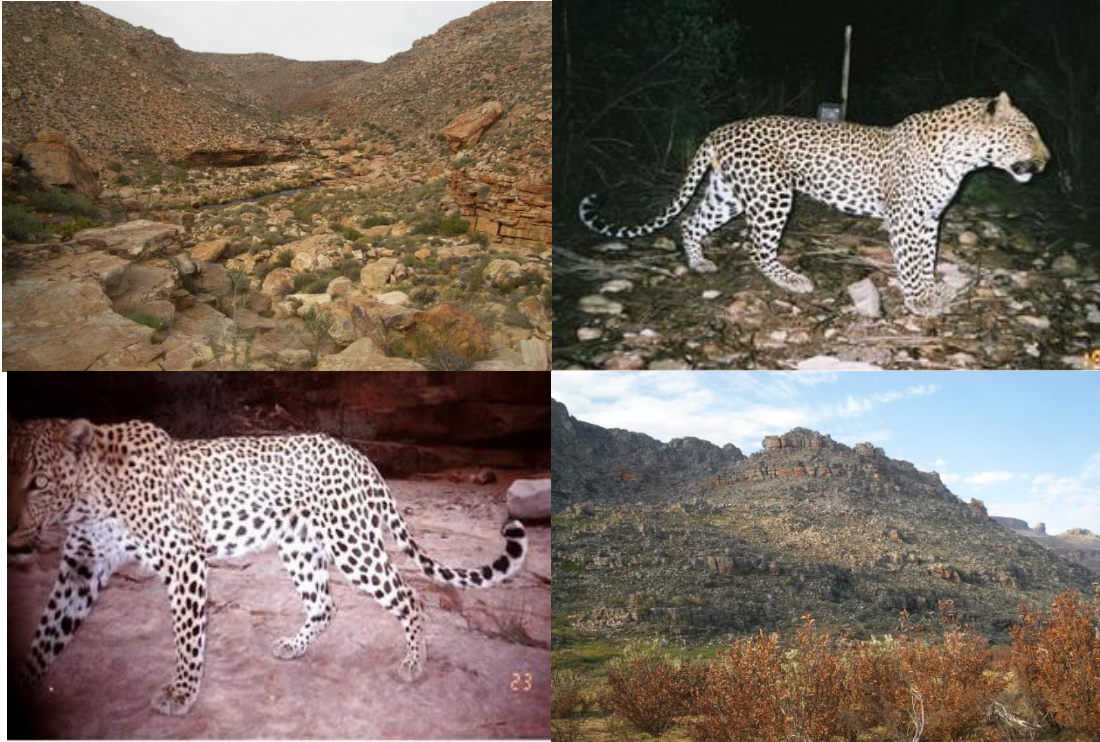


# A SPATIO-TEMPORAL ANALYSIS OF THE HABITAT USE OF LEOPARDS (*Panthera pardus*) IN THE KAROO BIOME OF THE CEDERBERG MOUNTAINS, SOUTH AFRICA



top left: Matjiesrivier, bottom right: Cederberg mountains (author)  
top right: Johan (M1), bottom left: Skinny (F6) (Cape Leopard Trust)

Lindsay Patterson (pttlin004@uct.ac.za)<sup>1</sup>

Mike Meadows (mikemeadows@uct.ac.za)<sup>1</sup>

Tali Hoffman (hfftal001@uct.ac.za)<sup>1</sup>

Quinton Martins (quinton@capeleopard.org.za)<sup>2</sup>

---

<sup>1</sup> University of Cape Town, Private Bag, Rondebosch 7701, South Africa

<sup>2</sup> The Cape Leopard Trust, South Africa;

# TABLE OF CONTENTS

TABLE OF CONTENTS .....	2
ABSTRACT.....	3
1.INTRODUCTION .....	4
1.1 Cederberg leopards .....	4
2. METHODS .....	7
2.1 Study Area .....	7
2.2 Study Animals.....	7
2.3 Data Collection .....	7
2.4 Data Analysis .....	8
2.4.1 Home Ranges .....	8
2.4.2 Area use .....	9
2.4.3 Seasonal area use .....	9
2.4.4 Habitat.....	10
2.4.5 Movement patterns.....	11
2.4.6 Water sources.....	12
2.4.7 Elevation .....	12
2.4.8 Remotely Sensed Data .....	12
3. RESULTS .....	13
3.1 Selective Habitat Use.....	14
3.1.1 Johan .....	15
3.1.2 Skinny .....	15
3.2 Area use and selection .....	15
3.2.2 Skinny .....	16
3.2.3 Johan vs. Skinny .....	18
4. DISCUSSION .....	21
4.1 Cederberg leopards .....	22
4.1.1 Johan versus males in other studies .....	22
4.1.2 Skinny vs. females in other studies.....	22
4.1.3 Skinny vs. Johan .....	23
4.2 Cederberg leopards vs. leopards elsewhere .....	23
4.2.1 Home range sizes .....	23
4.2.2 Habitat Use.....	24
4.2.3 Movement patterns.....	24
4.3 Implications for Management .....	25
4.4 Further Research and limitations of this study .....	26
ACKNOWLEDGEMENTS .....	27
REFERENCES: .....	27
APPENDIX.....	31

# A spatio-temporal analysis of the habitat use of leopards (*Panthera pardus*) in the Karoo Biome of the Cederberg Mountains, South Africa

LINDSAY PATTERSON, MIKE MEADOWS, TALI HOFFMAN, QUINTON MARTINS

## ABSTRACT

Leopards have the most wide ranging distribution of all wild felids, yet are amongst the most elusive. There is limited understanding of leopard spatial ecology in the Western Cape - an area rife with human-leopard conflict. This study examined GPS data collected from February 2006 to February 2008 to describe the home ranges and movement patterns of one male and one female Cape leopard (*Panthera pardus*) in the Karoo Biome of the Cederberg Mountains, South Africa. The leopards home ranges, ranging patterns and area usage were related to influences of habitat, altitude, distance from permanent water sources and seasonality. The home range sizes were larger than those of most leopards studied elsewhere. Neither sex exhibited exclusive habitat usage, with the females range being entirely contained within the males range. There were significant differences in daily travel distances between the male and female, and between summer and winter seasons for the female and winter seasons for both sexes. The areas utilised most frequently within the male and female home ranges comprised of Swartruggens Quartzite Fynbos and Swartruggens Quartzite Karoo. The large home range sizes in relation to the low population density of the Cederberg leopards implies the requirement of large areas of available and connected habitat to ensure the survival of the small leopard population in the area.

**Keywords:** *Panthera pardus*, spatial ecology, home ranges, movement patterns, seasonal range use

# 1.INTRODUCTION

Spatial ecological research and understanding has become fundamental to the management and conservation of large carnivores (Marker and Dickman, 2005). Quantifying spatial movements and ranges allows for the examination of factors - both current and historical - that impact on the range sizes and densities of species (Odden and Wegge, 2005). Large felids are found in low densities throughout sub-Saharan Africa and are under threat due to habitat loss (Jackson, 1996; Simcharoen *et al.*, 2008). Their effective conservation requires the development and implementation of practical conservation management strategies. These strategies are necessary in particular for leopards (*Panthera pardus*) within protected areas (Bailey, 1993; Marker and Dickman, 2005) as well as those with ranges outside conservancies, where it is estimated that over 80% of leopards potential range exists (Marker and Dickman, 2005).

Much of the leopard research carried out thus far has been conducted in sub-Saharan Africa (Grassman, 1999). Over 40 countries in Africa are inhabited by leopards and within South Africa studies have been conducted in the Kruger, the Kalahari, Londolozi, Stellenbosch and the Cederberg (Marker and Dickman, 2005). Leopards have a far reaching, worldwide distribution (Fig 2a), occupying a dynamic range of habitats that include the borders of agricultural and urban areas in close proximity to humans (Marker and Dickman, 2005) as well as natural mountain, forest and desert environments (Marker and Dickman, 2005; Gavashelishvili and Lukarevskiy, 2008). It is their ecological flexibility in the face of increasingly altered habitats, reduced prey base (Gavashelishvili and Lukarevskiy, 2008) and direct conflicts with humans (Nowell and Jackson, 1996) that has seen them become the most widespread representative of the cat family (Gavashelishvili and Lukarevskiy, 2008). To date, past-published studies of leopard spatial ecology in the Western Cape are minimal, with a large proportion of current research referring to studies conducted in the Stellenbosch area by Norton and Lawson (1985), and in the Cederberg area by Norton and Henley (1987).

## 1.1 Cederberg leopards

Leopards in the Cederberg and Western Cape mountains as a whole have and continue to be threatened by habitat loss and persecution due to farmer-predator conflict (Nowell and Jackson, 1996; Marker and Dickman, 2005). This has resulted in an urgent need for effective conservation intervention to ensure their survival (Martins and Martins, 2006). Leopards in the Cederberg are the apex predator, experiencing competition only from smaller predators such as

caracal (*Caracal caracal*) (Martins, pers. comm, 2008). Findings of a previous study have shown differences in leopards' behaviour in habitats where they have not had to compete with larger predators (Marker and Dickman, 2005), becoming much more ecologically flexible in areas where species diversity has become increasingly threatened.

Since the late 1980's private landowners and conservation groups have been working together to address and mitigate human-leopard conflict in the Cederberg (Martins, pers. comm., 2008). This collaboration has thus far resulted in the development of two conservancies in the area, the Cederberg and Biedouw Conservancies. Increasing farmland encroachment by farmers who consider leopards as 'problem individuals' (Linnell *et al.*, 1999) and a threat to their livestock has resulted in a decline in leopard population numbers. The decreasing amount of non-urbanised, suitable habitat available to leopards has also contributed to lowering the leopard population, however this has occurred over a longer period of time (Norton and Henley, 1987; Skinner and Smithers, 1990; Nowell and Jackson, 1996; Linnell *et al.*, 1999; Martins and Martins, 2006).

