Namibia University of Science and Technology (NUST)

School of Natural Resources and Spatial Sciences (SNRSS)

Mini Thesis

Determining wildlife numbers in the Fish River Canyon Reserve based on high resolution aerial photography.

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ABSTRACT

Determining wildlife numbers and their distribution patterns are an important and relevant factor for increasing scientific knowledge, to provide credible information for managerial decisions to conserve and protect biodiversity. This research was aimed at studying the distribution of wildlife species within the Fish River Canyon using different Geographical Information System (GIS) approaches and methods by analysing distribution patterns, slope and aspect analysis on which the animals were counted in, and favourable vegetation type from which different wildlife species were counted. The paper was also concerned with estimating wildlife population numbers within the reserve by extrapolating the numbers of wildlife counted in the surveyed areas to areas no surveyed based on the different vegetation coverage and different slope areas.

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ABBREVIATIONS & ACRONYMS

DEM	Digital Elevation Model
FRCR	Fish River Canyon Reserve
NASA	National Aeronautics and Space Administration
NUST	Namibia University of Science and Technology
FNRSS	Faculty of Natural Resources and Spatial Sciences
RGB	Red, Green, Blue
SRTM	Shuttle Radar Topography Mission
USGS	United States Geological Survey

1. INTRODUCTION

An important component for ensuring sustainable use and management of land being used for nature conservation is to ensure that the biodiversity of a conservation area, the flora and fauna are well maintained and monitored. Documenting and understanding distribution patterns of wildlife species is central to the fields of ecology, conservation biology and geography. Ecology has been defined as the study of distribution and abundance of organisms (Andrewartha & Birch, 1974; Andrewartha & Birch 1986). In wildlife conservation, relevant information of population and its distribution is required for a proper management system to be in place.

However, in many instances the actual location or distribution of wildlife is not known. Distribution modelling aims at filling the gap by making statements based on the geographic locations of species (Bahn et al, 2006).

Namibia is one of a few countries that addresses habitat conservation and protection of natural resources in its constitution, with over 82 conservancies, and 17 protected areas. The study area we will be focusing on in this research the Fish River Canyon Reserve (FRCR) has one of the 17 protected areas falling within it, the Ai-Ais hot spring.

However, even though of the reasonable effort in tackling the conservation of nature and its management, efficient spatial distribution and environmental parameters analysis remains a very big challenge. For example, there has not been any formal type of wildlife census conducted on some of Namibia's national parks and game reserves, including the FRCR. As a result, wildlife population numbers are not really known in this area.

No formal wildlife census has been conducted within the reserve so far. Due to the challenging terrain and availability of water traditional census methods cannot be applied. There are few roads and paths thus leaving out a great area of land that would not be seen, which will potentially result in leaving out a number of wildlife as uncounted if perhaps a road strip census method is being conducted. The reserve has multiple rivers and wildlife will tend to drink water from anywhere along these rivers, so the traditional waterhole census would also not work for this area because the fauna do not have a specific place where they go drink water, like at a specific water hole.

As a result of the challenges described above using traditional census methods, an innovative game count method is being explored. The method that is being explored is to count fauna from high resolution aerial images taken over a subset of the study area, and to extrapolate these to other areas not covered by the images.

The method is being investigated for not only its potential to determine the total population size of wildlife species, but through additional analysis we will explore spatial distribution studies, such as habitat selection. This will be based on linking the distribution data through to ancillary information such as terrain, vegetation and ecological factors etc.

1.1. AIMS AND OBJECTIVES

Research questions for this study are: What is the current population number certain wildlife species within the reserve in total? How are they distributed throughout the study area? What are their preferred vegetation and slope type? Those are the questions we will provide answers with this research. Based on the specified research questions, our aims and objectives with this research are to:

- Determine wildlife spatial distribution within the reserve, and see if any direct links can be made to physical parameters linked to vegetation and terrain.
- Establish the current population size and distribution of wildlife the FRCR based on the aerial flight survey.
- Map wildlife distribution within the FRCR.
- Conduct statistical analysis to determine and estimate the number of wildlife in areas not captured between flight lines. This would be based on areas not covered and from the spatial distribution input derived above.

2. LITERATURE REVIEW

No form of wildlife management is possible without reliable information on the numbers (population size), population dynamics, movements and distribution of the animals (Norton-Griffiths, 1978). The unknown wildlife population within the FRCR needs to be determined in order for effective conservation and management. In order for this to be done, it is important to provide accurate estimates of the wildlife population within the reserve. There are a number of traditional wildlife census methods available as compared by Terletzky and Ramsey in 2016.

2.1. TRADITIONAL WILDLIFE COUNTING METHODS

Most if not all of these methods are done visually and manually, and requires a lot of time and manpower, they also have a high probability of errors occurring and only a limited area can be considered for animal counting due to the effort required (Sirmacek et al., 2012). Counting wildlife using the traditional methods is not an easy task. This is primarily due to the fact that the animals are wild and they cannot be herded like domestic animals, wild animals are dangerous if one gets too close, they can hide well and are not easily seen. Some wild animals only move in the evening, and are often found in groups, which makes it hard to count individuals (WWF, 2002). Traditional wildlife census methods can be classified in two groups: Area sampling methods and non-sampling methods (Collinson, 1985).

2.1.1. Sampling methods

The sampling method happens when only a small percentage of the area is considered or counted and an estimate is conducted to cater for the rest of the remaining area. The advantages of the sampling methods are: less cost and time for fieldwork, chances of recounting an individual animal is reduced, and it is easier to standardize field processes between censuses. The main disadvantage of the sampling method is that: if the density of the population is low or the population is extremely clumped, then a considerable amount of sampling effort is needed to generate an estimation that would be considered as accurate. A sampling method is required where saving time is greater than accuracy, or where double counting chances or missing animal's possibilities are high, or where high repeatable estimates are needed (collinson, 1985). The method being investigated of its feasibility in this research is also a sampling method, some other examples of sampling census methods are presented below.

2.1.1.1. Quadrant method

Quadrat sampling is a special tool that can be used for the study of ecology, and in this case wildlife population. In general, a series of 4 quadrats of a certain size are placed in a habitat of interest and the species within those quadrats are identified and recorded. Population estimates of wildlife found on the study area can be calculated using the number found per quadrat and the size of the quadrat area (Cottam et al, 1953).

2.1.1.2. Block sampling

This is a type of sampling method whereby some type of wildlife species are chosen in sequential order. Once the initial item in the block has been chosen, then the balance of the block will be automatically selected. This method of sampling ensures that all items within a population stand an equal chance of selection by the use of random number tables or random number generators (Friedman, 2012).

2.1.1.3. Line transect method

This is a method used when few limited resources are available and when lower precision data is needed. Transect counts should be flown at a certain height that is constant throughout the study area and over a relatively flat terrain. Transects are long, narrow strips from which objects are detected out to a distance on both sides (left or right) of the centre lines. Transects are not a census where all animals are counted, but a survey were only some portion of the object in the sample area are detected and counted (Buckland et al, 1993). The method in this research closely resembles this method, the difference is that the recording of the animals is not done during the flight, but is captured or counted after the flight observed on images.

