Habitat use, feeding ecology and the impact of re-introduced elephants (*Loxodonta africana)* on trees within a restricted conservation area in the semi-arid, Little Karoo, South Africa

by

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ABSTRACT

The reintroduction of free-roaming elephants on the 540 km^2 Sanbona Wildlife Reserve in the Little Karoo, Western Cape, South Africa, raised concerns over the possible negative impacts that these animals may have on the biodiversity of the property, especially the tree component. The main objectives of this study were to determine the home range, habitat use and diet selection of the herd of re-introduced elephants and to document their impact primarily on the key tree species in the reserve. It was found that the home range of these animals was considerably smaller than expected (26 km^2) and was strongly associated with the flood plain and tributaries of the only extensive water body on SWR. Of the 12 habitat types present, the elephants showed a preference for the River Drainage habitat type and avoided other habitats due to their lack of accessibility, lack of cover or lack of their preferred food species. The elephants showed an almost equal amount of browse (shrubs and trees) and graze (grasses) material in their diet with the females having more browse (58%) and the males more graze (60%) material in their respective diets. Of the five common tree species on SWR the elephants preferred *Acacia karroo* particularly individuals taller than 4 m in height. Of the 1,013 marked trees which were studied over a period of four years only 0.7% of the individuals died as a direct result of elephant impacts from such activities as ringbarking, stem breakage and uprooting. *Rhus* spp. are the most affected and could become locally extinct in the core utilization distribution area of the elephant's home range which covers less than 1% of the SWR. The main conclusion from this study is that the current population of five elephants has not, as yet, had a detrimental effect on the main tree species on SWR.

TABLE OF CONTENTS

LIST OF FIGURES

Figure 14. Elephants feeding on the floodplain to the west of the Bellair Dam. Note the dense ground cover of *Cynodon dactylon* in the foreground.

Figure 15. The tree component of *Acacia karroo* and *Schotia afra* utilized by the elephants as a percentage of all trees of that species visited.

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CHAPTER 1. GENERAL INTRODUCTION

1.1 BACKGROUND AND RATIONALE

Sanbona Wildlife Reserve (SWR) is a 54,000 ha private conservation area situated about two-and-a-half hours by road east of Cape Town in the semi-arid Little Karoo region of the Western Cape Province in South Africa. It was established in 2002 when Mantis Collection (a private company) bought 19 farms to consolidate the reserve. The goal of this initiative was to create a commercially-viable tourist destination offering visitors the opportunity to see a wide range of Africa's unique wildlife including elephants (*Loxodonta africana*) and other large charismatic species such as lion (*Panthera leo*) and white rhinoceros (*Ceratotherium simum*). From 2002 until the present over 3,000 animals, of 18 species, have been introduced onto the reserve and two, five-star lodges have been built in order to generate funds for the project.

For many of the smaller ungulates re-introduced to the area (e.g. springbuck (*Antidorcas marsupialis*) and zebra (*Equus equus*)) their impact will in all likelihood be little different to that of the domesticated animals (Davies and Botha, 1986) which have utilized the region over the last 200 years, particularly if stocked at recommended stocking rates, as indicated in the SWR management plan (Erasmus, 2005). For other larger species, however, such as the African elephant (*Loxodonta africana*) the impact is unknown as their re-introduction to SWR is the first time the region has seen this species since they were exterminated from the area early in South Africa's colonial history. This venture furthermore posed another difficulty in that most aspects regarding the impacts and management of megaherbivores such as elephants have been studied in savanna ecosystems and therefore no information on this topic is available for the Little Karoo or the Fynbos biome.

Elephants are megaherbivores with a daily intake of up to 300 kg of vegetative matter per day (Cowling & Kerley, 2002). The combination of high densities and confinement to small reserve areas can exaggerate the impacts that elephants have on a local ecosystem (Tchamba, 1995; Wiseman *et al.,* 2004; Roux, 2006) and can result in the transformation of an ecosystem. Their effects on vegetation are varied and range from changing the woody structure of the area by reducing tree height and reducing tree species diversity to promoting higher species diversity by reducing the dominant woody species (Wiseman *et al.,* 2004) and by influencing species composition along a gradient away from water holes (De Beer *et al.,* 2006).

In the Addo Elephant National Park, for example, it was found that elephants caused a reduction in total plant biomass and abundance (Penzhorn *et al.,* 1974) as well as in species diversity and tree canopy volume (Barrat and Hall-Martin, 1991). Certain woody species on the other hand showed an increase in biomass as a response to elephant browsing by producing numerous secondary shoots or coppice's (Stuart-Hill, 1992).

On Kwandwe and Shamwari Game Reserves in the Eastern Cape it was found that elephant impacts were greater within their core habitat area than elsewhere on the properties (Roux, 2006). This study also suggests that the longer elephants remain in such small confined areas, the more pronounced their effects become. Dublin *et al.* (1990), suggest that once the vegetation has been degraded the presence of elephants reduces the possibility for it to return to its original state. This would be most prominent in core habitat areas, close to water points and along footpaths where they have the ability to remove all saplings due to trampling, path maintenance and general feeding patterns (Höft and Höft, 1995; Struhsaker *et al.*, 1996; Lawes and Chapman, 2006).

Given theses potential impacts that elephants may have on the vegetation of confined areas, it is not surprising that the introduction of elephants onto SWR, a semi-arid Karoo landscape, had widespread reactions and caused some concern over the well being of the biodiversity on the property. It is due to these concerns that CapeNature stipulated that a scientific research project be implemented in order to monitor the impact of elephants on the biodiversity of SWR. This study is the outcome of the stipulations of the elephant introduction permit granted to SWR.

1.2 STUDY OBJECTIVES AND KEY QUESTIONS

The main objectives of this study were to determine the habitat use and diet selection of the herd of re-introduced elephants and to document their impact primarily on the main tree species in the reserve. This was done not only to comply with the permit regulations issued by CapeNature but also for the wildlife management team so that informed decisions could be made regarding the elephant population on the reserve. The following key questions were addressed in this study:

1. What is the home range size of the elephants on SWR and to what extent are they utilizing the entire reserve?

2. What habitats within the home range are preferred by the elephants and therefore most likely to be impacted by the herd?

3. What is the diet composition of different individuals within the herd and for the herd as a whole within the preferred habitat and which plant species comprise the main component of the diets of the elephants on SWR?

4. What edible components (e.g. leaves, shoots, stems, bark) are consumed preferentially within the different height classes of the main tree species examined?

5. What is the impact of the SWR elephants on the growth and mortality of the main tree species on the reserve?

1.3 RESEARCH APPROACH

Detailed methodologies for each analysis are provided in chapters 3, 4 and 5. What follows is a general description of the approach adopted in this study. Elephant movement across the reserve was determined by means of daily observations of the location of the herd over a three year period from 2003 to 2006. From this data their home range and core utilization distribution areas were calculated within a Geographical Information System. Within the home range and core utilization distribution area the elephants' preference for different habitats was determined by counting all sightings over the study period that the elephants were observed within a range of habitat types. Chi square analyses and Bonferoni confidence intervals were used to test for habitat preferences. Within the determined core habitat area the feeding ecology of the herd was monitored over a three month period in order to determine the diet composition of each animal. During the monitoring sessions each animal was monitored for 20 minutes during which time all items consumed were identified. The cover of different plant species in the core feeding area was measured in the field using a drop point survey method. Chi square analyses and Bonferoni confidence intervals were then used to determine species preferences. In order to establish the impact that the elephants have on the trees, yearly observations between 2003 and 2006 were performed on a total of 1,013 marked trees in 34 transects at randomly selected points throughout the reserve consisting of the five most common tree species found on SWR. The data were then analyzed to obtain the number of affected trees within the sample, the type of tree utilization that occurred as well as the number of tree mortalities that had occurred over the study period.

1.4 LIMITATIONS OF THE STUDY

Elephants are large, potentially dangerous animals and extreme caution has to be taken when working with these relatively unpredictable creatures in the field. This obviously affected the nature and quality of the data that could be collected, particularly in terms of the diet selection study. Binoculars were needed to identify the species selected by individual animals and some error was undoubtedly present. This was further complicated by the fact that the elephants could only be followed in an area where it was safe to do so from a vehicle and close enough to be able to identify the species eaten. In addition, the original SWR herd was comprised of only five animals, two of which were relatively young individuals. This small sample size made comparative analyses difficult and only limited statistical analysis of the data was possible. Any analysis of the impact of elephants needs to be conducted over long time periods. The fact that this study was conducted only over three years suggests that caution should be used in interpreting the data. Although this analysis found relatively little direct impact of elephants on the main tree species in the reserve, over longer time frames the accumulative effects of elephants might be considerably greater than suggested by this study.

1.5 THESIS OUTLINE

Chapter 2 introduces the study site and familiarizes the reader with aspects of SWR such as the various management units and the habitat types found on the property. A brief description of the elephant population history on SWR is also provided in this chapter.

Chapter 3 investigates how the elephants utilize the space available to them at SWR. It determines home range size and how this varies between seasons. It also investigates the habitat preferences shown by the herd within its home range. The results of studies conducted elsewhere are compared to these findings.

Chapter 4 determines the plant species that makes up individual diets as well as the species preferences found in their diets. This chapter also investigates the ratio of browse to graze material in the diets of individuals and compares this with other studies.

Chapter 5 answers the main question concerning the impacts that the elephants have on the trees of SWR. It looks at the tree species that the elephants utilize and also investigates the preferred height classes within these species. It determines to what level the elephants play a role in tree mortalities on the reserve.

Chapter 6 summarizes the results of this study and determines if the current elephant population does indeed have a negative impact on the main tree species found within the SWR.

CHAPTER 2. DESCRIPTION OF THE STUDY SITE

2.1 LOCATION

The SWR is situated less than three hours drive from Cape Town. It lies to the north of Route 62 where it runs from Montagu to Barrydale and to the west of Route 62 as it turns northwards from Barrydale to Ladismith (Figure 1). It can be reached relatively easily from the towns of Swellendam and Heidelberg via the scenic Tradouw Pass. It is also located on a viable alternative route between Cape Town and the Garden Route via Worcester and Robertson (Erasmus, 2007).

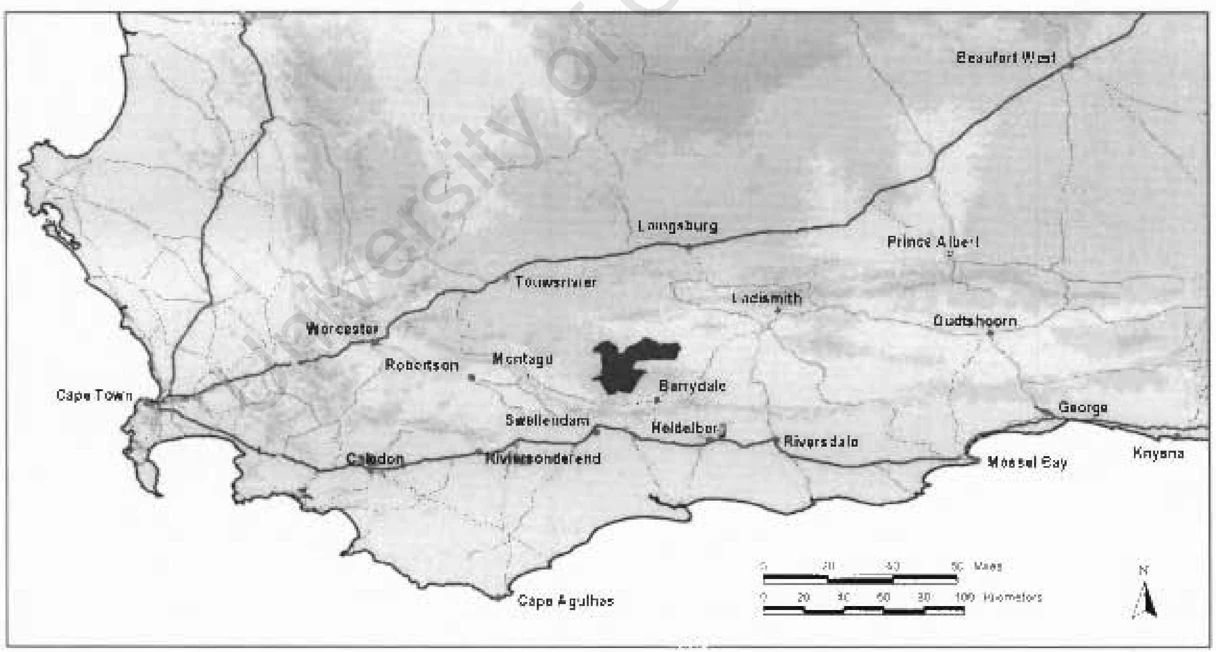


Figure 1. The location of the 54,000 ha Sanbona Wildlife Reserve (green shading) relative to Cape Town and surrounding areas (from Erasmus, 2007).

2.2 SIZE AND SHAPE

SWR is 54,000 ha with the southern section being narrower than the northern section, and the eastern area being larger than the western area (Figure 2). From east to west Sanbona is about 30 km wide and from north to south about 25 km long (Erasmus, 2007).

2.3 MANAGEMENT UNITS

2.3.1 Sanbona South

This area forms the largest part of the reserve and covers about 40,000 ha (Figure 2). This is where most of the reserve's tourism activities are focused. Sanbona South is managed under SWR management plan guidelines and only indigenous mammal species are found here. Within this area there are 8,000 ha of wilderness area that is managed under strict wilderness management ethics. Sanbona South is also the only area available to the elephants.

2.3.2 Sanbona North

This area forms the northern part of the reserve and is fenced off from the main reserve. This area of about 7,700 ha is free of large predators and houses the more expensive species such as disease-free buffalo (*Syncerus caffer*). This area is also home to two extra-limital species, giraffe (*Giraffa camelopardalis*) and white rhino (*Ceratotherium* *simum*). The reason for these species being on the reserve is to enhance the game experience of the guests who visit Sanbona.

