwellings	Far 1698-2264	0.49085	0.17936	2.737	0.006206*	0.842396	0.139304
Elevation	Upper midslopes 314-376	-0.78055	0.33491	-2.331	0.019772*	-0.12413	-1.43697
Burnt areas		-0.63772	0.28156	-2.265	0.023514*	-0.08586	-1.18958
Vegetation type	Rocky hills	0.60557	0.33886	1.787	0.073924	1.269736	-0.0586
Vegetation type	Old lands	-0.92089	0.53933	-1.707	0.087733	0.136197	-1.97798
Elevation	Uplands 376-438	-1.1011	0.80939	-1.36	0.173702	0.485304	-2.6875
Elevation	Low midslopes 191-253	0.12836	0.10467	1.226	0.220058	0.333513	-0.07679
Vegetation type	Open savanna	0.24808	0.30052	0.826	0.409082	0.837099	-0.34094
Perennial water	Close 548-1097	-0.04606	0.0955	-0.482	0.629566	0.14112	-0.23324
Elevation	Midslopes 253-314	0.03729	0.14512	0.257	0.797236	0.321725	-0.24715
(Intercept)		-3.35128	0.31166	-10.753	< 2e-16	-2.74043	-3.96213

*Indicates significant values P <0.05

Appendix A: The output summary of the logistic regression mixed-effects model for the different variables

Appendix B


Legend
Reserve boundary
Black rhino Adult Female 960
2.11km² - 95% LoCoH HR
0.29 km² - 50% core LoCoH HR
Black rhino Sub-adult Male 630
3.28 km² - 95% LoCoH HR
0.40 km² - 50% core LoCoH HR
Black rhino Adult Female 550
1.07 km² - 95% LoCoH HR
0.38 km² - 50% core LoCoH HR
Black rhino Adult Female 820
5.14 km² - 95% LoCoH HR
2.48 km² - 50% core LoCoH HR
Black rhino Sub-adult Male 400
1.50 km² - 95% LoCoH HR
0.32 km² - 50% core LoCoH HR
Black rhino Adult Male 250
5.52 km² - 95% LoCoH HR
1.74 km² - 95% LoCoH HR
0.46 km² - 50% core LoCoH HR
0.87 km² - 50% core LoCoH HR
1.01 km² - 50% core LoCoH HR
Black rhino Adult Female 000
1.13 km² - 95% LoCoH HR
0.29 km² - 50% core LoCoH HR
0.73 km² - 95% LoCoH HR
Black rhino Sub-adult Male 240
1.58 km² - 95% LoCoH HR
0.84 km² - 50% core LoCoH HR
0.86 km² - 95% LoCoH HR
Black rhino Sub-adult Male 300
2.45 km² - 95% LoCoH HR
0.76 km² - 50% core LoCoH HR
1.65 km² - 95% LoCoH HR
Black rhino Adult Male 130
4.16 km² - 95% LoCoH HR
0.93 km² - 50% core LoCoH HR
Black rhino Adult Male 110
5.06 km² - 95% LoCoH HR
0.91 km² - 50% core LoCoH HR
Black rhino Sub-adult Female 590
3.55 km² - 95% LoCoH HR
0.95 km² - 50% core LoCoH HR
1.39 km² - 95% LoCoH HR
Black rhino Adult Female 070
1.77 km² - 95% LoCoH HR
0.10 km² - 50% core LoCoH HR
Black rhino Adult Female 020
4.14 km² - 95% LoCoH HR
0.85 km² - 50% core LoCoH HR
Black rhino Sub-adult Female 030
5.91 km² - 95% LoCoH HR
1.75 km² - 50% core LoCoH HR
Black rhino Adult Male 990
3.48 km² - 95% LoCoH HR
0.51 km² - 50% core LoCoH HR
Black rhino Adult Male 950
7.71 km² - 95% LoCoH HR
1.15 km² - 50% core LoCoH HR
95% & 50% Core LoCoH Home Ranges (annual) .
for 17 black rhinos in the Zululand Rhino Reserve
0
2 600
5 200
10 400
Meters
N
W
E
S

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