FEEDING ECOLOGY, SPACE USE AND HABITAT SELECTION OF ELEPHANTS IN TWO ENCLOSED GAME RESERVES IN THE EASTERN CAPE PROVINCE, SOUTH AFRICA

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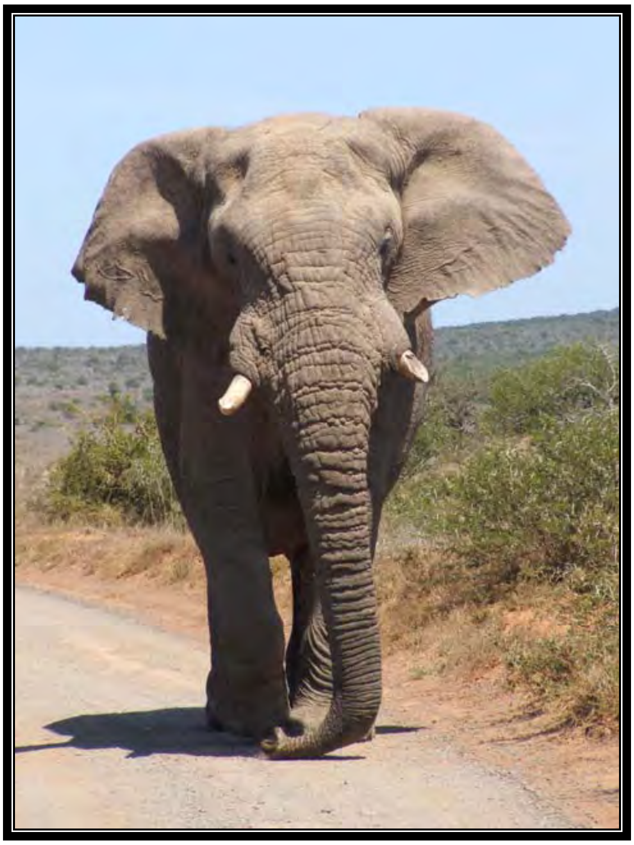
ABSTRACT

The development of small (<300 km^2), private game reserves has become a trend, not only in the Eastern Cape Province, but also elsewhere in South Africa as a result of a shift in land use practise from agriculture to ecotourism. The resultant re-introduction of elephants to many of these reserves has lead to management concerns because of the limited research on small reserves regarding their impact on the vegetation. In this study I assessed the space use, habitat selection, diet and impact of two elephant populations on the vegetation in the Eastern Cape Province between February 2004 and March 2005. Home range sizes were calculated using the kernel utilization distribution method. Home range sizes for elephants on Kwandwe were significantly larger during summer than winter ($p<0.05$). There was no significant difference between the home range sizes of the herds and males within a season and during summer the elephants utilized about 75 % of the reserve and only 54 % during winter. On Shamwari, the herd utilized about 92 % of the reserve during summer and 83 % during winter; while the males utilized 76 % of the reserve. Core areas for both elephant populations shrank from summer to winter and were concentrated around the permanent water sources on each reserve. Habitat selection was assessed using χ^2 tests and Bonferroni confidence intervals. On Kwandwe, there was a significant difference between observed and expected use of vegetation types ($p<0.05$) and karroid shrubland was strongly avoided by both herds during summer and winter. The preferred vegetation types of the males ranged from relatively open (short euphorbia thicket, bushclump karroid thicket and karroid shrubland) to completely open (old lands). On Shamwari, subtropical thicket, bontveld and montane grassland were avoided; while primary and secondary acacia thicket, riverine thicket and cultivated lands were preferred. The predominant vegetation type in the home ranges of herds on Kwandwe and Shamwari was subtropical thicket. The diet was assessed by direct observations over two seasons and dietary preferences were calculated. There was a significant difference in the frequency of occurrence of plants in the diet on the two reserves ($p<0.05$) and no significant effect of time of day or season ($p>0.05$). Seventeen woody plant species were utilized on Kwandwe and 23 species were utilized on Shamwari. Grass constituted a significantly greater percentage of the diet in summer than winter ($p<0.05$). Elephants on Kwandwe showed a selective preference for *Ozoroa mucronata*, *Pappea capensis* and *Acacia karroo*; while on Shamwari, *A. karroo* was selected. Transects were conducted in two different vegetation types on each reserve so as to assess the impact of elephant on the vegetation and damage scores were then calculated from these data. There was no significant effect of vegetation type or elephant density on mean damage scores in Kwandwe ($p>0.05$). Five hundred and seventy-eight plants were assessed in the subtropical thicket vegetation type and 225 plants were assessed in the savanna-type vegetation, with more than half the trees showing low levels of damage that could not only be attributed to elephants. Mean damage was highest for *Portulacaria afra* and *Pappea capensis* in subtropical thicket and for *Rhus* spp. in the savanna-type vegetation. On shamwari, 408 plants were assessed in subtropical thicket and 215 in the savanna-type vegetation, with more than 70 % of trees showing low levels of damage. There was a significant effect of plant species and elephant density on the mean damage scores in subtropical thicket, with *Aloe ferox* showing more damage than the other plant species ($p<0.01$). In the savanna-type vegetation, *A. karroo* was the most severely damaged. Overall, damage was greater in the thicket vegetation type compared to the more open vegetation type on both reserves.



The African elephant (*Loxodonta africana*: Blumenbach 1797). Adult male (30-35 yrs old; Photograph of ELM 1 on Kwandwe Private Game Reserve)

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CHAPTER 1

GENERAL INTRODUCTION

The drive for socio-economic development in the Eastern Cape (Kepe 2001) combined with the degradation of habitats, due to overgrazing and urbanization has lead to a shift in land use from agriculture to ecotourism (Kerley *et al.* 1995, Wiseman *et al.* 2004), and this has recently been promoted as one of the key economic growth strategies in the Eastern Cape (Kepe 2001). Consequently, the development of small (<300 km^2)*, private game reserves has become a trend, not only in the Eastern Cape Province, but also elsewhere in South Africa (Duffy *et al.* 2002). Some of these smaller game reserves include Shamwari Private Game Reserve, which was established in 1990; Kariega Game Reserve, which was opened in 1991; Kwandwe Private Game Reserve, which was opened in 2000 and Lalibela and Bayethe Private Game Reserves, which were opened in 2001. The major ‘draw-card’ of these reserves is that most, if not all, of them stock the ‘Big Five’ mammals (Kepe 2001). The re-introduction of elephants to these reserves, after their extirpation from the area in about 1900, was brought about in part due to the change in land-use practise and facilitated by the improved technology in transporting them (Slotow *et al*. 2004).

The African elephant belongs to the order Proboscidea and family Elephantidae. Two subspecies (Genus: *Loxodonta*) are found in southern Africa; *Loxodonta africana africana* (the African bush/savanna elephant) and *L. a. cyclotis* (the African forest elephant; Smithers 1983, Grzimek 1990, Shoshani & Tassy 2005). Historically, the savanna elephant was found south of the Sahara wherever sufficient water and trees

* None of the private reserves are larger than 300km^2 and in this study, this has been used to define a small reserve.

occurred, but its range and numbers have shrunk (1.3million in the 1980's to approximately 500 000 today) as human population, development and poaching have increased (Taylor 1978, Estes 1992, Poole & Granli 2003). In southern Africa, in the latter part of the 17th and during the 18th and 19th centuries, elephants were recorded on the coastal plain in the districts of Mossel Bay, George (400-500 individuals), Knysna, Plettenberg Bay and Humansdorp (Boshoff *et al*. 2002). In 1773 there was evidence of elephants near the coast west of Port Elizabeth (Boshoff *et al*. 2002). In the period 1790 to 1820 there were records of elephants in the Sundays River, Alexandria, Paterson, Albany, Bathurst and Peddie to East London Districts (Boshoff *et al*. 2002). The elephant's wide distribution range in the Cape Province (Ebedes *et al.* 1995) has since shrunk from the time of their first reporting in 1497 to their survival in Addo Elephant National Park (AENP) and Knysna Forest 20 years ago (Smithers 1983). Today, the savanna elephant (*L. a. africana*) is found in South and East Africa, extending to Ethiopia and Somaliland (Grzimek 1990, Skinner & Smithers 1990; Figure 1.1).

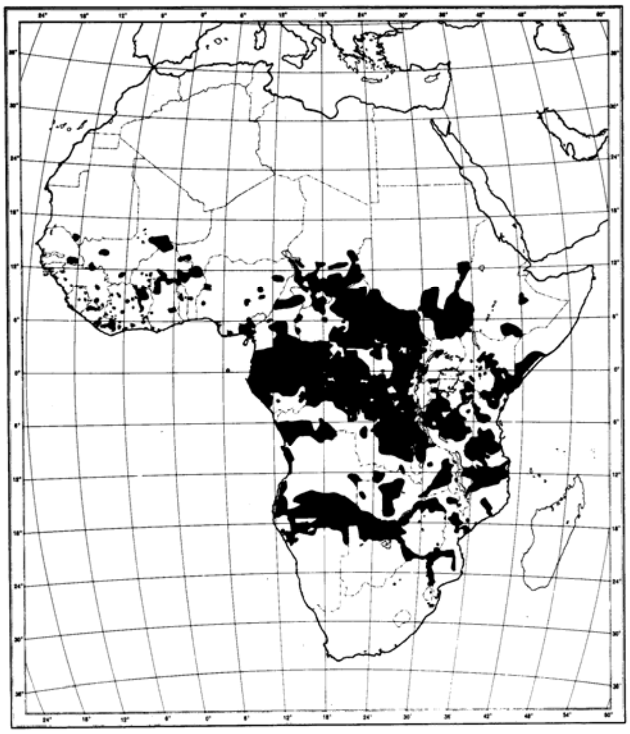


Figure 1.1: The present distribution of elephant in Africa (from Skinner & Smithers 1990).

Elephants are sociable and live in family groups consisting of a number of related females and their offspring (Smithers 1983, Estes 1992). They are not territorial and have large home ranges (e.g. ranging from 54 km^2 - 2178 km^2; Estes 1990, Smithers 1983, Whitehouse & Schoeman 2003, Jackson & Erasmus 2005). The family herd is lead by the matriarch (usually the largest cow or most experienced member of the group; Walker 1996), who determines the group’s activities and movement patterns (Estes 1992). Male elephants leave the maternal herd in adolescence (Estes 1990) and only join them again thereafter for short periods of time, for example, when a female is in oestrus (Smithers 1983). Younger male elephants often form temporary herds, with older bulls (Smithers 1983). Female elephants are seasonal breeders, mating and giving birth mostly during the wet season (Hanks 1979). First conception occurs at 10 – 11 years (Estes 1990). Gestation is close to 22 months, with a range from 17 – 25 months (Hanks 1979) and twins are rare (Smithers 1983, Estes 1990). At birth, the calf is approximately 90cm in height and 120kg in weight (Walker 1996) and usually suckled until about 2 years old. The calving interval ranges from 4 to 9 years, depending on nutrition and population density (Estes 1992). Suckling can occasionally occur even after another calf is born and weaning can be delayed if the calving interval is longer than 4 years (Hanks 1979). Some studies have shown that a switch from a low protein diet (i.e. browse) to a high protein diet (fresh grass) can stimulate ovulation and mating (Hanks 1979). Reproductive senescence starts occurring from 40 years (Hanks 1979). Male elephants reach sexual maturity at about the same age as females and it is at this time that they start to leave the family herd to wander alone or in bachelor herds (Hanks 1979).

Elephants are classified as megaherbivores, as they weigh more than 1000kg (Owen-Smith 1992). They graze and browse, feeding from a wide range of species (Estes 1992, Owen-Smith 1992), but are often extremely selective in their food choice depending on availability, palatability and nutritional quality of forage materials (Taylor 1978). Dietary preferences of elephants change seasonally and this is seen particularly in the occurrence of grass in the diet which is generally high during the wet season and lower during the dry season when browse becomes increasingly important (Wyatt & Eltringham 1974, Guy 1976a, Kabigumila 1993, Osborn 2004). Elephants occur in a wide variety of habitats and are both diurnal and nocturnal (Skinner & Smithers 1990). Seasonal changes in distribution, home range size and habitat selection of elephants has been well documented in Africa and coincide with seasonal climatic changes and the corresponding changes in food and water availability (Ottichilo 1986, Viljoen 1989, Lindeque & Lindeque 1991, De Villiers & Kok 1997, Whitehouse & Schoeman 2003, Tufto *et al*. 1996). Due to fluctuations in these resources, elephants show preferences for some habitats and avoid others.

During the wet season, elephant distribution is widespread and usually in areas with a high abundance of grass (Ottichilo 1986, Lindeque & Lindeque 1991, Tufto *et al*. 1996). In the dry season, a shrinkage of their range occurs and activity is concentrated near water sources (Dunham 1986, Osborn 2003), where tree species are often evergreen (Owen-Smith 1992).

Elephants are keystone species (Owen-Smith 1992), and known to be physical ecosystem engineers with an ability to directly or indirectly control the availability of resources to other organisms (Jones *et al*. 1997). Elephants have varied effects on the vegetation. They can cause detrimental changes to some species, at the same time increasing the abundance of other species (Pamo & Tchamba 2001, Mapaure & Campbell 2002, Wiseman *et al*. 2004). These effects are exaggerated in confined areas (e.g small reserves <300 km^2; Wiseman *et al.* 2004) and therefore a cause for concern (Novellie *et al*. 1991, MacGregor & O'Connor 2004). Previous studies on elephants in the Eastern Cape have been conducted in AENP only (Penzhorn *et al*. 1974, Novellie 1988, Novellie *et al*. 1991, Barratt & Hall-Martin 1991, Midgley & Joubert 1991, Stuart-Hill 1992, Moolman & Cowling 1994, Paley & Kerley 1998, Johnson *et al*. 1999, Kerley *et al*. 1999b, Lombard *et al*. 2001, Whitehouse & Schoeman 2003). These studies have focused on various aspects of elephant diet, habitat and space use and impact on vegetation. Whitehouse & Schoeman (2003) studied the ranging behaviour of male and female elephants to determine whether natural patterns were maintained in a confined area. They reported similar home range sizes for both sexes and found the range sizes to be much smaller (50 – 60 km^2) than the available area (103 km^2). Penzhorn *et al*. (1976), Barrat & Hall-Martin (1991), Stuart-Hill (1992) have shown that elephants have a significant effect on the vegetation, with biomass and cover of woody plant species decreasing considerably under continuous elephant browsing. In addition, Stuart-Hill (1992) and Barrat & Hall-Martin (1991) reported a complete loss of *Aloe africana* (an important component of thicket vegetation) from the park. Subtropical thicket is confined to the Eastern Cape (Everard 1987, Vlok *et al*. 2003) and makes up a major component of the vegetation in AENP (Penzhorn et al 1976, Stuart-Hill 1992, Lubke *et al*. 1986) and many of the smaller reserves in the Eastern Cape Province. It is characterised by a dense spiny thicket with high levels of endemism, a high standing biomass (Everard 1987, Vlok *et al*. 2003) and is highly nutritious (Stuart-Hill 1992). Monitoring of elephant impact in this vegetation type is therefore necessary as re-establishment of subtropical thicket is a long and slow process (Hoffman & Cowling 1990).

While there is no doubt that elephants occurred widely through what is now the Eastern Cape Province, it is also the case that prior to the arrival of European settlers, their movements were not restricted. The re-introduction of elephants to reserves in the Eastern Cape Province can be seen as a step towards returning the region to a more natural state. However, four observations together suggest that these introductions must be carefully monitored. Firstly, the systems to which elephants are re-introduced are mostly small and enclosed and thus movement will be restricted. Secondly, as megaherbivores, keystone species and physical ecosystem engineers, elephants are capable of driving habitat change and limiting resources to other organisms. Thirdly, the vegetation in the Eastern Cape is mainly characterised by subtropical thicket, and finally, apart from the studies in Addo Elephant National Park, there have been no studies of the ecology of elephants in thicket type vegetation. Thus the broad aims of this project were to examine aspects of space use (home range and core area size) habitat selection (Chapter 3), diet and the affect of elephant browsing on woody plant species in subtropical thicket in small reserves so as to provide information that can be used by the managers of small reserves. Data were collected from three private game reserves in the Eastern Cape Province; namely Lalibela, Kwandwe and Shamwari Private Game Reserves. However, due to a lack of quantity and quality, data from Lalibela Private Game Reserve could not be used for analysis and inclusion into this thesis.

CHAPTER 2

DESCRIPTION OF THE STUDY SITES

2.1 LOCATION

The study was conducted in two game reserves near Grahamstown in the Eastern Cape Province, South Africa (Figure 2.1). These sites were selected due to their small size (<300 km^2), which is typical of most of the private game reserves to which elephants have been re-introduced in the Eastern Cape, and proximity to Grahamstown and Rhodes University. Kwandwe Private Game Reserve (hereon referred to as Kwandwe) is approximately 35 km north of Grahamstown (33^{o}09'S, 26^{o}62'E). Shamwari Private Game Reserve (Shamwari) is approximately 60 km southwest of Grahamstown, along the N2 national road towards Port Elizabeth (33^{o}20'S, 26^{o}01'E).

2.2 KWANDWE PRIVATE GAME RESERVE

2.2.1 Site description

Kwandwe was established as an eco-tourism reserve in 1999 and is approximately 16 000 ha in size. Two rivers run through the reserve, being the perennial Great Fish River and the non-perennial Botha's River. The reserve is divided into ten vegetation types (Galpin & Bissett 2004 *pers. comm.*. Bissett 2004; Figure 2.2), but for the sake of simplicity and to allow comparison between Kwandwe and Shamwari, similar vegetation types have been combined (see pg 17-22 for details) using published vegetation descriptions for the Eastern Cape Province (Low & Rebelo 1996); unless otherwise stated. Kwandwe is dominated by subtropical thicket (61 %), while other important vegetation types include nama karroo (16 %), bushclump savanna (15 %), riverine thicket (6 %) and old lands (2 %). A description of each vegetation type is found later in the chapter.

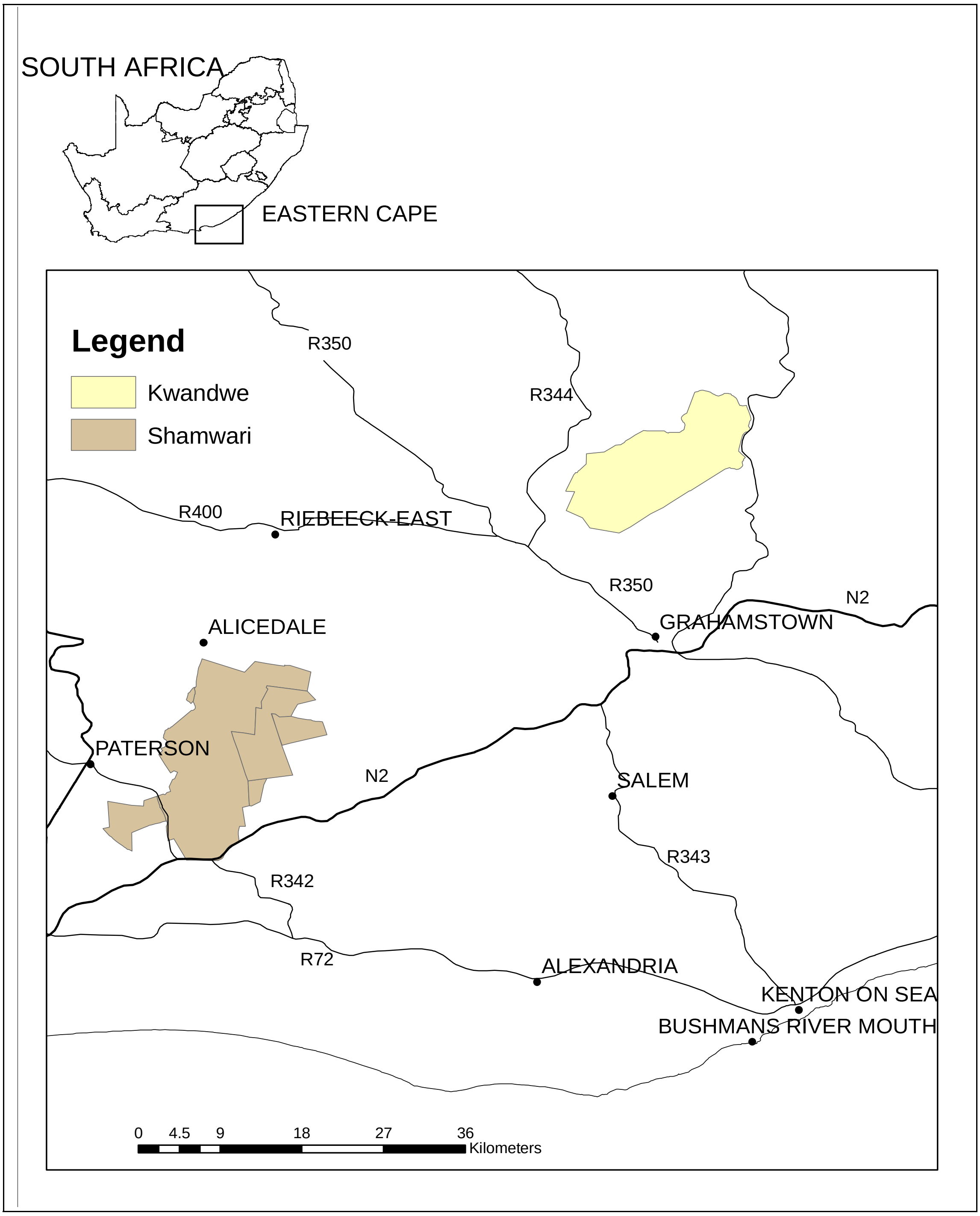


Figure 2.1: Location of the two study sites within the Eastern Cape Province (ArcGIS9; map units: decimal degrees; not projected).