The effectiveness of conservation efforts to manage these problems is fundamentally dependent upon an adequate understanding of the spatial requirements of leopards, in this case, in the Cederberg. In insular protected areas, as much as possible needs to be known about where leopards move and why, in order to safeguard these areas and mitigate potential conflicts that may arise in or near the areas most used by leopards (Wikramanayake *et al.*, 2004; Marker and Dickman, 2005; Gavashelishvili and Lukarevskiy, 2008).

In view of the limited knowledge on the spatial habits of the leopards in the Cederberg, focused research on the spatial ecology of a leopard population in and around the Cederberg Mountains commenced. This study is being conducted by Quinton Martins of the Cape Leopard Trust. Over the last five years Martins has made use of spoor for tracking as well as camera traps to determine the density of the leopard population in the Cederberg. He has also deployed GPS tracking collars on 12 leopards in the area to record leopard movement patterns (Martins, pers. comm., 2008). The collars are equipped with Very High Frequency (VHF), Ultra High Frequency (UHF) and data downloading capabilities to access and download the GPS points remotely from the ground and air, up to 15 km. The GPS units record the animal's location between one and six times a day and also indicate the temperature and altitude for each location. Thus the study contains a wealth of data that can be analysed using current and detailed

statistical models to explore the influence of, for example, habitat variables on the spatial ecology of leopards in the Cederberg area. Furthermore, the improvement of GIS systems, specifically for animal movement analyses, together with cutting edge image processing that can be achieved using remotely sensed data, means that the spatial information from this Cederberg study can now be analysed in greater detail and with higher levels of accuracy than has been done before.

The leopards of the Cederberg offer an opportunity for advancing an understanding of the variations in home ranges, movement patterns and landscape usage, and their influence on leopard spatial ecology within the Karoo part of the Cederberg. This information will be used to assist further research being conducted in the area.

The aim of the study is to address and develop an understanding of how the leopards in the Cederberg interact with their environment. In order to do this the study's objectives were to determine the leopards home ranges, quantify their movement patterns, determine which habitats are most utilised by the leopards, determine the significance of elevation, distance from water and habitat variables, and compare the results between sexes and leopard studies conducted elsewhere. In relation to these objectives, several key questions were raised:

- 1) Are there differences in male and female home ranges and do they vary seasonally?
- 2) Do leopards use certain habitats selectively?
- 3) How is leopard movement related to topographic factors?
- 4) What implications does an improved understanding of leopard spatial ecology mean for the management and mitigation of conflict between conservation and farming practices in the Cederberg area?

## 2. METHODS

### *2.1 Study Area*

This study is based on research conducted within the Karoo Biome of the Cederberg Mountains (CM) in the Western Cape, South Africa (32°27'S, 19°25'E) (Fig 1b). Situated approximately 200km to the north of Cape Town, the CM comprises the Cederberg Wilderness Area, the Cederberg State Forest, private farms and nature reserves, and the Matjiesrivier Nature Reserve - over 170, 000 hectares of mountainous terrain (Fig 2b). The CM falls within both the Karoo and Fynbos biomes and forms part of the Cape Floral Region. Restoration and conservation initiatives running in the Cederberg Nature Reserve are striving to re-populate and manage the high concentration of threatened flora and fauna that occur there. The region is rich in fynbos and succulent Karoo plant species, and is home to many predator and prey species including leopards, baboons, mongooses, dassies and wild cats.

### *2.2 Study Animals*

This study focuses on one male leopard, M1 (hereafter Johan) and one female leopard, F6 (hereafter Skinny) who are two of 12 leopards collared in the CM (Martins, unpubl. data, 2008). The study animals were tracked for over 10 months and found to utilise the most easterly and geographically isolated area of all the collared leopards in the CM. Furthermore, they are the only pair within the collared group to utilise land that falls predominantly in the Succulent Karoo biome, rather than in the Fynbos biome (Fig 2d). This unique area and habitat use is the reason that they were selected as the study animals for this study.

### *2.3 Data Collection*

Geographic Positioning System (GPS) tracking collars were fitted to the study animals. Johan's collar recorded data from February 2006 to June 2007. Within this time interval Johan's dataset contains a gap of four months, due to GPS collar failure from November 2006 to February 2007.

Skinny's collar recorded data from February 2007 to January 2008. Readings were set to six per day to ensure both detail in daily movement patterns, as well as long term data for home range analyses. In order to fit the collars to the animals, the leopards were trapped using capture cages with trigger plates positioned in the middle and trap release doors on either end. The captures were conducted without the use of bait but instead by placing the cages along frequently used paths (Marker and Dickman, 2005).

For Johan, GPS points were recorded on average four times daily ( $\bar{x} = 4.08$ ,  $SD = 1.52$ ,  $n = 221$  days) from February 2006 to June 2007. Johan's dataset consists of 1273 GPS points, each including values for altitude and temperature (a combination of animal and ambient) taken at the time of the recordings. For Skinny, GPS points were recorded on average three times daily ( $\bar{x} = 3.21$ ,  $SD = 1.46$ ,  $n = 353$  days) from February 2007 to January 2008. Skinny's dataset consists of 1135 data points, also including altitude and temperature values.

Variables that might influence the spatial ecology of the leopards were investigated by including climatic and landscape attribute data in the analyses. The climatic dataset - sourced from the South African Weather Services (Clanwilliam station 00846710, -32.18°S, 18.88°E, 102 m elevation) were supplied by the South African Weather Service – Climate information Office - and included temperature and rainfall data for the periods of February to November 2006 and February to December 2007 . GIS shapefiles were used for ArcView 3.3 (ESRI 2002), to identify landscape attributes in the region, namely: vegetation cover (Vegm2006.shp) (Fig 2d) and drainage systems (water\_sources\_50\_gw.shp, 2006) (Fig 2d).

## 2.4 Data Analysis

### 2.4.1 Home Ranges

GPS and landscape attribute data were analysed using GIS software ArcView 3.3 (ESRI 2002). GPS data were given in decimal degrees (D d) using Microsoft ® Excel 2003 (Microsoft, 2003). These data were imported into ArcView 3.3 (ESRI, 2002) where they were projected in the Transverse Mercator projection type, spheroid WGS84, with a central meridian of 21. Data analyses were based on Hoffman 2006. To calculate the leopards' home ranges the quadrature



method of home range analysis (e.g., Whiten *et al.* 1987, Henzi *et al.* 1992) was used. A grid with 1 km<sup>2</sup> cells was overlaid onto the datapoints using the Repeating\_shapes (repeat\_shapes.avx) extension for ArcView 3.x (Jenness 2005). The grid cell size was based on the average daily distance travelled by the female ( $\bar{x}$  = 1.1 km, SD = 1.3 km, n = 233 days) to allow an accurate assessment of daily landscape selection. Despite travelling further on the average day than the female ( $\bar{x}$  = 8.9 km, SD = 6.6 km, n = 221 days), the males home range grid cells were also set to a 1 km<sup>2</sup> area in order to make the analyses comparable. The homogenous nature of the regional habitat enabled both fine and broad scale patterns of habitat use to be identified with the selected grid cell size of 1 km<sup>2</sup>.

Cells containing one or more GPS datapoints were classed as 'entered cells'. The home range included all entered cells as well as all cells surrounded on at least three sides or completely encapsulated by entered cells. Any cells that were isolated were joined to the group of entered cells nearest them using the most direct route. The total number of cells within the home range grid was multiplied by the grid cell area to calculate total home range area.

#### 2.4.2 Area use

The overall use of the home range was analysed in terms of elevation, distance to water sources and habitat use. Statistical analyses for elevation and distance from water were conducted using non-parametric tests, due to the variables being non-normally distributed. Where a variable was normally distributed: daily distance travelled, t-tests were used to establish whether differences were statistically significant. The Mann Whitney U and T-tests were used to establish significant seasonal differences between elevations for both leopards respectively, as well as comparative seasonal and total elevation differences between the two. Similarly, the tests were used to test for significant differences in respect of the distance to water variable.

#### 2.4.3 Seasonal area use

To identify seasonal differences in area use, GPS datapoints were classified as winter (June-July 2007, n = 30 days) and summer (December-January 2007/08, n = 33 days) for Skinny, and winter (June-July 2006, n = 29 days) and spring (August-September 2006, n = 26 days) for

Johan. For Johan, the spring season was chosen due to the missing data between and including the months of November 2006 and February 2007. In the Cederberg, seasons are distinct in respect of temperature and rainfall (Table 3.1 and 3.2). Sex-specific habitat patterns were looked for by comparing Johan and Skinny's seasonal area use. Due to data availability, this part of the analysis was limited to the winter season only. Despite the years' winter seasons differing in temperature (T-test:  $t = -5.6927$ ,  $d.f = 408$ ,  $p = 0$ ) it is unlikely that these differences would cause significant changes to the leopards behaviour (Marker and Dickman, 2005), such that statistical comparisons of seasonal area use were continued. Tests for significant differences between Johan's daily distance travelled (T-test), elevation range (T-test) and distance to water (Mann-Whitney U) during winter and spring were conducted. Tests for significant differences between Skinny's daily distance travelled (T-test), elevation range (Mann-Whitney U) and distance to water (Mann-Whitney U) during winter and summer were also conducted. A comparative test for significant differences between daily distances travelled during winter for both leopards was conducted (T-test), as well as significant differences between elevation ranges (T-test) and distances to water sources during winter (Mann-Whitney U).