2.1.1.4. Road strip counts

Road strip counts are widely used in Africa (Dasmann & Mossman, 1962). This method is suitable for reserves or farms with a well-developed road network. For this to be possible, wildlife visibility from these roads should be really good, and sufficient road networks are required. The road and vehicle condition should be in such a good condition that the vehicle can approach animals in a way that it does not make noise to scare the animals and for them to end up running away without being counted. This method would not be at all suitable for the FRCR since it does not have any proper road network, and because of its terrain.

2.1.2. Non-Sampling methods

The non-sampling method considers the whole total study area to be counted, which means more time is needed to conduct the census. Examples of non-sampling methods are as follow:

2.1.2.1. Individual recognition count

With this method, an individual identification database needs to be built where each animal of a specific specie or herd needs to be individually identified and recorded by the combination of its physical parameters (horns, sex, body, etc.). No statistics is required for this method in order to get the population, because the total number of the recorded animals in the database would represent the total population size of the specific species being studied (Bouche, 2012).

2.1.2.2. Waterhole counts

This method is done by putting counters in hides near different waterhole points within reserves or farms during the dry seasons. These counters view different animals as they come to drink, the counters can then record for example the time of the day the animal came to drink water, whether it drank or not, its sex and the animal's age structure (Staff-reporter, 2009). Although this method is good and allows a lot of data to be recorded about animals, it comes with some issues as too, water requirements and drinking frequency of the various species influence the possibilities of finding and counting specific animals at waterholes (Young, 1972). It is time and labour intensive, requires dedicated, reliable people with the needed knowledge to avoid double counting of the same animals. Other factors like availability of salt licks, temperature, vegetation moisture contents, differences in species, will all contribute to the behaviour patterns of wildlife drinking and therefore some animals may be undercounted ("Practical game count," 2016). Since the FRCR doesn't have fixed waterholes, but river systems, this method is inappropriate for the reserve.

2.1.2.3. **Total ground count**

This method is only feasible when the study area is relatively small, the counters travel in the area to detect and count precisely each herd, and the sum of the counted animals give the population's size. Precise count and recording of every animal and its location helps to prevent double counting of animals and to remove it from final figures (Bouche, 2012).

2.1.2.4. **Total removal method**

This method is commonly used in small mammal's studies. It involves removing animals from the population temporary or permanently during the study. The logic behind this method is that the animals caught and removed during the trapping will always be greater than the number that will be caught at a later stage using the same process of sampling. Which means the more you reduce the size of the population, the more you reduce the size or number of animals you will catch (Buckland et al, 1993).

2.1.2.5. Aerial total count

Airborne surveys are a practical way of monitoring wildlife presence over large and remote areas. Helicopters are mainly used to conduct wildlife aerial surveys in rugged and mountainous terrain (planes are used too) where pictures may in addition be taken for further analysis in the office, but counts can also be made directly by counters on board of the helicopter. Wildlife managers use aerial surveys for counting a diverse array of wildlife species. Aerial surveys are mostly used in inaccessible terrains where aerial surveys are the only practical option to conduct game counts to determine population size and composition within areas (Gonzalez et al, 2001).

2.2. SPECIES DISTRIBUTION MODELING (SDM)

SDM's are models gotten from relating field observations to environmental predictor variables, based on statistically or theoretically generated response surfaces (Guisan & Zimmermann 2000). SDM is central to fundamental and research in the fields of biogeography, conservation biology, wildlife management, ecology and other related fields. Model fitting is usually based on pattern recognition approaches, whereby associations between geographic occurrence of a species and a set of predictor variables are explored to allow or support statements of the mechanisms governing species distributions (Araújo & Guisan, 2006).

Species can either occupy large areas or small area depending on their dispersal characteristics. Species distribution is also effected by human activities whom either create and destroy wildlife habitats, transporting species to new places and by building roads and barriers in what previously used to be wildlife territories. It is important to understand some of the terms related to distribution of species (Tablada, 2009).

Endemic species – Can be defined as, species restricted to a single region or area. Endemic references the area or region the specie is restricted to.

Native species – These are wildlife species that are found in their own original locality or area, they form an addition to the natural biotic environment in that area. They adapt well to local conditions within their area, and have evolutionary and ecological relationships with other animals in that area.

Exotic species – These are species taken from their original distribution areas and taken or put in new location. There are no evolutionary relationships of these species with other species found in the environment. Good examples of these species are domesticated animals.

Invasive species – These are species that take over an area, and multiply its population in order to exploit the area and to increase its geographic distribution within that area. A good example such type of species is rats. These species have a high dispersal capability and can cause extensive damages.

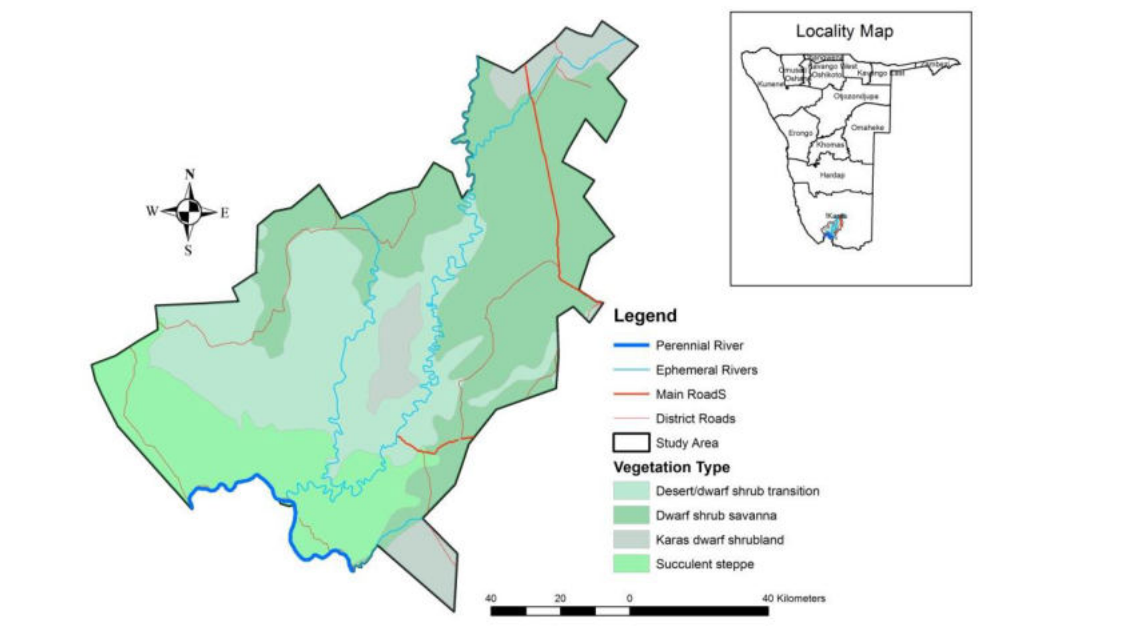
The analysis of wildlife distribution or/ species and environmental relationship is a very relevant initiative that has always been a central issue in ecology, to explain wildlife environmental patterns (Guisan & Zimmermann, 2000).