Figure 2.2: Vegetation map of Kwandwe showing the 10 different vegetation types (ArcGIS 9; map units: decimal degrees; not projected; source: Galpin & Bissett; Gillis Game Farm, Kwandwe 2004).

2.2.2 Climate

Kwandwe experiences maximum temperatures of over 40ºC in summer (October – March) and minimum temperatures of below 5ºC in winter (April – September; Figure 2.3). The reserve exhibits a bimodal pattern of rainfall with peaks in March (47.5 mm) and November (53.7 mm; Figure 2.3). The average rainfall during the study period, however, peaked in April (52.5 mm) and September (68.7 mm). The annual rainfall varies from a low of 179.5 mm recorded in 1992 to a high of 484.5 mm recorded in 2000.

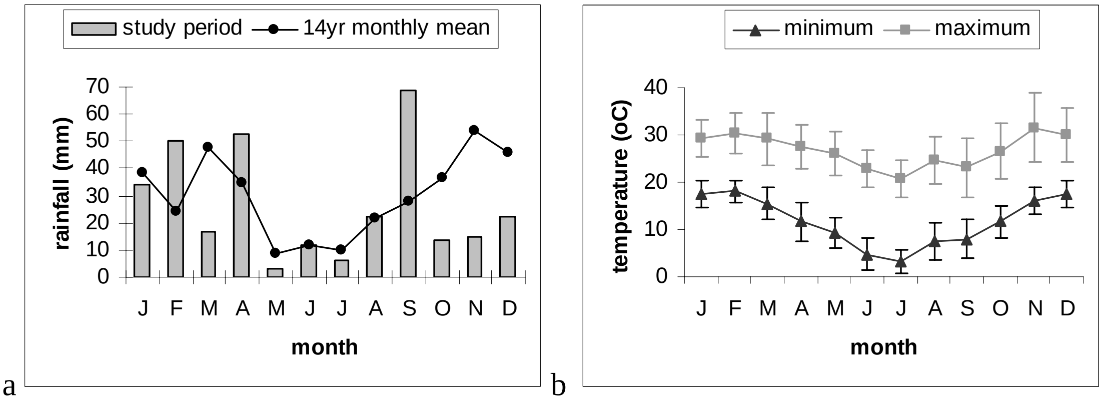


Figure 2.3: (a) Total monthly rainfall (the 14 year monthly mean is also shown for comparison) and (b) average monthly temperatures (values are mean daily maxima and minima for that month ± 1 S.D.) for the study period (February 2004 to March 2005). Data from the reserve.

2.2.3 Topography and geology

Kwandwe ranges in altitude from 170 m above sea level (a.s.l.) in the Great Fish River Valley to 600 m a.s.l. in the northeast. The reserve is dominated by steep valleys and gorges in the South and northeast and undulating hills in the central region (Figure 2.4). The dominant geological formations include the Karoo (Ecca Group shale and sandstone, and Dwyka Group shale and tillite) and Cape (Witteberg Group quartzite and shale) Supergroups (Rust 1998).

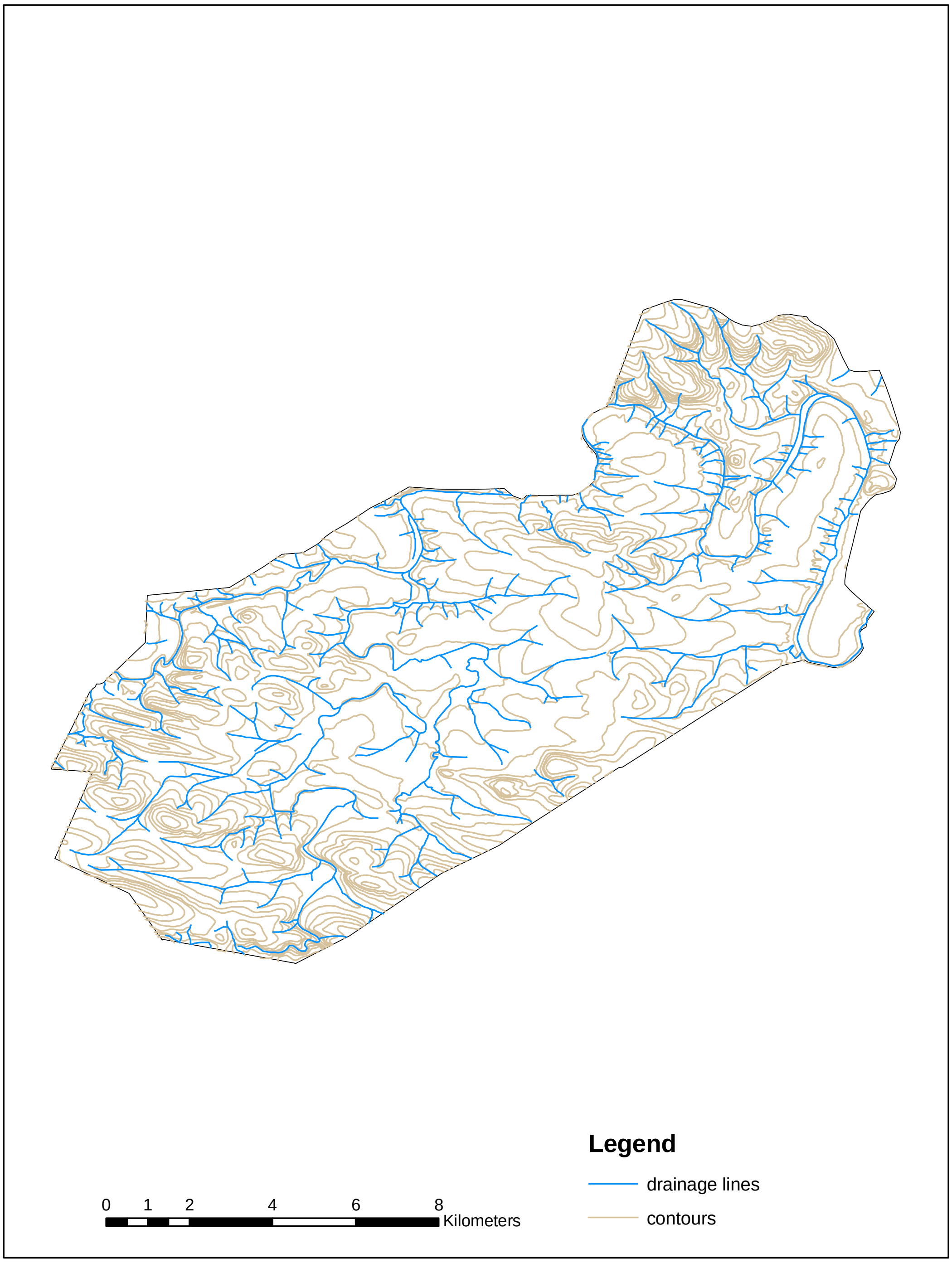


Figure 2.4: The topography and drainage patterns of Kwandwe (ArcGIS 9; map units: decimal degrees; not projected).

2.2.4 Elephant population history

In August 2001 a family herd (ELH5 = elephant herd 5) consisting of 10 individuals (3 adult females, 4 sub-adults and 3 calves) was translocated from the Kruger National Park (KNP). A month later, two bulls from KNP (ELM 1 ≈ 30-35 years and ELM 2 ≈ 20-25 years old) were moved to Kwandwe. In October of the same year, a family herd from Madikwe Game Reserve (ELH6) consisting of 9 individuals (3 adult females, 3 juveniles and 3 calves) and two bulls from Letaba Game Reserve (ELM 3 and ELM 4 ≈ 20-25 years old) were translocated to Kwandwe. The reserve currently (as of 31 March 2005) has 27 elephants (4 calves were born since relocation), with a density of 0.2 elephants per km^2. The matriarchs and bulls were fitted with AWT radio collars (African Wildlife Tracking cc) prior to release to aid in monitoring. There have been no “break-outs” since release and the collars on the bulls have subsequently been removed.

2.3 SHAMWARI PRIVATE GAME RESERVE

2.3.1 Site description

Shamwari was opened in 1992 and is approximately 20 000 ha in size, of which 15 500 ha is available to the elephants. The remaining 4500 ha falls outside the main reserve and comprises the breeding centre, Bayethe Game Reserve and the Ikhanda and Nyathi sections. The Bushmans River flows through the reserve for 28 km. The reserve is classified into 13 vegetation types (O’Brien 2000) and is dominated by subtropical thicket (43 %) and grassland (21 %; Figure 2.5). Other vegetation types include old lands (13 %), bushclump savanna (11 %), *Acacia* savanna (8 %), riverine thicket (3 %), fynbos (0.6 %) and afromontane forest (0.4 %). A description of each vegetation type is found later in the chapter.

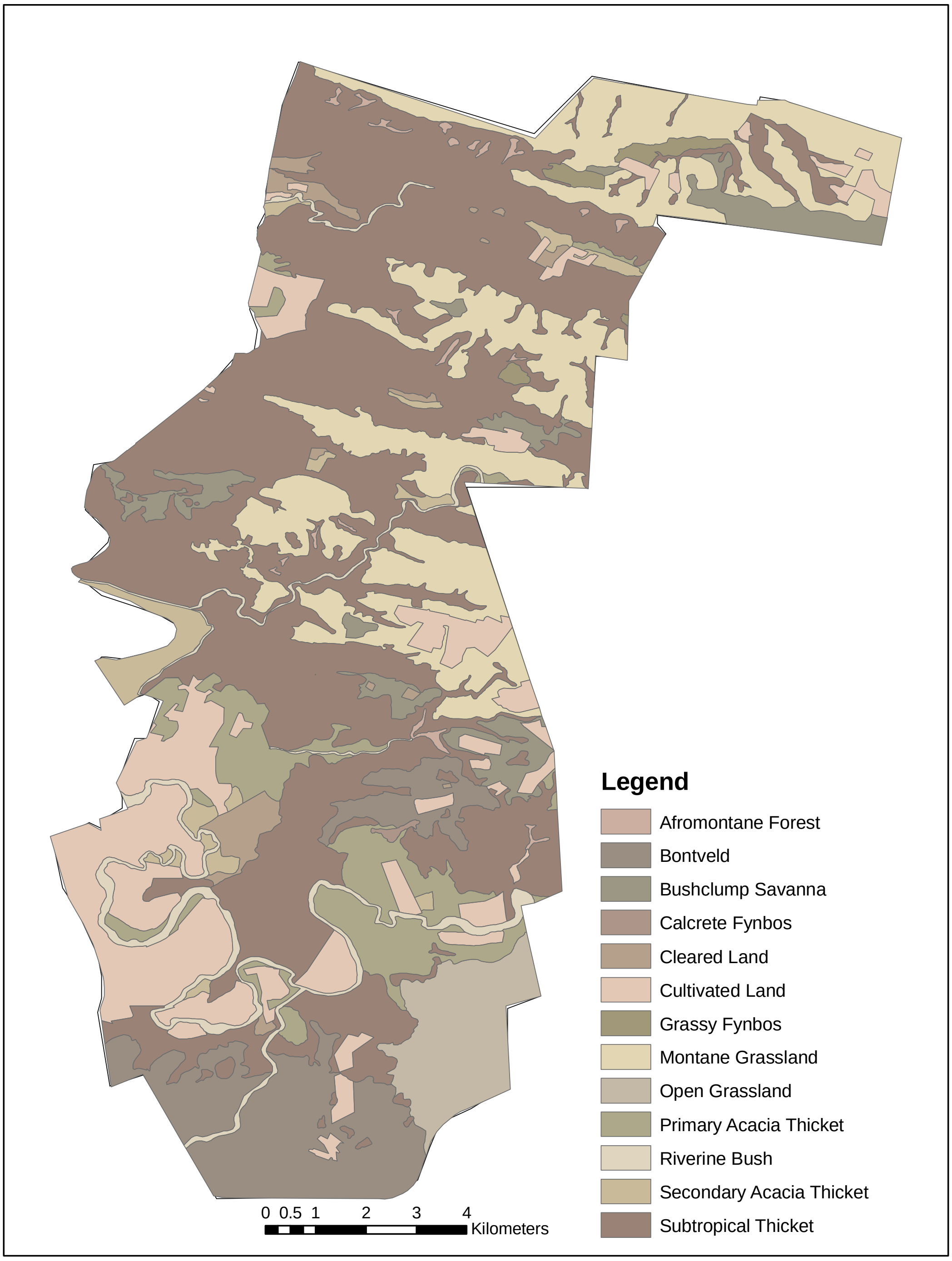
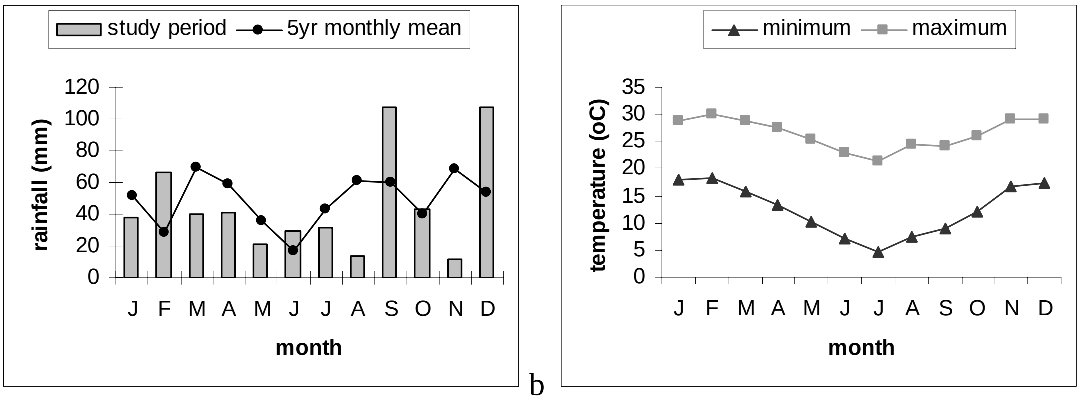


Figure 2.5: Vegetation map of Shamwari showing the 13 different vegetation types (ArcGIS 9; map units: decimal degrees; not projected; source: Shamwari Wildlife Department 2004).

2.3.2 Climate

Shamwari falls between the summer and winter rainfall areas in the Eastern Cape Province and therefore receives rainfall all year round, with peaks occurring in March (69.4 mm) and November (67.9 mm; Figure 2.6). The annual rainfall for the region varies from a low of 348.5 mm recorded in 1999 to a high of 766.5 mm recorded in 2001. Temperature data were not available for the reserve or for Paterson (approximately 11 km west of Shamwari), so data for Addo (≈ 40 km south-west of Shamwari) were used. Mean monthly temperatures reach maxima of 31ºC in summer and minima of 4ºC in winter.



a b

Figure 2.6: (a) Total monthly rainfall (the 5 year monthly mean is also shown for comparison) and (b) average monthly temperatures (values are mean daily maxima and minima for that month) for the study period (February 2004 to March 2005). Data from Addo.

2.3.3 Topography and Geology

Shamwari ranges in altitude from 196 m a.s.l. in the south, with gently undulating hills to 628 m a.s.l. in the north, with deep valleys and gorges (Figure 2.7). The dominant geological formations are Bokkeveld Series shale, Witteberg Quartzites, Karoo Sandstone and Sundays River Formations. The quartzite ridges dominate the central and northern parts of the reserve, while the Sundays River Formation, with shallow soils and underlying calcrete, dominates the southern part of the reserve. The steep elevation gradient results in four main substrata being available to the plants, namely shale, sandstone, quartzite and calcrete. In addition, some deeper alluvial soils are found on the lower lying lands (O'Brien 2000).

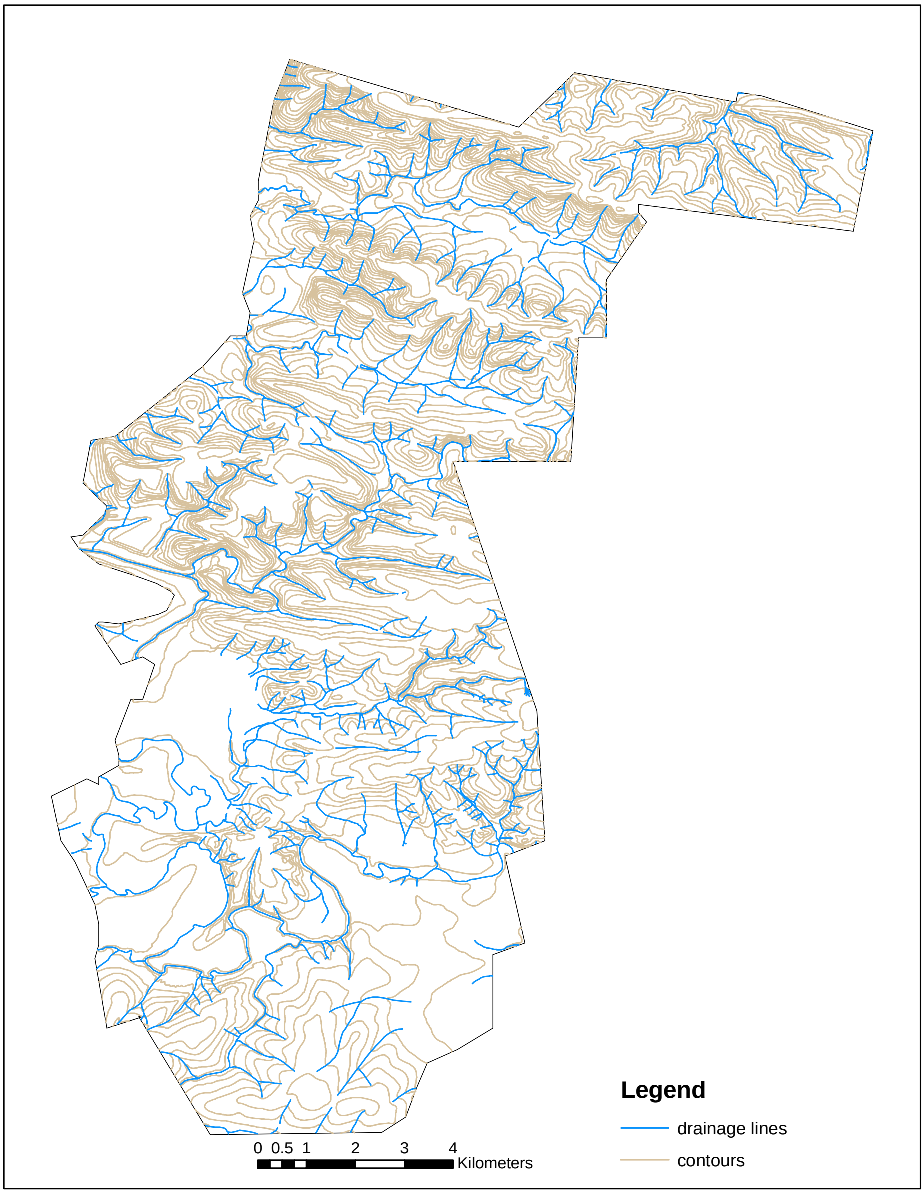


Figure 2.7: The topography and drainage patterns of Shamwari (ArcGIS9; map units: decimal degrees; not projected).

2.3.4 Elephant population history

There are 61 elephants on the reserve (as of 1 June 2005; 18 adult females, 10 adult males, 6 subadults, 8 intermediate, 13 juveniles and 6 calves). Between 1992 and 1994, 22 orphans were translocated from KNP. A family herd consisting of 7 individuals (3 adult females, 2 juvenile females and 2 male calves) was also translocated from KNP in 1996. The following year, 2 adult females were re-introduced from Knysna. In 2003, 13 elephants were relocated to Bushman Sands Game Reserve (3 adult females, 2 juvenile females, 1 sub-adult male and 2 juvenile males) and Sanbona Wildlife Centre (1 sub-adult male and 2 juvenile males). In the same year, 2 adult males were euthanased. The density is currently 0.4 elephants per km^2. The social structure of the family groups varies and more often than not, one large herd is formed.