#### 2.4.4 Habitat

An ArcView shapefile describing the regional habitat (Vegm2006.shp) was used to determine habitat proportions in the available area as well as the used area. The habitat types were classified into three broad vegetation types: fynbos vegetation, Succulent Karoo vegetation and azonal vegetation. The fynbos vegetation classification included Swartruggens quartzite fynbos, Cederberg sandstone fynbos, northern inland shale band vegetation, Ceres shale renosterveld and Kouebokkeveld alluvium fynbos. The Succulent Karoo classification included Swartruggens quartzite Karoo, Agter-Sederberg shrubland and Tanqua Karoo. Azonal vegetation was restricted to Tanqua Wash Riviere vegetation.

Habitat selection can be classed in various orders of use. Within the total available area for each leopard, the entry proportions into differing vegetation habitats can be calculated as second order habitat selection. Within the home range area of each leopard, entry proportions into differing vegetation habitats can be calculated as third order habitat selection. In order to test for habitat selection in second and third orders (Johnson, 1980) the Chesson's alpha (Chesson 1978)

method was used. The method has been applied to studies looking at prey selectivity as well as habitat selectivity (Hoffman, 2006) of predator species. The equation is as follows:

$$\alpha_i = \frac{r_i}{n_i} * \left( \sum_{l=1}^m \frac{r_l}{n_l} \right)^{-1}$$

$r_i$  = proportion of use of habitat type  $i$   
 $n_i$  = proportion of availability of habitat type  $i$   
 $m$  = number of habitat types in the study area

Alpha has a value range between 0 and 1, with 0 being habitats not visited at all and 1 being habitats visited to the exclusion of all others. Alpha is a measure of habitat type selectivity relative to habitat type availability.

The total area available to each leopard was computed to evaluate second order habitat selection and the leopards home ranges were used to evaluate third order habitat selection (Johnson 1980). The total area available to each leopard was defined as that which could be accessed within a single day's travel. For each leopard their total available area was calculated by placing buffers around their GPS points, basing buffer radii on the average daily distance that they travelled (Skinny = 1 km, Johan = 8 km). The area contained within the outermost boundaries of all of the drawn buffers combined was determined to be the leopard's available area.

#### 2.4.5 Movement patterns

The average daily distances travelled were calculated using the Nearest\_features (nearfeat.avx) extension for ArcView 3.x (Jenness, 2004). Movement patterns were determined from days with a specified number of GPS recordings. Johan's daily travel was calculated based on days with four or more points; this criterion was selected because the average number of daily points recorded ( $\bar{x} = 4.08$ ,  $SD = 1.52$ ,  $n = 221$  days) by his collar was four. Skinny's daily travel was calculated based on days with three points or more because the average number of daily points recorded ( $\bar{x} = 3.21$ ,  $SD = 1.46$ ,  $n = 353$  days) by her collar was three. Seasonal differences in each leopard's travels were tested for, using t-tests. In order to compare the two leopards seasonally, days with three or more GPS recordings were included in order to be statistically comparable to Skinny's data set.

#### 2.4.6 Water sources

The mean distance each GPS point was from a permanent water source was determined in ArcView 3.3 (ESRI 2002) using an ArcView shapefile detailing the rivers in the region (Vegm\_rivers.shp, 2006). For each leopard the daily mean ( $\pm$  st dev), and overall minimum and maximum distance to water values were calculated. Johan's distance to water values were compared with Skinny's using Mann Whitney U tests.

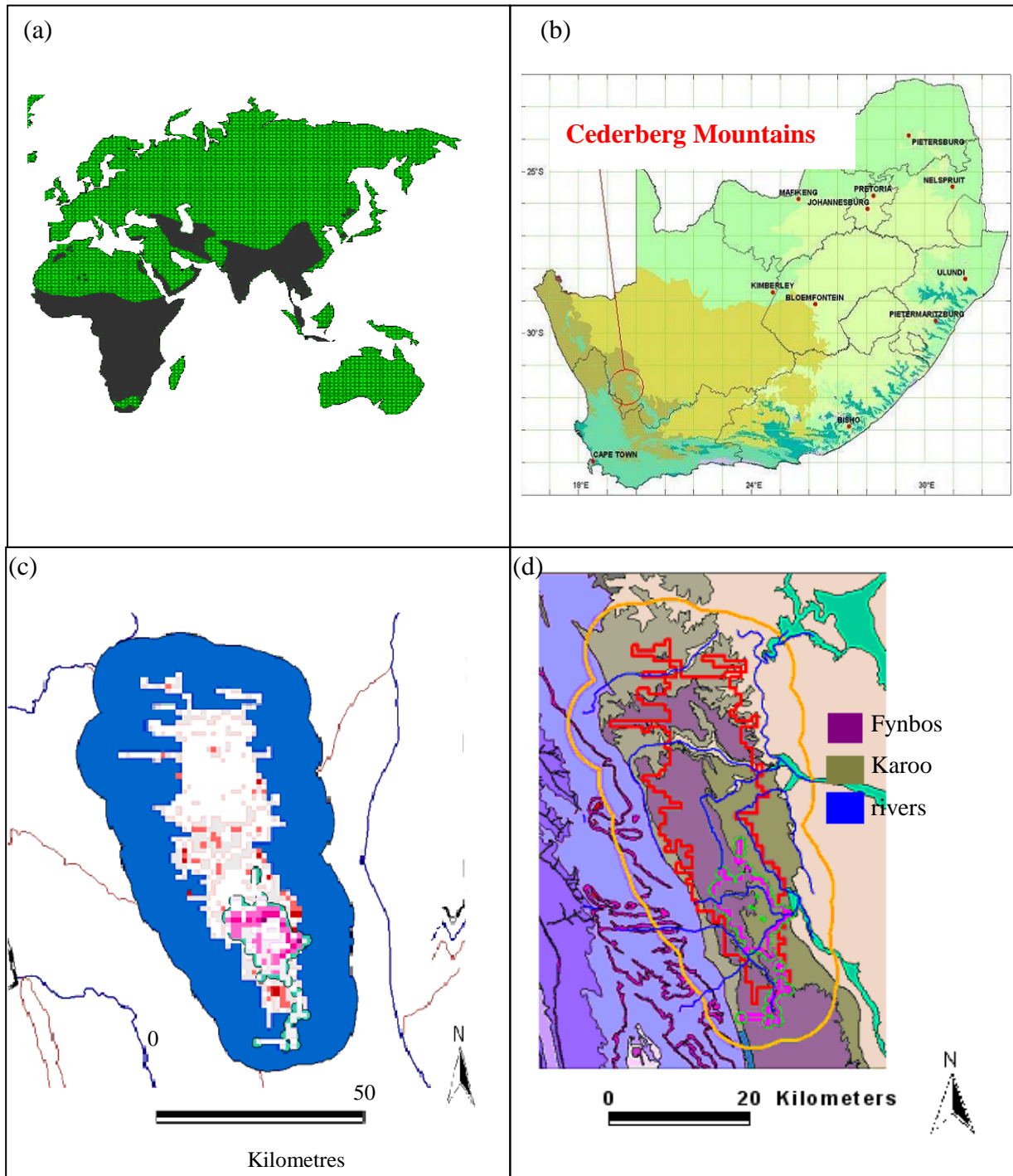
#### 2.4.7 Elevation

Each GPS point was assigned an elevation value. For each leopard the daily mean ( $\pm$  st dev), and overall minimum and maximum elevation values were calculated. We compared Johan's elevation range with Skinny's using Mann Whitney U tests.

#### 2.4.8 Remotely Sensed Data

Collaborative information from remotely sensed images obtained from the Global Land Cover Facility (University of Maryland, <http://glcf.umiacs.umd.edu>.) was used to support the data on habitat cover and altitudes. Two images covering the Cederberg mountain range as well as neighbouring agricultural areas and a small section of the Tanqua Karoo were sourced. Making use of a mosaic technique in Erdas Imagine (Erdas View Finder, 2008) the two images were combined, encompassing the leopards' home range area with an estimated buffer zone of approximately 20km, in order to account for any under-estimates in range size. The normalised difference vegetation index (NDVI) for the study area was also employed as this has been shown to strongly correlate with absorbed photosynthetically active radiation in an environment and is also highly sensitive to precipitation and temperature variations within a study area (Wikramanayake *et al.*, 2004; Kerr and Ostovsky, 2003) (Appendix A). By combining NDVI measurements and information on land use, conversions and loss to the habitat can be detected as a result of increasing agricultural practices (Kerr and Ostovsky, 2003). The Shuttle Radar Topography Mission (SRTM) digital elevation index was also acquired for the study area (Appendix B).

Fig 2 (a) Global distribution of leopards; (b) location of the study area in the Western Cape, South Africa; (c) the total area available to Johan (blue area) and his actual home range (red area), the total area available to Skinny (green area) and her actual home range (pink area) (d) Johan and Skinny's home ranges (red and pink outlines) and available areas (orange and green outlines) overlaid onto a map of the region's habitat divisions and permanent water sources.



### 3. RESULTS

In order to satisfy the conditions of the quadrat method, plots per month of the cumulative frequency of new cells that each leopard entered were calculated. These reached asymptotes by the end of their respective data collection periods (Fig 3.1 and 3.2).

Fig 3.1. Cumulative frequency of new cells entered per month for Skinny.