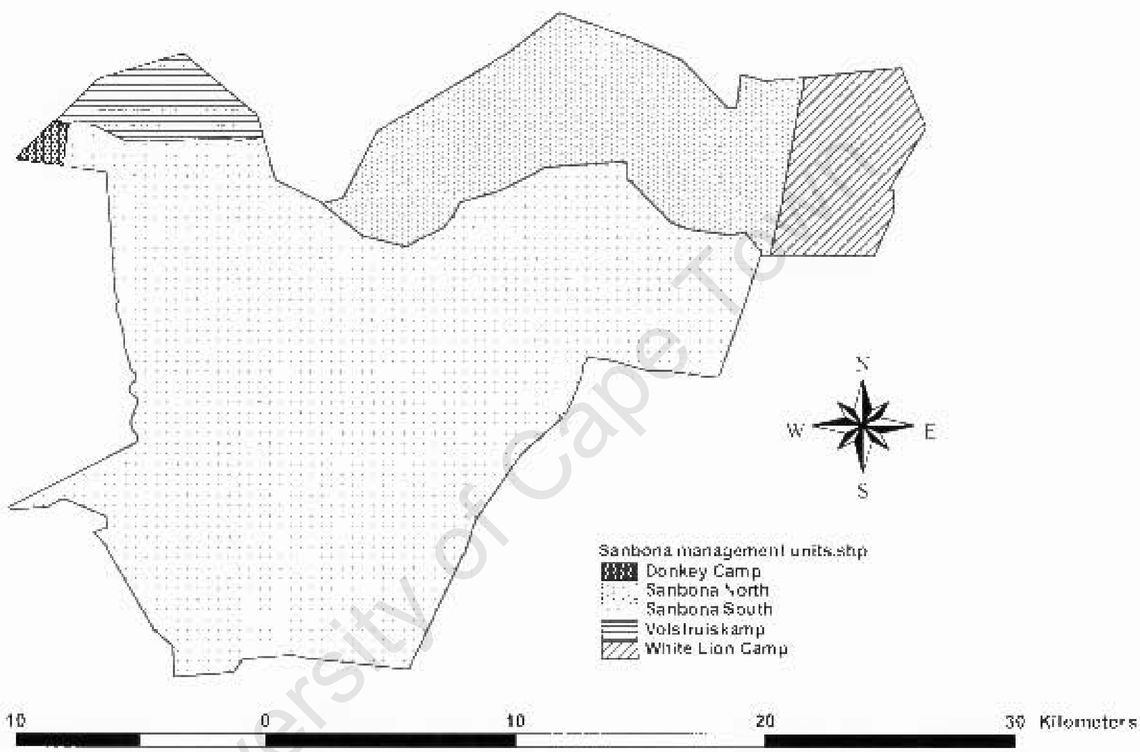


Figure 2. The five main management units of Sanbona Wildlife Reserve (from Erasmus, 2007).

2.3.3 Ostrich Camp (Volstruiskamp)

This 2,000 ha camp forms the north-western corner of the reserve. This is the only area which does not have a 2.4 m game fence enclosing it. At present this area is only stocked with ostriches (*Struthio camelus*) and springbok (*Antidorcas marsupialis*) and does not currently feature in the development plans of the reserve.

2.3.4 White Lion Camp

This 4,300 ha camp forms the north-eastern corner of the reserve. This is where SWR's white lions (*Panthera leo*) used to be kept before they were moved to the main reserve. It is currently stocked with only a few antelope species and does not feature in the plans for development in the near future.

2.3.5 Donkey Camp

This area of almost 200 ha does not form part of the general reserve and is also not fenced by a game proof fence. The reason for this is that this land is separated from the main reserve by a public road. It is used as a holding area for domestic stock if required.

2.4 CLIMATE

SWR lies within the transition zone of summer and winter rainfall areas of the Western Cape (Desmet and Cowling, 1999). Rain falls predominantly in winter in the southwestern parts of the reserve while rain falls predominantly in summer in the northeastern parts. At Die Vlakte Weather Station about 7 km south of SWR (Figure 3), there is a peak in rainfall in April and a dip in January and February. The average rainfall over the past 20 years at this site was 398 mm per year.

The coldest month of the year is July with an average daily minimum temperature of 4.6 °C, with the hottest month being February with an average daily maximum temperature of 27.1 °C (Figure 4).

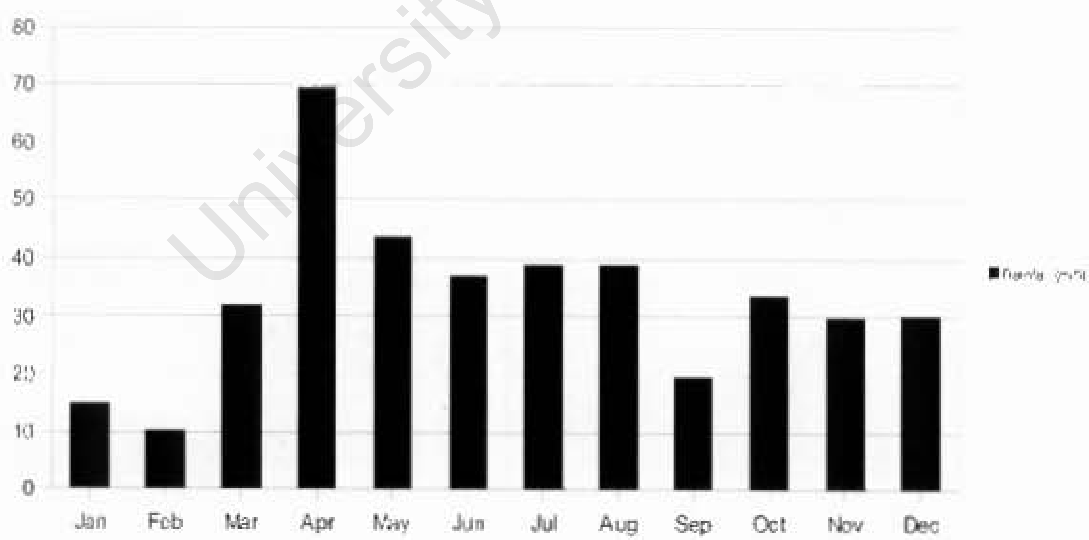


Figure 3. Monthly rainfall averages for the last 20 years for Die Vlakte Weather Station, Barrydale (Department of Agriculture archives, Elsenburg, 2007).

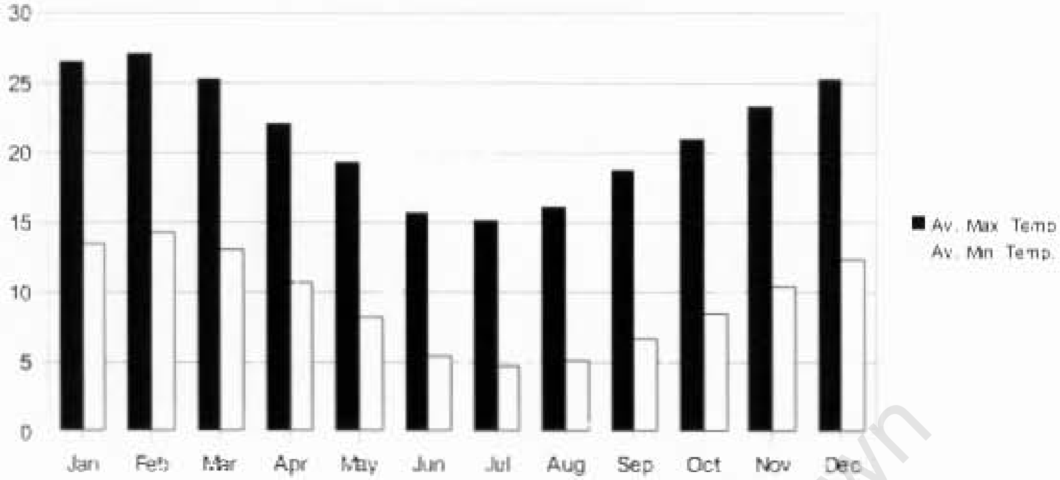


Figure 4. Average monthly minimum and maximum temperatures for the last 20 years for Die Vlakte Weather Station, Barrydale (Department of Agriculture archives, Elsenburg, 2007).

2.5 GEOLOGY AND TOPOGRAPHY

Two major geological types of the Cape Super Group can be found on SWR. The high lying areas fall within the Table Mountain Group (Arenite) whereas the lower lying areas fall within the Bokkeveld Group (Shales). These formations date back to between 400 and 510 million years (Norman and Whitfield, 2006).

The southern section of the reserve is made up of rolling hills and plains. This extends northwards to the Warmwaterberg that runs from east to west and divides the reserve into a northern and southern section. The northern section is made up of typical Karoo hills and valleys with some pans and quartz patches. The western section of the reserve is covered by a series of rugged mountains.

There are four main river systems on the reserve (Figure 5), all of which are ephemeral. The first is the Kalkoens River that runs from the southern section in a northerly direction until it meets up with the Gatskraal River. The Gatskraal River is the second main river and it enters the reserve through the western boundary and flows into the Bellair Dam. The third river is the Wilgerbos Kloof that runs from the south and flows into the Bellair dam from the south-east. The fourth river is the Brak River which enters the reserve from the north-west and does not flow into the Bellair Dam. All the rivers join below the wall of the Bellair Dam and exit the reserve in the north-eastern corner as the Brak River and then join up with the Touw River to the east of SWR.

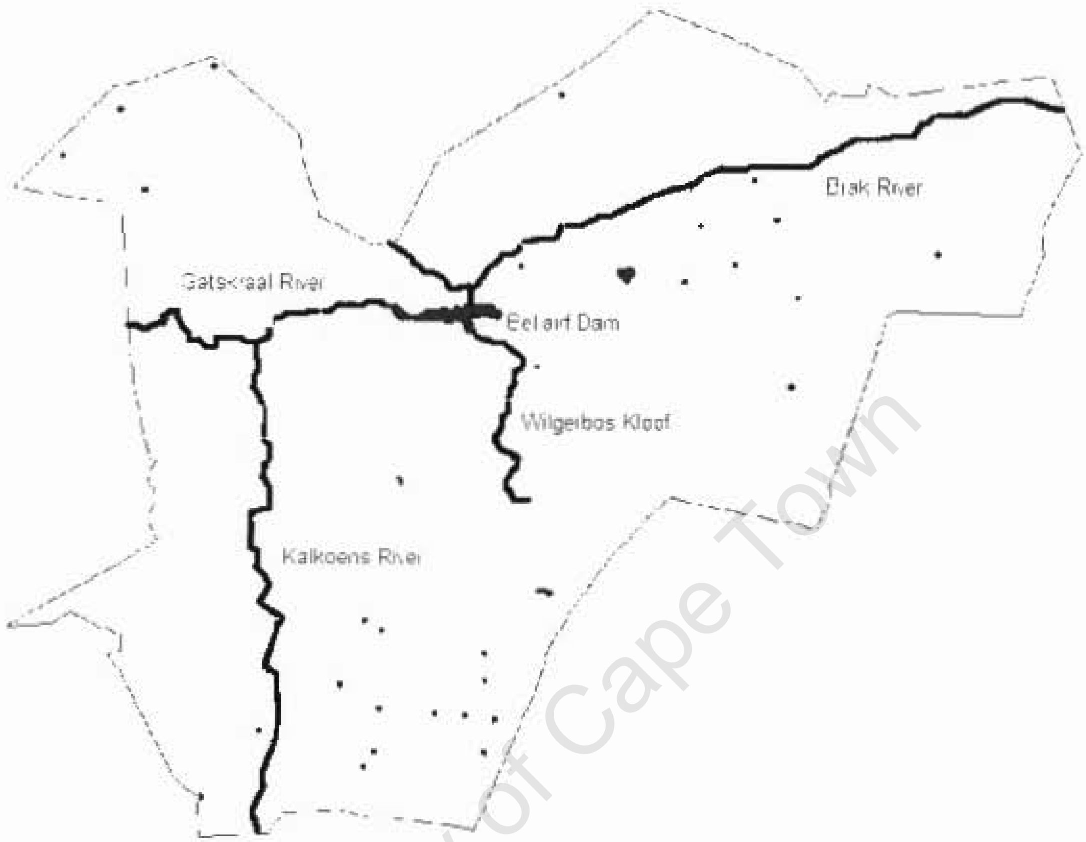


Figure 5. The main rivers on SWR and the Bellair Dam as well as the main permanent water bodies found on SWR (ARCVIEW 3,2. G.I.S., map units: Decimal degrees, Projection: Transverse Mercator WGS 84).

2.6 HABITAT TYPES

In order to manage SWR properly the management team decided to use the vegetation units defined by Vlok *et al.* (2005), as management units. This allowed for a scientifically-defensible platform from which to work. Using the vegetation units as a baseline, SWR was divided into 12 easily-identifiable habitat types (Figure 6).

2.6.1 River Drainage

It is easy to recognize this habitat as the riverine vegetation consists mostly of woody trees (e.g. *Acacia karroo, Rhus lancea, Tamarix usneoides*), reeds (*Phragmitis australis*) and bulrush (*Typha capensis*) that are resilient to brackish (i.e. slightly saline) conditions. Shrubs (defined as the multi-stemmed perennial, woody component of the vegetation usually less than 2 m in height) dominate the floodplain vegetation. Ganna (*Salsola aphylla*) is always abundant but a variety of other shrub species also occur here (e.g. *Atriplex vestita, Salsola glabrescens* and *Suaeda fruticosa*) (Vlok *et al.,* 2005).

The vegetation of the upper drainage areas is quite different to those of the main river channel, but *Acacia karroo* is always present except for the few small tributaries in the southern part of the reserve. An interesting feature on SWR is that *Schotia afra* is sometimes abundant in these seasonal drainage areas. After good rain the grass component may be well developed, often with *Cenchrus ciliaris, Cynodon dactylon, Ehrharta thunbergii* and *Fingerhuthia africana* locally abundant.