3. METHODOLOGY

3.1. STUDY AREA

Our study area, the FRCR measures at 11676 km^2 in size and it is home to the Fish River Canyon which is nearly 27 kilometres wide and 161 kilometres long ("Fish River Canyon," 2010), it is the second largest canyon on earth second to Americas Grand Canyon (Walker, 2014). The FRCR is located on the southern border of Namibia, bordering South Africa with the Orange River passing between the two countries. The canyons landscape was caused by heavy erosion and the collapse of the valley due to movement in the earth's crust over 500 million years ago (Theys, 2011).

Study Area



Source: Own compilation

Figure 1: Study area map, showing the FRC reserves boundary as the main map, and an insert map showing the locality of the FRCR within Namibia.

FRCR is home to a vast range of wildlife from as small as beetles to game as big as rhino's which were recently introduced. Opportunities for game seeing within the canyon are limited and only animals like springboks and hartebeest are sometimes seen on the plain. Baboon troops are more comfortable on the rocky slopes of the canyon while mountain zebras favour the rocky uneven, steep side of the canyon and are rarely seen. The reserve is home to 4 rivers, with 3 of these rivers flowing southwards into the great Orange River.

Vegetation can influence wildlife distribution because different vegetation would be favourable to different wildlife species, vegetation that specie A prefer to graze on would not be that same as that of specie B or specie C etc. Terrains also tend to influence wildlife distribution as there are some animals that prefer steep slope areas and there are those animals that prefer only flat areas. The 4 river systems in the reserve provide sufficient water for the animals and thus prevent the need for inclusion of waterholes which is necessary in many other nature reserves and would result in animals concentrating at these locations. In the FRCR animals would most likely be dispersed because water is easily available.

3.2. DATA USED

Data was collected from various data custodians, which included governmental institutions for most of the vector files, Strydom and Associates Land Surveyors for flight-lines and captured images over the study area. This company was contracted to do the surveying and flying over the study area. The Shuttle Radar Topography Mission (SRTM) raster files used were also acquired from the USGS. All the collected data are mentioned below with further discussion to their relevance in this research.

3.2.1. FRCR (Study Area)

The study area of FRCR is composed of the National Park and the Conservancy area. These two layers were combined to calculate the complete study area of the FRCR. These were the: GFRC_natpark and the GFRC_park layers. These layers are important because when combined, they form this research's study area. They were overlaid onto each other and the outer extent was captured based on their edges as the study area, which has an area of 11676 km^2.

3.2.1.1. Environmental data

FRCR Vegetation

Collected from the ministry of agriculture, water and forestry, this dataset covered the whole of Namibia. This was therefore clipped to the study area boundary. Vegetation data is relevant in this research as it is used in the analysis of wildlife distribution and patterns based on it.

This was used to give a clear indication or assumption of which type of vegetation is preferred by which type of animal species and thus resulting in the specific distributions. This was also used in the extrapolation methods for estimating wildlife population not captured or counted in areas not covered by the images.

Digital Elevation Model (DEM)

The National Aeronautics and Space Administration (NASA) Shuttle Radar Topography Mission (SRTM) provided digital elevation datasets for over 80% of the earth's surface. This data can be acquired through downloading from the United States Geological Survey (USGS) website free of charge. The data is available as 3 arc second DEM with a resolution of approximately 90m. There is a 1 arc second data product that was produced and has since been available since 2014. SRTM data that is currently being distributed by NASA/USGS are finished data that does not contain holes where water or heavy shadow prevented quantification of the terrains elevation. These no data holes are generally small, but make the data less useful especially in the field of hydrological modelling (Jarvis et al, 2002).

This data was important as it enabled one to provide information about the terrain and elevation of the study area. The DEM was used to generate slope, aspect and hillshade maps that are ideal for surface or terrain analysis which could also have an effect of wildlife distribution and numbers within the study area (see section 3.3.4 & 3.3.5).

3.2.2. Flight lines/Footprint

These are the different lines flown by the survey plane over the study area. The flight lines were delivered in .gpx data format which had to be converted to vector line shapefile data format. In total there were 19 flight lines. Images were captured along these 19 flight lines and it was on these images that wildlife was counted. The captured images had a high spatial resolution of between 4-7 cm, and were in .tif RGB format. The difference in the images spatial resolutions was caused by the flying elevation balance of the plane as well as the terrain elevation difference of the study area.

A polygon footprint was derived from these images. The footprint is a polygon representing the total area covered by the captured images from all 19 flight-lines. The total area captured in this survey was 3827km^2 which accounts for 33 percentage of the reserve.

3.2.3. Counted wildlife

A total of 2120 animals were counted, via visual interpretation, on the images from all 19 flight-lines as shown in Table 1 below. This process was done by someone else and did not fall within the scope of this research.

Table 1: The total number of wildlife species counted in the captured images over the study area.

Specie	Counted
Hartebeest	32
Rhino	3
Ostrich	113
Oryx	388
Kudu	185
Klipspringers	1
Jackals	1
Wildebeest	13
Zebra	605
Springbok	573
Baboon	44
Unknown	162
Total	2120

The unknown row in Table 1 represents animals visible and counted from the images but it was hard to determine exactly to which specie that animal belongs.

Zebra, Kudu, Springbok and Oryx where recorded to have the highest densities within the FRCR. These species are thus most likely to place greatest stress on the environment. We have selected to focus on these 4 species for the remainder of this study.

3.3. DATA ANALYSIS

As mentioned in section 3.1 the analysis will focus on four target species. The analysis outlined below was conducted on only these species.

3.3.1. Vegetation coverage

There are 4 different vegetation types that cover the study area, but we needed to determine the total vegetation area covered by the captured image footprints, and in turn determine the total area per vegetation type that wasn't covered by the footprint. This method is relevant when we refine the extrapolation techniques to take into account animal habitat preferences, such as their selection of the different vegetation types.

The total area for each vegetation was calculated within the study area, from this the vegetation that fell within the different flight line footprints were extracted and the area per vegetation type calculated, and the difference between the total and footprint area provided the vegetation area's not covered within the footprints.

3.3.2. Wildlife over vegetation

An analysis was made to determine the number of wildlife species present or counted in each vegetation type. Queries were conducted to show the number of wildlife species that were counted within each vegetation type. This provided input to enable us to determine species preference for the different vegetation types, and from which to extrapolate our wildlife estimates based on vegetation preference.

3.3.3. Terrain analysis

Slope analysis

Slopes within the study area need to be analysed with the purpose of finding out which areas within the study area have slopes and the degrees of these slopes. This process was done in ArcGIS using tools under terrain analysis.

For this research, the analysis was made so that areas with the highest and most steep slopes were displayed in a red colour, while areas with the least slopes (flat areas) were displayed in a green colour. The slope categories were broken down into 7 classes, with the first 6 classes being in intervals of 10 degrees, while the last class in an interval of 15.

Aspect analysis

An aspect map displays terrain aspects with a colourful representation of slope directions. The aspect map in figure 5 was created in such a way that the slopes facing the northward (315-45 degrees) direction were displayed in a green colour, slopes facing the eastwards (45-135 degrees) direction were displayed in a blue colour, slopes facing the southward (135-225 degrees) direction were displayed in a yellow colour, and slopes facing the westwards (255-315 degrees) direction were displayed in a red colour.