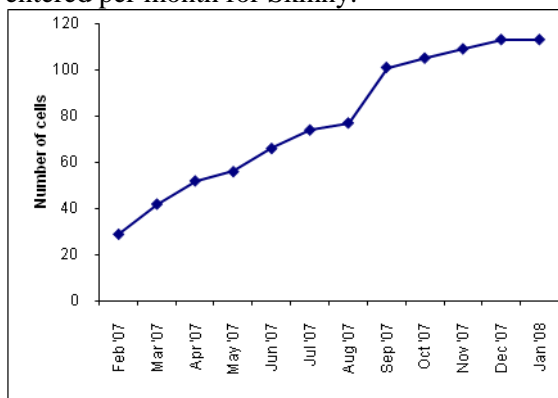
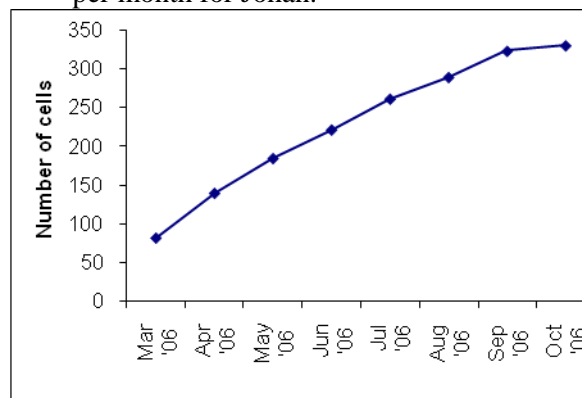


Fig 3.2. Cumulative frequency of new cells per month for Johan.



The total available areas for the leopards were estimated to cover 2750 km<sup>2</sup> for Johan and 582 km<sup>2</sup> for Skinny. Of these calculated areas, only 31.45 % was entered by Johan and 25.26 % was entered by Skinny (Fig 2c). The home range sizes for Johan and Skinny were 865 km<sup>2</sup> and 147 km<sup>2</sup> respectively. These sizes varied seasonally for both leopards; for Johan from 89 to 137 km<sup>2</sup> in winter and spring respectively and for Skinny from 55 to 42km<sup>2</sup> in winter and summer respectively. The elevation range of Johan's home range was between 320 and 1370 m and Skinny's home range between 420 and 1390 m.

#### 3.1 Selective Habitat Use

Certain areas of the leopards' home ranges were entered more often than others, and some areas not entered at all (Fig 3.3 and 3.4). Both leopard home ranges encompassed parts of the Fynbos and Succulent Karoo Biomes. The leopards utilized Succulent Karoo habitat types more than Quartzite and Tanqua Fynbos types (Table 3.3 and 3.4). The statistics showed the relative amount of use of each vegetation type. Within his total available area Johan had access to a total area of 2750 km<sup>2</sup> of land comprising 25.68 % Swartruggens Quartzite Fynbos, 20.01 % Agter-Sederberg Shrubland, 19.41% Tanqua Karoo, 16.52 % Swartruggens Quartzite Karoo, 15.14 %

Cederberg Sandstone Fynbos, 1.58 % Tanqua Wash Riviere, 1.52 % Northern Inland Shale Band Vegetation, 0.15 % Ceres Shale Renosterveld and 0.01 % Kouebokkeveld Alluvium Fynbos. Within her total available area Skinny had access to a total area of 582 km<sup>2</sup> of land comprising 62.41% Swartruggens Quartzite Karoo, 33.77% Swartruggens Quartzite Fynbos, 2.99% Agter-Sederberg Shrubland, 0.53% Tanqua Karoo and 0.31% Tanqua Wash Riviere.

### 3.1.1 Johan

Five habitat types were entered by Johan during the study period. Cederberg Sandstone Fynbos habitat type was not visited at all. In Johan's total available area the vegetation types selected, in proportion to the nine available habitat types, were in order of Swartruggens Quartzite Karoo (Chesson's  $\alpha = 0.65$ ), then Swartruggens Quartzite Fynbos (Chesson's  $\alpha = 0.25$ ), then Agter-Sederberg Shrubland (Chesson's  $\alpha = 0.06$ ), then Tanqua Karoo (Chesson's  $\alpha = 0.03$ ) and lastly Tanqua Wash Riviere (Chesson's  $\alpha = 0.02$ ). However within Johan's home range he selected vegetation types in the order of Tanqua Wash Riviere almost exclusively (Chesson's  $\alpha = 0.91$ ), Swartruggens Quartzite Karoo (Chesson's  $\alpha = 0.05$ ), then Swartruggens Quartzite Fynbos (Chesson's  $\alpha = 0.02$ ) and lastly Agter-Sederberg Shrubland and Tanqua Karoo (Chesson's  $\alpha = 0.01$  respectively) (Table 3.3a and 3.3b) (Fig. 3.7).

### 3.1.2 Skinny

Two habitat types were entered by Skinny during the study period. Agter-Sederberg Shrubland and Tanqua Karoo habitat types were never visited. In Skinny's total available area the vegetation types selected, in proportion to the five available habitat types, were in order of Swartruggens Quartzite Karoo (Chesson's  $\alpha = 0.57$ ) and then Swartruggens Quartzite Fynbos (Chesson's  $\alpha = 0.43$ ). Within Skinny's home range she selected vegetation types in the order of Swartruggens Quartzite Karoo (Chesson's  $\alpha = 0.70$ ) and then Swartruggens Quartzite Fynbos (Chesson's  $\alpha = 0.30$ ) (Table 3.4a and 3.4b) (Fig. 3.8).

## 3.2 Area use and selection

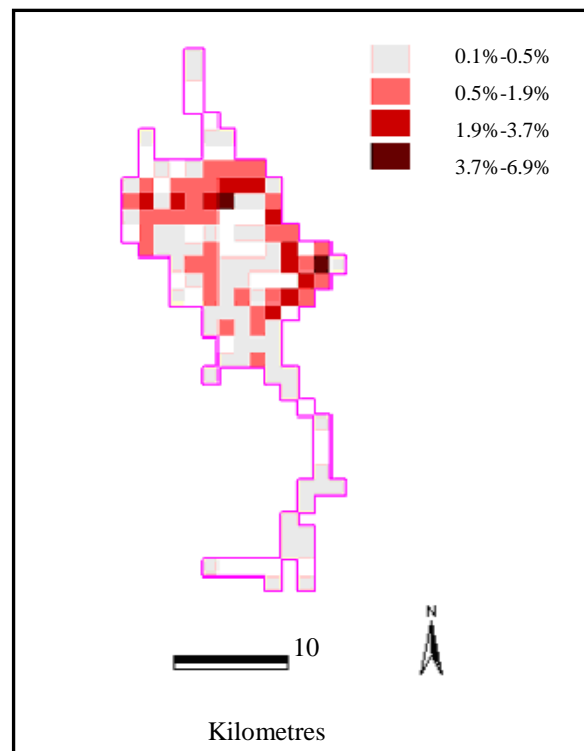
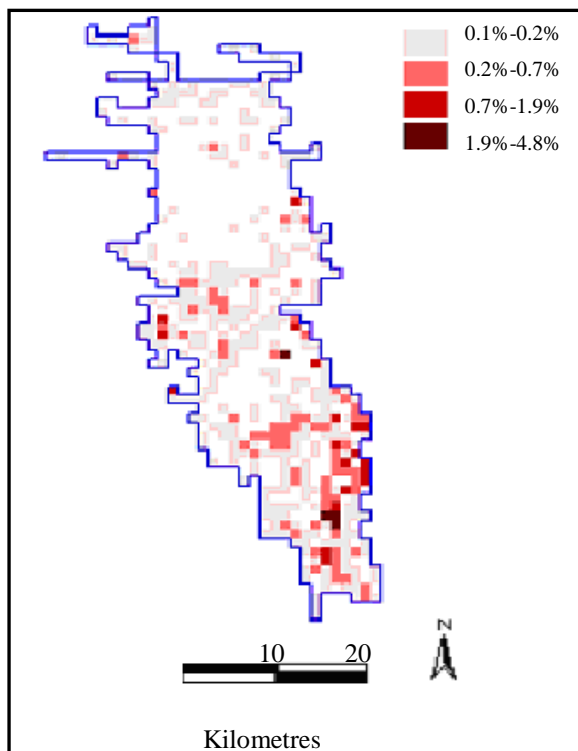
### 3.2.1 Johan

Johan's use of elevation ranged between 320 m and 1360 m, with his average annual elevation being 683 ( $\pm 191$  m). Johan showed no significant difference in use of elevation between winter

(767 m  $\pm$  206 m) and spring (737  $\pm$  205 m). His distance to water sources ranged between 0.002 km and 7.54 km, with his average distance to water annually being 1.49 ( $\pm$  1.52 km). There was no significant difference in his mean distance from water sources during winter (1.63  $\pm$  1.44 km) and spring (1.36  $\pm$  1.11 km) seasons. The average daily distance travelled by Johan was 8.9 km per day ( $\pm$  6.6 km, n = 221; range = 0.05 – 24.96 km).

Fig 3.3. General use of cells within F6’s home range from February 2007 to January 2008.

Fig 3.4. General use of cells within M1’s home range from March 2006 to June 2007 (excluding November-December 2006 and January-February 2007).



The average daily distance travelled did not differ significantly between his winter (11  $\pm$  7 km) and spring (11.1  $\pm$  6.4 km) seasons (Table 3.1).