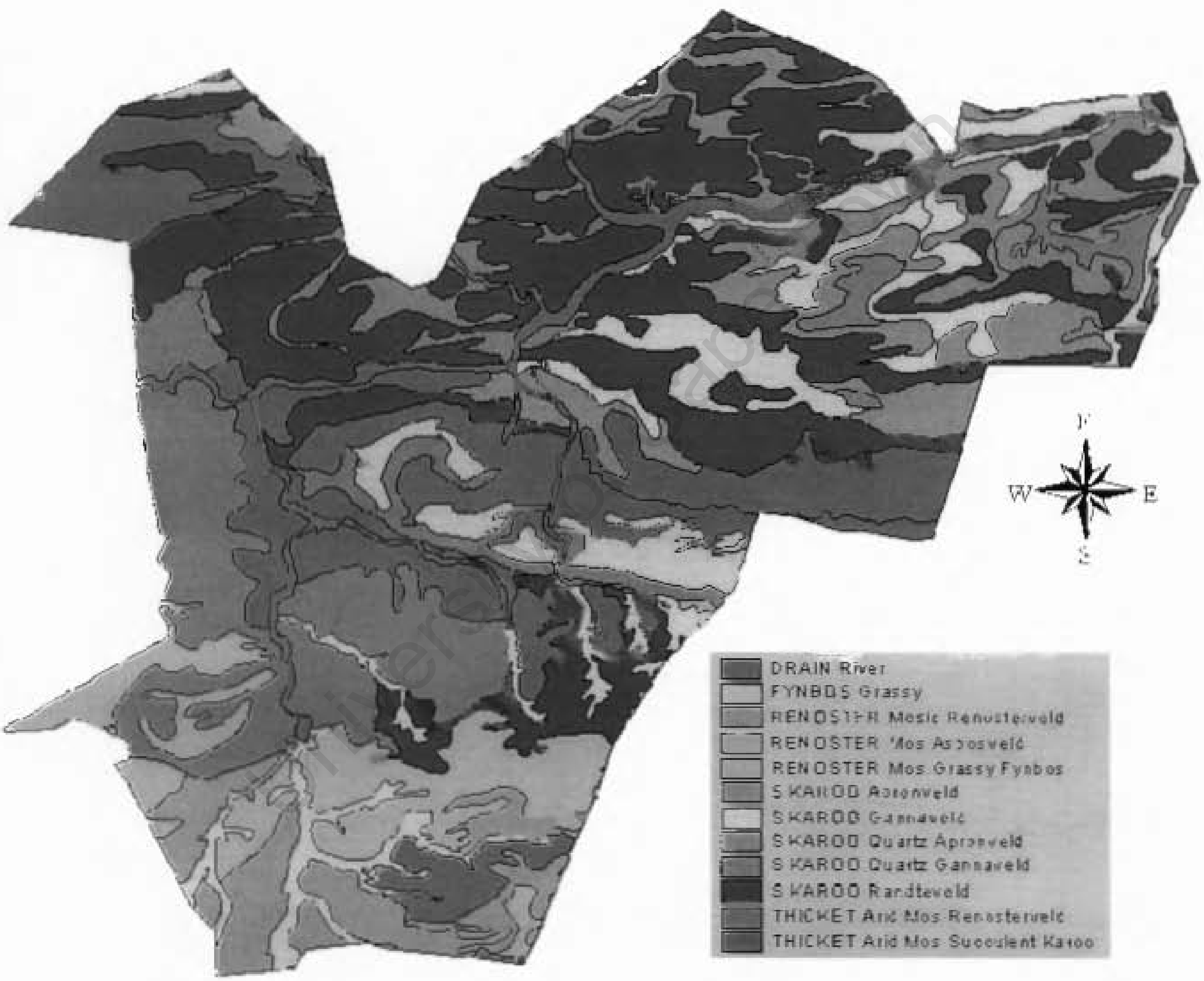


Figure 6. Vegetation map of Sanbona Wildlife Reserve showing the 12 habitat types. (after Vlok *et al.*, 2005).

Most of the Riverine and floodplain habitat on SWR has been negatively affected by a number of activities. Most of the fresh water that used to run from the upper catchment areas into the river systems has been cut off by the Bellair Dam. The removal of this perennial supply of fresh water would have altered the composition of the natural vegetation in the riverine areas. The lower floodplain embankments have, in many instances also been transformed to establish intensive agricultural crops. These have subsequently been transformed to a semi-natural state after the 2003 flood when the Bellair Dam burst through its wall and destroyed almost all evidence of former agricultural activities downstream.

Apart from providing many unique habitats for bird and invertebrate species, the River Drainage habitat probably also served as an important corridor for the long distance movements of plants and animals (*e.g.* elephant (*Loxodonta africana*), black rhinoceros (*Diceros bicornis*), hippopotamus (*Hippopotamus amphibius*)) in the past. They acted as important freshwater and fodder sources for these animals, which in turn probably maintained many open channels within the riverine vegetation, and limited flood damage to the upper floodplain zones.

2.6.2 Grassy Fynbos

The Grassy Fynbos habitat type is easy to recognize, as it is structurally very simple, with an abundance mostly of only C3-grass genera such as *Aristida, Merxmuellera, Pentameris,* and *Pentaschistis*. Members of the Restionaceae (e.g. *Calopsis, Hypodiscus,* *Ischyrolepis, Restio, Rhodocoma*) and Ericaceae are present, but are seldom prominent. Proteaceae (mostly only *Leucospermum* and *Paranomus*) are rare, but quite a variety of other typical Cape shrub genera (e.g. *Agathosma, Aspalathus, Euryops, Eriocephalus, Felicia, Heliophila, Hermannia, Montinia, Passerina, Phylica*) may be present. Some short-lived shrubs (e.g. *Aspalathus* and *Hermannia*) are often super-abundant after a fire, together with geophytes, although geophytes are never as abundant as they tend to be in the more mesic Fynbos habitats.

Despite the relative abundance of grasses the Grassy Fynbos habitat type is not particularly suitable for grazing purposes, except perhaps for bulk-grazers such as the cape mountain zebra (*Equus zebra zebra*) (Vlok *et al., 2005).*

2.6.3 Renosterveld (Mesic Renosterveld)

The Mesic Renosterveld is an easily-identifiable habitat, as it has a sparse tree cover, is dominated by renosterbos (*Dicerothamnus rhinocerotis*) and has few other shrub species abundant. The dominant renosterbos is not an introduced weed, as some people believe. It is a natural feature of this habitat type and is the host plant of a number of very specialized invertebrates, some of which are also localized endemics (Vlok *et al.,* 2005). However, few vertebrates utilize renosterbos, which is probably why it is often locally-dominant in heavily-grazed sites. When the grass component is heavily-utilized after fire by grazers, the competitive advantage of these grasses is weakened and renosterbos seedlings can establish unhindered. Repeated grazing after fires thus allows renosterbos to become abundant in some sites. The original grass component can be restored by not grazing these sites within the first two to three years after a fire. This would also be vital to restore healthy populations of many of the rare geophyte species that occur in this habitat.

This habitat occurs mostly along the lower slopes and foothills of mountains, where the soils are loamy and rich in nutrients and the winter rainfall is fairly high. With these characteristics it is easy to understand why most of this habitat has been transformed to establish wheat fields. Currently even the small, unploughed patches of this habitat are subjected to several inappropriate management practices on the farmlands surrounding SWR. Incorrect burning regimes are also often used, such as spring and winter burns, because landowners are afraid of runaway fires in summer and autumn. In some cases it is burned too frequently or not at all. If it is left unburned, tall woody shrubs, such as *Rhus lucida*, may invade this habitat type.

2.6.4 Renosterveld (Mesic Asbosveld)

This habitat type is very similar to the Mesic Renosterveld habitat type in that the tree component is very sparse or absent. However, it differs in being dominated by asbos (*Pteronia incana*) while renosterbos is still fairly abundant. Very few other shrub species are common. It has a fairly low grass component, which is only common after a burn (Vlok *et al.,* 2005). On SWR this habitat type is found within the southwestern section along the lower slopes of hills.

2.6.5 Renosterveld (Mesic Grassy Fynbos)

This habitat type closely resembles Mesic Renosterveld in that it has a sparse tree component with a very low diversity of shrub species. The most prominent characteristic is that in the first few years after a fire it may have a well-developed grass layer comprised of C3- grasses such as *Ehrharta, Merxmuellera* and *Pentaschistis* species and C4-grasses such as *Themeda triandra*. Renosterbos (*Dicerothamnus rhinocerotis*) usually displaces the grass cover over time (Vlok *et al.,* 2005). It is found mostly on the steeper slopes of hills in the southern part of SWR especially along south-facing slopes.

2.6.6 Succulent Karoo Apronveld

The Apronveld habitat type is always located at the base of hills and ridges. It never occurs on steep slopes or in valley bottoms, where the Gannaveld habitat type replaces it. The soils are usually loamy to clayey and surface rocks are usually abundant. The shrub cover is well developed with gombos (*Pteronia spp.*) and kapokbos (*Eriocephalus spp.*) often the most abundant species. Leaf- and stem-succulents, as well as a variety of bulbous plants (geophytes) are usually abundant here, but grasses are uncommon. It is one of the Little Karoo habitat types used most by domestic stock, as many of the common plant species are palatable and the terrain is easily accessible.

2.6.7 Succulent Karoo Quartz Apronveld

The Succulent Karoo Quartz Apronveld differs from Succulent Karoo Apronveld in that patches of white quartz pebbles are present. These quartz outcrops are located in the matrix Apronveld and possess significantly different species to that of the surrounding shrubby vegetation. A rich variety of small succulents (i.e. *Gibbaeum* spp.) can be found within these quartz patches (Vlok *et al.,* 2005). Only a few of the plant species on these quartz patches are grazed under severe grazing pressure. The biggest threat to these quartz patches is from trampling by domestic stock and other hoofed mammals.

2.6.8 Succulent Karoo Gannaveld

Gannaveld is an easy habitat to recognize. It is always located in valley bottoms and often forms large open plains just above the River Drainage habitat type. The soils are usually deep, loamy and saline. It is denuded of trees, but tall shrubs such as gannabos (*Salsola* spp.) and kriedoring (*Lycium* spp.) are usually abundant. Many other small shrubs (e.g. *Eriocephalus* spp., *Pentzia incana, Pteronia* spp., *Tripteris* spp.) also occur here. After rain it has many annual species, some of which are endemic to this habitat type. Succulents are uncommon, perhaps due to the occurrence of frost in these valley bottoms. Grasses are also uncommon, except in sandy patches where they may be locally abundant (e.g. *Stipagrostis* spp.) (Vlok *et al.,* 2005).

2.6.9 Succulent Karoo Quartz Gannaveld

The Quartz Gannaveld habitat is similar to the Apronveld versus Quartz Apronveld case. It only differs from Gannaveld in having patches of white quartz pebbles present, but gannabos (*Salsola aphylla*) remains the most abundant shrub in the matrix vegetation. Quartz Gannaveld only occurs in the western Little Karoo. Leaf succulents are only abundant in the quartz patches and where the quartz pebbles are sparse they are also sparse. Most of these species are different from those that occur in the quartz patches of the Quartz Apronveld habitat type, perhaps due to differences in the underlying soil..

A number of these succulents are localized endemics (Vlok *et al.,* 2005). SWR hosts one of the regions with the highest diversity of *Gibbeaum* spp. in the Little Karoo with up to five species found on its quartz patches (Manning, 2001). This habitat type is also very sensitive to overgrazing as it results in accelerated soil erosion and the introduction of alien plants. Soil stability in these quartz patches appears vital for regeneration of the succulents that are endemic to these patches.

2.6.10 Succulent Karoo Randteveld

This is a very arid habitat type and one of the most arid habitat types in the Little Karoo. It is only prominent in the western Little Karoo and is replaced in the east by the Arid Thicket Mosaic habitat. It differs from the latter habitat in having only a sparse woody tree (*Euclea undulata*) and tall shrub component (*Dicerothamnus rhinocerotis*) *present* and if present, it is mostly restricted to south-facing slopes. This habitat occurs on ridges and hills where the shale derived soils are very shallow. The vegetation consists mostly of a sparse cover of small shrubs and compact leaf-succulents. Even here one often finds a well-developed cover of lichens and mosses (Vlok *et al.,* 2005).

2.6.11 Arid Mosaic Thicket Succulent Karoo.

Typical of this habitat is a landscape dotted with thicket bush-clumps, usually with gwarrie (*Euclea undulata*) and koeniebos (*Rhus undulata*) the most abundant trees. On shale-derived soils the matrix vegetation is Succulent Karoo. Sosaties (*Crassula rupestris*) is usually abundant in this habitat, irrespective of the local soil conditions. This habitat may be confused with the Randteveld of the Succulent Karoo biome, but it differs in always having trees and bush-clumps present on the north-facing slopes. In the Randteveld only a few of these trees occur on south-facing slopes (Vlok *et al.,* 2005).

2.6.12 Arid Mosaic Thicket Renosterveld.

This habitat type is similar to Arid Mosaic Thicket Succulent Karoo in that it has scattered bush clumps with gwarrie (*Euclea undulata*) and koeniebos (*Rhus undulata*) the most abundant trees. It differs in having a higher rainfall with *Pteronia incana* being the dominant species.

2.7 Elephant Population History.

It is unknown to what extent elephants populated the area in the past. There are no references on historical population densities or if the elephants were present in the area permanently or if they only used the area as a passage between different feeding spots. Skead (1980), however, mentioned that people in the area hunted up to 23 elephants in a day on horseback. This suggests that elephants could have been present in the Little Karoo in larger numbers than one would expect for this relatively treeless, semi-arid environment. It was, however, decided that only a small number of elephants be introduced to SWR in order to determine the possible impacts they may have on the property and then adapt their numbers accordingly.

In 2003, five Elephants from Shamwari Game Reserve in the Eastern Cape were translocated to SWR. These elephants were carefully selected from a group of 61 elephants to make sure that the elephant bull was not related to the two adult females or their two young male calves (O'Brien, 2003). In November 2004 and February 2005 a calf was born to each of the two cows. This meant that the females which arrived at Sanbona were pregnant at the time of translocation. A further two calves, one to each of the adult females, were born in August 2007. Apart from the Knysna elephants, these were the first free-roaming calves born in the Western Cape since elephants became extinct in the area.

After all the problems that have been encountered by single or young elephant bulls translocated to new reserves it was decided to treat the Sanbona bull with a testosterone depressant, purely as a precautionary measure without testosterone level testing taking place before the implementation of the darting. The aim of this intervention was to reduce the production of testosterone and in so doing reduce the effect and occurrence of musth and thereby reduce the level of aggression exhibited by the male elephant (Fayrer-Hosken, *et al.,* 2001). A GnRH vaccine produced by Pepscan Systems in the Netherlands was used. This has been administered by darting the animal three times over a period of six months. Because this elephant had never previously been subjected to this treatment, dung samples were collected every two weeks and stored in a freezer until all the samples for the six month period had been collected. The dung samples were then sent to Onderstepoort in order to determine the testosterone levels of the bull over time so that the success of the experiment could be verified. The results of the dung analyses are not yet available.