3.3.4. Point density analysis

The general density distribution maps of the four selected wildlife species and all wildlife species together were generated using the point density estimation tool in arcMap. Output cell size for each analysis was made to be 500m, while the kernel size was set to radius 3km.

The tool shades and give a dark colour in areas were point are clustered or closer to each other and a lighter colour to areas where furthest from each other, meaning in areas were a lot on animals were counted would have a dark colour, and areas were few animals were counted would have lighter colours.

3.3.5. Population estimates

A cross multiplication extrapolation method was used to extrapolate and determine specie population estimates. First a generic method was determined to estimate wildlife numbers without putting into consideration other environmental parameters such as vegetation. This was done based on the area covered by the footprint (a) and the number of wildlife counted (b) over that footprint, the area not covered by the footprint (c), and the number of wildlife over the area not covered by the footprint(d), using the following formula: $(a / b) \times (c / d)$ = Total estimated population.

This same formula was then used for further calculations including the vegetation and slope parameters.

4.RESULTS

4.1. VEGETATION

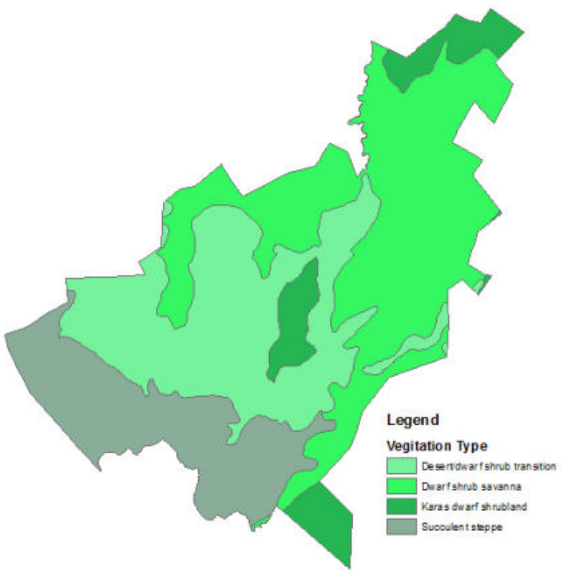
4.1.1. Vegetation coverage

There are 4 different type of vegetation classified within the study area, namely: Succulent steppe, Karas dwarf shrubland, dwarf shrub savannah, Desert/dwarf shrub transition, see table 2 and figure 2 below.

Table 2: Breakdown of area covered by the different vegetation types within the FRCR. The areas are broken down into those that fell within the survey footprint and those outside of this area.

	Total over FRCR	Area over footprint	Area not captured
Desert/ dwarf shrub transition	3635.9 km^2 (100%)	1430.98 km^2 (39%)	2204.99 km^2 (61%)
Dwarf shrub savannah	4698 km^2 (100%)	1329.11 km^2 (28%)	3368.92 km^2 (72%)
Karas dwarf shrubland	1012.2 km^2 (100%)	319.08 km^2 (32%)	693.153 km^2 (68%)
Succulent steppe	2330.1 km^2 (100%)	747.73 km^2 (32%)	1582.37 km^2 (68%)
Total areas	11676 km^2 (100%)	3827km^2 (33%)	7849km^2 (67%)

Study Area Vegetation



Source: Own compilation

Figure 2: This is a vegetation map showing the different vegetation types covering the entire study area.

4.1.2. Wildlife over vegetation

The wildlife and vegetation map shown in figure 3, as well as table 3 above shows that the dominant vegetation type that is favourable to all the 4 wildlife species is that of the dwarf shrub savannah, with 1131 wildlife animals of the 4 species counted in it, followed closely by karas dwarf shrublands and the desert/dwarf shrub transition. Zebra were the only animals identified within the succulent steppe vegetation class.

Wildlife over Vegetation

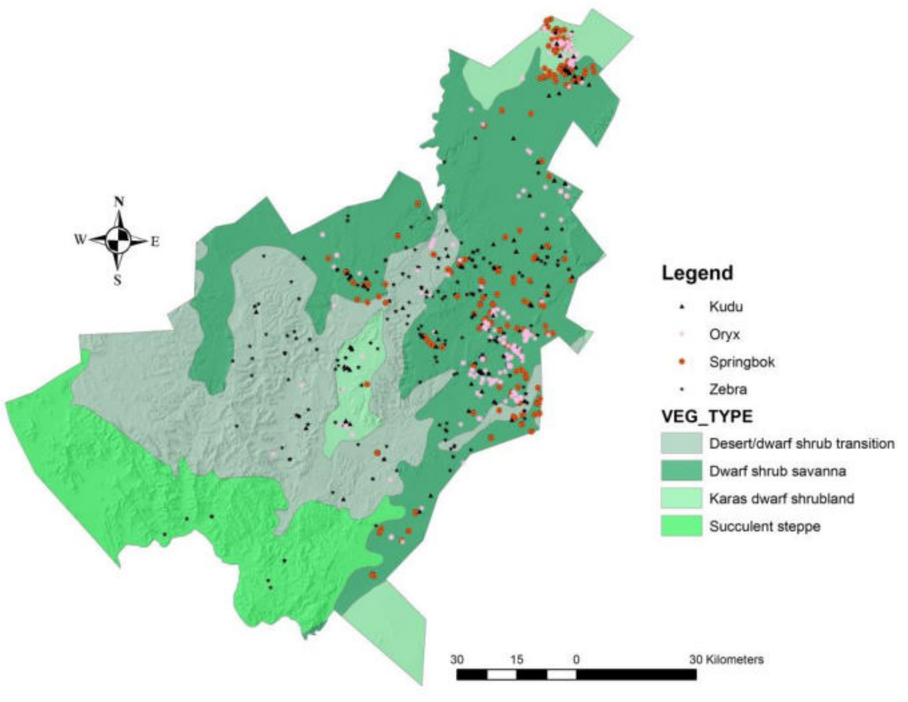


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Figure 3: A map showing wildlife location based on the vegetation type in that area. An additional hillshade map is made the base layer of this map.

Table 3: Vegetation type and the number of wildlife counted over that specific vegetation.

	Desert/ dwarf shrub transition	Dwarf shrub savannah	Karas dwarf shrubland	Succulent steppe
Zebra	189	350	42	24
Springbok	62	392	119	0
Kudu	21	131	33	0
Oryx	24	258	106	0
Total wildlife	296	1131	300	24

In addition to determining the animal preferences for vegetation, we also determined the terrain type, that the different vegetation classes where primarily found on. A hillshade layer was placed under the vegetation layer to analyse vegetation on terrain. And the result shows that the Succulent steppe and desert/dwarf shrub transition vegetation types were located over the mountainous areas, whereas the dwarf shrub savannah and the karas dwarf shrubland are found on relatively flat surfaced areas.