### 3.2.2 Skinny

Skinny’s use of elevation ranged between 408 m and 1389 m, with her average annual elevation being 655 ( $\pm$  159 m). Skinny was found at significantly (Mann Whitney U test:

U = 5245.0, p < 0.01) higher elevations during winter (773.12  $\pm$  150.35 m) than summer (649.8  $\pm$  128.91 m). Skinny’s distance to water sources ranged between 0.0003 km and 7.26 km, with her average distance to water annually being 0.85 ( $\pm$  1.1 km). Seasonal differences in distance to



water sources were apparent for Skinny with her winter average ( $0.99 \pm 0.87$  km) being significantly higher (Mann Whitney U test:  $U = 6428$ ,  $p < 0.01$ ) than her summer average ( $0.78 \pm 1.17$  km) (Table 3.2). Skinny averaged 1.1 km of travelling per day ( $\pm 1.3$  km,  $n = 233$ ; range = 0.0008 – 8.60 km) travelling further (T-test:  $t = - 10.13$ ,  $d.f = 192$ ,  $p < 0.01$ ) in winter ( $1.6 \pm 1.3$  km) than in summer ( $0.19 \pm 0.1$  km) (Fig. 3.5).

Table 3.1: Differences in seasonal measurements of variables for Johan HR. \* highlight variables with significant seasonal variance.

<i>Units</i>	<u>Winter(2006)</u>			<u>Spring(2006)</u>		
	<i>Mean</i>	<i>St Dev</i>	<i>n</i>	<i>Mean</i>	<i>St Dev</i>	<i>n</i>
*Mean Temperature °C	17.84	5.5	61 days	18.43	5.63	61 days
*Daily Rainfall mm	7.18	0.09	61 days	9.04	0.80	61 days
Elevation m	767.09	2.5.56	268 points	736.94	204.85	250points
Daily distance travelled km	11.01	7.06	224 points	11.17	6.43	198points
Distance to water km	1.63	1.44	268 points	1.36	1.11	250points

Table 3.2: Differences in seasonal measurements of variables for Skinny HR. \* highlight variables with significant seasonal variance.

<i>Units</i>	<u>Winter(2007)</u>			<u>Summer(2007/8)</u>		
	<i>Mean</i>	<i>St Dev</i>	<i>n</i>	<i>Mean</i>	<i>St Dev</i>	<i>n</i>
*Mean Temperature °C	20.97	4.86	61 days	27.4	4.77	61 days
*Daily Rainfall mm	7.24	0.74	61 days	6.54	0.01	61 days
*Elevation m	773.12	150.35	143 points	649.80	128.9	140points
Daily distance travelled km	1.55	1.32	98 points	0.19	0.10	99 points
Distance to water km	0.99	0.87	143 points	0.78	1.17	140points

### 3.2.3 Johan vs. Skinny

Annually, Johan ranged at significantly (Mann Whitney U test:  $U = 669962$ ,  $p < 0.01$ ) higher altitudes ( $682.77 \pm 190.53$  m) than Skinny ( $665.29 \pm 159.03$  m). When comparing the two leopards seasonally there was no significant difference in altitude use for Johan ( $767.09 \pm 205.56$  m) and Skinny ( $773.12 \pm 150.35$  m) during winter months. Johan was on average significantly further (Mann Whitney U test:  $U = 531214$ ,  $p < 0.01$ ) from water sources ( $1.49 \pm 1.52$  km) than Skinny ( $0.85 \pm 1.10$  km) in summer and Johan's winter average ( $1.63 \pm 1.44$  km) was also significantly further (Mann Whitney U test:  $U = 15945$ ,  $p < 0.01$ ) from water sources than Skinny's ( $0.99 \pm 0.87$  km). A comparison between seasons for Johan and Skinny revealed a significant seasonal difference (t-test:  $t = 11.59$ ,  $d.f = 150$ ,  $p < 0.01$ ) between the average daily distance travelled by Johan in winter ( $11 \pm 7$  km) and Skinny in winter ( $1.6 \pm 1.3$  km) (Fig. 3.6).

Fig 3.6. Daily distance travelled by M1 (Johan) and F6 (2007/8)(Skinny) in winter seasons of 2006 and 2007.

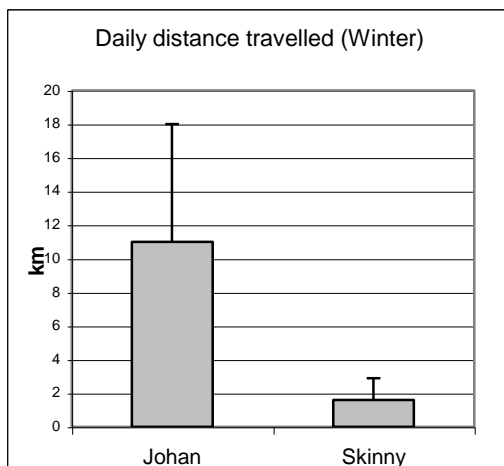


Fig 3.5. Daily distance travelled in summer and winter (2007) seasons by F6 (Skinny).

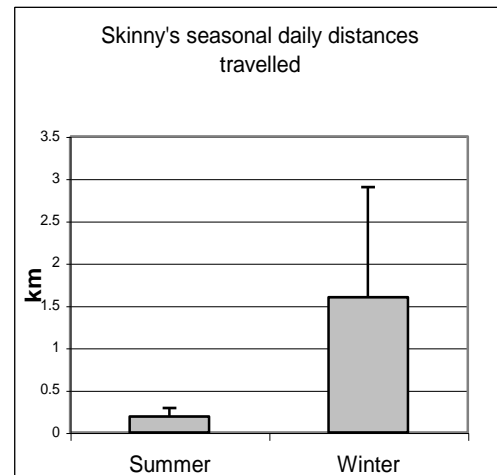


Table 3.3 a : Results from Chesson's Alpha 2<sup>nd</sup> Order and 3<sup>rd</sup> Order method for the total available area (entered and non-entered habitats) and home range area (entered and non-entered habitats) for Johan.

Habitat Type	2nd order % available	% Used	3rd order % available	% Used
Agter-Sederberg Shrubland	20.01	6.9	14.06	6.9
Cederberg Sandstone Fynbos	15.14	0	0.03	0
Ceres Shale Renosterveld	0.15	0	0.00	0
Kouebokkeveld Alluvium Fynbos	0.01	0	0.00	0
Northern Inland Shale Band Vegetation	1.52	0	0.00	0
Swartruggens Quartzite Fynbos	25.68	33.46	50.10	33.46
Swartruggens Quartzite Karoo	16.52	56.6	30.33	56.6
Tanqua Karoo	19.41	2.9	5.47	2.9
Tanqua Wash Riviere	1.58	0.14	0.004	0.14

Table 3.3 b : Results from Chesson's Alpha 2<sup>nd</sup> Order and 3<sup>rd</sup> Order method for the proportions of total available area (entered and non-entered habitats) and home range area (entered and non-entered habitats) for Johan.

Johan 2nd order	A-SSh	CS-Fyn	CS-Ren	KA-Fyn	NI-Sh	SO-Fyn	SO-K	TK	T-WR
Available area	0.20	0.15	0.00	0.00	0.02	0.26	0.17	0.19	0.02
Available area used	0.069	0	0	0	0	0.3346	0.566	0.029	0.0014
Use/available	0.34	0.00	0.00	0.00	0.00	1.30	3.43	0.15	0.09
Chesson's alpha value	<b>0.06</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.25</b>	<b>0.65</b>	<b>0.03</b>	<b>0.02</b>
Johan 3rd order	A-SSh	CS-Fyn	CS-Ren	KA-Fyn	NI-Sh	SO-Fyn	SO-K	TK	T-WR
Available area	0.14	0.00	0.00	0.00	0.00	0.50	0.30	0.05	0.00
Available area used	0.07	0.00	0.00	0.00	0.00	0.33	0.57	0.03	0.00
Use/available	0.49	0.00	0	0	0	0.67	1.87	0.53	36.75
Chesson's alpha value	<b>0.01</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.02</b>	<b>0.05</b>	<b>0.01</b>	<b>0.91</b>

Table 3.4a : Results from Chesson's Alpha 2<sup>nd</sup> Order and 3<sup>rd</sup> Order method for the total available area (entered and non-entered habitats) and home range area (entered and non-entered habitats) for Skimpy.

Habitat Type	2nd order % available	% Used	3rd order % available	% Used
Agter-Sederberg Shrubland	2.99	0.00	0.01	0.00
Swartruggens Quartzite Fynbos	33.77	29.20	49.32	29.20
Swartruggens Quartzite Karoo	62.41	70.80	50.60	70.80
Tanqua Karoo	0.53	0.00	0.07	0.00
Tanqua Wash Riviere	0.31	0.00	0.00	0.00

Table 3.4b : Results from Chesson's Alpha 2<sup>nd</sup> Order and 3<sup>rd</sup> Order method for the proportions of total available area (entered and non-entered habitats) and home range area (entered and non-entered habitats) for Skimpy.

Skimpy 2nd order	A-SSh	SO-Fyn	SO-K	TK	T-WR
Available area	0.03	0.34	0.62	0.01	0.00
Available area used	0	0.292	0.708	0	0
Use/available	0.00	0.86	1.13	0.00	0.00
<b>Chesson's alpha value</b>	<b>0.00</b>	<b>0.43</b>	<b>0.57</b>	<b>0.00</b>	<b>0.00</b>
Skimpy 3rd order	A-SSh	SO-Fyn	SO-K	TK	T-WR
Available area	0.00	0.49	0.51	0.00	0.00
Available area used	0.00	0.29	0.71	0.00	0.00
Use/available	0.00	0.59	1.40	0.00	0.00
<b>Chesson's alpha value</b>	<b>0.00</b>	<b>0.30</b>	<b>0.70</b>	<b>0.00</b>	<b>0.00</b>

Fig. 3.7. Johan's habitat selection using the Chesson's alpha method.