During 2008 one of the adult females died when she fell down a rock face along the banks of one of the rivers. Because her calf was still too young to fend for itself, it was moved to the rehabilitation center on Shamwari Game Reserve in the Eastern Cape. Apart from these two actions, the herd has been left to live a life as close to natural as possible.

CHAPTER 3. HOME RANGE SIZE AND HABITAT SELECTION OF ELEPHANTS ON SANBONA WILDLIFE RESERVE

3.1. INTRODUCTION

The size of an elephant herds' home range is influenced by several factors including the availability of fresh water (De Beer and van Aarde, 2008), shade (Skinner and Smithers, 1990), nutritional requirements (Schoener, 1981), the amount of space available to them (Whitehouse and Schoeman, 2003), the sex of the individual or group (Owen-Smith, 1988; Shannon *et al.*, 2005) and possibly the size of the population. Home ranges not only vary in size between different locations and populations, but also vary in size from season to season (De Beer and van Aarde, 2008). This seasonal variation in home range size is influenced by energetic constraints, social factors and the availability and distribution of resources (Shannon *et al.,* 2005). Within the broad home range distribution, however, elephants show preferences for various habitats due to closeness to water (De Boer *et al.*, 2000; Stokke and du Toit, 2002), dietary requirements (Dublin. 1996; Houston *et al.*, 2001), accessibility (Nellemann *et al.*, 2002), pressure from human activities (Hoare, 1999), cover (Smith *et al.*, 2007) and differences in ambient temperatures between habitats (Kinahan *et al.,* 2007a).

The availability of water in arid and semi-arid regions plays a major role in the distribution and home range sizes of elephants. This is evident in Namibia's Etosha

National Park where elephants only became permanent residents in most areas of the park after the introduction of artificial watering points (Lindeque, 1988). Home range variation can also occur as a result of food quality or nutrient requirements and feeding ecology. Dunham, (1986), found a difference between the larger home range sizes of elephants along the Zambezi River in comparison with the smaller home range sizes of elephants on the escarpment. He attributed this difference in home range size to the fact that less grass can be found in the woodlands along the river.

Due to the fact that elephants move great distances (measured at more than 30 km in a single night at SWR (unpublished data)) and that very few reserves can accommodate such large home ranges, the space available to them will also ultimately determine their home range size. This is supported by studies from Whitehouse and Schoeman (2003), and Osborn (2003), and will be discussed later on in the chapter.

Male and female home range sizes can also differ significantly (Shannon, 2005). Males typically (but not always) show a larger home range than females (Ntumi *et al.*, 2005; Shannon, 2005; Stokke and Du Toit, 2002). This can be attributed to the fact that males often move around singularly while females stay in groups. Males also space themselves in order to limit contact with other males that are in musth (Stokke and Du Toit, 2002). The smaller home ranges of females can be attributed to the higher energetic requirements due to smaller body size and substantial reproductive investment. Females therefore often concentrate their activities in areas with higher nutrient availability so that they are able to spend less energy to obtain the resources required (Shannon, 2005).

Jackson and Erasmus, (2005), found that in Etosha National Park, Namibia, males had a home range size of 2,029 km^2 while females had a home range of only 1,511 km^2. Similarly, in Kafue National Park, Zambia males had a home range of 884 km^2 and females 534 km^2 while in Tembe Elephant Park, South Africa the home range size of males was 235 km^2 while that of females was 62 km^2. This shows that in most cases the bull elephant home ranges were bigger than those of the females. This is not the case for all studies, however, since Roux (2006) found no significant differences in home range sizes of males and females on Shamwari and Kwandwe Game Reserves in the Eastern Cape. De Villiers & Kok (1997), on the other hand found the opposite to be true where the female herd home range sizes (116 km^2) were larger than those of the males (78 km^2) in the eastern Transvaal Lowveld.

The seasonal availability of drinking water has a critical influence on home range size, particularly in arid and semi-arid environments (De Beer and van Aarde, 2008). The trend is for herds to have a larger home range in the wet season when water is more readily available (Ntumi, 2003). Shannon *et al.* (2005), state that elephants in semi-arid regions show an expansion of their home range with the start of the wet season and that they are restricted to smaller areas around rivers and water points during the dry season. Roux (2006), found similar trends on Kwandwe and Shamwari Game Reserves in the Eastern Cape. Similar trends were also observed by De Villiers and Kok (1997), in the Transvaal Lowveld. In the Sengwa Wildlife Research area in Zimbabwe it was found that elephants showed a drastic increase in space use distribution towards the end of the wet season. This may be as a result of switching from grazing during the wet season to browsing during the dry season and therefore requiring more space to obtain the required amount of nutrition (Osborn, 2003).

Kinahan *et al.* (2007a; 2007b), inferred from their study that elephants show changes in seasonal home ranges due to their attempts to seek out suitable ambient environmental temperatures. They found that elephants moved to areas where the ambient temperatures are closer to their body temperatures during the colder periods and to cooler areas during the warmer periods. This is to minimize energy consumption to maintain body temperatures during cold spells and to effect the cooling of the body during warm spells.

Very few studies have actually determined habitat occupancy and use by elephants, particularly on a seasonal basis (Shannon *et al.*, 2005). Schindler (2005), and Roux (2006), suggest that in order to determine if habitat use is random or selective one needs to determine the preference shown towards a certain habitat. Jackson and Erasmus (2005), for example, found that elephants in Etosha National Park showed no particular preference for habitat types as long as they were closer than 4 km from water. At Shamwari Game Reserve it was found that elephants tend to spend more time around the Bushmans River rather than showing a preference for a specific vegetation or habitat type (Roux, 2006). Shannon *et al.* (2005) found that low-lying areas in the Pongola Nature Reserve were preferred due to the nutrient richness of the soils. Similarly, in Botswana it was found that elephants selected habitats during the dry season for their nutrient richness rather than other factors (Verlinden and Gavor, 1998).

Other factors influencing home range size are terrain steepness and the presence of human settlement. Elephants tend to avoid steep (Nelleman *et al.*, 2002) and rugged terrain and even small hills were found to be barriers for large animals (Wall *et al.*, 2006). Human activities play a major role in areas where human/elephant interactions are frequent. Skinner and Smithers (1990) suggest that elephants in the Knysna forests are found there purely because of the high human pressure around the forest. In Tanzania Mpanduji (2004), also found that elephant movements are influenced by repeated contact with people.

This chapter investigates the home range size of the elephant herd present on SWR over a three-year period. It determines (1) the home range size and core area used by the herd; (2) the seasonal variation in their movement patterns; (3) if the elephants show a preference or avoidance for any of the habitat types within their home range.

3.2. MATERIALS AND METHODS

3.2.1 Data Collection

A total of 595 elephant sightings recorded by SWR staff between 2003 and 2006 were used in this analysis. Only one sighting of the herd per day was recorded in order to ensure independence of the data (Roux, 2006; White and Garrot, 1990). All sightings were plotted on a map of SWR and the coordinates were obtained using ARCVIEW 3.2.

3.2.2 Data Analysis

3.2.2.1 Home Range Size

The home ranges and core areas were calculated in ARCVIEW 3.2 using the ANIMAL MOVEMENT extension package v. 2.04 BETA (Hooge and Eichenlaub, 1997). The parametric minimum convex polygon (MCP) method was used to determine home range sizes for comparison with other studies and the non-parametric kernel utilization distribution (UD) method was used to determine home range (95 % UD) and core area (50 % UD) sizes (White & Garrott 1990, Roux, 2006). An H value of 1,000 was used for all analyses in ARCVIEW 3.2 as the smoothing factor (Roux, 2006). In all cases the UDs were clipped to fit the space available (within the reserve boundaries) to the elephants and the area sizes were then re-calculated. UDs for the three summer months (Nov-Jan) and winter months (Jun-Aug) were calculated separately to determine if there were seasonal differences in home ranges. A total of 525 observations were made of which 173 observations were in summer and 113 were in winter. The remainder of the observations (70 in total) was in autumn and spring. These observations were not included in this analysis of seasonal home range size determination.

3.2.2.2 Habitat Selection

Habitat utilization on SWR was calculated at the 95% UD and 50% UD level. Habitat utilization and preference were determined separately for summer and winter to determine seasonal variation. All sightings were plotted on a GIS base map of the reserve. This was then joined with a vegetation map of the reserve from where all points in each vegetation type were manually counted in ARCVIEW 3.2. Vegetation use was then calculated by comparing the amount of points per vegetation type in relation to all the points observed (Duchamp *et al*., 2004; Roux, 2006).

Beyers *et al*. (1984) described methods to evaluate habitat preferences. A Chi-square goodness of fit test was performed to determine if a significant difference occurred between the expected and observed utilizations. After this Bonferroni confidence intervals were calculated to determine which habitat types were preferred by using the following formula (Schindler, 2005):

$$\bar{P}i - Z_{\alpha/2k}\sqrt{\bar{P}i(1-\bar{P}i)/n} \le Pi \le \bar{P}i + Z_{\alpha/2k}\sqrt{\bar{P}i(1-\bar{P}i)/n}$$

Where:

Pi is the observed proportion of utilization for the *i*th vegetation type.

Z is the z score based on: the chosen α level (e.g. 0.05) divided by two-times the total vegetation types (***k***).

n is the total number of all observations in all vegetation types.

3.3. RESULTS

3.3.1. Home Range Size

No difference between the spatial distribution of the adult male and that of the rest of the herd was found on SWR. This is due to the fact that the adult male has never been out of sight of the herd and each sighting was therefore noted for the herd as a whole.

In total the elephants utilized a surface area of 18,813 ha (Figure 7). This comprises nearly half (49%) of the 38,036 ha available to them. Their 95% UD was 2,636 ha (7% of available land) while the 50% UD was 761 ha (2% of available land). The core area (50% UD) of their distribution range focused around the Bellair Dam and the floodplain towards the west (Figure 8), whereas the 95% UD extends into the Kalkoens River to the south west.

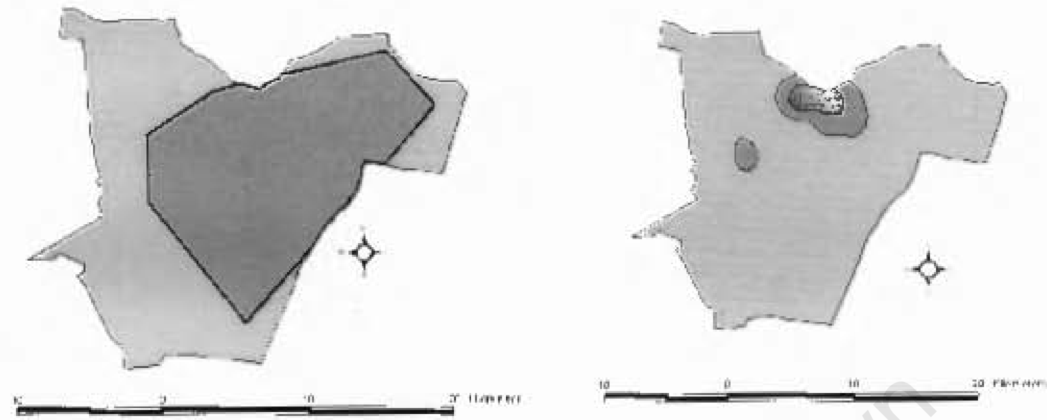


Figure 7. Total space used by elephants (left) on Sanbona throughout the study period (n=525 observations) and the home range of the elephants (right) with the 95% Utilisation Distribution (UD) in light grey and the 50% UD in dark grey.

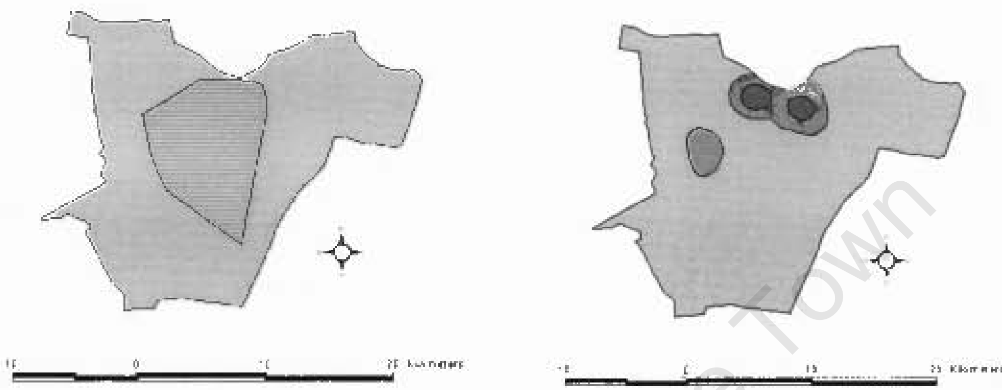
Figure 8. Elephants in River Drainage Habitat to the west of the Bellair Dam that forms the core of their Utilization Distribution (Photo: A. Mader, 2003).

During the summer months it was found that the elephants utilized a total area of 9,882 ha which represents 26% of the area available to them (Figure 9a)). Their summer home range (95% UD) covers an area of 2,041 ha which represents 5% of available land (Figure 9b)). Their summer 50% UD covers 498 ha or about 1% of available area. Again the 95% UD and the 50% UD were centered around the Bellair Dam, the floodplain to the west and the tributaries feeding the dam.

a) b)

Figure 9. a) Total space utilization by elephants during the summer months (n=173); b) The summer 95% Utilization Distribution (UD) in grey and 50% UD in dark grey.

During the winter months the elephants utilized a total area of 8,411 ha which represents 22% of available land (Figure 10 a)) Their winter 95% U.D. covers 3,432 ha or 9% of available land (Figure 10 b)), while their winter 50% U.D. covers 736 ha or about 2% of available land. As in the case of the summer months the home range in winter was also centered on the Bellair dam although there was an extension into the Kalkoens River to the south west and the tributaries further towards the east were also used.



a) b)

Figure 10. a) Total space utilization of elephants on Sanbona during the winter months (n=117); b) The 95% winter Utilization Distribution (UD) in grey and 50% winter UD in dark grey.