4.2. TERRAIN

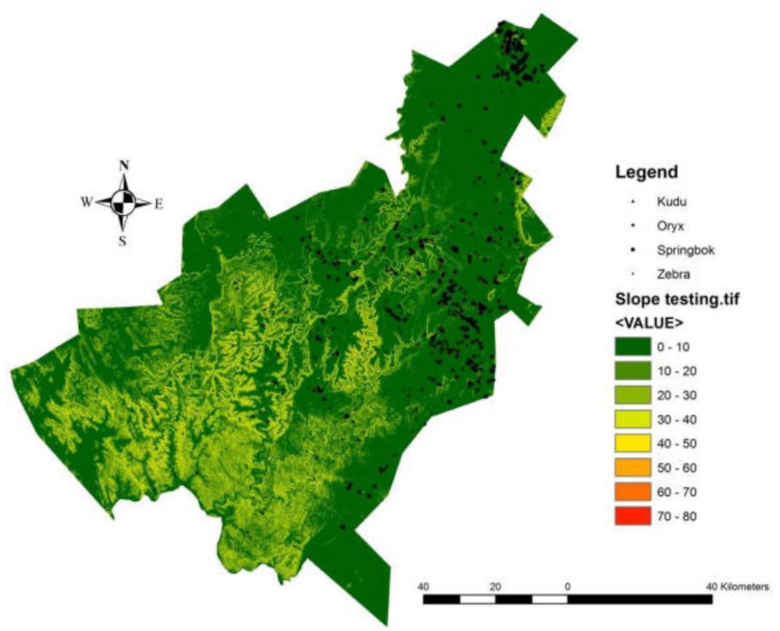
4.2.1. Slope map

The flat areas are situated north eastern and east sides of the study area and this where most of the wildlife was recorded.

The figure 4 below shows that there are differences in elevation within the study area which starts from 0 to 75 degrees.

The green areas are those areas with the least slope differences from 0 degrees to around 20 degrees slope differences, while the orange to red areas are the areas with the highest slope differences, of about 40 degrees to 75 degrees but these areas are relatively few. Most of the sloppy areas within the study area fall within the range slope differences of 20 degrees to 40 degrees, which is displayed with green yellow to yellow colours, and that's why the maps looks yellowy.

Slope



Source: Own compilation

Figure 4: A slope map showing the breakdown of slopes into different classes.

In table 4, we are showing the number of animals per slope class. As can be seen most of the animals that were counted are found in the slopes between 0 and 10 degrees, followed by the slopes between 10 to 20 degree, and a small number counted in slopes between 20 to 40 degrees

Table 4: The number of wildlife species counted over different slopes in the study area.

	0-10	10-20	20-30	30-40	40-50	50-60	60-75
Zebra	518	82	3	2	0	0	0
Springbok	566	6	0	0	0	0	0
Kudu	183	2	0	0	0	0	0
Oryx	382	6	0	0	0	0	0
Total wildlife	1648	96	3	2	0	0	0

4.2.2. Aspect map

Figure 5 bellow shows wildlife aspect results over the slope, after analysing the results it became evident that the slope aspect direction that most of the counted wildlife species were found in is the one facing westwards. The results of the direction of the slopes the different wildlife were counted in are presented in table 5 below, as well as the total number of wildlife counted in that slope direction is presented below.

Aspect

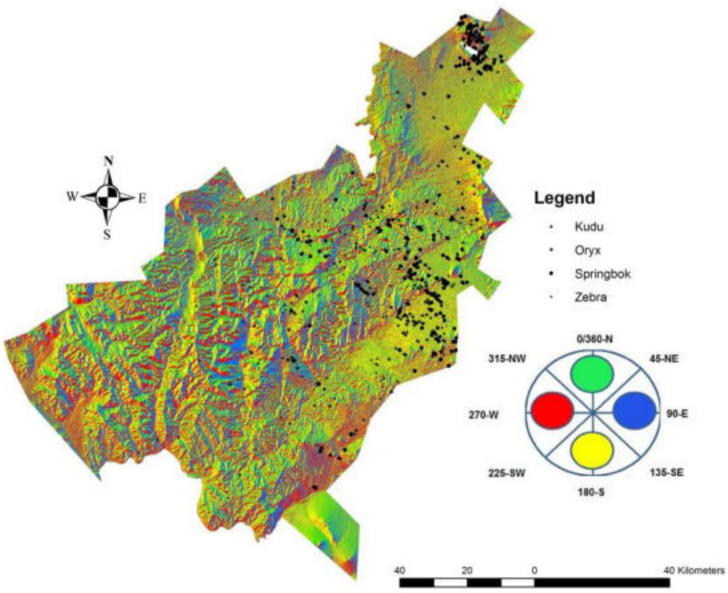


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Figure 5: An aspect map showing the different directions faced by the slopes within the study are. The 4 different directions are represented by the different colours.

The flat area/ no direction field in table 5 below represent the number of wildlife counted in an area that is totally flat. The application found it hard to figure out the direction the slope was facing in which the animal was found in.

Table 5: The number of wildlife counted based on the direction (aspect) of the slope they were found or counted in.

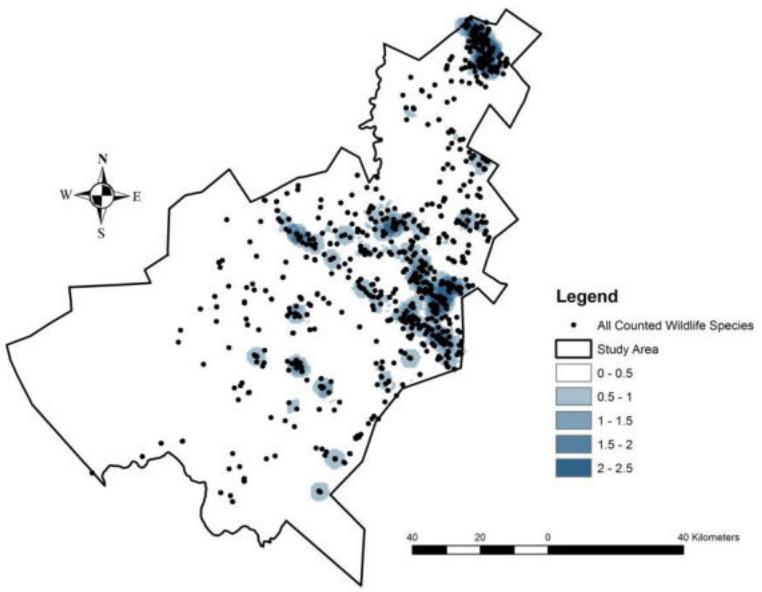
	Northward direction	Eastward direction	Southward direction	Westward direction	Flat area/ no direction
All	449	396	517	718	50
Zebra	131	122	124	222	6
Kudu	36	31	43	69	6
Oryx	72	64	110	136	6
Springbok	135	85	153	180	20

4.3. POINT DENSITY DISTRIBUTION ESTIMATE

The distribution analysis shows that the wildlife species do tend to cluster. For the 4 species and all the combined wildlife, the clusters are concentrated mostly on the central to the north eastern parts of the reserve, see figure 6-10.