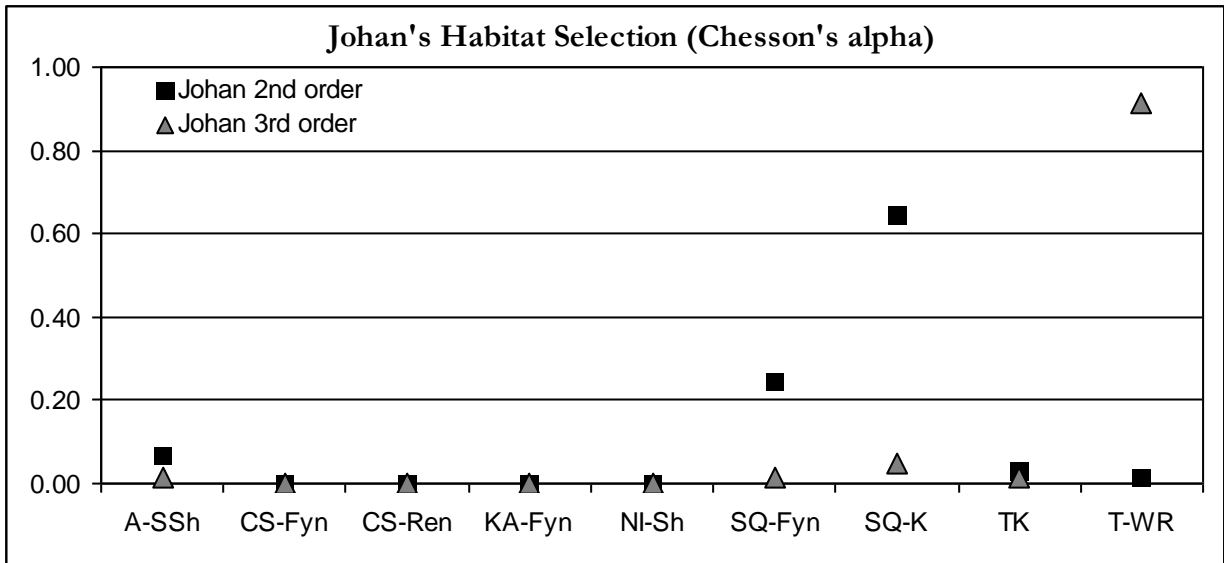
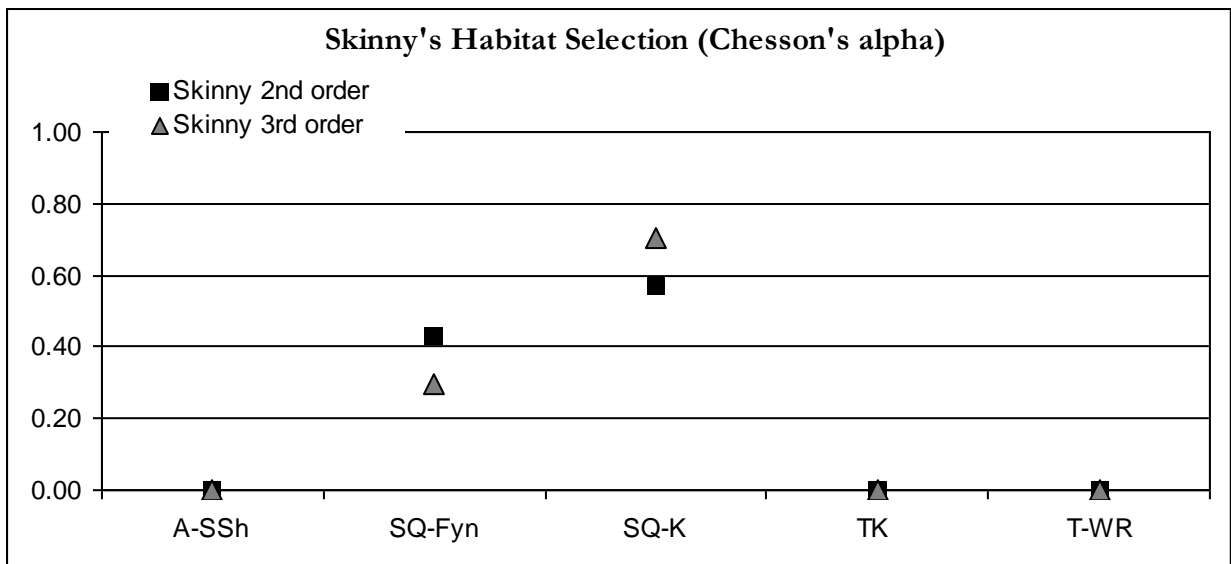


Fig. 3.8. Skinny's habitat selection using the Chesson's alpha method



## 4. DISCUSSION

### 4.1 Cederberg leopards

#### 4.1.1 Johan versus males in other studies

Johan's home range was much larger than those previously reported for males in the Cederberg (51 km<sup>2</sup> – Norton and Henley, 1987) and Stellenbosch (388 km<sup>2</sup> – Norton and Lawson, 1985). Other home range estimates for male leopards in South Africa include 27.7km<sup>2</sup> and 76.2km<sup>2</sup> in the Kruger National Park (Maan and Chaudry, 2000; Marker and Dickman, 2005). Furthermore, Johan's daily travel distance (8.9 km) is further than previous records for male leopards in the Cederberg (2.6 km – Norton and Henley, 1987), and other studies in South Africa (2.8 km - Maan and Chaudry, 2000; 2.8 km – Marker and Dickman, 2005).

Based on the results of Marker and Dickman (2005) we consider it unlikely that the cause of the size discrepancy between Johan's range and the ranges of other male leopards is the absence of other large carnivores in the study area. In their study in Namibia, Marker and Dickman (2005) showed the presence of large carnivores to have no detectable influence on either the home range size or the leopard density in the area. If the leopards were however faced with the presence of other large carnivores spatially overlapping their home ranges, their ability to adapt behaviourally and in terms of diet would mean they could effectively compete for resources (Marker and Dickman, 2005).

#### 4.1.2 Skinny vs. females in other studies

Skinny's home range (147 km<sup>2</sup>) is much larger compared to other studies in Africa (Bertram, 1982; Norton and Lawson, 1985; LeRoux and Skinner, 1989; Stander *et al.*, 1997). Compared to other studies in South Africa, Mizutani and Jewell (1998) recorded one female home range of 23-33 km<sup>2</sup> in Londolozi Game Reserve, Maan and Chaudhry (2000) one of 18 km<sup>2</sup> in Sabie River, Kruger National Park, and Marker and Dickman (2005) four of 14.8 km<sup>2</sup> in Nwaswitshaka River, Kruger National Park. Sample size and study time may have influenced differences between studies.

### 4.1.3 *Skinny vs. Johan*

The similarity of Skinny's summer and winter range sizes follows patterns observed for female leopards in Huai Kha Khaeng Wildlife Sanctuary in Thailand (Simcharoen *et al.*, 2008) and in Namibia (Marker and Dickman, 2005). Skinny's daily travel distance (1.1 km) is similar but slightly lower than previous recordings for female leopards in South Africa (1.2, 1.9 – Marker and Dickman, 2005) and Kenya (2.0 – Bertram, 1982; 1.3 – LeRoux and Skinner, 1989). The presence of cubs during the last few months of the study period (Martins, pers. comm., 2008) may have restricted Skinny's daily movement at times likely to be when Johan, as well as a male south of her home range, were active. A case for this was suggested by Odden and Wegge (2005) as a strategy to protect cubs from infanticide. However, Skinny did show seasonal differences in her altitudinal range patterns and proximity to water sources – both of which have the potential to influence prey density and availability (Simcharoen *et al.*, 2008).

## 4.2 *Cederberg leopards vs. leopards elsewhere*

### 4.2.1 *Home range sizes*

It must be noted that the overall home range sizes of Johan and Skinny may be minimum estimates due to the infrequent number of recordings through the study period and the four month period where Johan could not be located. The relative sizes of Johan and Skinny's home ranges follow the patterns of many studies of solitary, territorial cats (Rabinowitz, 1989; Grassman, 1999; Marker and Dickman, 2005; Bitetti *et al.*, 2006), which show male home ranges to be upwards of two to four times larger than females. The complete encompassment of Skinny's home range by Johan's was in accordance with previous findings revealing home range overlaps that suggest a strong tolerance of the opposite sex (Eaton, 1971; Rabinowitz, 1989; Bailey, 1993; Grassman, 1999). This tolerance may result from the combination of minimal competition for prey with a surplus of opportunities for mating encounters with the opposite sex (Grassman, 1999).

The small area that Skinny's home range comprises, relative to the large area available to her, follows with findings for female home ranges elsewhere in Africa and Asia (Rabinowitz, 1989; Grassman, 1999; Marker and Dickman, 2005; Bitetti *et al.*, 2006) and supports the suggestion that females utilise the smallest area possible to satisfy their requirements for food and water,

irrespective of the land available to them (Gittleman and Harvey, 1982; Marker and Dickman, 2005). Males, who utilise much larger areas than females, have claim of territories, defense of territories, and contact with females as their primary focus (Marker and Dickman, 2005).

#### 4.2.2 Habitat Use

The results of the study showed that certain areas of the leopards' home ranges were entered more often than others, while some areas were not entered at all. This begs the question as to whether the leopards were selecting certain areas and their attributes and others were left alone by chance or active avoidance.