2.4 VEGETATION DESCRIPTION

As mentioned earlier, there is considerable confusion over the identification of different vegetation types, with the same vegetation on different reserves given different names. For this reason, it was attempted to standardize the names used with descriptions from Low & Rebelo (1996). In the following section, the vegetation types are described using names from Low and Rebelo (1996), clearly indicating which of the vegetation types from the two reserves should be regarded as equivalent (Table 2.1).

2.4.1 Subtropical thicket

This vegetation type is analogous to euphorbia portulacaria mosaic, medium portulacaria thicket, short and tall euphorbia thicket found at Kwandwe and subtropical thicket found at Shamwari. It is characterised by a dense thicket of evergreen succulent and woody shrubs and trees. Characteristic woody species are *Schotia afra*, *Carissa bispinosa*, *Cussonia spicata*, *Pappea capensis*, *Euclea undulata*, *Sideroxylon inerme*, *Grewia robusta*, *Brachylaena ilicifolia*, *Maytenus capitata*, *Lycium campanulatum*, *Maytenus procumbens*, *Polygala myrtifolia*, *Scutia myrtina*, *Plumbago auriculata* and *Mystroxylon aethiopicum*, while succulent species include *Aloe africana*, *A. ferox*, *Portulacaria afra*, *Euphorbia bothae*, *E. tetragona*, *E. triangularis* and *Crassula* spp. Herbs and grasses are sparse but include *Pentzia incana*, *Chrysocoma ciliata* and *Cynodon dactylon*.

2.4.2 Drainage line thicket

This vegetation type is only found on Kwandwe and is characterised by the woody species *Rhus refracta* and *Plumbago auriculata*, with the grass species *Panicum maximum* growing on the edge of the thicket (Galpin & Bissett 2004 *pers. comm.* Bissett 2004).

2.4.3 *Acacia* savanna

This vegetation type is analogous to primary and secondary *Acacia* thicket at Shamwari. Primary *Acacia* thicket is characterised by *Acacia karroo* trees and thicket species such as *Diospyros lycoides*, *Rhus* spp., *Scutia myrtina*, *Gymnosporia polyacantha* and *Ehretia rigida*. Grasses are dense and include *Themeda triandra*, *Sporobolus fimbriatus*, *Digitaria eriantha* and *Eragrostis curvula* (Lubke & Bredenkamp 1996). Secondary *Acacia* thicket is dominated by bushclumps or individuals of *Acacia karroo* and *Rhus* spp. The grass layer includes *Themeda triandra*, *Cymbopogon plurinodis*, *Eragrostis curvula*, *Sporobolus fimbriatus*, *Heteropogon contortus, Digitaria eriantha and Eustachys paspaloides.* (Lubke & Bredenkamp 1996).

2.4.4 Riverine thicket

This vegetation type is found at Kwandwe and Shamwari. Characteristic species include *Rhus lancea*, *Acacia karroo* and *Combretum caffrum.* The grass layer is dominated by *Panicum maximum*. Riverine bush at Shamwari is restricted to the banks of the Bushmans River as well as some of the larger temporary watercourses. The indicator species are *Combretum caffrum, Acacia caffra* and *Rhus* spp.

2.4.5 Bushclump Savanna

This vegetation type is found on both reserves and is also analogous to bushclump karroid thicket (Kwandwe) and bontveld (Shamwari). The vegetation consists of bushclumps interspersed with grass and/or karroid shrubs. The dominant woody plant species are *Canthium inerme*, *Euclea undulata*, *Gymnosporia buxifolia*, *Scutia myrtina*, *Rhus* spp., *Aloe ferox*, *Grewia occidentalis*, *Cussonia spicata*, *Fluggea verucossa*, *Psydrax ovata*, *Olea europea* and *Pteroxylon obliquum*. The dominant grass species are *Digitaria eriantha*, *Setaria neglecta*, *Eustachys paspaloides*, *Themeda triandra* and *Eragrostis curvula*.

2.4.6 Nama Karoo

This vegetation type is analogous to karroid shrubland at Kwandwe. It is characterised by large open areas interspersed with trees and shrubs. Common tree species, although not abundant, include *Pappea capensis*, *Rhus refracta* and *Acacia karroo* (Galpin & Bissett 2004 and Hoffman 1996). A karroid herbaceous layer, made up exclusively of *Pentzia incana* dominates this vegetation (Galpin & Bissett 2004 *pers. comm.* Bissett 2004). Grass cover is generally sparse although *Digitaria eriantha*, *Cynodon dactylon* and *Aristida congesta* have been recorded (Hoffman 1996).

2.4.7 Afromontane Forest

This vegetation type is found at Shamwari. Afromontane forest occurs in patches restricted to deep valleys with steep gradients and is dominated by trees up to 30 or 40 m tall with the presence of distinct strata of emergent trees, canopy trees and shrub and herb layers (Lubke & Mackenzie 1996). Tree species include: *Podocarpus latifolius, P. falcatus, Trichocladus ellipticus, Rhus chirendensis, Harpephyllum caffrum* and *Hippobromus pauciflorus*. Shrubs and climbers are common and include: *Gymnosporia heterophylla, Scutia myrtina, Carissa bispinosa, Secamone alpinii, Canthium ciliatum, Rhoicissus tridentata, Zanthoxylum capense* and *Burchellia bubalina.* In the undergrowth grasses, herbs and ferns may be common (Lubke & McKenzie 1996).

2.4.8 Grassland

Grassland occurs in Shamwari (montane and open). The dominant grass species are *Themeda triandra, Heteropogan contortus* and *Eragrostis curvula* and *Digitaria eriantha* (O'Brien 2000).

2.4.9 Old Lands

Old lands are found on Kwandwe and are also analogous to cultivated lands on Shamwari. They are areas that were previously used for the cultivation of crops and are in various stages of rehabilitation (O'Brien 2000). Grass species include

Pennisetum clandestinum, Cenchrus ciliaris, Cynodon dactylon, Sporobolus africanus and *Eragrostis plana*.

2.4.10 Cleared Lands

Cleared lands are found Shamwari and refer to areas where the vegetation has either been mechanically cleared to create grazing for livestock, or has been severely over utilized in the past so that it no longer resembles its original state (O'Brien 2000). New vegetation growth includes *Azima tetracantha* and *Panicum maximum*.

2.4.11 Fynbos

(a) Grassy Fynbos

Grassy fynbos is found at Shamwari and is situated on the quartzite ridges in the northern parts of the reserve (O'Brien 2000). The communities consist of a complex mixture of grasses, woody shrubs and small-leaved fynbos elements. Some of the dominant species include *Leucadendron salignum, Phylica axillaries, Passerina vulgaris* and *Themeda triandra*.

(b) Calcrete Fynbos

Calcrete fynbos is found at Shamwari and limited to only one eighth of a hectare. It is dominated by *Syncarpha recurvata* (O'Brien 2000).

Table 2.1: Analogous vegetation types found on Kwandwe and Shamwari. EPM: euphorbia portulacaria mosaic; MPT: medium portulacaria thicket; SET: short euphorbia thicket; TET: tall euphorbia thicket; ST: subtropical thicket; DLT: drainage line thicket; PAT: primary acacia thicket; SAT: secondary acacia thicket; RT: riverne thicket; RB: riverine bush; BS: bushclump savanna; BKT: bushclump karroid thicket; BV: bontveld; KS: karroid shrubland; AF: afromontane forest; MG: montane grassland; OG: open grassland; OL: old lands; CL: cultivated lands; C: cleared lands; GF: grassy fynbos and CF: calcrete fynbos.

Low & Rebelo	Kwandwe	Shamwari
Subtropical thicket	EPM	ST
	MPT	
	SET	
	TET	
No equivalent vegetation type	DLT	
Acacia savanna	-	PAT
		SAT
Riverine thicket	RT	RB
Bushclump savanna	BS	BS
	BKT	BV
Nama Karoo	KS	
Afromontane forest	-	AF
Grassland	-	MG
		OG
Old lands	OL	CL
Cleared Lands	-	C
Fynbos	-	GF
		CF

CHAPTER 3

HOME RANGE SIZE, SPATIAL DISTRIBUTION AND HABITAT USE OF ELEPHANTS IN TWO GAME RESERVES IN THE EASTERN CAPE PROVINCE

3.1 INTRODUCTION

Home range sizes of elephants depend largely on the seasonal availability of water and food, habitat heterogeneity (Tufto *et al*. 1996), the amount of space available (Whitehouse & Schoeman 2003) and the sex of the elephants (De Villiers & Kok 1997, Jackson & Erasmus 2005). Unlike many other large mammals, there is little evidence to suggest that space use by elephants is affected by their density (Watson & Bell 1969) or by the presence of other large mammal species due to their status as a keystone species in an ecosystem (Owen-Smith 1992). In regions where water availability is highly seasonal, elephants concentrate near water points in the dry season, while expanding their range in the wet season (Ottichilo 1986, Lindeque & Lindeque 1991). For example, in the eastern Transvaal Lowveld, range size differed seasonally, being smaller in the dry season (females: 85.8 km^2, males: 36.7 km^2) than the wet season (females: 122.8 km^2, males: 128.6 km^2; De Villiers & Kok 1997). Range expansion may also result from a change in food quality and quantity and feeding ecology. In the Sengwa Wildlife Research Area (Zimbabwe), Osborn (2003) noted an increase in range size towards the end of the wet season and attributed this to a decrease in grass growth from the early wet season to the late wet season. He suggested that a switch from grazing to browsing might result in an expansion of their range because of a need to increase their foraging area. Dunham (1986) found that females near the Zambezi River had larger home ranges than those in the escarpment and related this to the difference in food abundance and quality because of the low grass biomass in the woodlands surrounding the river in the dry season. Elephants would therefore have to expand their range to find suitable forage in this area (Dunham 1986). Seasonal distribution will thus be more or less pronounced depending on the rainfall pattern and vegetation types of the particular area and the feeding ecology of the elephants. With habitat heterogeneity, complementary resources become available (e.g. food and cover) and shrinkage of the home range might occur (Tilman 1982; Tufto *et al*. 1996).

In several studies it has been observed that bull elephants have larger home range sizes compared to cows. This was seen in southern Kafue National Park; Zambia where the mean home range size for bulls was 884 km^2 and 534 km^2 for females (Jackson & Erasmus 2005). Similar results were found in the Kunene region of the Etosha National Park; Namibia (males, mean home range 2029 km^2, females 1511 km^2) and Chobe National Park; Botswana (males 1422 km^2, females 1254 km^2; Jackson & Erasmus 2005). In a smaller reserve (Tembe Elephant Park; South Africa: 300 km^2), the mean home range size for a male was 235 km^2, while the mean home range for females was much smaller at 62 km^2. Home range sizes in the Addo Elephant National Park however, were similar for both females (55 km^2) and non-musth males (53 km^2; Whitehouse & Schoeman 2003). De Villiers & Kok (1997) found contradicting results in the eastern Transvaal Lowveld, where home range sizes were significantly larger for females (116 km^2) compared to males (78 km^2).

A home range can be defined as ‘the area occupied by an individual or group, and is determined by plotting the perimeter of points where the individual or group is seen over a period of time' (Estes 1992). Typically a home range has been defined as including 95 % of the sightings of an animal (White & Garrott 1990), while the core area (50 % MCP or UD) defines those areas used more frequently (Samuel *et al*. 1985, Schindler 2005). Because the core area represents an area that is more heavily used, its calculation can be important in determining critical habitats (Schindler 2005) and interactions with the environment (Samuel *et al*. 1985). Various methods have been used to determine home range sizes of animals including the harmonic mean (HM), minimum convex polygon (MCP) and kernel methods (UD), each with their own advantages and disadvantages (Worton 1989, Lawson & Rogers 1997, Hemson *et al*. 2005). It has also been suggested that the estimated home range of an animal is dependent on the method used because biases occur when too few locations are used (Girard *et al*. 2002). The disadvantages with the MCP method are that it includes a large amount of unused space, as the outer locations are included in the area calculated for the polygon (White & Garrott 1990, De Villiers & Kok 1997, Whitehouse & Schoeman 2003), and that it is dependent on sample size (Dunham 1986). Jackson & Erasmus (2005) found that a minimum of 120 fixes were needed to calculate a reliable home range estimate using the MCP method. The main advantages of using contouring methods (HMs and UDs) are that 'they can accommodate multiple areas of high density, do not rely on outlying points and therefore do not include unused areas which can lead to an overestimate of home range size' (Hemson *et al*. 2005). The UD method is a probability density function that estimates home range by adding the total number of data points in a particular area and calculating the density, thus excluding unused space (Worton 1989). A smoothing parameter (H) is used to control the amount of variation in the UD.

Seasonal changes in habitat use are likely to be most obvious in large species that can easily move large distances and Leuthold (1977) suggested that this ability to move large distances enables elephants to make use of resources that are only temporarily available from season to season. Because of their large home ranges, and ability to move long distances, it is likely that the amount of available space (reserve size) will have an effect on home range sizes of elephants (Whitehouse & Schoeman 2003). The available evidence from reserves of different sizes supports this (Leuthold 1977, Verlinden & Gavor 1998, De Villiers & Kok 1997, Osborn 2003, Jackson & Erasmus 2005) and is further discussed later in this chapter.

Determining whether observed habitat use is random or represents a selection from what is available is important in understanding the habitat requirements of a species and one of the common ways to evaluate habitat use is to determine preference (Neu *et al*. 1974, Byers *et al*. 1984, Anderson & Gutzwiller 1996, Litvaitis *et al.* 1996, Dellinger 2003, Schindler 2005). A preferred habitat type is one that is used more than expected from its availability (Aebischer *et al*. 1993). An understanding of the habitat requirements and seasonal changes in these requirements is important for the effective conservation (Osborn 2003, Traill 2004) and management (Schindler 2005) of a species.

In this chapter three closely interlinked aspects of the behaviour of elephants in small reserves were examined. Habitat use and seasonal changes in habitat use will affect the distribution of the elephants within the reserves and are likely to affect the size of the home range and core area (see Chapter 1). The aims of this chapter were thus to determine 1) home range and core area sizes in relation to total available space using radio telemetry and GIS software, 2) whether these change seasonally and 3) whether there is a preference for certain habitat types.

3.2 MATERIALS AND METHODS

3.2.1 Data Collection

Elephant sightings were recorded on a daily basis by the staff of each reserve. On Kwandwe, a 'homing-in' method was used whereby the transmitted signal was followed using a TELONICS TR-4 receiver with a two-element antenna until the specific animal was observed and its position recorded with a GARMIN GPS (White & Garrott 1990). On Shamwari, whenever a herd or individual was seen by the staff, its location was recorded on a map of the reserve from which co-ordinates were determined. One fix per elephant, or herd, per day was used to ensure independence of samples (White & Garrot 1990, De Villiers & Kok 1997, Whitehouse & Schoeman 2003).

3.2.2 Data Analyses

(a) Spatial distribution

Home range and core areas were calculated in ARCVIEW 3.2 using the ANIMAL MOVEMENT extension package v. 2.04 BETA (Hooge & 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 utilisation distribution (UD) method was used to determine home range (95 % UD) and core area (50 % UD) sizes (Worton 1989, White & Garrott 1990, Hemson *et al*. 2005). In this study, the least-square cross-validation method (Worton 1989) was used to determine the smoothing parameter (H) in BIOTAS 1.03 ALPHA (Ecological Software Solutions). This was then modified to best fit the data and an H value of 1000 was used for all analyses in ARCVIEW 3.2. Where necessary, the UDs were clipped to the reserve boundary to exclude areas outside the boundaries and the new areas were recalculated. Distance to drainage lines were automatically calculated in ARCVIEW 3.2 after joining the sightings data attribute table with the vegetation map attribute table. The home range and core area UDs were calculated for summer and winter to determine potential effects of season. For the MCPs, 5 % of the outliers were removed using the harmonic mean method in ARCVIEW 3.2. The data for each of the bulls and the two family herds (Kwandwe) and the herd (Shamwari) were analysed separately. However, the GPS fixes for the bulls on Shamwari were often not allocated to an individual bull a the data were therefore pooled. The effect of season and sex on home range sizes were tested using a two-way ANOVA.

(b) Habitat use

Habitat use was evaluated at two scales; at a home range level, where habitat use was compared to what was available in the 95 % UD area, and at a finer core area level, where use within the 50 % UD area was assessed. Typically, habitat use is assessed at a reserve level but in this study the 95 % UDs comprised ≈ 70-95 % of the two reserves and thus analysis is at a 95 % UD level. These analyses were done for summer and winter separately. The data (GPS fixes for elephants) were plotted on a GIS base map of each reserve which included all vegetation types present at each site. Use (number of point locations within a habitat relative to the total number of point locations) and availability data (proportion of habitat available to the elephants either within the home range or core area) (Duchamp *et al*. 2004) were then manually calculated in ARCVIEW 3.2.

Habitat preferences were evaluated using the methods described by Neu *et al*. (1974) and Byers *et al*. (1984); whereby a chi-square goodness-of-fit test was used to determine whether a significant difference occurred between the expected utilization of habitat types and the observed frequency of their usage (Byers *et al*. 1984), after which Bonferroni confidence intervals were calculated to determine which habitat types were being preferred, using the following formula (Litvaitis *et al*. 1996, Dellinger 2003, Schindler 2005):

$$\overline{P}i - Z_{\propto/2k}\sqrt{\overline{P}i(1-\overline{P}i)/n} \leq Pi \leq \overline{P}i + Z_{\propto/2k}\sqrt{\overline{P}i(1-\overline{P}i)/n}$$

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 Spatial Distribution

(a) Kwandwe

Home range sizes for both herds and all four males were significantly larger during summer than winter (Table 3.1; two-way ANOVA, F=36.9, p<0.005). However, there was no significant difference between the home range sizes of the males and herds within a season (Table 3.1; two way ANOVA, F=-0.062, p>0.1). A similar trend was seen with the core areas which were smaller in winter than summer, however these differences were not significant (two way ANOVA, F=2.81, p>0.1). During summer, the herds utilised about 76 % of the reserve and their home ranges shrank considerably during winter (52 % of the reserve) and were concentrated near the permanent water source (The Great Fish River) in the N/NE of the reserve (compare Figures 3.1 and 3.2). The mean distances of ELH 5 and ELH 6 to drainage lines did not change significantly from summer to winter (paired t-test, $p>0.05$; Table 3.1). Drainage lines are ephemeral water courses that run rarely and do not include dams or standing water. The four bulls used most of the reserve in summer (mean 95 % UD 118 km^2; 74 % of the reserve) with core areas either close to the Great Fish River (see for example ELM 2 & 3; Figures 3.4 & 3.5) or in the vicinity of one of the dams (see for example ELM 2 & 4; Figures 3.4 & 3.6). In winter, home ranges contracted and home ranges and core areas were centred around either the Great Fish River or one or more of the dams (compare Figures 3.3 – 3.6). This is clearly illustrated by ELM 1, where the three core areas in winter were all around dams (Figure 3.3), ELM 2 where one section of the home range surrounded three dams (Figure 3.4) and ELM 3, where one section of the core area was around a dam and a length of the Great Fish River (Figure 3.5). In spite of this apparent movement towards water in winter, there was no significant difference in the mean distance to drainage lines for the four males in summer and winter (paired t-test, $t=0.99$, $p>0.1$).

Table 3.1: Seasonal home range and core area sizes (95% & 50% UDs) and mean distance to drainage lines (± 1 S.D.) for each of the family herds and bulls in Kwandwe and the family herd and bulls in Shamwari.