3.3.2. Habitat Selection

During the summer months the elephants preferred using the River Drainage and Grassy Fynbos habitat types at the broad home range level. At the core level, the only preference was for the River Drainage habitat type. All other habitat types were avoided (Table 1).

Table 1. Habitat use and preferences of (a) Home range (95% Utilization Distribution (UD) level) and (b) Core area (50% UD level) during summer by the elephants. P = Preference, CI = Bonferoni confidence levels.

a) Home range

Vegetation Type	Total area (Ha)	Proportion of area	Observed visits	Expected visits	Expected proportion	Observed proportion	Lower CI	Upper CI	P
Succullent Karoo Apronveld	421	0.21	11	35.72	0.21	0.06	0.01	0.11	-
Arid Mosaic Succullent Karoo	536	0.26	9	45.48	0.26	0.05	0.01	0.09	-
Succullent Karoo Gannaveld	129	0.06	13	10.95	0.06	0.08	0.02	0.14	
Grassy Fynbos	7	0	13	0.59	0	0.08	0.02	0.14	+
Succullent Karoo Quartz Gannaveld	113	0.06	3	9.59	0.06	0.02	-0.01	0.05	-
Succullent Karroo Randteveld	655	0.32	19	55.57	0.32	0.11	0.05	0.17	-
River Drainage	178	0.09	105	15.1	0.09	0.61	0.51	0.71	+

b) Core area

Vegetation Type	Total area (Ha)	Proportion of area	Observed visits	Expected visits	Expected proportion	Observed proportion	Lower CI	Upper CI	P
Succullent Karoo Apronveld	165	0.33	5	36.45	0.33	0.05	0	0.1	-
Arid Mosaic Succullent Karoo	56	0.11	7	12.37	0.11	0.06	0	0.12	
Succullent Karoo Gannaveld	33	0.07	8	7.29	0.07	0.07	0.01	0.13	
Succullent Karoo Quartz Gannaveld	43	0.09	0	9.5	0.09	0	0	0	-
Succullent Karroo Randteveld	115	0.23	13	25.4	0.23	0.12	0.04	0.2	-
River Drainage	86	0.17	77	19	0.17	0.7	0.58	0.82	+

During the winter months the elephants showed a preference for the River Drainage, Succulent Karoo Gannaveld and Arid Mosaic Renosterveld habitat types (Table 2) within their 95% UD. Succulent Karoo Quartz Gannaveld was utilized in the same ratio as is available in the 95% UD. All other vegetation types were avoided. At a core level (50% UD) the River Drainage and Arid Mosaic Succulent Karoo habitat types were preferred. All other habitat types in the core area were avoided.

Table 2. Habitat use and preferences of (a) Home range (95% UD level) and (b) Core area (50% UD level) during winter by the elephants. P = Preference, CI = Bonferoni confidence levels.

a) Home range

Vegetation Type	Total area (Ha)	Proportion of area	Observed visits	Expected visits	Expected proportion	Observed proportion	Lower CI	Upper CI	P
Succullent Karoo Apronveld	253	0.34	6	28	0.34	0.07	0	0.14	-
Arid Mosaic Succullent Karoo	141	0.19	27	15.6	0.19	0.33	0.19	0.47	
Succullent Karoo Gannaveld	34	0.05	0	3.76	0.05	0	0	0	-
Succullent Karoo Quartz Gannaveld	34	0.05	0	3.76	0.05	0	0	0	-
Succullent Karroo Randteveld	196	0.26	8	21.69	0.26	0.1	0.01	0.19	-
River Drainage	83	0.11	41	9.18	0.11	0.5	0.35	0.65	+

b) Core area

Vegetation Type	Total area (Ha)	Proportion of area	Observed visits	Expected visits	Expected proportion	Observed proportion	Lower CI	Upper CI	P
Succullent Karoo Apronveld	475	0.14	0	16.19	0.14	0	0	0	-
Arid Mosaic Succullent Karoo	1336	0.39	28	45.55	0.39	0.24	0.13	0.35	-
Succullent Karoo Gannaveld	160	0.05	10	5.45	0.05	0.09	0.02	0.16	
Arid Mosaic Renosterveld	86	0.03	10	2.93	0.03	0.09	0.02	0.16	
Grassy Fynbos	33	0.01	0	1.13	0.01	0	0	0	-
Succullent Karoo Quartz Gannaveld	134	0.04	9	4.57	0.04	0.08	0.01	0.15	
Succullent Karroo Randteveld	873	0.25	0	29.76	0.25	0	0	0	-
River Drainage	335	0.1	60	11.42	0.1	0.51	0.38	0.64	+

3.3.3 Comparative Studies.

Table 3. Home range sizes of elephants in relation to the rainfall of that area.

Location	Rainfall (mm)	Home range area (km2)	Reference
Northern Namib Desert	64	2172	Viljoen 1988
Etosha National Park	171	7250	Lindeque & Lindeque 1991
Tsavo National Park (West)	260	746	Leuthold & Sale 1973
Laikipia-Samburu	400	5144	Thouless 1996b
Sanbona Wildlife Reserve	400	26	This study
Tsavo National Park (East)	550	1620	Leuthold & Sale 1973
Kruger National Park	550	436	Hall-Martin 1984
Kruger National Park	590	523	Whyte 2001
Sabi Sand Reserve	619	200	Fairall 1979
Tarangire Game Reserve	650	330	Douglas-Hamilton 1972
Waza National Park	700	1660	Tchamba 1996
Middle Zambezi Valley	793	179	Dunham 1986
Lake Manyara National Park	825	33	Douglas-Hamilton 1972
Maputo Elephant Reserve	845	311	Ntumi et al 2005
Maputo Elephant Reserve	845	129	Ntumi 1997

The linear regression line in Figure 11 shows the relationship between rainfall and the home range size of elephants. This relationship is derived from similar studies as set out in Table 3. It is clear from the regression line that the home range of the SWR elephants (26 km^2) is significantly smaller than was expected from an area with such a low average annual rainfall.

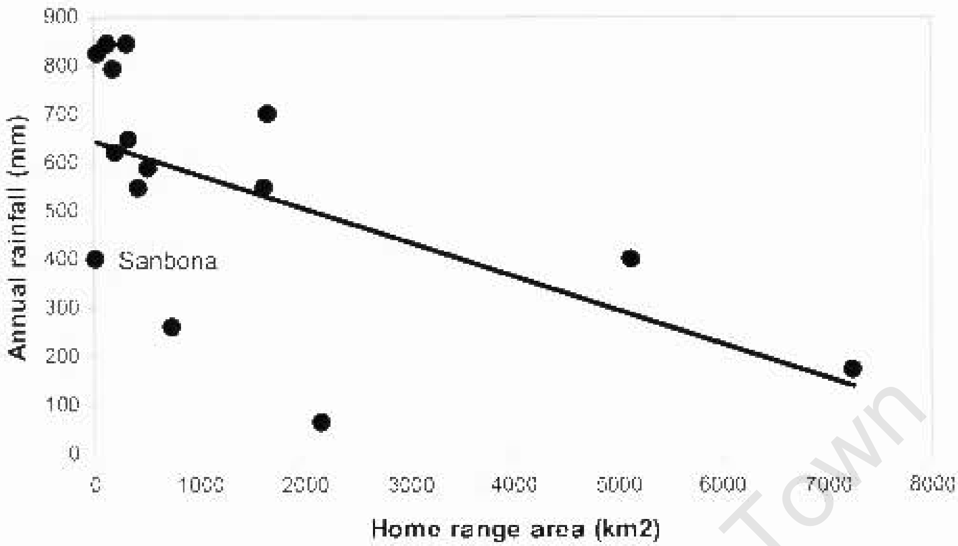


Figure 11. Linear regression showing the relationship between rainfall and home range size for the data from Table 3. (n = 15; y = -0.0699x + 647.52; R^2 = 0.3519; $p < 0.05$).

Table 4. Home range sizes of elephants in relation to the area available to them for reserves smaller than 1,000 km².

Locality	Reserve Size (km2)	Home Range Size (km2)	Popn. size	Reference
Addo Elephant National Park	103	54	324	Whitehouse & Schoeman 2003
Shamwari Game Reserve	155	111	61	Roux 2005
Kwandwe Game Reserve	160	112	27	Roux 2005
Tembe National Elephant Park	300	72	180	Jackson & Erasmus 2005
Sengwa Wildlife Research Area	390	323	650	Osbom 2003
Sanbona Wildlife Reserve	400	26	5	This study
Pilanesburg National Park	500	24	180	Slotow & van Dyk 2004
Pilanesburg National Park	500	139	180	Slotow & van Dyk 2004
Klaseri Private Nature Reserve	840	183	Unknown	De Villiers & Kok 1997
Timbavati Private Nature Reserve	880	414	Unknown	De Villiers & Kok 1997
Vwaza Marsh Game Reserve	986	326	Unknown	Jackson & Erasmus 2005

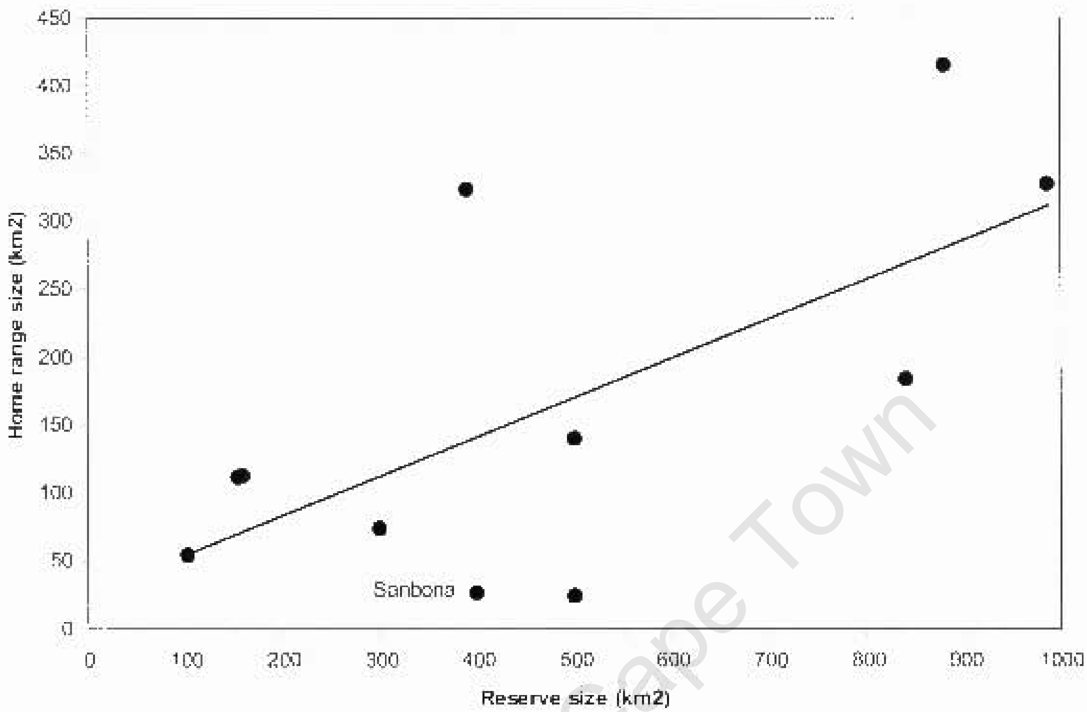


Figure 12. Linear regression showing the relationship between the size of reserves smaller than 1,000 km² and the home range size of elephants for the data from Table 6. ($n = 11$; $y = 0.2906x + 24.461$; $R^2 = 0.4431$; $p < 0.05$).

When comparing the space available to elephants on reserves smaller than 1,000 km² (Table 4), one would have expected the home range of elephants on the SWR to be around 140 km² (Figure 12). This figure of 26 km², however, is only 18% of this value.

3.4. DISCUSSION

3.4.1 Home Range Size

Several factors such as availability of fresh water, nutrient requirements, available space and sexual dimorphism can influence the home range size of elephants (De Beer and van Aarde, 2008; Schoener, 1981; Whitehouse and Schoeman, 2003; Owen-Smith, 1988; Shannon *et al*., 2005). On SWR sexual dimorphism did not contribute to a variation in home range sizes between males and females. This is due to the fact that only one herd of elephants is present on the reserve and that only one adult bull is present in the population. This resulted in the herd staying together for the entire period of study and all sightings were of the herd as a whole.

Since the availability of fresh water plays a big role in the distribution (Skinner and Smithers, 1990) and home ranges (De Boer, *et a*l., 2000; Stokke and du Toit, 2002; De Beer and van Aarde, 2008) of elephants, one can compare the home range size of Sanbona's elephants to other studies in relation to the average rainfall of these areas. This analysis shows that the size of the home range of the SWR elephants is well below the size expected for such an arid region. This suggests that other factors besides rainfall are responsible for the small home range size of this particular herd of elephants.

On SWR water is fairly well spread out on the reserve in the form of old farm dams and artificial watering points. At any point on the reserve, elephants will be within a comfortable range of water points with fresh drinking water. It is for this reason that the availability of fresh water as a source of drinking water is excluded as a limiting factor of elephant home range size on SWR.

Another factor to consider is the role that the reserve size or the space available to the elephants plays on their home range size. A comparison of home range sizes related to reserve sizes in Table 4 for reserves smaller than 1,000 km^2 shows that one would expect the home range for the elephants on SWR to be around 140 km^2 in stead of 26 km^2. However, since the elephants on SWR use less than 50% of the available space it is unlikely that the size of the reserve limits the home range size of the elephants. The negative role of human activities is also unlikely to affect the home range size of the herd on SWR since the core of the elephant habitat is around the Bellair Dam and its tributaries, which are where most of the human activities are based (Erasmus, 2007). Most of the studies carried out in reserves less than 1,000 km^2 (Table 4) were undertaken on elephant populations in excess of 180 animals, except for the two smallest properties in the Eastern Cape. It is, therefore, likely that elephant population size also has an important influence on home range size due to competition for limited resources, such as food, cover, water, and mates amongst other factors. With only five animals in the herd it is possible that they have not had enough time to deplete their primary food source around the Bellair Dam and therefore have not been forced to use a large portion of the reserve. This may, however, change with an increase in the population size or the advent of severe, prolonged drought in the region.