The homogenous nature of the broad scale habitat of the Cederberg provided a consistent, year round environment for the leopards to use. While the rivers are generally stronger and fuller during winter and diminished during summer months, they provide a year-round regular and reliable source of water for leopards and prey species alike. It is unlikely that the selective habitat use shown by the leopards is linked to the distribution of water sources given that water is available to them throughout the year. While prey distribution in the study area has yet to be quantified, we hypothesize that habitat selection by the leopards is related to the distribution of prey within the habitat types (Marker and Dickman, 2005). We further hypothesize that prey is distributed within the habitat types in similar proportions to the leopards selection of the habitat types, as shown by Gittleman and Harvey (1982). However there have been cases where habitat selection was based on habitats where prey was easier to catch rather than more abundant (Balme *et al.*, 2007).

#### 4.2.3 Movement patterns

Several studies have noted the preference of large felids for walking on old or used trails instead of steeply sloped, rocky areas (Bitetti *et al.*, 2006) The paths used by researchers and hikers, especially those following the river courses, were often frequented by both the male and female under study, indeed these paths were chosen for locations of camera-traps and cages (Martins, pers. comm., 2008).

Temperature and rainfall for the spring 2006 dataset differed from that of the summer 2007 dataset which may compromise the comparative results between spring and summer data for



other habitat variables relating to the leopards movements and preferences. Little significant altitudinal differences were found between seasons, suggesting that altitude was not a significant influence on home range use or movement patterns. No other studies referenced have revealed leopards showing altitudinal patterns that significantly affect their movement patterns. Links could not be determined between home range sizes and prey abundance, due to lack of data on prey species in the area. However, the link found between home range use and distance to rivers could serve as a proxy for a link between these predators and their prey as prey is found in greater densities near water sources (Marker and Dickman, 2005).

#### 4.3 Implications for Management

To best manage leopard populations emphasis needs to be placed on the protection of source populations in core areas in tandem with landscape connectivity that allows for leopard dispersal through core areas (Wikramanayake *et al.*, 2004; Gavashelishvili and Lukarevskiy, 2008; Vogt *et al.*, 2008). In the Cederberg Wilderness Area this strategy is made challenging by the low density and large home ranges of leopards which require large, homogeneous and contiguous areas of natural veld be kept available for use by leopards and their natural prey (Marker and Dickman, 2005). For many years the Cederberg has seen increasing interest in private and commercial agricultural farming, which have taken over more open land and complicated the effectiveness of initiatives such as the Greater Cederberg Biodiversity Corridor that is trying to ensure landscape connectivity for the fauna and flora in the Cederberg.

Awareness of the ecological flexibility of leopards in the face of expanding livestock land use is necessary as ignorance of it will most certainly exacerbate leopard-human conflicts. While the Cederberg is home to many prey species, the decreasing availability of natural land and its resources is bound to negatively impact on natural prey densities. Studies, such as Kolowski and Holekamp's (2006) on livestock depredation by large carnivores on the Kenyan border, have shown increases in livestock predation as the abundance of natural prey decreases. However the increased interest in agricultural farming over livestock farming in the Cederberg may have increased habitat for leopards (Martins, pers. comm., 2008) and begun to minimise farmer-leopard conflict. The challenge lies with conservation groups and researchers to form long lasting, informative, reliable and transparent lines of communication amongst farmers and private land owners.

#### 4.4 Further Research and limitations of this study

The dynamics of carnivore home ranges are dependent on several key factors, including seasonal variation of resources (Grassman, 1999; Simcharoen *et al.*, 2008), densities between and within carnivore species (Bailey, 2003), metabolic needs of species (Gittleman and Harvey, 1982), as well as the amount and availability of prey species (Norton and Henley, 1987; Bailey, 2003). A lack of sufficient data for these factors meant that this study could only briefly examine the home range characteristics and dynamics of leopards. Further studies should focus on collection detailed and long-term monitoring of environmental and socio-ecological variables, along with in-depth information of prey abundances and predation rates. This information is vital if practical solutions to leopard-human conflict management (Kolowski and Holekamp, 2006) in the CM are to be generated.

Due to the small sample size and the study being limited to inter-sexual comparison analyses, we were unable to verify the common social system pattern of intra-sexual territoriality - males and females evicting same sex individuals from their home ranges - as shown in past studies (Bitetti *et al.*, 2006). This would make an interesting topic of a future study.

This study is based on a very small sample size over approximately an 11 month period for the male and a 12 month period for the female. In order to complete comparisons of seasonal ranges between the sexes, complete data for the summer months in 2006, are needed. This study is constrained in missing four months of data between November 2006 and February 2007 due to GPS collar failure, which meant that Johan's seasonal range comparisons consisted of spring and winter data, where a summer-winter comparison would have been preferred. The unavailability of 2008 daily rainfall data meant that comparative results for climatic shifts in seasonal ranges was also limited.

## ACKNOWLEDGEMENTS

I would like to thank Tali Hoffman for her valuable supply of knowledge, advice and understanding during this study, and for her interest, generosity and willingness to be involved with the work. I am hugely grateful to Quinton Martins for involving me in the great work being done in the Cederberg and for supplying the necessary data used for analysis in this study. I also thank Willem Titus as well as Quinton for welcoming me to the Cederberg to see and be involved in the work being done there. I thank Mike Meadows for his guidance and helpful advice.

## REFERENCES:

BAILEY, T.N. 1993: The African leopard. – Columbia University Press, New York, pp 429

BALME, G., HUNTER, L., SLOTOW, R., 2007: Feeding habitat selection by hunting leopards (*Panthera pardus*) in a woodland savanna: prey catchability versus abundance. *Animal Behaviour*, No. 74, pp. 589-598

BERTRAM, B.C.R., 1982: Leopard ecology as studied by radio tracking. *Zoological Society*, London, No. 49, pp. 341-352

BITETTI, M.S., PAVIOLO, A., De ANGELO, C. 2006: Density, habitat use and activity patterns of ocelots (*Leopardus pardalis*) in the Atlantic Forest of Misiones, Argentina. *Journal of Zoology*, No. 270, pp. 153-163

EATON, R.L. 1971: Cat Conference. *Science*, New Series, Vol. 174, No. 4009, pp. 615-616

ERDAS Imagine. 2008 Version. ViewFinder (ERDAS software). Earth Resources Data Analysis System

ESRI (Environmental Systems Research Institute, Inc.) 2002 ArcView GIS (GIS software): Version 3.3. Environmental Systems Research Institute, Inc., Redlands, CA.

GAVASHELISHVILI, A. and LUKAREVSKIY, V. 2007: Modelling the habitat requirements of leopard (*Panthera pardus*) in west and central Asia. – *Journal of Applied Ecology* 2008, 45, 579-588.

GITTLEMAN, J.L. and HARVEY, P.H.1982: Carnivore Home Range Size, Metabolic Needs and Ecology. *Behavioural Ecology and Sociobiology* 10: pp. 57-63

GLCF (Global Land Cover Facility).University of Maryland, <http://glcf.umiacs.umd.edu>

GRASSMAN JR, L.I. 1999: Ecology and behaviour of the Indochinese leopard in Kaeng Krachan National Park, Thailand. *Natural History Bulletin, Siam Society*. 47: 77-93

HENZI, S.P., BYRNE, R.W., WHITEN, A. 1992. Patterns of movement by baboons in the Drakensberg Mountains: primary responses to the environment. *International Journal of Primatology* 13:601–629.

HOFFMAN, T.S. 2006: The Spatial Ecology of a Semi Urban Baboon Troop. Honours Thesis, University of Cape Town, pp. 1-39

HOFFMAN, T.S. 2006: Arcview Instructions for Home Range and Movement Analysis: Using GPS data to track animal movement and generate animal home ranges, pp. 1-13

JACKSON, R.M. 1996: Home Range, Movements and Habitat Use of Snow leopard (*Uncia Uncia*) in Nepal. Ph.D. Thesis, University of London (External Programme), London, United Kingdom. 233 pgs.

JENNESS, J. 2004: Nearest features (nearfeat.avx) extension for ArcView 3.x. Jenness Enterprises. Available at: [http://www.jennessent.com/arcview/repeat\\_shapes.htm](http://www.jennessent.com/arcview/repeat_shapes.htm).

JENNESS, J. 2005: Repeating shapes (repeat\_shapes.avx) extension for Arcview 3.x. Jenness Enterprises. Available at: [http://www.jennessent.com/arcview/repeat\\_shapes.htm](http://www.jennessent.com/arcview/repeat_shapes.htm).

JOHNSON, D.H. 1980: The comparison of usage and availability measurements for evaluating resource preference. *Ecology* No. 61, pp. 65-71

KERR, J.T. and OSTROVSKY, M. 2003: From space to species: ecological applications for remote sensing. Elsevier: *TRENDS in Ecology and Evolution*, Vol. 18 No. 6, Department of Biology, University of Ottawa

KOLOWSKI, J.M. and HOLEKAMP, K.E. 2006: Spatial, temporal, and physical characteristics of livestock depredations by large carnivores along a Kenyan reserve border. *Biological Conservation* 128, pp. 529-541

LeROUX, P.G. and SKINNER, J.D. 1989: A note on the ecology of the leopard (*Panthera pardus* Linnaeus) in the Londolozi Game Reserve, South Africa. – *African Journal of Ecology* 27: 167-171.

LINNELL, J.D.C., ODDEN, J., SMITH, M.E., AANES, R., SWENSON, J.E. 1999: Large carnivores that kill livestock: do ‘problem individuals’ really exist? – *Wildlife Society Bulletin*, No. 27 (3), pp. 698-705

MAAN, M.A. and CHAUDRY, A.A. 2000: Common leopard (*Panthera pardus*) – our endangered heritage needs special conservation. *Tigerpaper* No. 27, pp. 14-16

MARKER, L.L., DICKMAN, A.J. 2005: Factors affecting leopard (*Panthera pardus*) spatial ecology, with particular reference to Namibian farmlands. – *South African Journal of Wildlife Research*, No. 35(2), pp. 105-115

MARTINS, Q. and MARTINS, N. 2006. Leopards of the Cape: Conservation and Conservation concerns. *International Journal of Environmental Studies*, No. 63(5), pp. 579 -585.