Herd/Male	**Home range size (km^2)**		**Core area size (km^2)**		**Mean distance (m) to drainage lines (mean ± 1 S.D.)**	
	Summer	**Winter**	**Summer**	**Winter**	**Summer**	**Winter**
			Kwandwe			
ELH 5	119	88	12	13	150±122	128±101
ELH 6	123	78	24	13	154±123	152±159
Mean	**121±2.8**	**83±7.1**	**18±8.5**	**13**	**152±123**	**140±130**
ELM 1	105	101	12	6	511±3667	184±510
ELM 2	126	78	13	6	595±4746	135±110
ELM 3	117	94	15	18	150±129	363±2792
ELM 4	123	83	17	7	149±112	123±104
Mean	**118±9.3**	**89±10.4**	**14±2.2**	**9±5.9**	**351±2164**	**201±879**
			Shamwari			
HERD	142	129	27	17	431±527	1022±819
MALES*		118		22		1269±837

* Data for summer and winter combined due to small sample size (114 fixes)

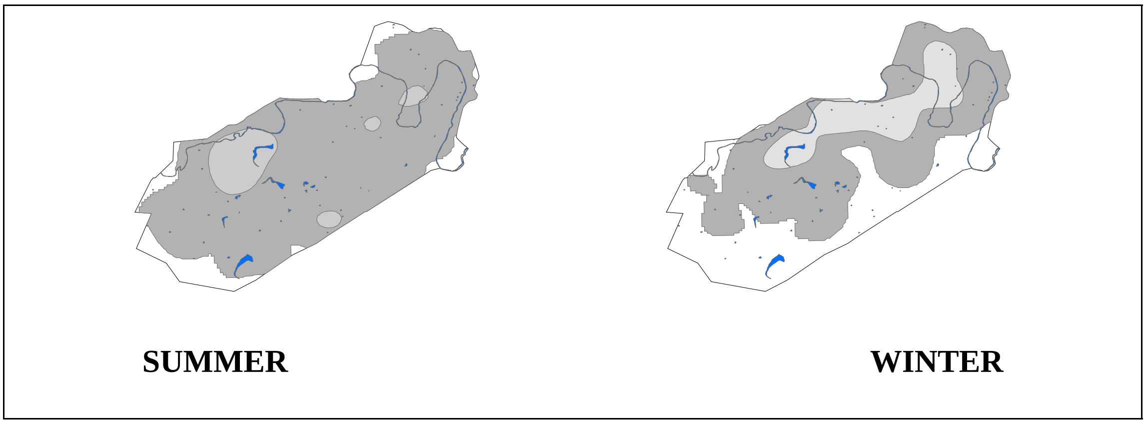


Figure 3.1: Home ranges (dark grey) and core areas (light grey) of ELH 5 on Kwandwe for summer (n=165) and winter (n=144). Rivers and dams are shown. Arcview 3.2, map units: meters, projection: Albers Equal-Area Conic, WGS84 and ARCMAP 9, map units=decimal degrees, not projected.

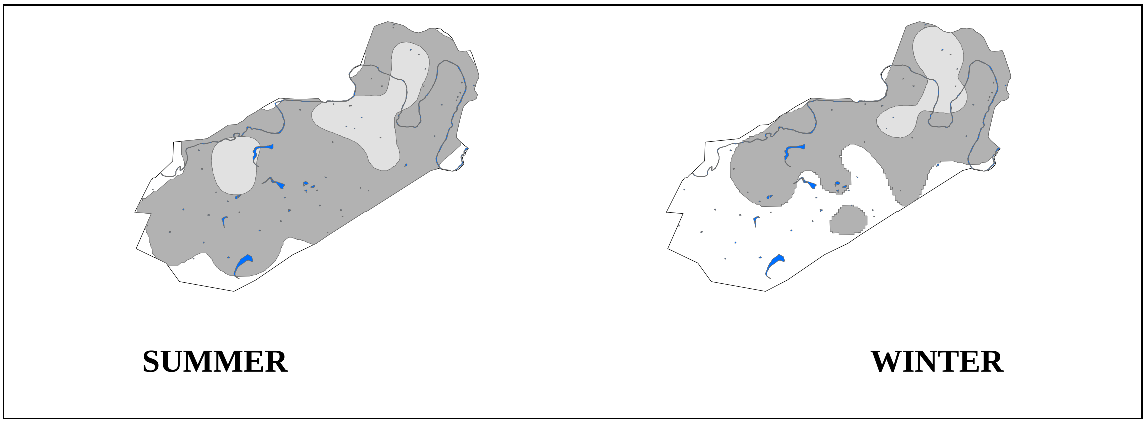


Figure 3.2: Home ranges (dark grey) and core areas (light grey) of ELH 6 on Kwandwe for summer (n=187) and winter (n=151). Rivers and dams are shown. Arcview 3.2, map units: meters, projection: Albers Equal-Area Conic, WGS84 and ARCMAP 9, map units=decimal degrees, not projected.

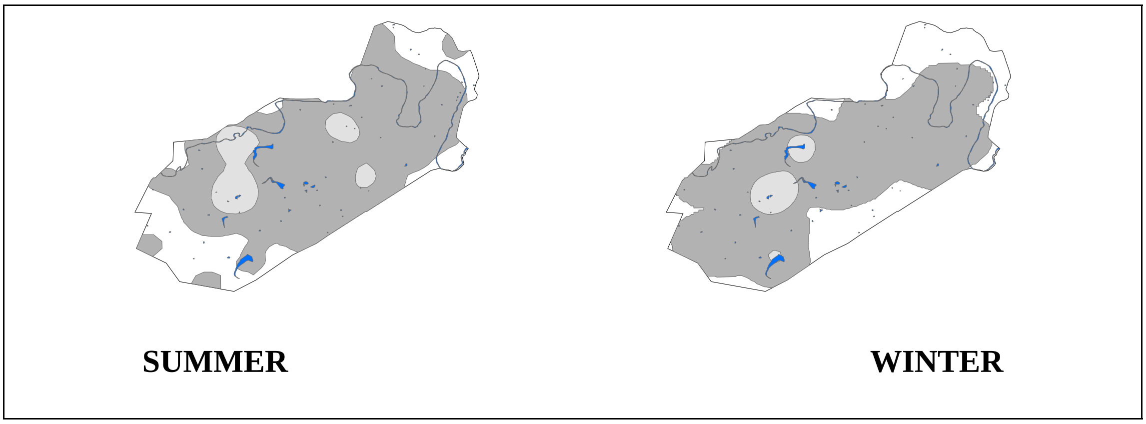


Figure 3.3: Home ranges (dark grey) and core areas (light grey) of ELM 1 Kwandwe for summer (n=109) and winter (n=112). Rivers and dams are shown. Arcview 3.2, map units: meters, projection: Albers Equal-Area Conic, WGS84 and ARCMAP 9, map units=decimal degrees, not projected.

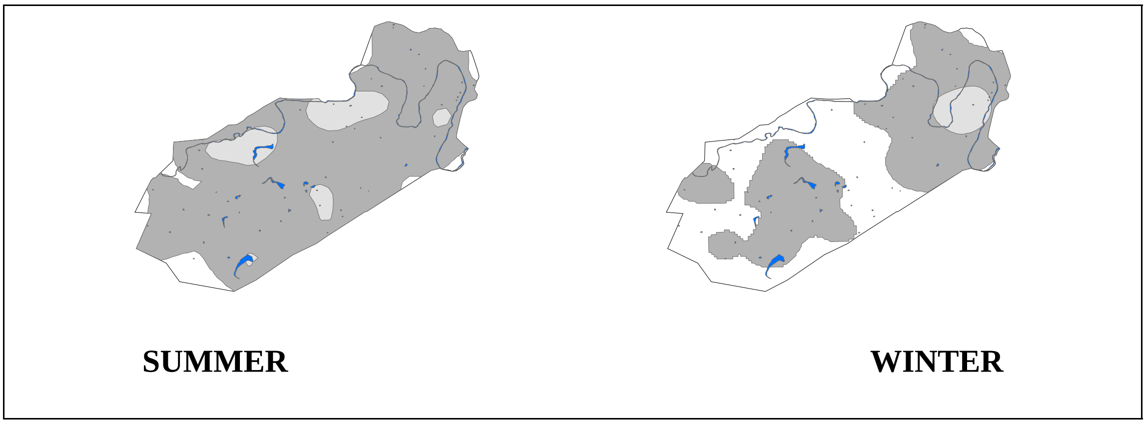


Figure 3.4: Home ranges (dark grey) and core areas (light grey) of ELM 2 Kwandwe for summer (n=121) and winter (n=137). Rivers and dams are shown. Arcview 3.2, map units: meters, projection: Albers Equal-Area Conic, WGS84 and ARCMAP 9, map units=decimal degrees, not projected.

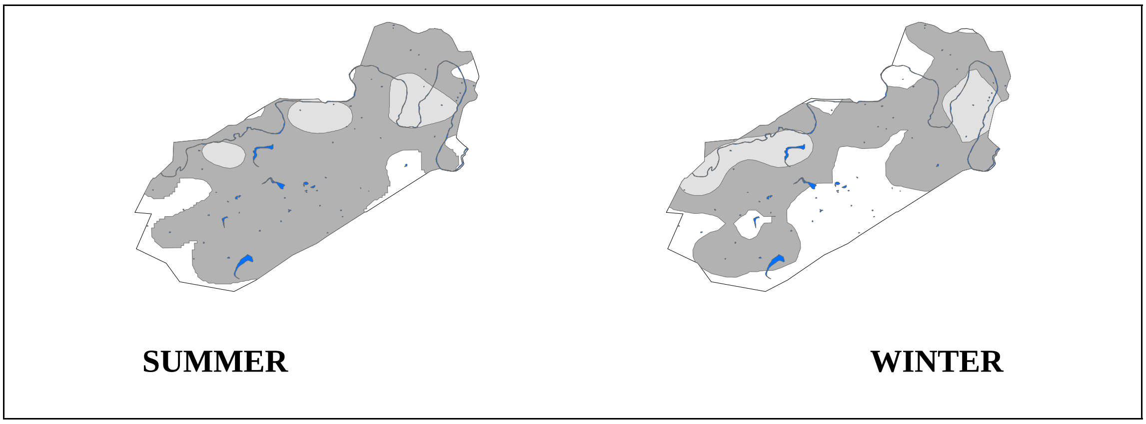


Figure 3.5: Home ranges (dark grey) and core areas (light grey) of ELM 3 Kwandwe for summer (n=92) and winter (n=154). Rivers and dams are shown. Arcview 3.2, map units: meters, projection: Albers Equal-Area Conic, WGS84 and ARCMAP 9, map units=decimal degrees, not projected.

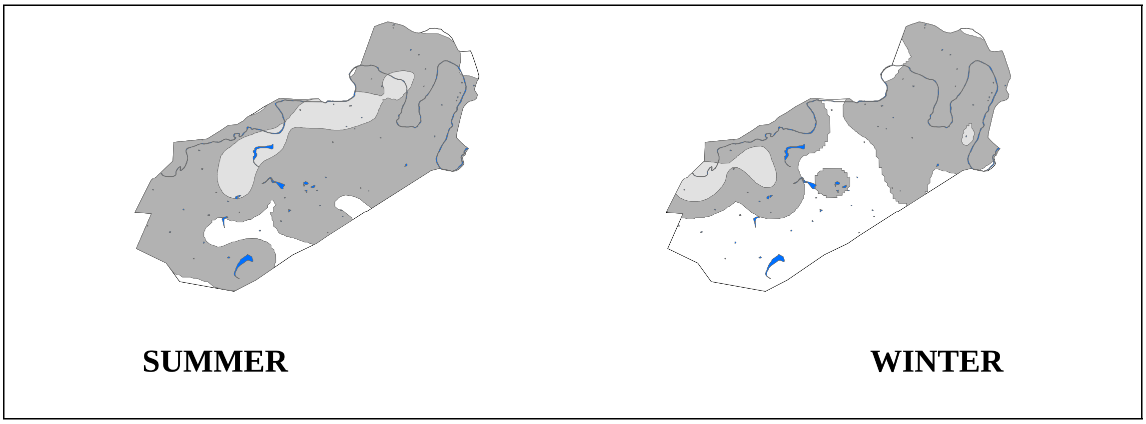


Figure 3.6: Home ranges (dark grey) and core areas (light grey) of ELM 4 Kwandwe for summer (n=68) and winter (n=76). Rivers and dams are shown. Arcview 3.2, map units: meters, projection: Albers Equal-Area Conic, WGS84 and ARCMAP 9, map units=decimal degrees, not projected.

(b) Shamwari

The data for home range size for the elephants in Shamwari were not sufficient to allow statistical analyses. However, in summer the home range of the herd was of a similar size to those of the herds on Kwandwe, and home range area decreased slightly in winter (Table 3.1). On Shamwari, the herd utilised 92 % of the reserve during summer and 83 % during winter. The home range of the bulls (both seasons combined) was very similar in size to that of the bulls on Kwandwe in summer but greater than the area used in winter (Table 3.1). On Shamwari, the home range of the bulls represented 76 % of the reserve. The core area of the herd was smaller in winter (17 km^2) than summer (27 km^2; Table 3.1). The herd was closer to drainage lines during summer (431 m) compared to winter (1022 m) and compared to males (1269 m; Table 4.1). The herd and the males' core areas were centred around the Bushmans River in the south-west of the reserve during summer and winter (Figure 3.7).

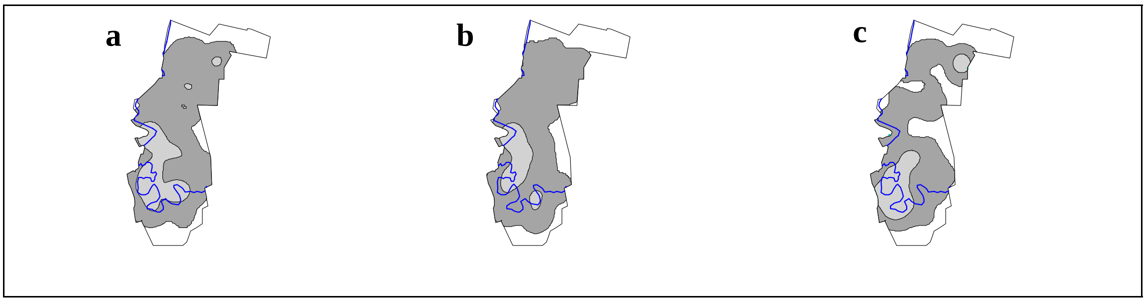


Figure 3.7: Home ranges (dark grey) and core areas (light grey) for the herd in (a) summer (n=429) and (b) winter (n=310) and (c) for the males (n=114) on Shamwari. Rivers are shown. (Arcview 3.2, map units: meters, projection: Albers Equal-Area Conic, WGS84).

3.3.2 Habitat Use

Results presented below reflect either a preference or avoidance for certain vegetation types. Vegetation types not mentioned in the text were utilised according to their abundance on the reserve. Results for all vegetation types are presented in the appendices.

(a) Kwandwe (see Appendix B for full results of the analysis of habitat preferences)

The home ranges of the herds included all ten vegetation types for summer and winter, with predominant vegetation types being euphorbia portulacaria mosaic (27 % summer, 21 % winter; data are means for the two herds), short euphorbia thicket (23 % summer, 26 % winter) and karroid shrubland (17 % summer, 15 % winter; see appendix A1.1 - A1.4 for proportions for all vegetation types). There was a significant difference between observed and expected use of vegetation types for the herds and karroid shrubland was strongly avoided by both herds during summer and winter. Bushclump karroid thicket was avoided by ELH 5 during summer and by ELH 6 during winter (Table 3.2). Both karroid shrubland and bushclump karroid thicket vegetation types are characterized by open grassland or shrubland interspersed with bushclumps or single stands of plant species. Only medium portulacaria thicket was strongly preferred by ELH 5, and only during summer (Table 3.2). However, medium portulacaria thicket comprised only 7 % of the home range in summer and 5 % in winter (appendix A1.1). The two predominant vegetation types (euphorbia portulacaria mosaic and short euphorbia thicket) which comprised almost 50% of the home ranges were used as expected. The core area of ELH 5 included 8 vegetation types in summer and all in winter and was predominantly euphorbia portulacaria mosaic (32 % summer, 30 % winter) and karroid shrubland (19 % summer) and short euphorbia thicket (28 % winter). Bushclump savanna and tall euphorbia thicket were not included in the summer core area. The core area of ELH 6 included all ten vegetation types in summer and winter and was predominantly euphorbia portulacaria mosaic (34 % summer, 26 % winter) and short euphorbia thicket (34 % summer, 24 % winter). As in the 95 % UD, karroid shrubland was strongly avoided by both herds in summer and winter, and bushclump karroid thicket was avoided by ELH 6 during winter (Table 3.2). Neither herd showed a preference for a vegetation type within their core areas. The general trend for the two herds on Kwandwe was to include a large amount of subtropical thicket type vegetation (euphorbia portulacaria mosaic and short euphorbia thicket) in both the home ranges and core areas, and in both seasons, and to use these vegetation types as expected. The next most common vegetation type in the both home ranges and core areas was karroid shrubland, a more open vegetation type, but this was used less than expected.

The home ranges of the males included all ten vegetation types for summer and winter and the predominant vegetation types for all four males were euphorbia portulacaria (44 % summer, 34 % winter; data are means for the four males), short euphorbia thicket (17 % summer, 20 % winter) and karroid shrubland (11 % summer, 25 % winter; see appendix A1.5 - A1.12 for proportion for all vegetation types). There was a significant difference between observed and expected use of habitats. Euphorbia portulacaria mosaic, which formed the greatest proportion of the home ranges of all males, was strongly avoided by ELM 1, ELM 2 and ELM 3 in one or both seasons (Table 3.3). Short euphorbia thicket was strongly preferred by ELM 1 in summer and ELM 2 in winter, and tall euphorbia thicket was strongly avoided by ELM 3 (Table 3.3). Karroid shrubland was selected for by ELM 1 in winter and avoided by ELM 2 during winter, while bushclump karroid thicket was preferred by ELM 2, 3 and 4 during winter (Table 3.3). Old lands were strongly selected for by ELM 1 during summer and winter and by ELM 3 in winter (Table 3.2). The preferred vegetation types range from relatively open (short euphorbia thicket, bushclump karroid thicket, karroid shrubland) to completely open (old lands). The individual core areas of the males included 9 vegetation types during summer with no males using bushclump savanna, while in winter, the core areas of ELM 1, 2 and 4 included 7 vegetation types and the core area of ELM 3 included 8 vegetation types. In winter, none of the core areas incorporated bushclump savanna or tall euphorbia thicket, two males did not use drainage line thicket and for a third, there was no old lands in the core area (Table 3.3; see appendix A1.5 – A1.12). The core areas were predominantly euphorbia portulacaria mosaic (33 % summer, 34 % winter), short euphorbia thicket (30 % summer, 13 % winter) and karroid shrubland (17 % summer, 26 % winter). There was a significant difference between the observed and expected use of the vegetation types for the males in their core areas. Euphorbia portulacaria mosaic was strongly avoided by ELM 1 during summer and winter and by ELM 3 and 4 in winter, while bushclump karroid thicket was strongly preferred by ELM 1 and 3 during winter. ELM 2 preferred short euphorbia thicket during summer and avoided karroid shrubland during summer and riverine thicket during winter. ELM 4 avoided short euphorbia thicket in winter. Although it is difficult to generalise, male elephants incorporated large amounts of short euphorbia thicket, euphorbia portulacaria mosaic and karroid shrubland in both their home ranges and core areas. In most cases, euphorbia portulacaria mosaic was avoided in the home range and less often in the core area but because it comprised a large proportion of most home ranges and core areas, elephants were regularly recorded in it (see appendix A). Bushclump karroid thicket, which comprised a small but variable proportion of the home ranges and core areas, was often preferred and between 10 and 20 % of sightings were in this vegetation type. Short euphorbia thicket, which formed a large proportion of the home ranges and core areas, was often preferred and this combination resulted in a high percentage of all observations of elephants being in this vegetation type (appendix A).

(b) Shamwari (see Appendix B for full results of the analysis of habitat preferences)

The home range of the herd included 11 of the 13 vegetation types in summer and nine in winter, and was predominantly subtropical thicket (53 % in summer, 68 % in winter; see appendix B for proportions for all vegetation types). Grassy fynbos and calcrete fynbos, two very small vegetation types on Shamwari, were not included in the summer or winter home ranges. Afromontane forest (<1 % of the summer home range) and open grassland (5 % of the summer home range), were not in the winter home range. There was a significant difference between observed and expected use of vegetation types for the herd during summer and winter. Although subtropical thicket comprised more than 50 % of the home ranges it was avoided (used less than available) in summer and winter, as were bontveld and montane grassland. Open grassland was avoided during summer (Table 3.3). The herd showed a selective preference for primary acacia thicket and secondary acacia thicket in summer and winter and, in addition, for riverine thicket during summer and cultivated land during winter (Table 3.3). Cultivated land is an open vegetation type, while primary and secondary acacia thickets are relatively open vegetation types dominated by *Acacia karroo* and riverine thicket is a more dense vegetation type in which *A. karroo* and *Rhus* spp. are common trees. The core area of the herd included 6 vegetation types during summer and 7 during winter and subtropical thicket was the predominant vegetation type (68 % in summer, 71 % in winter). Subtropical thicket, however, was avoided during winter and summer, while cultivated lands were avoided during summer (Table 3.3). A selective preference was shown for primary and secondary acacia thicket during summer and winter, as was seen in the 95 % UD and for riverine thicket in summer (Table 3.3). The general trend for the herd at Shamwari was to incorporate a large amount of subtropical thicket into the home range and the core area but to use less of this than was available. In spite of this avoidance, between 30 and 40 % of all observations of elephants were in subtropical thicket. The herd showed a preference for vegetation types in which *A. karroo* was a dominant species with between 20 and 60 % of all observations in primary acacia thicket, secondary acacia thicket and riverine thicket. Habitat use, as seasonal space use by the males on Shamwari was not analysed because the limited number of sightings would not allow for an analysis of seasonal changes.