Figure 6 below is showing point data density distribution map for all wildlife over the area combined. The map shows that there is a presence of wildlife over much areas of the reserve except in the south west. Although wildlife is present almost over the whole reserve, clustering of wildlife is happening mostly on the north eastern part of the reserve, and on the east with clustering also occurring in the central part of the reserve.

All Wildlife Density Distribution

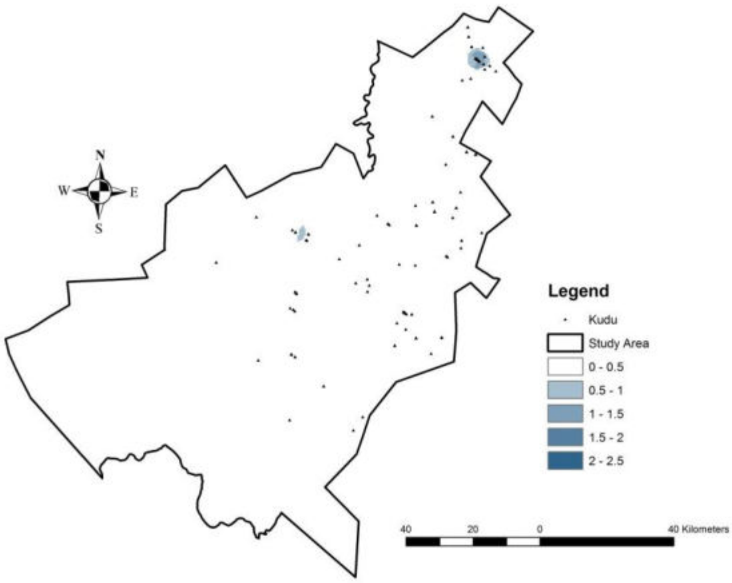


Source: Own compilation

Figure 6: A distribution map of the density of all the wildlife species counted within the study area.

Figure 7 below shows that kudus cluster on the north eastern side of the reserve. Although the kudu points are distributed almost around the whole north eastern area going down to the central part of the reserve, high clustering only occur at one specific area in the north eastern part of the reserve.

Kudu Distribution Density

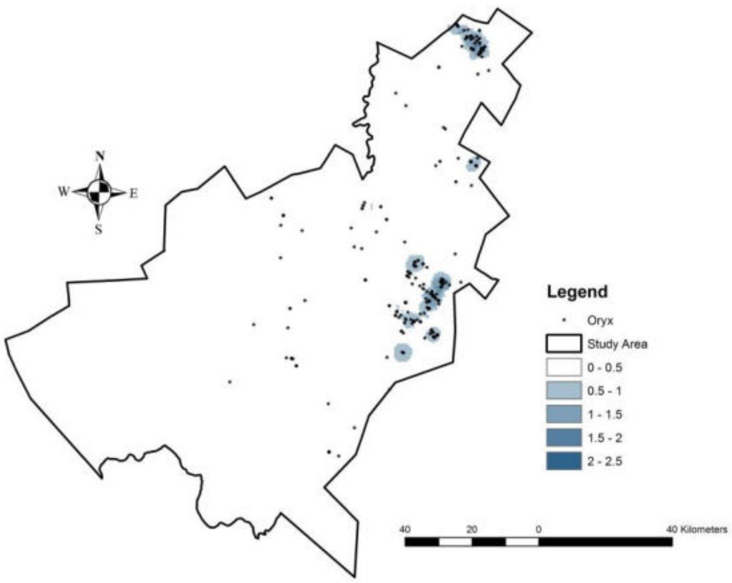


Source: Own compilation

Figure 7: A distribution map of the density of kudus within the study area.

Figure 8 and figure 9 below shows that Oryx and springboks have a high clustering on the north eastern parts of the reserve where they are found in large numbers. High numbers of Oryx and springboks can also be found in high numbers on the eastern part of the reserve where clusters are also observed, less so in the case of springboks compared to that of oryx. The distribution of springboks is more or less similar to that of Oryx's.

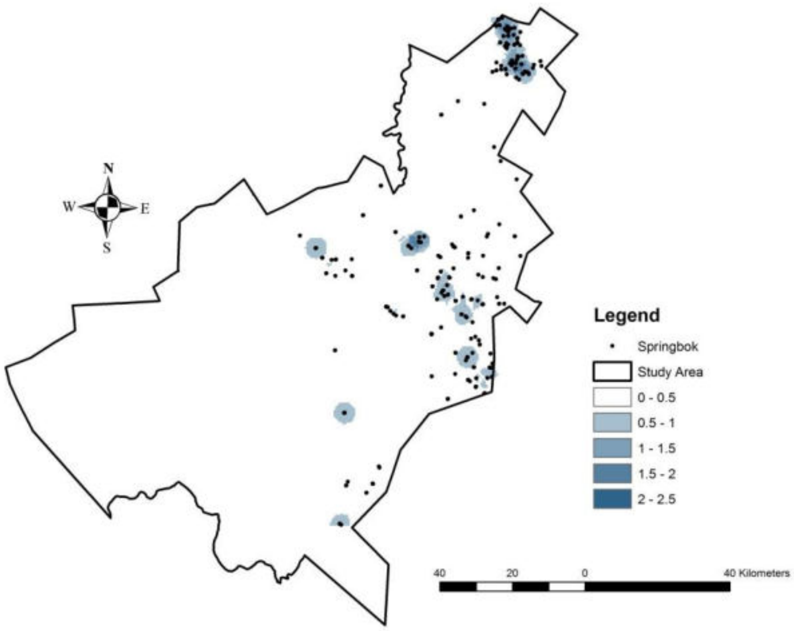
Oryx Distribution Density



Source: Own compilation

Figure 8: A distribution map of the density of Oryx's within the study area.

Springbok Distribution Density

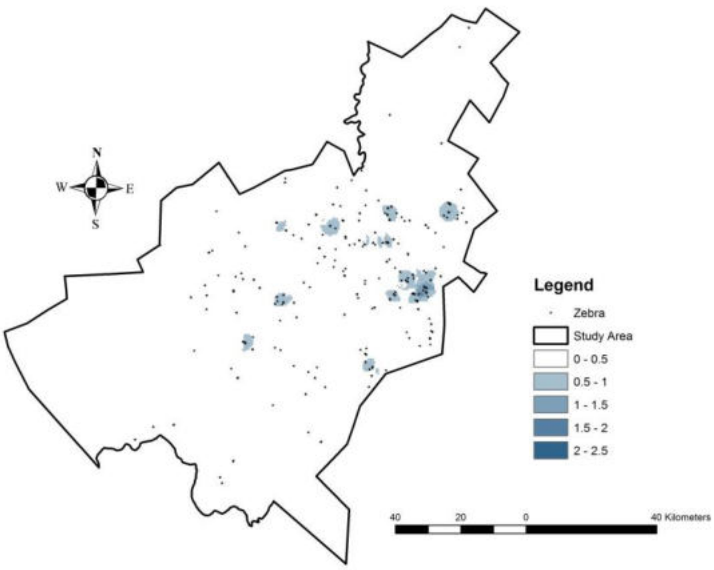


Source: Own compilation

Figure 9: A distribution map of the density of springboks within the study area.