MICROSOFT 2003. Microsoft Office Professional Edition 2003 Copyright © 1985 – 2003.  
Microsoft Corporation

MIZUTANI, F. and JEWELL, P.A. 1998: Home-range and movements of leopards (*Panthera pardus*) on a live-stock ranch in Kenya. *Journal of Zoology*, London, No. 244, pp. 269-286

NORTON, P.M. and LAWSON A.B. 1985: Radio tracking of leopards and caracal in the Stellenbosch areas, Cape Province. *South African Journal of Wildlife Research*, No. 15, pp.17-24.

NORTON, P.M. and HENLEY, S.R., 1987, Home range and movements of male leopards in the Cederberg Wilderness area, Cape Province. *South African Journal of Wildlife Research*, No.17, pp. 41-48

NOWELL, K. and JACKSON, P. 1996: *Wild cats: Status survey and conservation action plan*. Burlington press, Cambridge

ODDEN, M. and WEGGE, P. 2005: Spacing and activity patterns of leopards (*Panthera pardus*) in the Royal Bardia National Park, Nepal. – *Wildl.Biol.*, No.11, pp.145-152

RABINOWITZ, A. 1989: The density and behaviour of large cats in a dry tropical forest mosaic in Huai Kha Khaeng wildlife sanctuary, Thailand. *Natural History Bulletin*, No. 37, pp. 235-251

SAWS (South African Weather Services) – Climate information Office. 2006 and 2007 Rainfall and Temperature data

SIMCHAROEN, S., BARLOW, A.C.D., SIMCHAROEN, A., SMITH, J.L.D. 2008: Home range size and daytime habitat selection of leopards in Huai Kha Khaeng Wildlife Sanctuary, Thailand. *Biological Conservation*, No 141, pp. 2242-2250

SKINNER. J.D, SMITHERS, R.H.N. 1990: *The mammals of the Southern African Sub-region*, 2<sup>nd</sup> edition, pp. 397-401

STANDER, P.E., HADEN, P.J., KAZECE, GHAU. 1997: The ecology of asociality in Namibian leopards. *Journal of Zoology*, London, No. 242, pp. 343-364

VOGT, P., FERRARI, J.R., LOOKINGBILL, T.R., GARDNER, R.H., RIITERS, K.H., OSTAPOWICZ, K. 2008: Mapping functional connectivity. *Ecological Indicators* 9, pp. 64-71

WCNCBoard (Western Cape Nature Conservation Board). 2006a. Digitised vegetation data for the Western Cape [Vegm2006.shp]. Western Cape Nature Conservation Board, Western Cape

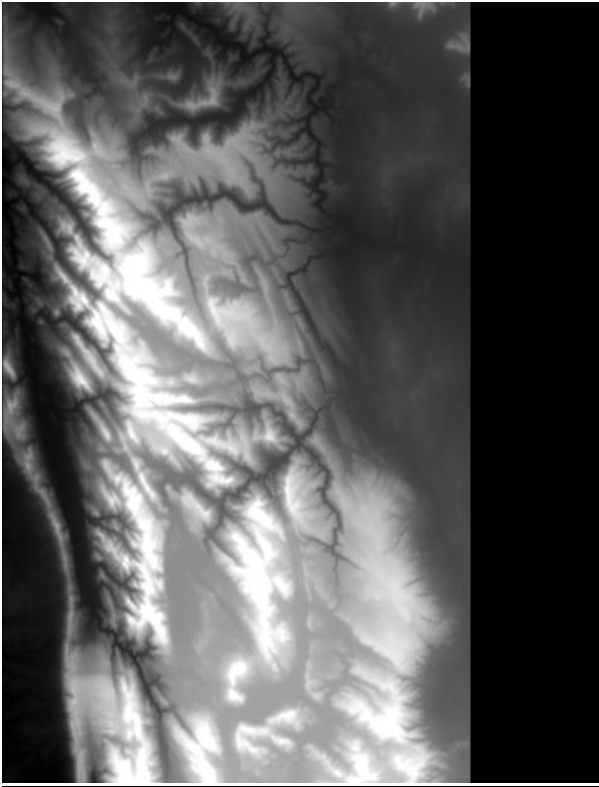
WCNCBoard (Western Cape Nature Conservation Board). 2006b. Digitised data of permanent water sources in the Western Cape [water\_sources\_50\_gw.shp]. Western Cape Nature Conservation Board, Western Cape

WHITEN, A., BYRNE, R.W., HENZI, S.P. 1987. The behavioral ecology of mountain baboons. *International Journal of Primatology* 8:367–389.

WIKRAMANAYAKE, E., McKNIGHT, M., DINERSTEIN, E., JOSHI, A., GURUNG, B., SMITH, D. 2003: Designing a Conservation landscape for Tigers in Human-Dominated Environments. – Conservation Science Program, World Wildlife Fund-U.S.

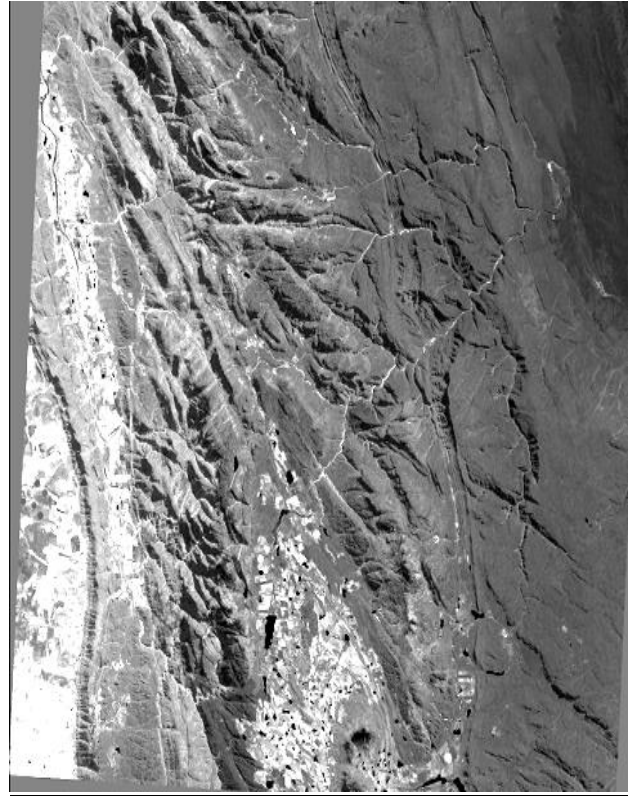
Appendix A.

The SRTM digital elevation image indicating the flattest areas as dark and the higher elevations as the lighter grey tones grading up to white showing the high mountain ranges of the Cederberg.



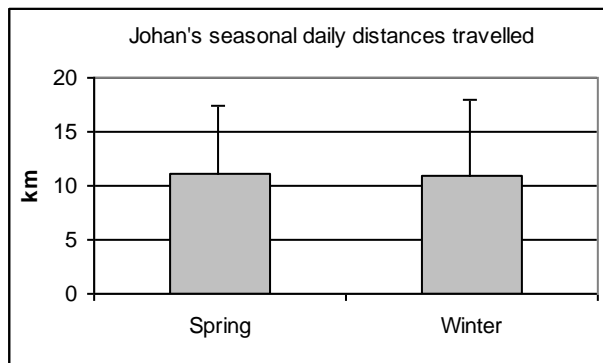
Appendix B.

B. NDVI image, light indicating areas with high vegetation cover contrasting with dark non-vegetated areas of the Cederberg at a 40m resolution.



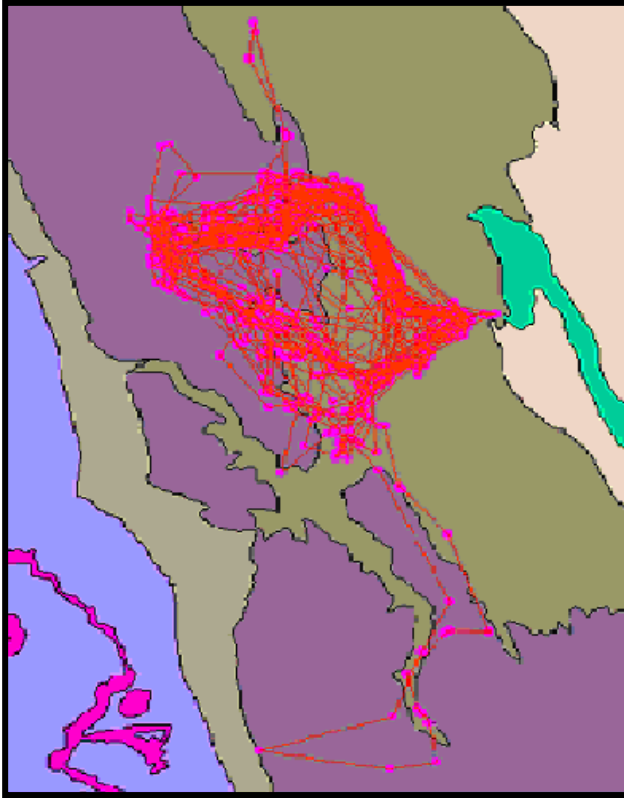
Appendix C.

Johan's daily distance travelled during spring and winter seasons.





Appendix D.  
Skinny's home range path indicating the location of each  
GPS point recorded.



Appendix E.  
Johan's home range path indicating the location of each  
GPS point recorded.