Table 3.2: Summary of habitat preferences and χ^2 results for the herds on Kwandwe. Full results are presented in Appendix A.

UD	S	BKT	BS	DLT	EPM	KS	MPT	OL	RT	SET	TET	$\chi^{2\dagger}$
ELH5 50%	**S**		/			-					/	19.9
	W					-						31.1
95%	**S**	-				-	+					58.7
	W					-						63.2
ELH6 50%	**S**					-						40.6
	W	-				-						47.9
95%	**S**					-						88.6
	W	-				-						87.3
ELM1 50%	**S**		/		-							144.0
	W	+	/	/	-						/	351.7
95%	**S**				-			+		+		243.2
	W				-	+		+		-		202.4
ELM2 50%	**S**		/			-				+		73.8
	W		/	/					-		/	38.2
95%	**S**				-							87.0
	W	+			-	-				+		343.3
ELM3 50%	**S**		/									40.0
	W	+	/		-						/	96.6
95%	**S**				-							68.0
	W	+			-	-		+			-	183.2
ELM4 50%	**S**		/									19.1
	W		/		-			/		-	/	53.7
95%	**S**											32.2
	W	+				-						52.8

Areas left blank are when a vegetation type was used according to its abundance on the reserve; + = preference, - = avoidance, / = vegetation type not in the area. S= season; S=summer, W=winter. Vegetation types are described in Chapter 2; BKT: bushclump karroid thicket; BS: bushclump savanna; DLT: drainage line thicket; EPM: euphorbia portulacaria mosaic; KS: karroid shrubland; MPT: medium portulacaria thicket; OL: old lands; RT; riverine thicket; SET: short euphorbia thicket; TET: tall euphorbia thicket. $^{\dagger}p<0.05$.

Table 3.3: Summary of habitat preferences and χ^2 results for the herd on Shamwari. Full results are presented in Appendix B.

UD	S	AF	B	BS	CL	CUL	MG	OG	PAT	RT	SAT	ST	$\chi^{2\dagger}$
50%	**S**	/	/	/	/	-		/	+	+	+	-	297.5
	W	/	/	/				/	+		+	-	262.4
95%	**S**		-				-	-	+	+	+	-	277.6
	W	/	-			+	-	/	+		+	-	182.1

Areas left blank are when a vegetation type was used according to its abundance on the reserve; + = preference, - = avoidance, / vegetation type not in the area. S= season; S=summer, W=winter. Vegetation types are described in Chapter 2; AF: afromontane forest; B: bontveld; BS: bushclump savanna; CL: cleared land; CUL: cultivated land; MG: montane grassland; OG: open grassland; PAT: primary acacia thicket; RT: rivrine thicket; SAT: secondary acacia thicket; ST: subtropical thicket. † $p<0.05$.

3.4 DISCUSSION

3.4.1 Home range size

Home range of herds and bulls on Kwandwe and Shamwari were of similar sizes and occupied the majority of the two reserves, suggesting that their space use was affected by the size of the reserves. There is now a substantial data set for elephant home range sizes in reserves and parks of different sizes in Africa (Table 3.4) and an analysis of these data indicate the extent to which reserve size affects home range size. For all data, there is a weak and not statistically significant positive correlation between home range (95 % MCP) and reserve size (Figure 3.8a). However, Figure 3.8a suggests that within the whole data set there may be two relationships, one where home range size increases with increasing reserve size up to a reserve size of about 20 000 km^2 and a second relationship for reserves above this size where there is either no relationship or a negative relationship. Separate analysis for smaller (<1000 km^2) and larger (>10 000 km^2) reserves tends to support this although in both cases, relationships are weak and not statistically significant (Figures 3.8b & c).

Nevertheless, it seems likely that on Kwandwe and Shamwari, and possibly other small reserves, home range size is limited by the size of the reserve. Various factors other than available space will affect home range size and it is likely that the small home ranges of elephant in Addo Elephant National Park and Tembe National Elephant Park (Table 3.5) can be explained in terms of food quality and or quantity and access to water. For example, in the middle Zambezi Valley home range sizes are affected by food quality and distribution of surface water and home range sizes are smaller in areas with high food quality (94 km^2) compared to areas with low food quality (263 km^2 ; Dunham 1986). On Kwandwe home ranges of bulls and herds were significantly larger in the wet season (summer) than in the drier winter. Although sample sizes for Kwandwe were small (2 herds) and the statistical analyses lacked power, a reduction in home range sizes in winter has been reported in a number of other studies (Dunham 1986, Ottichilo 1986, Lindeque & Lindeque 1991, de Villiers & Kok 1997, Osborn 2003, Jackson & Erasmus 2005). The same trend was seen in the core areas and in the home ranges on Shamwari. Although there was no significant difference in the mean distance between elephants and drainage lines (stream beds) in summer and winter, the core areas were clearly centred around dams and the perennial Great Fish River. This further emphasises the important affect that water has on home range size and habitat selection (Leuthold 1977, Traill 2004). Although several previous studies have suggested that bull elephants have larger home ranges than herds (Jackson & Erasmus 2005, Kafue National Park, Etosha Nationa Park and Chobe National Park; Stokke & du Toit 2002, Chobe National Park) this was not the case in the present study and both home ranges and core areas of bulls and herds were of similar sizes. The results from Kwandwe and Shamwari may be an artefact of the small size of the reserve which limits the upper size of the home range of bulls and this is supported by results from Addo National Park which is smaller than Kwandwe and Shamwari and where bulls and herds have home ranges of similar sizes (Whitehouse & Schoeman 2003).

3.4.2 Habitat use and selection

Habitat use at the home range level must be interpreted with care because the home ranges occupied the majority of both reserves. So, for example on Kwandwe, short euphorbia thicket and euphorbia portulacaria mosaic comprised about 50 % of the home ranges of the herds and this could be interpreted as a strong selection for these vegetation types. However these two vegetation types comprise about 50 % of the whole reserve and their large contribution to the home range simply reflects the fact that the home range occupies most of the reserve. By contrast, the core areas were very much smaller and the positioning of the core areas within the reserves can be interpreted as a form of selection. Similarly, the way the elephants used the available space within the home ranges and core areas can also be interpreted as selection. Several pieces of evidence suggest that subtropical thicket vegetation (short euphorbia thicket, euphorbia portulacaria mosaic and medium portulacaria thicket) was important to the herds on Kwandwe. These vegetation types, due to their abundance on the reserve, comprised a large proportion of the home range and were used as expected. The only preference within the home range was for medium portulacaria thicket. The core areas, which were small enough to avoid all subtropical thicket, included more subtropical thicket than did the home ranges, suggesting that this vegetation type had been selected, and within the core areas, the herds used the vegetation as expected. The bulls behaved slightly differently, and while the home ranges and core areas included a high proportion of subtropical thicket vegetation, euphorbia portulacaria mosaic was often avoided but short euphorbia thicket was often preferred. Bushclump karroid thicket, which is not a subtropical thicket vegetation type and which is characteristic of the colluvial slopes and alluvial plains of the Great Fish River was preferred. Although short euphorbia thicket is a subtropical thicket vegetation, both it and bushclump karroid thicket are characterised by grass/herbs and groups of non-succulent trees. It has been suggested that bull elephants utilise different vegetation types compared to herds due to indirect competition with females (Clutton-Brock *et al*. 1987, Conradt *et al*. 1999). Stokke & du Toit (2002) contradicted these results for elephants and found that bull elephants are more tolerant of lower quality food and lower diversity habitats and are able to roam further from water than herds. Since elephants are essentially grazers, especially bull elephants (Owen-Smith 1992), they are often found in habitats that provide good grazing. The selection for bushclump karroid thicket which occurred in both the home range and core areas was seen in the dry season (winter) only and this probably reflects the movement of the animals towards the Great Fish River and longer grass, rather than a preference for bushclump karroid thicket.

On Shamwari, subtropical thicket was the predominant vegetation type both within the home range and the core area. As argued previously, the abundance in the home range simply reflects the abundance of this vegetation type in the whole reserve (subtropical thicket occupies 44 % of the reserve), but at the core area level, it may reflect a preference. However, the core area on Shamwari is centred around the Bushmans River and the vegetation types in the area include subtropical thicket, cultivated lands, primary acacia thicket, secondary acacia thicket and riverine thicket and thus what appears to be a selection for vegetation types might simply result from a requirement for water. Nevertheless, 30 - 40 % of all observations of the herd were in subtropical thicket, suggesting that, as in Kwandwe, subtropical thicket is an important vegetation type. In addition, the herd showed a preference for primary acacia thicket, secondary acacia thicket and riverine thicket in both seasons suggesting the trees in these vegetation types are being used, probably due to their nutritional quality.

Table 3.4: Home range sizes (95 % MCPs; km^2) for African elephants, showing reserve size (km^2) and sample size (n = number of fixes).

Locality	Home Range Size (km^2)	Reserve Size (km^2)	n	Reference
Addo Elephant National Park	54	103	100	Whitehouse & Schoeman 2003
Shamwari PGR*	111±7.1	155	406	This study
Kwandwe PGR	112±9.3	160	247	This study
Tembe National Elephant Park	72	300	137	Jackson & Erasmus 2005
Sengwa Wildlife Research Area	323	390	668	Osborn 2003
Pilanesburg National Park	24 - 139	500	2016	Slotow & van Dyk 2004
Klaseri Private Nature Reserve	183	840	76	De Villiers & Kok 1997
Timbavati Private Nature Reserve	414	880	103	De Villiers & Kok 1997
Vwaza Marsh Game Reserve	326	986	285	Jackson & Erasmus 2005
Maputo Elephant Reserve	291	1040	368	Jackson & Erasmus 2005
Kasunga National Park	273	2070	267	Jackson & Erasmus 2005
Nyika National Park	470	3000	153	Jackson & Erasmus 2005
North Luangwa National Park	175	4636	261	Jackson & Erasmus 2005
South Luangwa National Park	219	9050	208	Jackson & Erasmus 2005
Tsavo National Park	1235	20 000	21	Leuthold 1977
Kruger National Park	1407	20 000	279	Jackson & Erasmus 2005
Kafue National Park	956.3	22 400	2151	Jackson & Erasmus 2005
Etosha National Park	2179	23 175	1448	Jackson & Erasmus 2005
Northern Botswana	1406	80 000	210	Verlinden & Gavor 1998
Limpopo National Park	598	90 938	1141	Jackson & Erasmus 2005

* PGR = Private Game Reserve

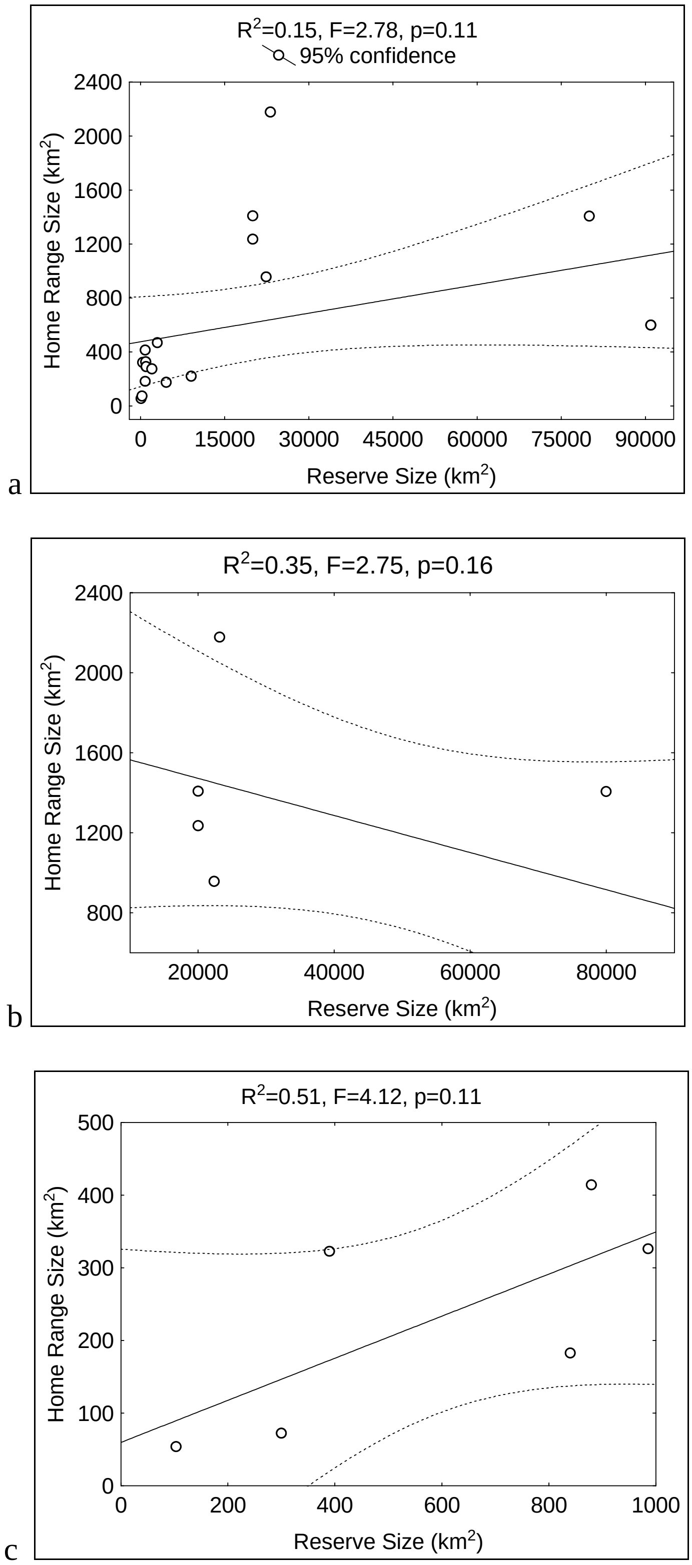


Figure 3.8: Results of the linear regression (STATISTICA 7) showing the relationship between reserve size and home range size for elephant populations across Africa; (a) all reserves in Table3.2 and (b) reserves >10 000 km^2 and (c) reserves <1000 km^2.

CHAPTER 4

DIETARY PREFERENCES OF ELEPHANTS IN TWO GAME RESERVES IN THE EASTERN CAPE PROVINCE

4.1 INTRODUCTION

The assessment of the diets of herbivores is an important step towards understanding the trophic relationships within ecosystems and may provide insight into the influences herbivores have in an ecosystem (Bookhout 1996). Diet studies can also provide the initial step towards understanding the resource and habitat requirements of a species before any management efforts are initiated (Bookhout 1996). This may be particularly important where elephants have been re-introduced to small reserves and where the effect of elephants on the vegetation might be exaggerated.

In general, herbivores select the best quality food to satisfy their metabolic requirements. This selection is dependent on the plant availability, plant defences and chemical composition (Owen-Smith 1992) and, based on these factors, herbivores either select or avoid forage items (Engen & Stenseth 1984, Owen-Smith 1982). Foraging time increases with increasing body size (e.g. elephants ≈ 75 % of a 24-hour day) and can also be affected by decreasing browse density, resulting in the animal having to walk further distances between feeding stations (Owen-Smith 1982). Primarily, as a consequence of their very large size, elephants are essentially generalist feeders (Walker 1996, Stokke 1999, Sukumar 2003), exhibiting variation in the proportions of grass and browse in their diet. They do however show a surprising degree of choice in their diet both on a short-term and seasonal basis (Field & Ross 1976, De Boer *et al.* 2000, Sukumar 2003 and Osborn 2004), depending on the habitat type and structure (Owen-Smith 1992). The amount of grass in an elephant's diet varies both spatially (between sites) and temporally (between seasons), and grass is more important in the rainy season than the dry season (Wyatt & Eltringham 1974, Guy 1976a, Kabigumila 1993, Osborn 2004). The diet of elephants often include a wide range of monocotyledonous and dicotyledonous species with as many as 50 - 120 species being used (De Boer *et al*. 2000, Field & Ross 1976, Kabigumila 1993, Paley & Kerley 1998). In spite of their very high daily food requirements (300 kg per day for a bull elephant) they feed from both abundant food sources such as grasses and large trees but will also use small, rare shrubs and bulbs such as *Scilla nervosa* and *Bobartia orientalis* (*pers. obs.*). Although the use of rare plants may seem counter intuitive in terms of Optimal Foraging Theory, it has been reported in other studies (see Engen & Stenseth 1984) and has been included in modified forms of the Optimal Foraging Theory (Engen & Stenseth 1984). The most common genera of dicotyledonous plants found in the diet of elephants across their distributional range include *Acacia*, *Azima*, *Combretum*, *Cussonia*, *Euclea*, *Ozoroa*, *Ziziphus*, *Brachylaena*, *Aloe*, *Grewia*, *Gymnosporia*, *Pappea*, *Portulacaria*, *Rhus*, *Rhoicissus Scutia* and *Sideroxylon* (Field & Ross 1976, Viljoen 1989, Jachmann & Bell 1985, De Boer *et al.* 2000, MacGregor & O'Connor 2004, Wiseman *et al*. 2004, Milewski 2002). The limited studies conducted in the Eastern Cape Province have shown the following species to be common in the diet: *Portulacaria afra*, *Rhus* spp., *Euclea undulata*, *Lycium* spp., *Azima tetracantha*, *Protasparagus* spp. and *Schotia afra* (Paley and Kerley 1998), *Grewia* spp., *Solanum* spp., *Sideroxylon inerme*, *Scutia myrtina*, *Ficus* sp., *Cassine* sp. and *Acacia karroo* (Robertson 1995). All of these species are evergreen, except *A. karroo* and all except *Protosparagus* spp are trees or shrubs.

There are various direct and indirect methods to determine the diet of herbivores, each with their own advantages and disadvantages. Indirect methods include chemical analyses of diet quality, and faecal analyses. Chemical analyses include measurement of total digestible nutrients, crude protein and fibre of plants (Osborn 2004) and using stable isotopes to determine dietary preferences from hair or tooth enamel (Cerling *et al.* 2004). Faecal analyses can be conducted either by identifying epidermal fragments under a microscope using an epidermal reference collection (De Boer *et al*. 2000) or by visual identification of seeds and germination trials in the laboratory (Tchamba & Seme 1993, Robertson 1995). Faecal analyses can be advantageous in that samples are easy to collect, without adversely disturbing the sample animal and may be particularly suitable for species that occur in thick vegetation or that feed at night (Norbury & Sanson 1992, Bookhout 1996). However, disadvantages arise due to the differential digestion of certain plant species (Dearden *et al*. 1975, Westoby *et al*.1976) and the lack of expertise for identifying seeds and epidermal fragments, thus creating either an under- or overestimate of certain plant species in the diet (Westoby *et al*. 1976, Parker 2005).

Direct methods include focal animal sampling by means of descriptive feeding observations (Rose 2000, Osborn 2004). Observations can be recorded continuously (continuous focal sampling) or at pre-determined intervals (focal interval sampling) (Rose 2000). Rose (2000) found that interval sampling was 25 % more time efficient because samples were easier to obtain in difficult conditions. The advantages of direct observations are that elephants are often easily approached in the study sites and one can observe the sample animal in its ‘natural’ environment, thus decreasing the chance of drawing false conclusions with regard to its diet (Parker 2005).

Disadvantages include difficulty with observation when the animals move into thick vegetation and identifying small plants from a distance.

In view of the paucity of studies of diet in subtropical thicket, the important status of this vegetation type in the Eastern Cape Province and the re-introduction of elephants to the region, the aim of this chapter is to present some additional base-line data on the diet of elephants in subtropical thicket. In addition, this information forms an important basis for the study of the impact of elephants in subtropical thicket presented in Chapter 5. The specific aims of the chapter are to describe the diet of elephants in two reserves in the Eastern Cape Province and, using data on food availability in the reserves, to establish the degree of selectivity shown by the elephants. The chapter also explores seasonal changes in diet and compares the diet of elephants in Africa to those re-introduced to small game reserves in the Eastern Cape Province.

4.2 MATERIALS AND METHODS

4.2.1 Data collection

(a) Direct observations of diet

Direct observation was selected over an indirect method for several reasons. Previous experience with faecal analysis in subtropical thicket has indicated that a high percentage of fragments remain unidentified (Parker *et al*. 2003). Direct observations, although often difficult in the subtropical thicket, yield not only information about the diet but also information about how the elephants damage the vegetation. It was also hoped that direct observations would allow sex differences in diet to be studied, something that faecal analysis would not have allowed.