Figure 10 shows that, unlike the rest of the animals zebras are clustered more in the central parts of the reserve and not in the north east, and they are present almost around the whole reserve, even on the south western side were the other 3 species were not found.

Zebra Distribution Density



Source: Own compilation

Figure 10: A distribution map of the density of zebras within the study area.

4.4. SPECIES POPULATION ESTIMATE

4.4.1. Generic extrapolation method

Table 6: The generic estimation uses to make the first assumption of population numbers over the study area.

	No within footprint area	Estimate outside area	Total estimate
All	2201 in 33%	? * 67%	4469
Zebra	605 in 33%	? * 67%	1228
Kudu	185 in 33%	? * 67%	376
Oryx	388 in 33%	? * 67%	788
Springbok	573 in 33%	? * 67%	1163

After the generic estimation of wildlife numbers in table 6 was done and figures were acquired, and the results show that there are more than 4000 animals estimated to be present in the fish river canyon, and from the 4 selected species zebras are estimated to have the most majority in the area, while kudus are the least estimated. Other extrapolation methods were to be made, these methods would be based on habitat selectivity. The generic extrapolation result would tend to be less than those results of when habitat selectivity would be considered.

4.4.2. Vegetation extrapolation method

Table 7: Zebra population estimate using the vegetation extrapolation method.

Vegetation Type	Covered area + Zebra counted	Uncovered area	Zebra estimate	Total Zebra estimates
Desert/ dwarf shrub transition	1430.98 km^2 = 189	2204.99 km^2 = ?	291	480
Dwarf shrub savannah	1329.11 km^2 = 350	3368.92 km^2 = ?	887	1237
Karas dwarf shrubland	319.08 km^2 = 42	693.153 km^2 = ?	91	133
Succulent steppe	747.73 km^2 = 24	1582.37 km^2 = ?	51	75
Total Zebra				1925

Figures in table 7 show that there are 1925 Zebra's estimated within the reserve based on vegetation. The estimated number using this method is more compared to the one using the generic method which was 1228. Most of these Zebras are found within the "Dwarf shrub savannah" vegetation type, although a number can also be found in the "Desert/ dwarf shrub transition" and "Karas dwarf shrubland" vegetation type. Zebras are also found within the "Succulent steppe" vegetation type, which is unique to that specific species because other animal species in question are not found in that type of vegetation.

Table 8: Springbok population estimate using the vegetation extrapolation method.

Vegetation Type	Covered area + Springbok counted	Uncovered area	Springbok estimate	Total Springbok estimates
Desert/ dwarf shrub transition	1430.98 km^2 = 62	2204.99 km^2 = ?	96	158
Dwarf shrub savannah	1329.11 km^2 = 392	3368.92 km^2 = ?	994	1386
Karas dwarf shrubland	319.08 km^2 = 119	693.153 km^2 = ?	259	378
Succulent steppe	747.73 km^2 = 0	1582.37 km^2 = ?	0	0
Total Springbok				1922

Table 8 shows a total of 1922 Springboks are estimated to be present within the FRCR based on vegetation, which is more compared to the 1163 estimates generated from the generic estimation method, as shown by table 6, like Zebra's, the vegetation type that dominates by catering for this specie the most is "Dwarf shrub savannah".

Springboks are also found in the other vegetation types, but in smaller quantities when compared to the dwarf shrub savannah vegetation type, and have zero presence In the Succulent steppe vegetation type.

Table 9: Kudu population estimate using the vegetation extrapolation method.

Vegetation Type	Covered area + Kudu counted	Uncovered area	Kudu estimate	Total Kudu estimate
Desert/ dwarf shrub transition	1430.98 km^2 = 21	2204.99 km^2 = ?	32	53
Dwarf shrub savannah	1329.11 km^2 = 131	3368.92 km^2 = ?	332	463
Karas dwarf shrubland	319.08 km^2 = 33	693.153 km^2 = ?	72	105
Succulent steppe	747.73 km^2 = 0	1582.37 km^2 = ?	0	0
Total Kudu				621

Table 9 shows that Kudu's are the least of the 4 selected animal species within the reserve according to the vegetation extrapolation method. They were still the least estimated when using the generic extrapolation method with a total estimate of 376 kudus only. Their number is now estimated to be 621 when extrapolating using vegetation cover, with most of them being found and estimated to be in the dwarf shrub savannah vegetation type, and non over the succulent steppe vegetation type.

Table 10: Oryx population estimate using the vegetation extrapolation method.

Vegetation Type	Covered area + Oryx counted	Uncovered area	Oryx estimate	Total Oryx estimates
Desert/ dwarf shrub transition	1430.98 km^2 = 24	2204.99 km^2 = ?	37	61
Dwarf shrub savannah	1329.11 km^2 = 258	3368.92 km^2 = ?	654	912
Karas dwarf shrubland	319.08 km^2 = 106	693.153 km^2 = ?	230	336
Succulent steppe	747.73 km^2 = 0	1582.37 km^2 = ?	0	0
Total Oryx				1309

Of the 4 species of interest, Oryx's are the second least counted animals within the reserve as shown by table 10, with an estimated number of 1309, this number is also more compared to the number (788) estimated when the generic method was used. Like the rest of the species, Oryx's are found mostly in the dwarf shrub savannah vegetation type, and are not found in the succulent steppe vegetation type.

4.4.3. Slope extrapolation method

Analysis were made to see the area in km^2 coved by each slope class within the study area, in both the areas covered by the captured footprint and the area that was not covered by the footprint. Table 11 below shows the slope classifications, the area and its percentage covered over the study area, the area covered by the footprint, as well as the area not captured by the footprint. Area percentage figures in these fields are further going to be used to make slope extrapolation estimates for wildlife species population over the slope classes in areas not covered.

Table 11: Slopes area percentages over the study area.

	Total study area	Footprint area	Area not covered
1-10	7686.15 - 100%	2318.41 – 30%	5367.74 – 70%
10-20	1928.01 – 100%	694.15 – 36%	1233.86 – 64%
20-30	1408.19 – 100%	549.17 – 39%	859.02 – 61%
30-40	554.32 – 100%	221.98 – 40%	332.35 – 60%
40-50	90.42 – 100%	37.26 – 41%	53.15 – 59%
50-60	14.63 – 100%	5.86 – 40%	8.76 – 60%
60-70	2.74 – 100%	0.99 – 36%	1.75 – 64%
70-80	0.29 – 100%	0.09 – 32%	0.20 – 68%

Table 12 below shows that there are a total of 1969 zebras estimated to be present in the reserve based on the extrapolation of slopes. Most of these zebras are in slopes ranging from 0 to 10 degrees, followed by the slope between 10 and 20 degrees. Few zebras (14 in total) are estimated to be present in the slopes between 20 and 40 degrees.

Table 12: Zebra population number estimate based on the slope extrapolation method.

	Footprint	Not covered	Total
1-10	30% - 518	70% - 1209	1727
10-20	36% - 82	64% - 146	228
20-30	39% - 3	61% - 7	9
30-40	40% - 2	60% - 3	5
Total Zebras			1969

Springboks are the second of the 4 selected species to be estimated the most using this method, with a total estimate number 1906. 1890 of that total number is estimated to be in slopes between 0 and 10 degrees, while a small number is estimated to be present in slopes between 10 and 20 degrees as shown by table 13 bellow.