3.4.2 Seasonal Variation in Home Range

The SWR receives more of its rain in early winter than in summer and one would expect this to influence inter-seasonal differences in home range size as has been found in other studies (Kinahan, *et al.*, 2007a; 2007b; Osborn, 2003; De Beer and van Aarde, 2008) where the home range size increase during the rainy season. While the winter home range (3,432 ha) of the SWR herd was 68% larger than the summer home range (2,041 ha) this difference cannot be attributed to the higher availability of drinking water since water is readily available throughout the reserve throughout the year. Rainfall undoubtedly affects other aspects such as food quality and quantity which in turn may affect home range size and habitat selection.

It is suggested, however, that the SWR elephants move into the south western drainage area in the winter months due to the protection that this mountainous area provides against the cold winter winds. In selecting a slightly warmer location than the open areas to the south they are probably better able to maintain optimum body temperatures as was suggested by Kinahan, *et al.* (2007a; 2007b). The majority of trees in this area are also evergreen and do not lose their leaves in winter, unlike the predominantly deciduous species which occur in the more open areas to the north and east. The lower incidence of frost in the south western drainage area thus extends the home range towards the southwards during winter.

3.4.3 Habitat Selection

The habitats that were selected preferentially by the elephants are the areas around the Bellair Dam and its tributaries and the River Drainage habitat to the south west of the Bellair Dam. Perhaps because of the availability of water, all these habitats have taller woody vegetation than the other habitats and also have a higher occurrence of grasses. Although the feeding ecology of the elephants will be looked at in the next chapter it is important to know that all of the preferred species in the elephants' diet are found in these habitats as well. Dietary requirements are therefore, likely to play a major role on SWR when it comes to elephant habitat selection.

Accessibility of habitat also needs to be considered. The fact that elephants were never seen in habitats of the mountainous western and central areas of the reserve suggest that the Sanbona elephants do not like to climb mountains to find resources as was suggested for other populations by Nelleman, *et al.* (2002), and Wall, *et al*. (2006). Elephants were also rarely seen in the northeastern and southeastern sections of the SWR. While habitats in these areas are not located in mountainous terrain they are characterized by rolling hills and short shrubby vegetation. It seems that these areas have been avoided due to the lack of cover, since these areas were only visited on a few occasions during the night. Kinahan, *et al.* (2007a; 2007b) suggested that habitat selection particularly for cover and ambient temperature optimization went hand in hand. Similarly, this could be suggested for the elephants on SWR, since they selected habitats with taller trees and extended their range towards the southwest during the colder winter months. This implies that they also selected areas within which they could maintain optimum body temperature more easily.

In conclusion, it seems that the availability of water, human activities, competitive interactions and the amount of space available are not the primary factors influencing the home range distribution and habitat selection of the SWR's elephant population. The elephants appear to have selected areas for the availability of cover under which to hide from the warm Karoo sun in summer as well as to hide in from the cold winter winds. They also avoided areas with high mountains and steep slopes and perhaps most importantly they selected areas that can supply their nutritional requirements in terms of both the right quantity and quality of food supply. A more detailed analysis of diet composition is the main subject of the next chapter.

CHAPTER 4. THE DIET COMPOSITION AND PLANT SPECIES PREFERENCES OF ELEPHANTS ON SANBONA WILDLIFE RESERVE

4.1. INTRODUCTION

Herbivores larger than 1,000 kg are non-selective feeders (Owen-Smith, 1992) and often live on large amounts of low quality food (Archie *et al.,* 2006; Shannon, 2005; Makhabu, 2006). The inverse relationship between body size and dietary quality, which is generally referred to as the Jarman-Bell principle (Geist, 1974), exists because large-bodied animals are more energy-efficient and lose less energy per unit mass (Owen-Smith, 1992). Large-bodied herbivores are also able to tolerate lower quality food and higher quantities due to larger gut capacities and longer retention times (Ginnett and Demment, 1997; Shannon, 2005).

Small herbivores are non-ruminants, since they cannot afford to waste time to obtain energy due to their high specific energy demands (Shannon, 2005). Medium-sized herbivores that are ruminants show a greater ability to extract nutrients than similar-sized non-ruminants (Shannon, 2005). Elephants, on the other hand, have greater absolute energy requirements and the amount of food ingested as well as the large particle size means that they are not able to ruminate (Shannon, 2005). Therefore, they rely on longer retention times rather than selective retention to obtain the required nutrients and are therefore generalist feeders in stead of selective feeders (Shannon, 2005).

Elephants are mixed feeding mega herbivores (Owen-Smith, 1988, Kerley, *et al.,* 2003 and Codron, *et al.,* 2005) and their dietary intake is considerable with up to 1 % (dry matter) of their body mass being consumed daily (Baxter, 1996). Generally, an animal's diet can be seen as being composed of an interplay between the availability and quality of food and the ability of the animal to ingest and digest various food items (Landman and Kerley, 2001). A change in diet occurs when a species adapts its diet in response to an extrinsic factor and is seen as a response to varying dietary availability or quality (Smith, 1990).

The proportion of various food types in the diet of elephants can vary from area to area depending on the availability of the resource and the season (Skinner and Smithers, 1990). Elephants have been found to survive almost exclusively as grazers (Owen-Smith, 1988) or almost exclusively as browsers (Lindsay, 1994; Codron, *et al.,* 2005). Codron, *et al.* (2005), found that elephant diets in the Waterberg, South Africa, contain only 10 – 20% grass. This figure can even be lower in other areas, as was found in Zimbabwe's Hwange National Park, where browsing comprised 98.8% of the elephant population's diet (Williamson, 1975). Kabigumila (1993), on the other hand, found that single bull elephants in the Ngorongoro Crater in Tanzania lived almost exclusively on grass.

Due to the fact that woody plants contain higher concentrations of crude protein during dry months than grass (Field, 1971) this can lead to a shift in diet towards an increase in browsing during this period (Kalemera, 1989). The percentage of browsing in the diet may also be increased as elephants seek refuge in woody habitat as a result of human disturbance (De Boer, *et al.,* 2000). A distinct difference in food intake may also occur between seasons when grazing is more frequent during the wet season and browsing more frequent during the dry season (Osborn, 2004). Contradictions in the range of species utilized between seasons have also been observed. De Boer *et al.* (2000), for example, found the diet to become narrower (i.e. more restricted suite of species selected) during the dry season, but Napier Bax and Sheldrick (1963) found a wider range of species used during the dry season than the wet season.

Sexual dimorphism in elephants also results in a difference in food intake and energy requirements (Stokke and Du Toit, 2000; Shannon, 2005). This is because females have higher energy requirements during pregnancy and lactation and would therefore require food with higher quality (Blanchard, 2005; Shannon, 2005). It has also been shown that males tolerate a higher fiber content in their diet as a result of lower relative energy demands and greater digestive efficiency than females (Demment and Van Soest, 1985).

A very diverse range of methods, grouped broadly into direct and indirect methods, have been used in the past to determine the diet composition of elephants. Indirect methods include chemical analysis of the bones, teeth and dung of animals (Codron, *et al.,* 2005) to an analysis of the vegetative remains within the dung (Landman and Kerley, 2001). The analysis of the nitrogen and phosphorous content of faeces also gives an indication of the quality of the forage (Grant *et al.*, 2000) while a comparison between carbon 12 and carbon 13 isotopes gives an indication of the ratio of browse to graze material in the diet (Cerling and Harris, 1999). The advantage of the chemical analysis of faeces over that of bones and teeth is that faeces show ecological variability of forage over the short term whereas that of bones and teeth show long term trends (Codron *et al.,* 2005).

The analysis of faecal components involves the identification of plant epidermal fragments from reference collections (Landman and Kerley, 2001; De Boer *et al.,* 2000.) or by the identification of seeds and germination trials in the laboratory (Tchamba and Seme, 1993). The advantage of faecal analysis is that it is easy to obtain and does not disturb the sample animal and may be particularly suitable for species that feed at night or in dense thickets (Bookhout, 1996). The disadvantage of faecal analysis is the different digestive properties of various plant species (Westoby, *et al.,* 1976) and the lack of expertise to identify seeds and epidermal fragments that may lead to an over- or under-estimation of some species in the diet (Westoby *et al.,* 1976; Parker, 2005).

Direct methods of diet composition determination include focal animal sampling by means of descriptive feeding observations (Osborn, 2004). Observations can either be recorded continuously or at selected intervals (Rose, 2000). The advantage of direct observations is that if the animals can be easily approached, then they can be studied in their natural environment and the chances of drawing false conclusions are limited (Parker, 2005). The disadvantage of direct methods is the difficulty of observing animals when they move into dense vegetation and the difficulty of identifying plant species from long distances (Roux, 2006).

The aim of this study was to determine the food preferences of SWR's elephants. A thorough analysis of dietary composition will help to explain elephant movement patterns. It will also help to identify those plant species which may be under threat from over-exploitation by the elephants and to help in the determination of sustainable elephant stocking rates for the reserve.

4.2. MATERIALS AND METHODS

4.2.1 Data Collection

4.2.1.1 Diet composition

The feeding habits of each of the five elephants were observed for twenty minutes every two weeks for a period of three months. This was done during the summer months (November 2006 to February 2007) when the herd was located predominantly around the Bellair Dam inside their 50% utilization distribution range (see previous chapter) and in an area where they could be followed by a vehicle no further than 20 m away in order to correctly identify each species eaten. A feeding record was defined as an instance in which any part of a plant species was consumed by the elephant in question (Roux, 2006) and from here onwards referred to as bites, which, for the purpose of this study is the currency used for determining diet composition. All feeding records were then counted and entered into a spread sheet.

4.2.1.2 Vegetation composition.

The drop point survey method (Du Toit, 1997) was used to determine the species composition within the core area where the feeding observations took place. A 25 m line with knots at 1 m intervals was used to obtain unbiased points to identify plants in the natural vegetation. The rope was moved 40 times in the same direction in order to obtain 1,000 points in a straight line so that a good representation of the vegetation composition was obtained. All plants touched by the pointer were identified even if more than 1 plant was hit. The aim of this part of the study was to determine the abundance of different species within the core area in order to compare them with the composition of the elephants' diet and in so doing, determine species preferences.

4.2.2 Data Analysis

For the calculation of the browse to graze ratio the reed *Phragmites australis* (Family Poaceae) was classed as a grazing species together with the two grass species (*Cynodon dactylon* and *Digitaria sp.*). All other non-woody and woody species were classed as browsing species. Species preferences were calculated using a Chi-Square goodness of fit test and Bonferoni confidence intervals.

4.3. RESULTS

The diet composition of all elephants (Figure 13) were found to be 44% browse and 56% graze (n = 4,320 observations). The adult male (which was between 19 and 21 years old) and the male calves (which were 6 to 8 years old) showed similar dietary trends with the browse to graze ratio of the bull being 40:60 (n = 911) and that of the calves being 32:68 (n = 1,663). The dict composition of the adult females (which ranged from 22 to 25 years old) showed a difference in diet composition with 58% browse and 42% graze (n = 1,746).

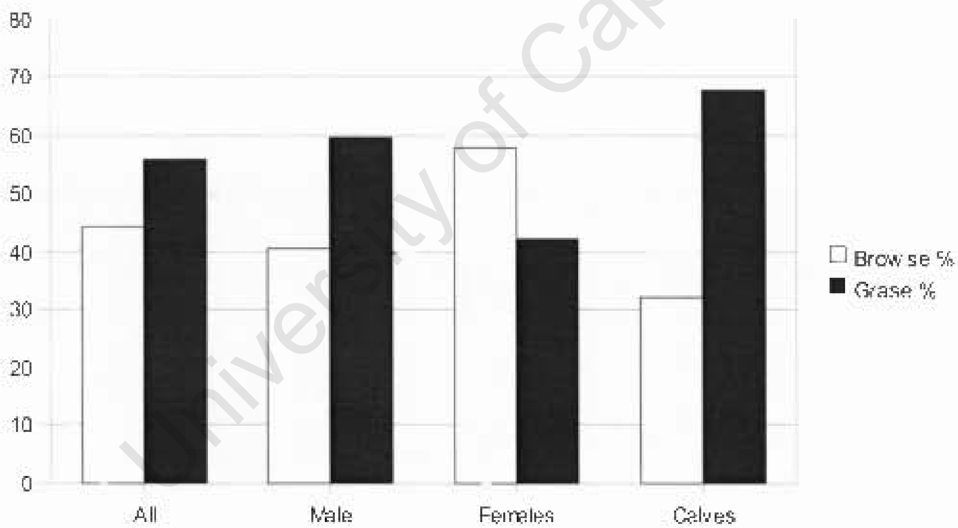


Figure 13. Comparisons between the percentage browse and graze in the diets of the elephants on Sanbona Wildlife Reserve.

Of the 26 plant species found within the vegetation sample only 10 were utilized by the elephants (Table 5). Amongst these, only three (*Atriplex semibaccata, Cynodon dactylon* and *Tamarix usneoides*) were preferred forage species with the exotic, *Atriplex semibaccata,* being favoured the most (Table 6). *Acacia karroo* was utilized in the same proportion as was present in the vegetation sample. The other species were utilized to a lesser degree than the available proportion in the vegetation or totally avoided.

Table 5. The frequency of species found within the vegetation sample and the diets of the various elephants studied on Sanbona Wildlife Reserve. Short tail and Long tail refer to the two different adult females on the reserve.

Species	Veg. Sample	Bull	Short tail	Long tail	Calf 1	Calf 2
Acacia karroo	44	6	31	78	2	14
Asclepias fruticosa	9	0	0	0	0	0
Atriplex nummularia	7	0	0	0	0	0
Atriplex semibaccata	71	279	344	297	287	152
Berkheya glabrata	2	0	0	0	0	0
Cynodon dactylon	493	543	328	395	553	566
Digitaria sp	54	0	0	12	0	0
Drosanthemum sp	1	0	0	0	0	0
Euryops nodosus	2	0	0	0	0	0
Felicia sp	21	0	0	0	0	0
Fingerhuthia africana	16	0	0	0	0	0
Galenia africana	49	0	0	0	0	0
Juncus punctorius	5	0	0	0	0	0
Lycium cinereum	4	0	0	0	0	0
Melianthus comosus	1	0	0	0	0	0
Oncosiphon pilulifera	6	0	0	0	0	0
Oxalis pes-caprae	2	0	0	0	0	0
Phragmites australis	49	0	0	0	7	0
Phyllobolus sp	7	0	5	0	0	0
Salsola sp	7	0	3	0	0	0
Scirpus dioecus	56	0	0	0	0	2
Sueda fruticosa	14	0	0	0	0	0
Tamarix usneoides	61	82	184	67	27	53
Tribulus sp	1	1	0	2	0	0
Urtica sp.	3	0	0	0	0	0
Zygophyllum sp	1	0	0	0	0	0
Total	986	911	895	851	876	787

Table 6. Combination of all elephant diet composition (n = 4320) showing the preference or avoidance for species. (P = preference index, + = preferred and, - = avoided and a blank space = consumption is equal to availability in the vegetation). CI = Bonferoni confidence levels.