Opportunistic observations of elephant feeding were conducted using the focal interval sampling method, whereby a focal group or individual was selected at random and monitored every five minutes over a period of one hour (Rose 2000). Because the movement of the elephants was not predictable, it was not possible to pre-select the vegetation type in which observations would be made and thus recording started whenever an elephant or herd was seen. In the case of a herd, the first individual that was seen feeding at the start of every 5 min scan was recorded (Hiscocks 1999). The individual or herd was then followed for as long as possible but no longer than one hour, and a maximum of 13 feeding records (one every five minutes for an hour) were made. A feeding record was defined as an instance in which any part of a plant species was consumed by one animal. These observations were made in the morning (08:00 am to 12:00 pm) and in the afternoon (14:00 pm to 18:00 pm) on separate days, once a week or twice a month until five hours of observations per reserve per season had been made. Observations were made on both reserves in summer and winter. Elephants were located and observed from a vehicle using binoculars. It was generally possible to identify the species being eaten, however, at longer distances (>100 m) or in thick bush, it was often necessary to follow up with direct examination of the vegetation. A GARMIN 72 GPS was used to note the location at the start of each sampling period and the following data were recorded: time of day, number of elephants and plant species eaten. Any species that could not be identified in the field were pressed and taken to the Selmar Schönland Herbarium in Grahamstown for identification. Herbs or succulent species less than 0.5 m high were classified as 'ground cover'. Grass species were not identified, due to the difficulty of identification from long distances and the impossibility of determining which grass species was selected upon later examination of the vegetation, and thus collectively recorded as 'grass'. The feeding records for each species consumed on separate days were totalled for morning and afternoon and expressed as a percentage of the total feeding records for that season and time (= frequency of occurrence). Although it was originally planned that observations of diet would be made in different vegetation types, and that it would be possible to compare diet in different vegetation types, the unpredictable movement of the elephants made this impossible and observations of feeding are for the whole reserve.

(b) Vegetation characterization (calculation of food availability)

Vegetation analysis is a key component of Chapter 5, which looks at the affect of elephants on the vegetation, and the data generated for Chapter 5 have been used here to reflect the abundance of different plant species. To meet the aims of Chapter 5, the analysis of vegetation composition was done separately for two vegetation types (subtropical thicket and bushclump savanna). However, since feeding observations have been pooled and are at a whole reserve level, the vegetation composition data have also been pooled in this chapter to make the data comparable.

Strip transects (Eberhardt 1978, Coetzee *et al*. 1979, Wiseman *et al*. 2004) were used to investigate the composition of the vegetation in Kwandwe and Shamwari, in subtropical thicket and bushclump savanna and within the home ranges and core areas of the elephants. Since the transects were in the home ranges of the elephants, it is likely that the results reflect the availability of food to the elephants. Transects, 40 m long x 4 m wide, were randomly laid out using a 10m rope and each transect was divided into three plots of 4 x 10 m. Each plot was separated by 5 m to ensure that no plant specimens were assessed more than once (Figure 4.1). A digital photograph was taken of the vegetation type and a GPS fix was recorded at the start of each transect.

Transects in the same vegetation were at least 10 – 50 m apart. All plant specimens with their stems found within each plot were assessed and the following data were recorded; species, height, status (alive or dead) and level of impact. In addition, the percentage of grass cover in each 10 x 4 m plot was assessed qualitatively. A total of 20 transects were completed on each reserve. These data were then used to calculate mean density for each plant species per hectare.

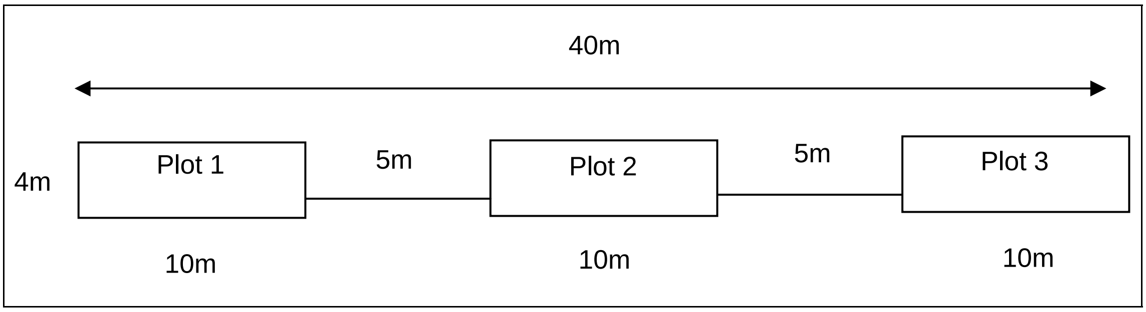


Figure 4.1: Diagram showing the design of the strip transect used to assess the vegetation on each reserve.

(c) Preference

Dietary preference by elephants was quantified using the use (number of feeding observations) and availability (number of tree species) data (see Chapter 3).

4.2.2 Data analyses

Frequency of occurrence data were analysed using PRIMER v5 (Primer-E Ltd; Plymouth Marine Laboratory). An ANOSIM was used to determine differences in frequency of occurrence of plants species in the diet between reserves, time of day and season. Preferences were calculated using the Chi-Square goodness-of-fit test and Bonferroni confidence intervals.

4.3 RESULTS

4.3.1 Direct observations

Direct observations of elephant feeding revealed that a total of 17 species from 12 families were eaten on Kwandwe and 23 species from 19 families were eaten on Shamwari. There was no significant effect of time of day or season on the frequency of occurrence values for the different species (Table 4.1) and the data were combined for each reserve. On Kwandwe, *Portulacaria afra* (18 %), *Pappea capensis* (18 %), *Acacia karroo* (15 %) and *Ozoroa mucronata* (13 %) were the four most important species eaten and 10 species had frequency of occurrence scores of less than 5% (Table 4.2). On Shamwari, *A. karroo* (36 %), *Rhus* spp. (11 %) and *Opuntia ficus-indica* (10 %) were the most important species and 13 species had frequency of occurrence scores less than 5 % (Table 4.2). There was a significant difference in the frequency of occurrence of plants in the diet of elephants on the two reserves (ANOSIM: PRIMERv5, $p<0.05$). Ten species were fed from on both reserves, the most important being *A. karroo* and *Azima tetracantha* (≈ 10 % on both reserves for *A. tetracantha*). Nine species were unique to the elephant diet on Shamwari, all with frequency of occurrences of less than 5 % and five species were unique to Kwandwe, the most important being *O. mucronata* (13 %; Figure 4.2). Grass constituted a significantly greater percentage of the diet in summer (22 %, Kwandwe, 27 % Shawmwari) than winter (17 % for both reserves; χ^2 4.84, df 1, $p<0.05$). Ground cover contributed less than 5 % to the diet on each reserve.

Table 4.1: ANOSIM results testing the effect of season and time of day, on each reserve, on the frequency of occurrence of woody plants in the diet.

	Kwandwe		**Shamwari**	
	Summer R	**Winter p**	**Summer R**	**Winter p**
Time of day	-0.026	0.597	0.125	0.051
Season	0.041	0.181	0.021	0.354

4.3.2 Vegetation characterization

In the two vegetation types sampled on each reserve; Kwandwe, with 16 plant species was slightly more diverse than Shamwari (13 species; Table 4.3). The vegetation on both Kwandwe (62 %) and Shamwari (52 %) was dominated by shrubs/bushes, while woody trees made up 38 % of the vegetation on Kwandwe and 48 % on Shamwari and succulent species made up 39 % on Kwandwe and 27 % on Shamwari (Table 4.3). On Kwandwe, *P. afra*, *Euphorbia bothae* and *Gymnosporia* spp. dominated the vegetation and comprised 53 % of all woody plants (Table 4.3). On Shamwari, *Aloe ferox*, *Gymnosporia* spp. and *Rhus* spp were the most abundant woody plants and comprised 49 % of all woody plants while *A. tetracantha*, *E. undulata*, *P. afra* and *Schotia afra* were common (Table 4.3).

Table 4.2: Frequency of occurrence of plant species (%) found in the diet of elephants on Kwandwe and Shamwari

Plant Species	**Kwandwe**	**Shamwari**
Pappea capensis	18	3
Portulacaria afra	18	1
Acacia karroo	15	36
Ozoroa mucronata	13	-
Azima tetracantha	8	9
Opuntia ficus-indica	5	10
Rhus spp.	4	11
Schotia afra	4	3
Crassula ovata	3	-
Lycium ferocissimum	3	-
Schinus molle	3	-
Euclea undulata	2	2
Gymnosporia spp.	1	6
Grewia spp.	1	1
Brachylaena spp.	1	-
Zygophyllum morgsana	-	4
Combretum caffrum	-	3
Aloe ferox	-	2
Olea europaea	-	2
Gardenia thunbergia	-	2
Cussonia spicata	-	2
Sideroxyon inerme	-	2
Rhoicissus tridentata	-	1
Scutia myrtina	-	1

Table 4.3: Botanical composition of the habitat types sampled on Kwandwe. Values are total number of trees per hectare. B/S/T = bush, shrub or tree; NS/S = non-succulent or succulent.

Plant species	**B/S/T**	**NS/S**	**Kwandwe (# trees/ha)**	**Shamwari (# trees/ha)**
Aloe ferox	T	S	56.3	312.5
Azima tetracantha	B	NS	215.6	234.4
Acacia karroo	T	NS	71.9	115.6
Brachylaena spp.	S	NS	53.1	-
Carrissa haematocarpa	S	NS	56.3	62.5
Crassula ovata	T	S	-	43.8
Euphorbia bothae	S	S	403.1	-
Euclea undulata	T	NS	159.4	175.0
Portulacaria afra	T	S	484.4	153.1
Grewia spp.	S	NS	140.6	31.3
Gymnosporia spp.	S	NS	403.1	337.5
Lycium ferocissimum	S	NS	84.4	-
Opuntia ficus-indica	T	S	21.9	28.1
Ozoroa mucronata	T	NS	31.2	-
Pappea capensis	T	NS	46.9	-
Rhus spp.	B	NS	140.6	337.5
Schotia afra	T	NS	59.4	140.6
Scutia myrtina	S	NS	-	40.6
Shrubs & bushes			**1496.8***	**1043.8***
Woody trees			**931.4***	**968.7***
Succulent species			**965.7***	**537.5***
Mean			**151.8**	**154.8**
Total			**2428.2**	**2012.5**

* Total numbers

4.3.3 Preference

On Kwandwe, elephants showed a selective preference for three of the four most important species in the diet. The strongest preference was for *O. mucronata*, while *Pappea capensis* and *A. karroo* were the 2nd and 3rd most preferred species respectively (Table 4.4). Although *P. afra* was the most utilized species, based on observations, it was the most available plant on the reserve and its use was substantially lower than availability ($p<0.05$). *Euclea undulata, Gymnosporia* spp. and *Grewia* spp. were strongly avoided (Table 4.4) and all comprised a small percentage of the feeding observations (Figure 4.2). On Shamwari, elephants showed a strong preference for one of the three most important species in the diet; namely *A. karroo* and *Rhus* spp, which were also important in the diet were used less than available but this difference was not significant ($p>0.05$). *S. afra*, *P. afra*, *Gymnosporia* spp., *A. ferox* and *E. undulata* were avoided (Table 4.5).

Table 4.4: Plant species preference on Kwandwe. Use = number of feeding observations, available = total number of trees of that species in 20 transects (euphorbia portulacaria mosaic & bushclump karroid thicket combined). P = Preference; + (preference) and – (avoidance).

Plant species	Use	Available	Observed proportion	Expected proportion	Lower CI*	Upper CI*	P
AT	13	69	0.085	0.116	0.021	0.149	
EU	3	51	0.020	0.086	-0.012	0.052	-
R	6	45	0.039	0.076	-0.005	0.083	
GB	2	129	0.013	0.217	-0.013	0.039	-
AK	23	23	0.150	0.039	0.068	0.232	+
SA	6	19	0.039	0.032	-0.005	0.083	
PA	28	155	0.183	0.261	0.094	0.272	
OF-I	7	7	0.046	0.012	-0.002	0.094	
PC	28	15	0.183	0.025	0.094	0.272	+
OM	20	10	0.131	0.017	0.054	0.208	+
CO	5	0	0.033	0.000	0.000	0.000	
SM	4	0	0.026	0.000	0.000	0.000	
LF	5	27	0.033	0.045	-0.008	0.074	
G	2	45	0.013	0.076	-0.013	0.039	-
B	1	0	0.000	0.000	0.000	0.000	

* CI = Bonferroni confidence interval. AT: *Azima tetracantha*, EU: *Euclea undulata*, R: *Rhus* spp., GB: *Gymnosporia* spp., AK: *Acacia karroo*, SA: *Schotia afra*, PA: *Portulacaria afra*, OF-I: *Opuntia ficus-indica*, PC: *Pappea capensis*, OM: *Ozoroa mucronata*, CO: *Crassula ovata*, SM: *Schinus molle*, LF: *Lycium ferocissimum*, G: *Grewia* spp. and BI: *Brachylaena illicifolia*.

Table 4.5: Plant species preference on Shamwari. Use = number of feeding observations, available = total number of trees of that species in 10 transects (subtropical thicket & primary acacia thicket combined). P = Preference; + (preference) and – (avoidance).

Plant species	Use	Available	Observed proportion	Expected proportion	Lower CI*	Upper CI*	P
AK	44	37	0.358	0.064	0.240	0.476	+
RT	1	0	0.008	0.000			
GAR	2	0	0.016	0.000			
OF-I	12	0	0.098	0.000			
SA	4	45	0.033	0.078	-0.011	0.077	-
PA	1	49	0.008	0.085	-0.014	0.030	-
GB	7	108	0.057	0.187	0.000	0.114	-
PC	4	0	0.033	0.000			
AT	11	75	0.089	0.130			
SM	1	0	0.008	0.000			
R	14	108	0.114	0.187	0.036	0.192	
AF	3	100	0.024	0.173	-0.014	0.062	-
G	1	0	0.008	0.000			
ZM	5	0	0.041	0.000			
CC	4	0	0.033	0.000			
EU	2	56	0.016	0.097	-0.015	0.047	-
CS	2	0	0.016	0.000			
OE	3	0	0.024	0.000			
SI	2	0	0.016	0.000			

* CI = Bonferroni confidence interval. AK: *Acacia karroo*, RT: *Rhoicissus tridentata*, GAR: *Gardenia thunbergia*, OF-I: *Opuntia ficus-indica*, SA: *Schotia afra*, PA: *Portulacaria afra*, GB: *Gymnosporia* spp., PC: *Pappea capensis*, AT: *Azima tetracantha*, SM: *Scutia myrtina*, R: *Rhus* spp., AF: *Aloe ferox*, G: *Grewia* spp., ZM: *Zygophyllum morgsana*, CC: *Combretum caffrum*, EU: *Euclea undulata*, CS: *Cussonia spicata*, OE: *Olea europaea*, SI: *Sideroxylon inerme*.

4.4 DISCUSSION

It is recognised that the robustness of the results presented in this chapter is negatively affected by the relatively small sample sizes (5 hours of observations in each reserve per season). The results have therefore been interpreted with caution and will not be used for any management considerations.

Previous studies have indicated that elephants feed from a diverse array of plant species with as many as 50 - 120 different species being utilized (Pienaar *et al*. 1966, Guy 1976, Paley & Kerley 1998, De Boer *et al*. 2000). The numbers of species used on Kwandwe (17 species) and Shamwari (23 species) are substantially lower and likely to be underestimates, possibly as a result of the small sample size for observations. The difference could also be explained by the fact that the other studies have included not only woody plants but also herbs and forbs which were not individually identified in this study. It should be noted that the vegetation surveys on Kwandwe and Shamwari did not document very high species diversity and thus while the diet list may not be complete; it is unlikely that there are many species of woody plant missing. The failure to detect a seasonal change in use of woody plants (not grass) is unexpected and could also be a result of the low sample size. Bax & Warden 1963 found that during the wet season, elephants in Tsavo National Park fed on the bark from four species (*Acacia tortilis*, *Delonix elata*, *Sterculia africana* and *S. rhynchocarpa*) and the leaves of two species (*Abutilon mauritianum* and *Delonix elata*); while in the dry season, bark from the Baobab and *Commiphora* spp. and leaves from *Cordia gharaf* and *Grewia bicolour* were fed upon. De Boer *et al*. 2000 noted a shift in diet from a high percentage of *Acacia* spp. in the wet season to a high percentage of *Rhus* spp. in the dry season; among other woody plant species. In addition, *Aloe bainsii*, *Brachylaena discolour*, *Commiphora neglecta* and *Scutia myrtina* were neglected during the dry season (De Boer *et al*. 2000).

Based on feeding observations, there was a significant difference in important food species between Shamwari and Kwandwe. On Shamwari, two trees that are not typical components of subtropical thicket (*Acacia karroo* and *Rhus* spp.) had the highest frequency of occurrence values, while on Kwandwe, two plants (*P. afra* and *Pappea capensis*), which are important components of subtropical thicket, were important in the diet. It is likely that these differences simply reflect differences in the vegetation of the regions used by the elephants on the two reserves. On Shamwari, the core area of the elephants was around the Bushmans river in a region characterized by primary and secondary acacia thicket (see Chapter 3). By contrast, on Kwandwe the home range and core areas were characterized by subtropical thicket (≈ 50 %). Previous studies of elephant diet in subtropical thicket of the Eastern Cape Province have also identified *P. afra* and *Pappea capensis* as important species (Penzhorn *et al*. 1974, Paley & Kerley 1998). In addition, these studies identified *Rhus* spp., *E. undulata* and *A. tetracantha* as being important food species in the Addo Elephant National Park. Of these, only *A. tetracantha* was an important component of the diet on Kwandwe while *E. undulata* and *Rhus* spp. were used less than available on both reserves. The similarities and differences between the diet of elephants in different reserves in the Eastern Cape Province is not surprising and probably reflects the fact that while the reserves have some vegetation types in common, they also differ in species composition (see Chapter 2). Many previous studies have highlighted a seasonal change in the importance of grass from the wet season to the dry season (Wyatt & Eltringham, Williamson 1975 and Osborn 2004). In most systems grass is more important in the wet season (when it is more available) than during the dry season, however, the level of importance varies between regions (Table 4.6). In Kidepo Valley National Park, Kenya (Field & Ross 1976) and Ngorongoro Crater, Tanzania (Kabigumila 1993), grass is more important than browse in the wet season and this is reversed in the dry season. By contrast, in Maputo Elephant Reserve, browse is more important than grass in both wet and dry seasons (De Boer *et al*. 2000; Table 4.6). Grass is lower in toxins and fibre, but high in nutrients in the wet season and is also easier to harvest and handle (Osborn 2004). However, in the dry season, when grasses die off, browse, which generally has higher levels and diversity of nutrients, becomes important (Osborn 2004). Williamson (1975) suggested that where grass is highly seasonal, browse makes up the majority of the diet of elephants in southern Africa.

Table 4.6: The proportions of grass and browse in an elephants diet across Africa (MER: Maputo Elephant Reserve, Mozambique; KVNP: Kidepo Valley National Park, Kenya (other = herbs); NC: Ngorongoro Crater, Tanzania (other = forbs and sedges). Values are percentages.

Location	**Wet season**			**Dry season**		
	Grass	**Browse**	**Other**	**Grass**	**Browse**	**Other**
MER[1]	32.0	58.0	10.0	14.0	55.7	30.3
KVNP[2]	57.2	20.8	22.0	28.6	58.6	12.8
NC[3]	24.3	14.8	60.9	9.0	44.9	46.1

[1] De Boer *et al*. (2000); [2] Field & Ross (1976); [3] Kabigumila (1993)

While a study of elephant feeding, either using direct or indirect methods, provides information about the frequency with which certain species are used, it does not identify which, if any of the species are selected. A comparison of the use of a species with its availability will provide a measure of preference or avoidance but preference values have to be interpreted with care. Artificially high preference values can be generated if a plant species is undercounted, or misidentified in the vegetation survey (which is unlikely for a large tree), or if it is rare and if elephants spend a long time feeding from the species. Avoidance can result if a plant species is common and easily counted (i.e. not overlooked) and if elephants spend a very short length of time feeding from it. In Kwandwe the elephants showed a strong preference for *O. mucronata*, *Pappea capensis* and *A. karroo.* These species are easily identified at a distance, should not be undercounted in vegetation surveys and the preferences are probably real. *E. undulata*, *Gymnosporia* spp and *Grewia* spp were avoided and, for the same reasons as above, it is likely that these avoidance values are real. On Shamwari, only *A. karroo* was preferred and since this is an easily identified, easily counted, common species it is likely that the preference is real. *Gymnosporia* spp, *E. undulata* and *S. afra* were avoided and it is likely that these species are genuinely avoided. The apparent avoidance of *P. afra* may be real but its low growth form could have resulted in feeding observations being missed. The strong avoidance of *A. ferox* is interesting because the assessment of damage in Chapter 5 suggests that this species is regularly used by elephants. Since *A. ferox* is a large, easily identified and easy to count species, it would not have been undercounted or over-counted (through misidentification) in the vegetation transects. The avoidance can only have resulted from a small number of observations of elephants feeding on *A. ferox*, as was the case, and it is likely that this resulted from elephants spending very little time at each plant. Other studies measuring preference have shown that elephants have a definite preference for certain woody plant species and an avoidance of others (see Viljoen 1989).