Table 13: Springboks population number estimate based on the slope extrapolation method.

	Footprint	Not covered	Total
1-10	30% - 567	70% - 1323	1890
10-20	36% - 6	64% - 11	17
Total Springboks			1907

Table 14 shows that kudus have the smallest numbers within the reserve. With an estimated population of just over 600, kudus are also mostly just found in relatively flat areas with degrees between 0 and 10. 6 other kudus are estimated to be present in slope areas between 10 and 20 degrees.

Table 14: Kudu population's number estimate based on the slope extrapolation method.

	Footprint	Not covered	Total
1-10	30% - 183	70% - 427	610
10-20	36% - 2	64% - 4	6
Total Kudus			616

Oryx are the third of the 4 selected species to be estimated with the most numbers in the reserve using this method, with a total estimated number of 1290. 1273 of that total number is estimated to be in slopes between 0 and 10 degrees, while a small numbers of just 17 Oryx are estimated to be present in slopes between 10 and 20 degrees as shown by table 15 bellow.

Table 15: Oryx population number estimate based on the slope extrapolation method.

	Footprint	Not covered	Total
1-10	30% - 382	70% - 891	1273
10-20	36% - 6	64% - 11	17
Total Oryx			1290

5. DISCUSSIONS

5.1. DISTRIBUTION

Reasons for the distribution patterns illustrated in figures 6-10 to appear as they appear can be attributed to the terrain and vegetation characteristics. Animals tend to be in areas where they feel comfortable and where their favourite vegetation is. The dwarf shrub savannah and the karas dwarf shrubland vegetation type that is favourable to most wildlife does not grow in areas with high slopes, they grow in close to flat or in low-laying areas.

As the results shown in figure 3 and table 3, most animals are located and distributed in the flatter parts of the study area which is between 0 to 20 degrees, and this is where their favourite vegetation types grow, this could also be that because of the flatness of that area, wildlife would be easier to pick out and count in those specific areas as compared to areas with slopes, or maybe different vegetation may be easier to spot wildlife compared to other areas as mention by (Gould, 2000), although I say flatter area, the surface is not completely flat as there is differences in slope of between 0 to 20 meters as shown by the slope map in figure 4, but it is considered a flat area compared to the slope of 75 meters.

Zebras are the most estimated wildlife species of the 4 selected species within the study are, zebras are also the only wildlife species of the 4 selected species that is present in all vegetation types covering the study area. The succulent steppe vegetation type that zebras were the only species counted over it grows over very mountainous surfaces that are relatively sloppy. It was mentioned by (Brown, 2006) that there are 2 different type of zebra species within the reserve, and although it is not possible to discriminate the different zebra species when counting the animals from the images, it was through spatial analysis that allowed me to make possible judgements as to which may be the two possible species based on habitat selectivity, which left me with the assumption that these zebras counted over this mountainous succulent steppe vegetation type can only be the Hartmann's mountain Zebras that prefers sloppy terrains, and the zebras counted over the flatter surfaces are the other zebra type called Burchell's Zebra.

Springboks are the second largest estimated specie within the reserve, they are a lot because the vegetation is perhaps good for them and the habitat might be suitable for a higher survival of their offspring's. They are more frequent and prefer the flatter surfaces of the reserve where they are clustered and do not prefer mountainous areas at all as compared to Zebras. Like all the animals, they prefer the dwarf shrub savannah and the karas dwarf shrubland vegetation type. Springbok's have the highest clustering of the 4, reasons for this clustering may be because they love being in herds and they love crowds, so large numbers of springboks were probably counted at the same location at a time.

Ideally kudus prefer densely vegetated areas as "tree density is the most critical parameter governing their choice of habitat" (Furstenburg, 2010). Of all vegetation types within the study area, dwarf shrub savannah and the karas dwarf shrubland is the most dense of all vegetation types. Which makes it ideal for Kudu's to be found mostly in these 2 vegetation types. Kudus were the least in numbers of the 4 species to be counted and estimated within the study area, with its estimated number being just over 600. Kudus are lone animals that don't prefer being in herds, and thus that explains the distribution patterns in figure 7, although the map appears to have a lot of points, these points are scattered and not a lot of them are in the same place. Clustering of kudu points occur only at a small area.

5.2. WILDLIFE POPULATION ESTIMATES

Table 16: A comparison between figures generated during the different wildlife population extrapolation estimation methods.

	Generic estimate	Vegetation based	Slope based
Zebra's	1228	1925	1969
Springbok's	1163	1922	1907
Kudu's	376	621	616
Oryx	788	1309	1290

Table 15 show the different population figures or results generated from using the different extrapolation methods. As one can tell from the results estimates made using the vegetation extrapolation method are more compared to the rest of the methods except in the case of zebra estimation of which the figure is more on the slope based method. The generic method contains the least estimated figures.

Although these findings and results need to be treated in an assumption context, the result acquired from the vegetation extrapolation method was considered as more accurate when compared to the rest of the two methods. This is because when the results are compared to a (Gondwana-Canyon-Park, 2013) poster results, the vegetation extrapolation method makes more sense. This poster shows wildlife estimates within the reserve starting 2003 to 2013 based on different survey. Since the data for this research the surveying was done in the end of 2015, there is only the 2014 year that passed in between, and after a careful analysis of the result it came to the decision that the vegetation extrapolation results are more accurate.

They are more accurate compared to the other methods because they have the largest figures. Total accuracy is an issue on its own here because possibilities that there has been undercounting in different vegetation and terrain due to animals being more difficult to spot are high. The other methods generated figures that are too little to be possible as the population over the study are.

The counting and extrapolation methods were really effective because it produced results close to the expected figures, these figures being in comparison with the poster mentioned above. The generic method is generic, and does not take into account any additional parameters to make its estimation, apart from the area covered and the area not covered, meaning results generated from this method would be the furthest from the accurate results.

The slope extrapolation result can also be considered correct to a certain point when compared to the results from the vegetation method. The issues are just because the figures or numbers are small.

6.CONCLUSION

Wildlife population numbers generated in this paper are estimates, and should be treated as assumptions, but these assumptions are very close to what could be the real population figures within the reserve, thus these results can be considered accurate to a certain point. The true population numbers can be more or can be less than the estimated figures (with a very small margin), if perhaps more factors were put into consideration, but the results will be more or less similar to the figures acquired in this research.

The vegetation extrapolation population estimate method being investigated in this paper proved itself worthy for future use in areas with similar characteristics in regards to terrains or other conditions that makes the area inhospitable. It can also be used for further determining population numbers for the other wildlife species within this reserve. It is a simple method, not at all complex, but the tasks or duties it does are very powerful tasks that are relevant in the field of nature conservation and management.

The method is not intensive when it comes to labour requirements as it does not need a large group of people to count or work on generating the wildlife population numbers within an area, but mostly in the comfort of one’s office. Fieldwork is limited in this case and is only done once at the beginning when the surveying/flaying of the areas is made. It is also an ideal method when limited resources are available such as money.

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