Species	Vegetation sample	Proportion of vegetation	Observed diet	Expected diet	Expected proportion	Observed proportion	Lower CI	Upper CI	P
Acacia karroo	44	0.04	131	192.58	0.04	0.03	0.02	0.04	
Asclepias fruticosa	9	0.01	0	39.39	0.01	0	0	0	-
Atriplex nummularia	7	0.01	0	30.64	0.01	0	0	0	-
Atriplex semibaccata	71	0.07	1359	310.76	0.07	0.31	0.29	0.33	+
Berkheya glabrata	2	0	0	8.75	0	0	0	0	-
Cynodon dactylon	493	0.5	2385	2157.81	0.5	0.55	0.53	0.57	+
Digitaria sp	54	0.05	12	236.35	0.05	0	0	0	-
Drosanthemum sp	1	0	0	4.38	0	0	0	0	-
Euryops nodosus	2	0	0	8.75	0	0	0	0	-
Felicia sp	21	0.02	0	91.91	0.02	0	0	0	-
Fingerhuthia africana	16	0.02	0	70.03	0.02	0	0	0	-
Galenia africana	49	0.05	0	214.47	0.05	0	0	0	-
Juncus punctorius	5	0.01	0	21.88	0.01	0	0	0	-
Lycium cinereum	4	0	0	17.51	0	0	0	0	-
Melianthus comosus	1	0	0	4.38	0	0	0	0	-
Oncosiphon pilulifera	6	0.01	0	26.26	0.01	0	0	0	-
Oxalis pes-caprae	2	0	0	8.75	0	0	0	0	-
Phragmites australis	49	0.05	7	214.47	0.05	0	0	0	-
Phyllobolus sp	7	0.01	5	30.64	0.01	0	0	0	-
Salsola sp	7	0.01	3	30.64	0.01	0	0	0	-
Scirpus dioecus	56	0.06	2	245.11	0.06	0	0	0	-
Sueda fruticosa	14	0.01	0	61.28	0.01	0	0	0	-
Tamarix usneoides	61	0.06	413	266.99	0.06	0.1	0.09	0.11	+
Tribulus sp	1	0	3	4.38	0	0	0	0	-
Urtica sp.	4	0	0	17.51	0	0	0	0	-
Zygophyllum sp	1	0	0	4.38	0	0	0	0	-
Total	987	1	4320	4320	1	1			

Cynodon dactylon was the species that the elephants utilized the most (55%), but is also the species that was found to be the most available in the vegetation sample of the core area (50%). *Atriplex semibaccata* on the other hand comprises only 6% of the available forage, but made up 26% of the total diet of the elephants, therefore being the most preferred species (Table 6).

The bull elephant (Aged 21 to 22 years) preferred *Atriplex semibaccata* and *Cynodon dactylon,* with *Atriplex semibaccata,* being the most favoured. *Tamarix usneoides* was utilized in the same frequency that it occurs within the vegetation sample. *Tribulus sp.* and *Acacia karroo* were utilized to a lesser degree than the proportion within the vegetation sample and all the other species were avoided (Table 7).

The adult female called Long Tail (Age = 24 to 25 years old) preferred *Atriplex semibaccata*. *Acacia karroo, Cynodon dactylon* and *Tamarix usneoides* were utilised in the same proportions as was found in the vegetation sample. *Digitaria sp.* and *Tribulus sp.* were eaten, but to a lesser degree than was found in the vegetation sample. All other species were avoided (Table 7).

The adult female called Short Tail (Age = 22 to 23 years old) preferred *Atriplex semibaccata. Phyllobolus sp., Acacia karroo* and *Tamarix usneoides* were eaten in the same proportion as was found in the vegetation sample. *Salsola sp.* and *Cynodon dactylon* were eaten at a lower proportion than were present in the vegetation sample. All other species were avoided (Table 7).

Table 7. The species preference within the diet of all elephants studied on Sanbona Wildlife Reserve (+ = preference, 0 = same proportion to vegetation sample and a blank space = avoidance).

Species	Bull	Short tail	Long tail	Calf 1	Calf 2
Acacia karoo		0	0		0
Asclepias fruticosa					
Atriplex nummularia					
Atriplex semibaccata	+	+	+	+	+
Berkheya glabrata					
Cynodon dactylon	+		0	+	+
Digitaria sp					
Drosanthemum sp					
Euryops nodosus					
Filicia sp					
Fingerhuthia africana					
Galenia africana					
Juncus punctorius					
Lycium cinerium					
Melianthus comosus					
Oncosiphon pilulifera					
Oxalis pes-carpae					
Phragmites australis					
Phyllobolus sp		0			
Salsola sp					
Scirpus dioecus					
Sueda fruticosa					
Tamaryx usneoides	0	0	0	+	0
Tribulus sp					
Urtica sp.					
Zygophyllum sp					

Calf 1 (age = 6 to 7 years old) preferred *Atriplex semibaccata, Cynodon dactylon* and *Tamarix usneoides* with *Atriplex semibaccata* being the most favoured species. *Phragmites australis* and *Acacia karroo* were eaten at a lower proportion than was present in the vegetation sample. All other species were rejected (Table 7).

Calf 2 (age = 6 to 7 years old) also preferred *Atriplex semibaccata* and *Cynodon dactylon. Acacia karroo* and *Tamarix usneoides* were utilized in the same proportion as was found in the vegetation sample. *Scirpus dioecus* was eaten at a lower frequency than was present in the vegetation sample. All other species were avoided (Table 7).

4.4. DISCUSSION

The study on the diet composition of the elephants on SWR was only carried out in the summer months when the elephants could be relatively easily observed. The results, therefore, do not indicate whether there were inter-seasonal differences. However, they do provide an account of elephant diet selection in the core habitat area during summer.

In previous studies it has been shown that elephants utilize a wide variety of plant species (De Boer *et al.,* 2000). However, only 10 species were utilized by the elephants on SWR. This may be explained by the fact that the vegetation within the core area of the elephants' utilization distribution range contained a relatively low number of species (n = 26) perhaps as a result of the extensive impact of agricultural activities in the region prior to the establishment of Sanbona.

The results from this study suggest that while the elephants on SWR generally ate what was available in the vegetation they also exhibited distinct preferences for particular items. For example, *Cynodon dactylon* comprised 50% of the available forage and made up a high proportion of the diet of SWR elephants. Similarly, the two most common tree species in the study site, *Acacia karroo* and *Tamarix usneoides*, comprised 10% of the available forage and were also prominent (13%) in the diet of the elephants. Another prominent plant species in the vegetation sample, *Atriplex semibaccata*, which comprised 7% of the vegetation, was the most favoured plant and made up 31% of the total elephant diet. *Atriplex semibaccata* is an exotic species and while it is an important species within the elephant diet, it also therefore relieves pressure from possible higher utilization of the indigenous species.

Figure 14. Elephants feeding on the floodplain to the west of the Beltair Dam. Note the dense ground cover of the grass, *Cynodon dactylon*, in the foreground.

Although all animals showed a preference for the same species, there were differences in the composition of the species in the diets of sexes. The females showed a higher proportion of browse than graze material in their diet whereas the opposite was true for the bull and the male calves. Field (1971) suggests that browse material generally contains a higher proportion of crude protein during the dry season than grass. The higher specific energy demand required by females relative to males (Shannon, 2005), as well as the ability of males to tolerate lower quality food than females (Demment and Van Soest, 1985), might explain the differences in browse to graze ratios between the male and female elephants on SWR.

If one looks at the species preferred by the elephants, it can help one to understand their utilization distribution patterns on SWR. Most of the species utilized by the elephants in this study grow along tributaries that flow into the Bellair dam and this may explain the location of the home range of the herd (Figure 6). Seasonal variation in grass availability and the loss of leaves by *Acacia karroo* and *Tamarix usneoides* during the winter months may also help to explain their movement towards the river systems in the south and west of the Bellair Dam during this period.

CHAPTER 5. THE IMPACT OF ELEPHANTS (*Loxodonta africana*) ON THE MAIN TREE SPECIES OF THE SANBONA WILDLIFE RESERVE

5.1. INTRODUCTION

Elephants are a keystone species (Gordon, 2003) that possess the ability to transform habitats, sometimes irreversibly so (Lindsay, 1993). When they are kept in an enclosed area for long periods, concern is always raised over their potential impact on the region's biodiversity since they have a greater impact on the environment than any other mammal, except perhaps humans (Estes, 1991). This is particularly evident in woodlands and forests (Laws, 1970; Dublin *et al.,* 1990) where dense forests can be changed into open canopy systems ((Struhsaker *et al.*, 1996; Lawes and Chapman, 2006) and woodland to savanna (Gordon, 2003) with concomitant cascade effects on the biodiversity of these ecosystems.

Large herbivores, such as elephants, have the ability to alter the architecture, physiology and productivity of the plants they feed on (Laws, 1970). They have been found to be the main cause of the loss of well established woody plants (Barnes, 2001). This is particularly true close to water points which are frequented by elephants (Ben-Shahar, 1993; Brits *et al.*, 2002). Together with other browsers their impacts often create a gradient of plant compositional change away from heavily utilized water points (De Beer *et al.,* 2006). In forests it was found that elephants inhibit regeneration by direct (browsing) and indirect (trampling) methods (Struhsaker *et al.*, 1996; Lawes and

Chapman, 2006) where the maintenance and trampling along paths lead to an almost total eradication of seedlings (Höft and Höft, 1995).

Many vegetation types in southern Africa can be seen as elephant-induced degraded sub-climaxes (Höft and Höft, 1995). However, these effects are not attributed to elephants alone (Dublin *et al.,* 1990) and can be exaggerated by the effect of high numbers of other browsers (Lock, 1993; Ben-Shahar, 1993; Barnes, 2001), by fire (Dublin *et al.*, 1990; Eckhardt *et al.,* 2000) and by drought (Tafangenyasha, 1997). Elephants also have the ability to inhibit the return of a degraded vegetation type to its original state (Dublin *et al.,* 1990). An example of this is the slow recovery of the vegetation in the Queen Elizabeth National Park in Uganda after the reduction in elephant numbers in this conservation area (Lock, 1993).

Elephants frequently break off the main axis and stems of saplings and young trees, results in secondary growth or resprouting which often leads to a shrub-like or stunted growth form. This secondary growth, however, is often more palatable and may result in an increase in the probability of repeated foraging on the same individual (Cates and Orians, 1975; Du Toit *et al.*, 1990; Duncan *et al.*, 1998; Bergström *et al.,* 2000). This breaking of large stems also reduces the height of individual trees. Since most browsers prefer to feed at neck height (Du Toit *el al.*, 1990; Makhabu, 2005; Rutina *et al.*, 2005) the subsequent resprouting often aids smaller herbivores, such as impala (*Aepyceros malampus*) and kudu (*Tragelaphus strepsiceros*), to access otherwise unreachable forage (Makhabu *et al.*, 2006). Elephants also debark trees, and in Kenya's Shimba Hills

National Reserve, for example, it was found that elephants preferred the bark of trees with latex. The death of trees from debarking does not, however, always arise from the debarking alone, but often occurs as a result of fungal infection of the debarked areas (Höft and Höft, 1995).

An increase in elephant numbers can lead to a decline in woody tree species or even the local extinction of some heavily-utilized species (Pamo and Tchamba, 2001). Duffy *et al.,* (1999), however, stipulate that elephants and trees can reach equilibrium if the elephants are dependent on one main species as their food source and if that species is the dominant species in the system. Caughley (1976), however, suggests that no equilibrium is possible due to the time lags between changes in tree cover and elephant population size. This also does not apply to areas where the regeneration of the food source is low and other parameters, such as browsing and uprooting, are high. In many arid and semi-arid regions, however, the rate of food production often determines carrying capacity.

The absence of elephants in some areas may reduce seed dispersal and germination of some tree species (Babweteera *et al.*, 2007). Studies done on *Acacia erioloba,* for example, show that elephants may play a major role in the germination of the seed through the scarification of the seeds in the gut and the subsequent increase in water uptake while in the digestive system (Hoffman *et al.,* 1989). Another study carried out in northern Botswana has shown that elephant dung can contain several hundred viable seeds (Barnes, 2001b). This same study found seedlings and young trees up to 20 km from the nearest seed-bearing tree and attributed this to the fact that elephants move long distances in a day or even overnight and could therefore have dispersed the seeds over this area.

Many protected areas in Africa cannot support viable populations of elephants since they are unable to absorb the impact that large numbers of elephants may have on biodiversity (Laws, 1970). The area required to support a viable population of elephant in the Little Karoo is also unknown. Because of their potential to transform the SWR with concomitant disastrous consequences for the biodiversity of the area, the management team on SWR felt that the introduction of elephant on the reserve required an investigation into the possible negative effects that this introduction may have on the vegetation of the reserve. This became particularly urgent after Lombard *et al.* (2001) found that elephants had a negative impact on the diversity and abundance of plant species in the Addo Elephant National Park, South Africa. Another factor contributing to this study of the SWR elephant population is that this is the only reintroduction of free-roaming, self-sustaining elephants (i.e. no additional feeding of the elephant population is undertaken) that has taken place into one of South Africa's arid environments. No information is available on the possible effect this action may have on the biodiversity and the survival of the tree species of an area such as SWR since elephants have not been in the area for at least 250 years (Refer to section 2.7).