A combination of the analyses of diet (based on observation) and preference can be used to identify plant species that may be threatened by elephants. For example, on Kwandwe, *P. afra* and *Pappea capensis* had the same frequency of occurrence in the diet (18%) but *P. afra* was an order of magnitude more abundant in the transects. Thus, while both are important in the diet, *Pappea capensis* was significantly preferred while *P. afra* was used less than available, and it is far more likely that elephants will have a negative effect on *Pappea capensis* than on *P. afra*. In addition, the growth forms of the two species are quite different (see Chapter 5) and while *P. afra* may be resilient to browsing, *Pappea capensis* is less so. On Shamwari, more than 33% of all feeding observations were on *A. karroo* and the analysis of preference suggests that the species was significantly preferred. Although *A. karroo* is susceptible to elephant browsing (Anderson & Walker 1974, Campbell *et al*. 1996) it is unlikely that this is an immediate problem on Shamwari since *A. karroo* is a semi-invasive species that can form a mono-culture in disturbed habitats.

CHAPTER 5

THE IMPACT OF ELEPHANTS ON VEGETATION IN TWO GAME RESERVES IN THE EASTERN CAPE PROVINCE

5.1 INTRODUCTION

To satisfy their nutrient requirements, herbivores selectively forage from different parts of the landscape at different scales (Scholes 1997) and, together with climate and fire, affect the balance between woody and herbaceous vegetation in African savannas (Buechner & Dawkins 1961, Augustine & McNaughton 2004). Large herbivores in particular can have marked effects on vegetation composition. These effects range from the determination of both the species composition and the prevailing plant growth form of grasslands, to regulation of the balance between shrub and herbaceous layers in thicket communities (Pacala & Crawley 1992, Rambo & Faeth 1999, Richardson-Kageler 2004, Augustine & McNaughton 2004). Since much of conservation is based on maintaining ecological processes (Trollope *et al*. 1998, Jacobs & Biggs 2002b, Grassman *et al*. 2005), the nature of the interaction between herbivores and vegetation must be fully understood.

Elephants are classified as megaherbivores (>1000 kg) (Owen-Smith 1992), with their daily food consumption amounting to approximately 150 kg for an adult cow and about 300 kg for an adult bull (Laws 1970, Estes 1990, Cowling & Kerley 2002). In addition they may be destructive and wasteful foragers (Cowling & Kerley 2002) and can have a profound effect on the surrounding floral and faunal communities (Owen-Smith 1992, Trollope *et al*. 1998, Bezuidenhout 2004). High densities of elephants (>0.5/km^2) can result in an irreversible change to habitats (Tchamba 1995, Trollope *et al.* 1998) and this effect is exaggerated when elephants are confined to small areas

(<300 km^2) (Wiseman *et al.* 2004). Although the home ranges of elephants vary in size, even in small reserves they are typically large (116 km^2 females; 78km^2 males; De Villiers & Kok 1997 and 55 km^2 females; 53km^2 males; Whitehouse & Schoeman 2003 and see chapter 3) and the restriction of movement concentrates their feeding and exaggerates their effect on the environment (Ben-Shahar 1993, MacGregor & O'Connor 2004, Wiseman *et al*. 2004). This has become a primary concern with the development of small game reserves, since there is little focussed research on the impact of elephant in these small areas (Novellie *et al*. 1991, MacGregor & O'Connor 2004).

An analysis of studies on the feeding ecology of elephants suggests that their effect on the vegetation is variable, from causing detrimental changes in woody species composition to promoting growth of other species, thereby increasing woody species diversity (Pamo & Tchamba 2001, Mapaure & Campbell 2002, Wiseman *et al*. 2004). Penzhorn *et al*. (1974; Addo Elephant National Park) and Croze (1974; Serengeti National Park) found that elephant foraging resulted in the reduction of plant biomass and abundance. MacGregor & O'Connor (2004) found similar results in the Venetia-Limpopo Nature Reserve, where the mortality rate of *Acacia* spp. increased by 16 % over 4 years. In Ithala game reserve, the density of 31 of the most abundant species decreased by 11 % in 8 years (Wiseman *et al*. 2004). However, Stuart-Hill (1992) contradicted these results by showing that the density of woody plants (*Portulacaria afra*, *Euclea undulata*, *Capparis sepiara* and *Schotia afra*) in the Addo Elephant National Park increased with elephant defoliation and attributed this to the fact that the removal of the canopy allows for coppicing to occur. Huntly (1991) suggested that elephant foraging can suppress the growth of palatable species, while promoting an increase in abundance of highly unpalatable species such as *Lycium oxycarpum* (*pers.*

obs., Stuart-Hill & Danckwerts 1988). However, plant responses to elephant foraging is dependant on the type of use, where certain species do not coppice after elephant utilisation (e.g. *Euphorbia tetragona*, *E. triangularis* and *Crassula ovata*) or are totally destroyed (*Cussonia spicata* and *Aloe* spp.); whilst other species (*Euclea* spp., *Colophospermum mopane* and *Portulacaria afra*) can withstand high levels of elephant damage (Steyn & Stalmans 2001, MacGregor & O'Connor 2004, Midgley *et al*. 2005). This will then result in the opposite occurring where palatable species which are tolerant of high levels of elephant damage will increase (Jachmann & Bell 1985). Huntly (1991) also suggested that elephant foraging can increase plant diversity by disproportionately damaging the more common species or decrease diversity by damaging rare species.

The Eastern Cape Province contains four major phytogeographical regions: Afromontane, Cape, Tongaland-Pondoland and Karoo-Namib (Kerley *et al.* 1995, Cowling & Hilton-Taylor 1997). Subtropical thicket makes up 25% of the area of the region (Kerley *et al*. 1995) and is recognised as an important centre of plant species endemism (Lubke *et al*. 1986). Due to the slow regeneration rate and low resilience, thicket communities are believed to be extremely vulnerable to large browsers (e.g. elephant, rhinoceros and kudu) and can be 'eliminated if browser disturbances occur at intervals of less than a few decades' (Spriggs 2001). However, Everard (1987) contradicted this and suggested that since most of the trees and shrubs produce bird-dispersed fruits, they are able to recolonize areas successfully and Stuart-Hill (1992) concluded that certain species in subtropical thicket are adapted to elephant utilization.

Most of the research investigating the impact of elephants on the vegetation comes from large, open systems greater than 5000 km^2 (MacGregor & O'Connor 2004, Wiseman *et al*. 2004). Smaller reserves restrict the movement of elephants and thus any effect could be magnified (Moolman & Cowling 1994). The limited research in small reserves and the resultant concern has led to the need for the initiation of long-term monitoring programs of elephants in these areas. This chapter aims to assess the impact of elephants and the extent thereof on two small game reserves ($<300\ km^2$) within two different vegetation types; namely subtropical thicket because of its importance in the Eastern Cape, and bushclump savanna, being a very different and more 'open' vegetation type that occurs frequently in the Province. The hypotheses that were tested were that (1) there will be a significant difference in damage to vegetation in core areas and home ranges and (2) damage in different vegetation types would be significantly different.

5.2 MATERIALS AND METHODS

5.2.1 Selection of sampling sites

Two similar vegetation types were selected on each reserve, one a thicket vegetation and the other a more open savanna vegetation. On Kwandwe, the vegetation types were euphorbia portulacaria mosaic (EPM; Figure 5.1) and bushclump karroid thicket (BKT; Figure 5.2) and on Shamwari, the vegetation types were subtropical thicket (ST; Figure 5.3) and primary acacia thicket (PAT; Figure 5.4). Twenty transects were completed in each vegetation type, 10 within the 50 % UD and 10 within the 95 % UD areas (calculated using the total elephant sightings from 2003 to 2005; see Chapter 3) to sample areas of 'high' and 'low' elephant densities.

Figure 5.1: Euphorbia portulacaria mosaic on Kwandwe with *Euphorbia bothae* in the foreground and *Portulacaria afra* in the background.

Figure 5.2: Bushclump karroid thicket on Kwandwe with scattered bushclumps of various *Rhus* spp., *Azima tetracantha* and *Gymnosporia buxifolia*. The ground cover includes the grass species *Setaria neglecta* and *Digitaria eriantha* and the shrub *Pentzia incana*.

Figure 5.3: Subtropical thicket on Shamwari with a mixture of succulent and woody shrubs and trees.

Figure 5.4: Primary acacia thicket on Shamwari with scattered bushclumps of various *Rhus* spp., *Azima tetracantha*, *Gymnosporia buxifolia*, *Acacia karroo* and occasionally single stands of *Aloe ferox*.

5.2.2 Vegetation assessment

Strip transects (adapted from Eberhardt 1978, Coetzee *et al*. 1979, Wiseman *et al*. 2004); 40 m long x 4 m wide, were randomly laid out using a 10 m rope. The transects (as described in Chapter 4) were divided into three plots of 4 x 10 m. Each plot was separated by 5 m to ensure that no plant specimens were assessed more than once. A digital photograph was taken of the vegetation type and a GPS fix was recorded at the start of each transect. Transects in the same vegetation were at least 10 – 50 m apart. All plant specimens with their stems found within each plot were assessed and the following data recorded; perpendicular distance from transect line, species, height, status (alive or dead) and level of impact. In addition, the percentage of grass cover in each 10 x 4 m plot was assessed qualitatively.

The level of impact to a plant was scored using six categories: (0) no damage; (1) very little use; (2) secondary branches broken; (3) more than one primary branch broken; (4) main stem broken, heavily browsed or bark-stripped and (5) whole tree uprooted (modified from Tchamba 1995 and Hiscocks 1999). Levels 1 and 2 cannot only be attributed to elephants, as many other herbivores browse on the same plant species and can cause minor damage. Levels 3 to 5 however can only be attributed to elephants.

5.2.3 Data Analyses

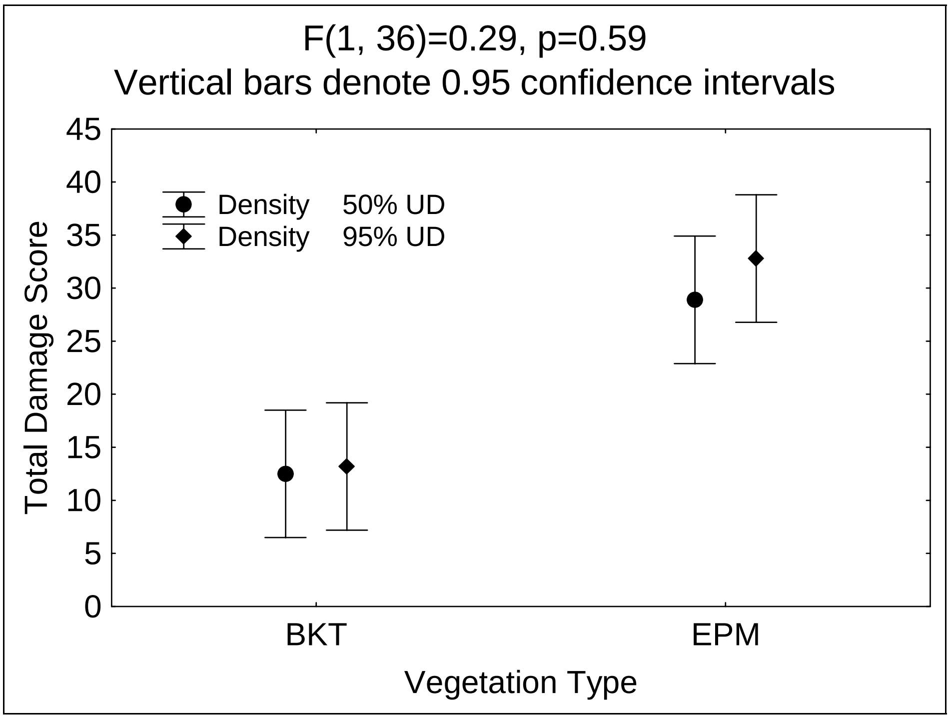
The total level of damage per species per transect was calculated using the following formula: Σ (# trees per damage category per species per transect x damage category). These data were then used to calculate the mean damage per species per transect by dividing the total damage per transect by the number of damaged trees of that species in that transect (level 0 excluded). The total damage per species per vegetation type and the overall total per vegetation type was then calculated. The data were tested for normality and two two-way ANOVA (STATISTICA 7) were used to determine whether vegetation type and elephant density areas (50 % and 95 % UDs) and plant species and elephant density areas had an effect on the levels of damage in each reserve. Average height of the most common species were calculated for the 50 % and 95 % UDs in each vegetation type and analyzed using a student's t-test to determine whether there was a significant difference between areas.

5.3 RESULTS

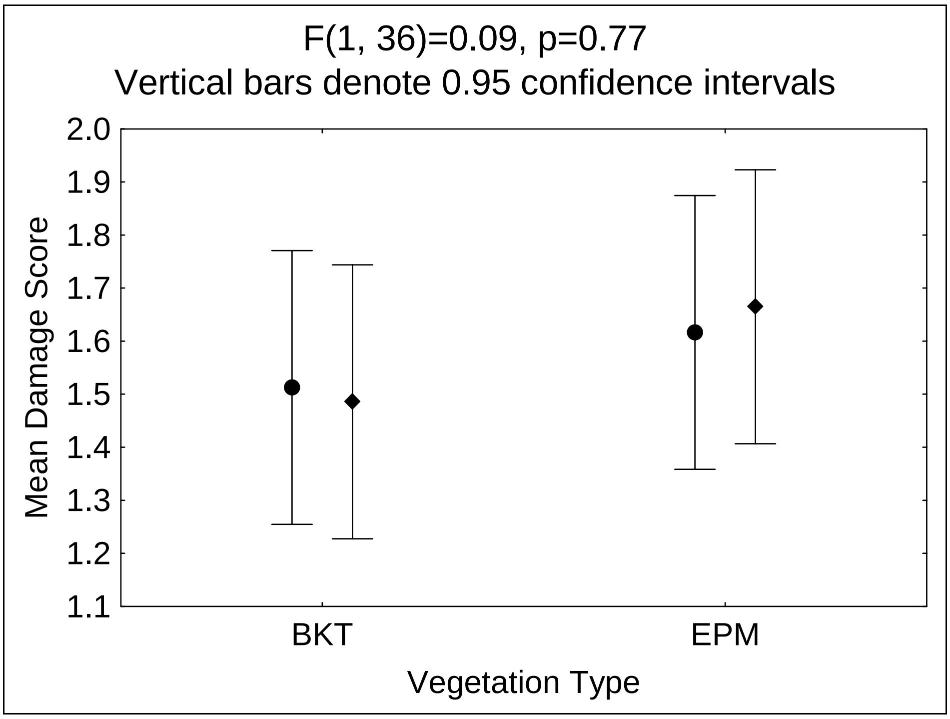
5.3.1 Kwandwe Private Game Reserve

There was a significant effect of vegetation type on total damage ($F=36.8$, $p<0.001$), but elephant density had no effect ($F=0.29$, $p=0.59$) and there was no interaction between the two factors ($p>0.05$; Figure 5.5a). By contrast, neither vegetation type nor density had a significant effect on the mean levels of damage ($F=0.09$, $p=0.77$ for both factors; Figure 5.5b).

Within EPM, five hundred and seventy-eight plants belonging to 14 species were sampled. More than half of the trees assessed showed low levels of damage (levels 1 - 2) that could not be attributed to elephants alone, while 9 % (50 % UD) and 10 % (95 % UD) showed high levels of damage including uprooting that could only have been attributed to elephants. Five species (Figure 5.6) occurred more than 5 times in each transect and were regarded as the most commons species. No *Pappea capensis* and a small percentage of the other species were undamaged (Figure 5.6). At a species level, there was no significant effect of plant species (refere to figure 5.6) or elephant density on mean damage score ($p>0.05$ for both factors) although mean damage was highest for *P. afra* and *Pappea capensis* in both 50 % and 95 % UDs (Table 5.1; Figure 5.7). Total damage was 3 – 4 times greater for *P. afra* than the other species (Table 5.1; Figure 5.6). Because levels of damage were generally low, the mean values tend to conceal the occurrence of relatively uncommon high levels of damage that result from elephant feeding. If the occurrence of damage levels 3 – 5 are analysed separately then it can be seen that in the core area, *P. afra* was the most severely affected (20 % of plants with damage levels 3 – 5) while no *Pappea capensis* were severely damaged (Figure 5.6). A similar pattern was seen in the home range where severe damage was greatest for *P. afra* (17 % of plants with damage levels 3 – 5; Figure 5.6).



a



b

Figure 5.5: Results of a two-way ANOVA showing the effect of vegetation type and elephant density area on (a) the total and (b) mean damage scores on Kwandwe. BKT = bushclump karroid thicket (n; # of trees: 50% UD=64, 95% UD=120); EPM = euphorbia portulacaria mosaic (n: 50% UD=239, 95% UD=212).

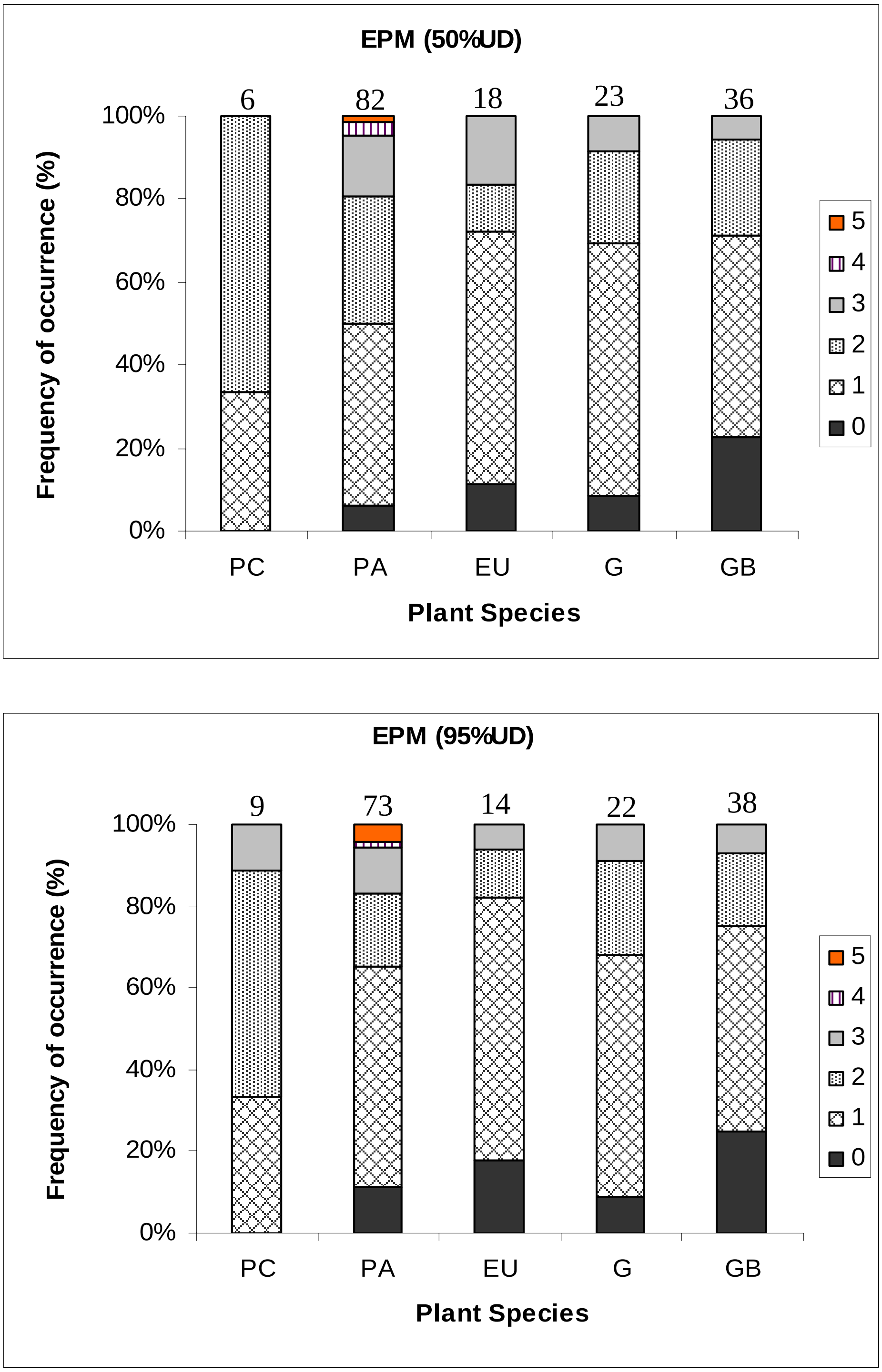
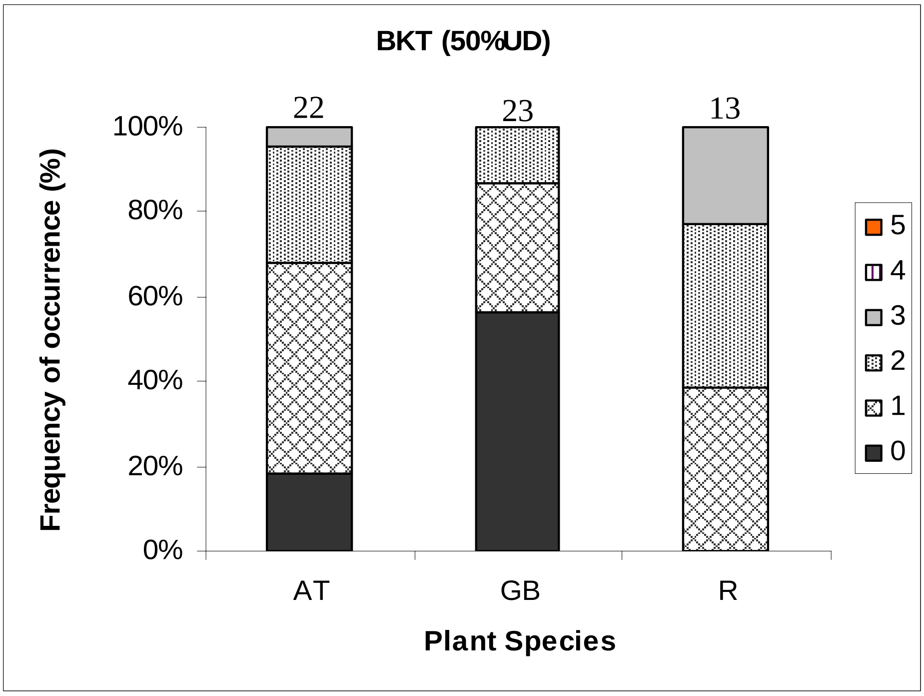


Figure 5.6: Percentage occurrence of damage levels for the most common species (n>5 number of trees per transect) in euphorbia portulacaria mosaic on Kwandwe. PC: *Pappea capensis*; PA: *Portulacaria afra*; EU: *Euclea undulata*; G: *Grewia* spp. and GB: *Gymnosporia* spp. Values above bars are sample sizes (# of trees). Legend at the side of each bar chart shows the level of damage.