Five elephants were introduced onto this 54,000 ha property in 2003. The study commenced only a few months after their introduction onto SWR. The number of individuals increased to 9 (4 calves were born) and was subsequently reduced to 6 again

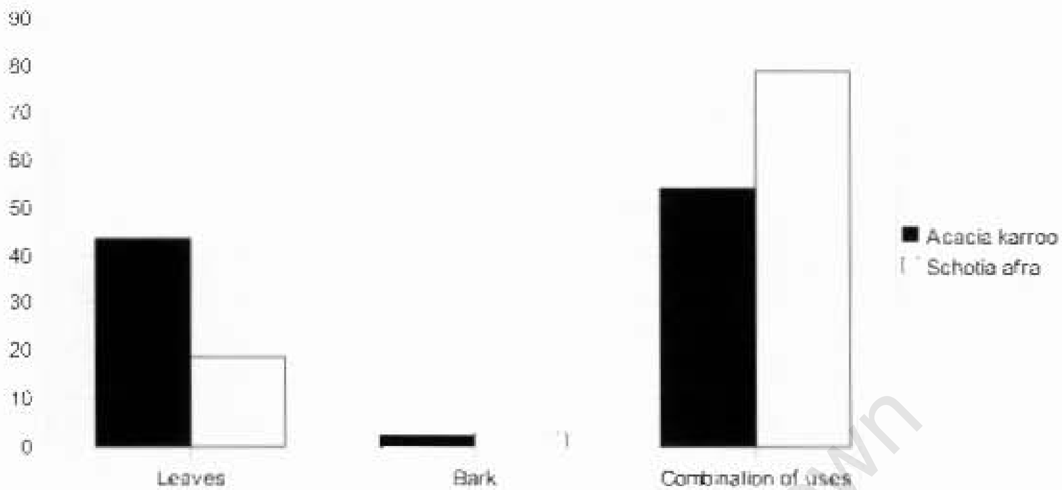


Figure 15. The tree component of *Acacia karroo* and *Schotia afra* utilized by the elephants as a percentage of all trees of that species utilized on Sanbona Wildlife Reserve.

5.3.4 Tree Mortalities

A total of 29 marked trees (2.9% of the total tree sample) of all species died over the 4 year study period (Table 11). Of these none of the *Euclea undulata* and *Nymania capensis* deaths were as a result of elephant damage. These mortalities were as a result of various diseases and parasites as well as browsing by other browsers.

Table 11. The number of marked tree mortalities on the Sanbona Wildlife Reserve from 2003 to 2006 and the various causes of mortalities.

Cause of death	Acacia karroo	Schotia afra	Euclea undulata	Rhus spp.	Nymania capensis
n	384	218	278	62	71
Flood damage	9	0	0	0	0
Disease	4	0	2	0	0
Elephant damage	3	3	0	1	0
Other browsers	0	0	0	0	7
Total deaths	16	3	2	1	7

Of the 62 *Rhus* spp. trees monitored only one tree (1.6% of the total number of *Rhus* spp. individuals) died as a result of elephant damage. The death of this particular tree was caused by the total debarking and breakage of both the main branches just above ground level. A similarly low mortality for *Schotia afra* trees was observed. Only 3 trees (1.4%) within the tree sample for this species died. They were all less than 4 m in height and all died as a result of being uprooted by the elephants.

Due to the fact that most of the *Acacia karroo* trees on SWR are found along water causeways and in ephemeral river systems it is to be expected that some individuals would have died from being uprooted by the force of flash flood waters which swept through the area occasionally during the study period. Nine trees (2.3%) were killed in this manner between the period 2003-2006. Four trees (1%) within the tree sample died as a result of diseases and parasites while only 3 (0.8% of tree sample) of the tree deaths could be attributed to elephant damage. These deaths occurred in relatively small trees (< 4 m) and in individuals that were totally debarked and had all their branches broken off close to the ground or close to the stem. In total, 16 deaths (4.2%) were found within the *Acacia karroo* tree sample of 384 individuals examined over the four year study period.

5.4 DISCUSSION

Acacia karroo is a highly palatable species and animals can feed on the leaves, shoots, bark, flowers and seed pods (Shearing 1994; Palgrave, 1984). It was therefore no surprise to find that this legume was indeed the tree species favoured most by the elephants. This species is also the most common tree species found on SWR and was the most represented tree in the sample. The fact that the elephants prefer *Acacia karroo* above the other species decreases the concern around the possible negative influence elephants might have on the other less common species and reduces the chances of these species being removed from the system.

Elephant damage to trees results in trees resprouting and producing more palatable shoots (Cates and Orians, 1975; Du Toit *et al.*, 1990; Duncan *et al.*, 1998; Bergström *et al.*, 2000). This in turn promotes the revisitation rate as elephants return to previously-damaged trees in search of high quality forage material. Evidence from this study supports this view since 33% of *Acacia karroo* and up to 41% of *Schotia afra* trees were also visited in the year prior to the survey being carried out. This suggests that for these relatively abundant species a large proportion of trees will remain unutilized over long periods of a decade or even longer and disruptions to seed production and dispersal will probably not be affected by elephants over their entire range within the reserve.

However, for *Rhus* spp. which are found in relatively low frequencies on SWR their long-term survival might be affected by the elephant population on Sanbona. Their relatively scarcity could explain the high revisitation rates and raises some concern that this species might become locally extinct within the home range of the elephants if continuous visits to heavily damaged individuals continues over a decade or longer. *Rhus* spp., however, are common in riverbeds outside SWR.

The results of this study showed that elephants rarely utilized *Euclea undulata*. This is somewhat surprising as Shearing (1994), refers to this species as providing good fodder for domestic stock. Because of the low utilization impact, however, this species is unlikely to be negatively affected by the presence of elephants on SWR. *Nymania capensis* was also not at all affected by elephants and would therefore not be considered as a species under threat from elephant utilization.

A study conducted in Botswana on several tree species found that elephant impacts were greatest for trees which were between 2 and 3 m in height (Makhabu *et al.,* 2006). Shannon (2005), however, reported that elephants in Kwazulu Natal fed across a wide range of heights which varied between 0 and 5.5 m with an average height of between 2.2 m and 2.45 m. For the case of both *Schotia afra* and *Rhus* spp. trees of all heights were utilized while elephants preferred to feed on *Acacia karroo* trees larger than 4 m and tended to ignore trees smaller than 2 m. These results suggest that feeding height differs for different tree species and is partly dependent on the availability and abundance of individuals within each of the height classes. For example, there are relatively few

Schotia afra individuals smaller than 2 m on Sanbona and this height class is rare across the species range in the Little Karoo region.

In terms of the different tree components utilized by elephants it is clear that the elephants consume *Acacia karroo* leaves in much the same proportion as they do a mixture of components. However, for *Schotia afra* elephants tend to use a tree more for a combination of components rather than just for leaves or bark alone. These two species differ considerably in the quantity of leaf, bark and stem material available for elephants as well as in their release of secondary compounds following browsing (see Scogings, 2005). A detailed analysis of the feeding ecology of elephants on these two species is needed to better understand the potential long-term impact of elephants on their response to browsing and their survival.

With the high food demands of elephants and the often destructive nature that elephants exhibit in obtaining these resources it was thought that elephant activities may result in a high mortality rate amongst the trees on SWR. However, only 2.9% of the marked trees died from all causes over the study period of four years providing an annual mortality rate of about 0.7% per year. Also, most of these deaths were as a result of factors other than elephants and only 0.7% of the total number of trees died as a direct result of the impact of elephants on the SWR. Although elephant damage to a tree can increase the possibility of infections of various types, these types of deaths were also found to be minimal (0.6%) and did not necessarily result from the impact of elephants on these individuals.

In general, it appears that the direct and indirect impacts that the elephants have on the trees of the SWR are relatively low and will probably remain so if the population is maintained at the current low number. The only concern identified in this study is for *Rhus* spp. which could be driven to local extinction within the home range of these elephants even under the low population pressure which currently exists. In addition, it is still unknown to what extent the elephants might influence the key regeneration and seed dispersal processes of the main tree species. This is particularly important for *Schotia afra* as almost no young trees have been found in the area and little recruitment of this species has occurred in the region over several decades. It is not known why the recruitment of *Scotia afra* is so low for the Little Karoo. Additional studies of the population ecology of the main species are therefore needed in order to determine the differential impact that the Sanbona elephants are likely to have on the mortality and recruitment of these species.

CHAPTER 6. GENERAL DISCUSSION: WHAT IS THE IMPACT OF ELEPHANTS ON SANBONA WILDLIFE RESERVE?

The first reintroduction of free-roaming elephants to the semi-arid regions of the Western Cape raised concerns over the sustainability of such a venture. Although historical information (Skead, 1980) confirmed that there were significant numbers of elephants in the area it was doubtful that they would have remained in the area for extended periods of time. The concern was that confined elephants may have a detrimental effect on the biodiversity of the area, especially by decreasing the tree component of Sanbona Wildlife Reserve. This was the main objective addressed by this study. In trying to determine to what extent the current population of elephants are affecting the trees on the property several factors of elephant ecology were taken into consideration. This included determining the size of the elephant home range on Sanbona. Within this home range, the preferred habitat of the elephants needed to be determined in order to be able to know which areas to focus on for the diet composition studies. It was important to determine the diet composition of the elephants since this showed what species are being impacted on the most by the elephants. Since the main aim of the study was to determine the impact of the elephants on trees, 1,013 of the five most common tree species were marked and monitored over four years. The factors monitored were species utilized, component of tree utilized, height class of trees utilized and the cause of mortality for the trees that died.

Several studies have shown that the home ranges sizes of elephants in smaller than 1,000 km² are affected by being confined (Roux, 2006l; Whitehouse and Schoeman, 2003). It is also well documented that the distribution and seasonal movements of elephants are greatly impacted on by the availability of drinking water (Skinner and Smithers,1990; De Beer and van Aarde, 2008). This study showed that these factors are unlikely to be critical determinants of the home range size or seasonal movements of the elephants on the Sanbona Wildlife Reserve. This is primarily because their home range covered only 6.9% of the area available to them and free standing water was also readily available throughout the reserve in the form of old farm dams. It was, however, found that food requirements are the most likely determinants of the location and size of the home range. Similar findings have been reported elsewhere (Schoener, 1981; Shannon *et al.,* 2005). The importance of available cover and ambient temperature differences are factors that could be studied in the future to further explain the variation in home range size and habitat preferences.

Within the home range it was found that the River Drainage habitat type was preferred above others. Again, the selection of habitat type had little to do with the availability of water or the close association with water as was the case in other studies (De Boer *et al.*, 2000; Stokke and du Toit, 2002; Roux, 2006). Rather it was the accessibility of the habitat, the presence of significant tree cover and the availability of food which were the most likely factors determining the habitat preferences of Sanbona's elephants. Similar trends were also observed by Dublin (1996), Houston *et al.* (2001), Nellemann *et al.* (2002) and Smith *et al.* (2007). The fact that only one small herd has been translocated and no competition for resources by the elephants was evident, has undoubtedly also influenced this pattern.

Although diet selection and composition was only monitored for a relatively short period, and seasonal differences were not determined, interesting conclusions are still possible. For example, a clear difference exists between the diet of the male and female elephants. Similar differences in diet between sexes have been noted in studies by Stokke and Du Toit (2000), and Shannon (2005). The general trend for the male elephants on Sanbona was that a higher proportion of grass was eaten than browse. The higher intake of browsing species by females, suggests that at the time of the study, the browsing species contained a higher energy level since the females have a higher specific energy demand than the males (Blanchard, 2005 and Shannon, 2005).

It is well documented that *Acacia* spp. are the preferred food of elephants (Roux, 2006) and this was supported by the research on Sanbona Wildlife Reserve. What was interesting in this study, however, was the low percentage of mortalities which occurred in this and the other four species studied, as a direct or indirect result of elephant damage. The only species that warrants closer attention is *Rhus* spp. which appears to be significantly more heavily-impacted by elephants than the other tree species on the Sanbona Wildlife Reserve. There are, however, large areas outside the home range of the elephants that still contain numerous *Rhus* spp. trees and it is unlikely that they will become extinct over the entire reserve.

One of the most significant conclusions of this research is that the current population of elephants on Sanbona Wildlife Reserve does not appear to pose a significant and immediate threat to the tree populations on the property. Furthermore, their role in the promotion of beneficial ecosystem process has not been determined. For example, it is unknown if these elephants play an important role in the dispersal and germination of *Schotia afra* and *Acacia karroo* as was found to be the case for *Acacia erioloba* (Hoffman *et al.,* 1989; Babweteera *et al.*, 2007). The presence of elephants also reduce the height of some trees such as *Acacia karroo*. This leads to an increase in shoot growth through resprouting and coppicing which makes food available for other browsers such as kudu (Cates and Orians, 1975; Du Toit *et al.*, 1990; Duncan *et al.*, 1998; Bergström *et al.,* 2000). In addition, it is a well established fact that A*cacia karroo* can become an aggressive invader species in arid and semi-arid environments and can form dense stands along drainage areas (Nyamukanza and Scogings, 2008). Elephants can therefore be used as important agents in reducing the threat of dense growth of *Acacia karroo* along riverbeds and by providing paths through the dense tree stands to allow access to smaller animals.

It must be emphasized that the current area of optimum habitat for the elephants is relatively small and if the population were to increase this may result in the serious overexploitation of resources. It is therefore advised that to allow for future elephant population increase that the elephants be allowed to gain access to Sanbona North. This area contains a further 12 km^2 of floodplain with dense tree stands of *Acacia karroo* and comprises an area which is very similar to the core area utilized by the elephants on

Sanbona South. It is expected that this area will form the new core area of their utilization distribution if the elephants are allowed access. The dense stands of trees in this area would also allow the animals to hide from adverse weather conditions and probably will limit their visits to the southwestern regions of SWR. After the flood of 2003 when the Bellair Dam broke its wall, *Acacia karroo* showed signs of totally dominating the Brak River system. Allowing elephants access to this area will reduce the possibility of having a dense, inaccessible fertile piece of land by them reducing the tree growth and maintaining game paths to allow other animals, especially grazers, access to the lush grass growth in this area.

If the elephants do not gain access to the north, only a small population increase within the existing area may result in the loss of tree species. It is therefore important that the monitoring of the marked trees be continued in order to determine their continued impact on these species and when critical thresholds have been reached. If access to the north is allowed, an increase in numbers to about 15 individuals should not have a negative impact on diversity. Again it must be emphasized that monitoring of the impacts of the elephants should be extended into the northern section in order to make sure that excessive tree loss does not occur and that unforeseen impacts on the biodiversity of the region are identified as soon as they become evident.

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