Within BKT, two hundred and twenty-five plants representing 10 species were sampled. More than half of trees assessed in both 50 % and 95 % UDs showed low levels of damage (0-2), while 10 % (50 % UD) and 12 % (95 % UD) of the trees showed high levels of damage. Three species (*Azima tetracantha*, *G. buxifolia* and *Rhus* spp.) occurred more than 5 times in every transect and were regarded as the most common species. At a species level, there was no significant effect of plant species or elephant density on mean damage ($p>0.05$ for both factors; Table 5.1; Figure 5.7). In the core area, damage was most severe for *Rhus* spp. (23 % of plants had a damage level of 3; Figure 5.7) and no *Gymnosporia* spp. had damage that could be unequivocally attributed to elephants. In the home range, *Rhus* spp. were again the most severely damaged (19 %; Figure 5.7) while about 10 % of *A. tetracantha* and *Gymnosporia* spp. showed damage that could be attributed to elephants.



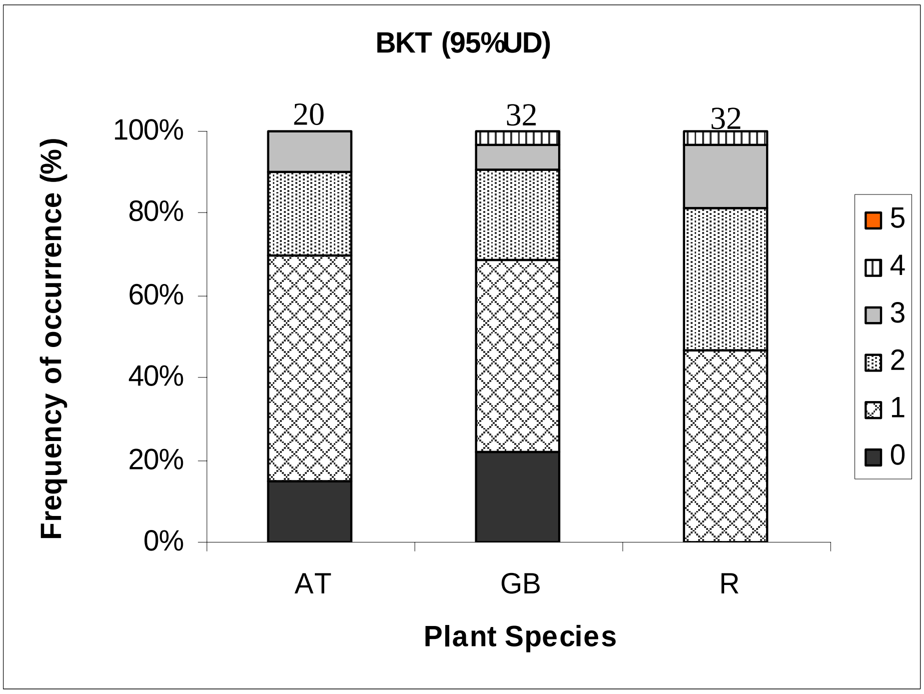


Figure 5.7: Percentage occurrence of damage levels for the most common species (n>5 number of trees per transect) in bushclump karroid thicket on Kwandwe. AT: *Azima tetracantha*; GB: *Gymnosporia* spp. and R: *Rhus* spp. Values above bars are sample sizes (# of trees). Legend at the side of each bar chart shows the level of damage.

Table 5.1: Total and mean damage scores for the most common species (n>5 trees per transect) in EPM and BKT on Kwandwe. n = total number of damaged trees in 10 transects (number of undamaged trees in brackets). PC: *Pappea capensis*; PA: *Portulacaria afra*; G: *Grewia* spp.; EU: *Euclea undulata*; GB: *Gymnosporia* spp.; AT: *Azima tetracantha* and R: *Rhus* spp.

Sp	n		Total DS* ±SD		Mean DS† ±SD	
	50% UD	95% UD	50%UD	95%UD	50%UD	95%UD
Euphorbia Portulacaria Mosaic						
PC	6(0)	9(0)	10±1.6	17±2.1	1.7±0.5	1.8±0.8
PA	75(7)	64(9)	133±9.5	110±4.4	1.8±0.7	1.9±0.8
G	21(2)	20(2)	30±2.9	29±2.4	1.4±0.5	1.4±0.5
EU	16(2)	11(3)	24±2.5	13±1.6	1.6±0.8	1.2±0.4
GB	29(7)	30(8)	42±3.5	43±4.4	1.4±0.5	1.3±0.4
Bushclump Karroid Thicket						
AT	22(4)	20(3)	27±2.2	25±2.5	1.5±0.6	1.4±0.5
R	13(0)	32(0)	24±2.9	56±4.5	1.7±0.6	1.9±0.9
GB	10(13)	25(7)	13±1.3	39±4.0	1.3±0.5	1.8±1.1

* Total DS = Total damage score

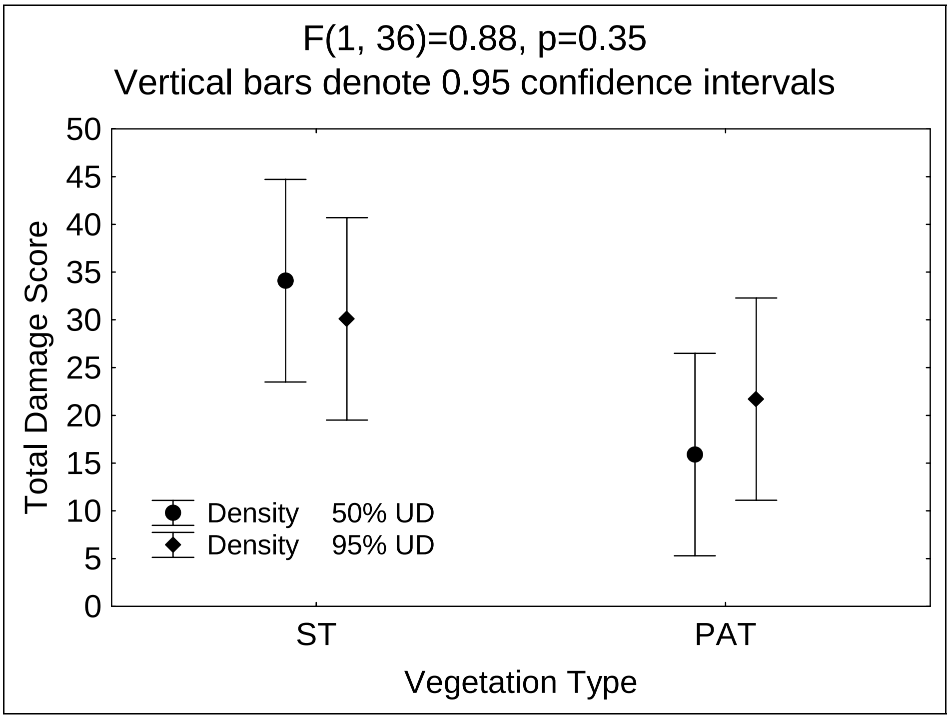
† Mean DS = Total damage score per transect / total # damaged trees per transect

5.3.2 Shamwari Private Game Reserve

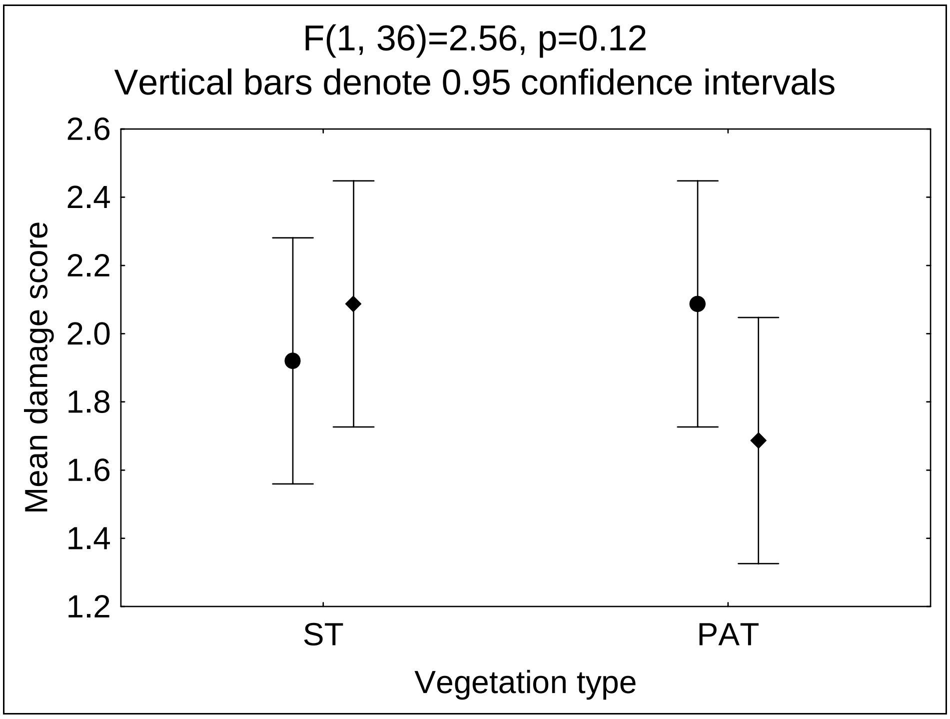
There was a statistically significant effect of vegetation type on total damage ($F=6.48$, $p=0.02$), with total damage being greater in subtropical thicket than primary acacia thicket (Figure 5.8). However, elephant density had no effect ($F=0.88$, $p=0.35$) and there was no interaction between the two factors ($p>0.05$; Figure 5.8). Neither vegetation type nor density had a significant effect on the mean levels of damage ($F=2.56$, $p=0.12$ for both factors; Figure 5.8).

In subtropical thicket, four hundred and eight plants representing approximately 23 species were assessed. The exact number of species is not given because the *Rhus* and *Gymnosporia* group included several species. About eighty percent of trees showed low levels of damage (0-2) in both 50 % and 95 % UDs, while 21 % (50 % UD) and 20 % (95 % UD) of all trees showed high levels of damage (3-5). Seven species (Figure 5.11) occurred more than 5 times in each transect and are regarded as common. No *P. afra* and *S. afra* were left undamaged in the 50 % UD and no *A. ferox*, *S. afra* and *Rhus* spp. were left undamaged in the 95 % UD (Figure 5.9).

At a plant species level, there was a significant effect of plant species and elephant density on the mean damage scores (F=2.84, p=0.02 for both factors; Figure 5.10). *A. ferox* was significantly more damaged than the other plant species (p<0.001), except *P. afra* in the 95 % UD (p>0.05; Appendix C1.1). *P. afra* was significantly more damaged than *A. tetracantha* (p=0.014), *Rhus* sp. (p=0.008) and *Gymnosporia* spp. (p=0.018) in the 95 % UD, while *S. afra* was significantly more damaged than *Rhus* spp. in the 50 % UD (p=0.043; Appendix C1.1). Within the core area, damage was most severe for *A. ferox* (40 % of all plants with damage levels between 3 & 5) and lowest for *Gymnosporia* spp. (Figure 5.9). A similar trend was seen in the home range where 92 % of *A. ferox* were severely damaged and 55 % of *Gymnosporia* spp. were undamaged (Figure 5.9).

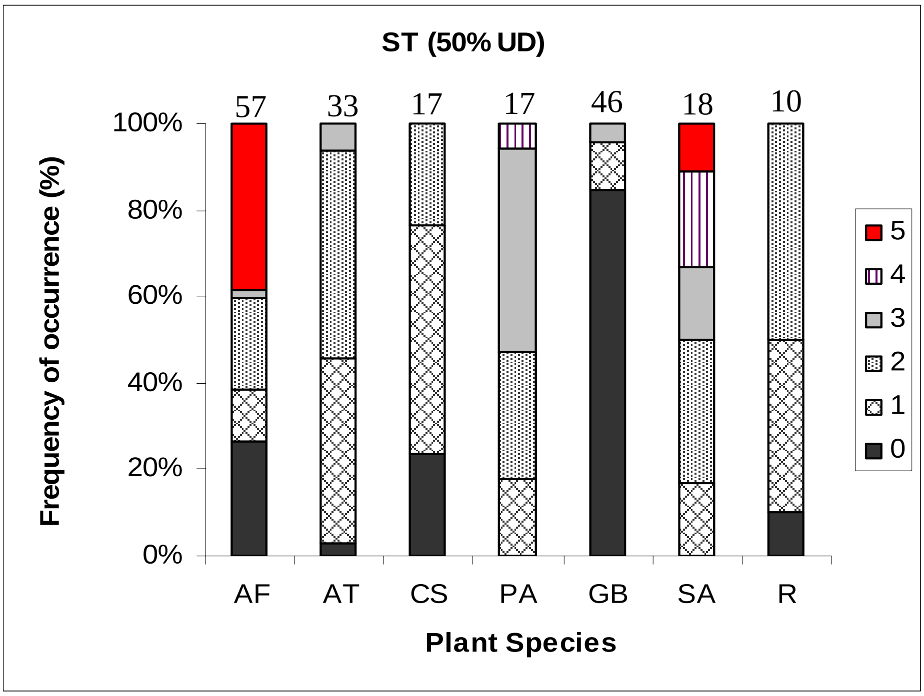


a



b

Figure 5.8: Results of a two-way ANNOVA showing the effect of vegetation type and elephant density area on (a) the total and (b) mean damage scores on Shamwari. ST = subtropical thicket (n; # of trees: 50% UD=329, 95% UD=253); PAT = primary acacia thicket (n: 50% UD=94, 95% UD=83).



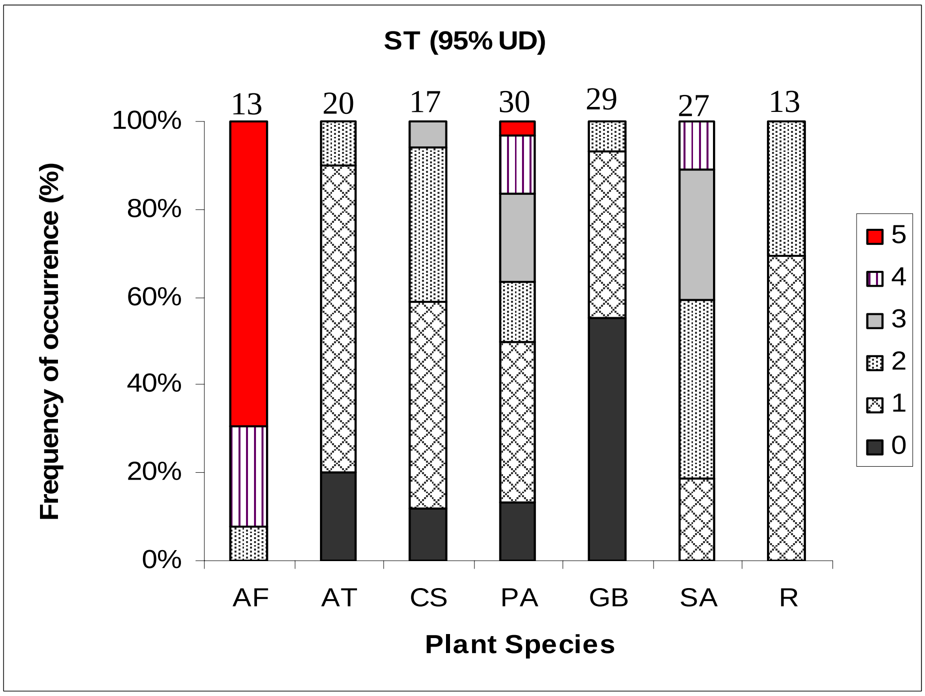


Figure 5.9: Percentage occurrence of damage levels for the most common species (n>5 number of trees per transect) in subtropical thicket on Shamwari. AF: *Aloe ferox*; AT: *Azima tetracantha*; CS: *Capparis sepiaria*; PA: *Portulacaria afra*; GB: *Gymnosporia* spp.; SA: *Schotia afra* and R: *Rhus* spp. Values above bars are sample sizes (# of trees). Legend at the side of each bar chart shows the levels of damage.

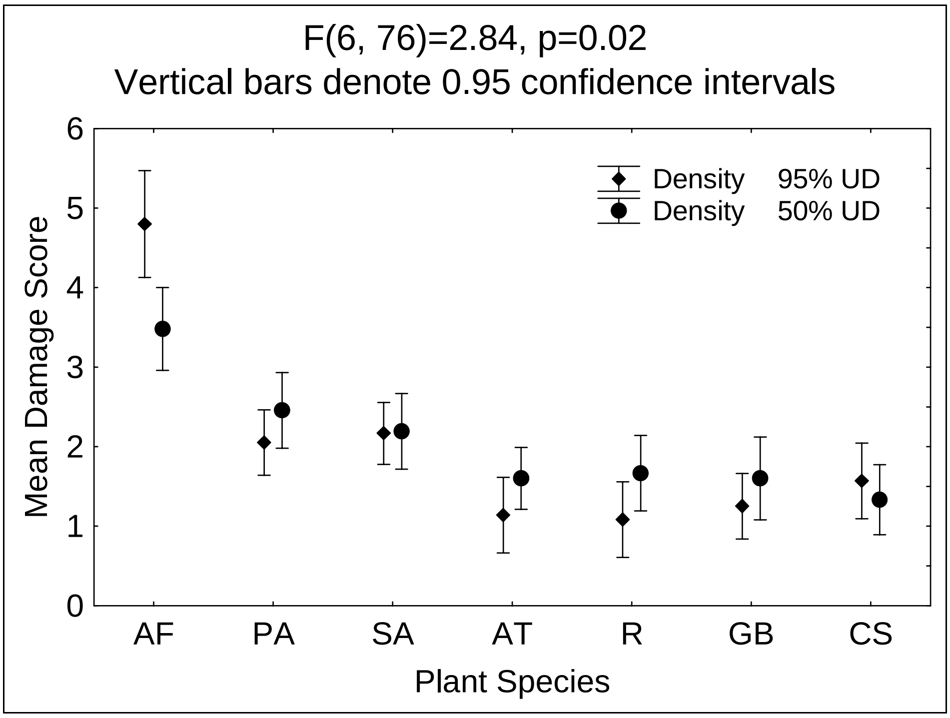
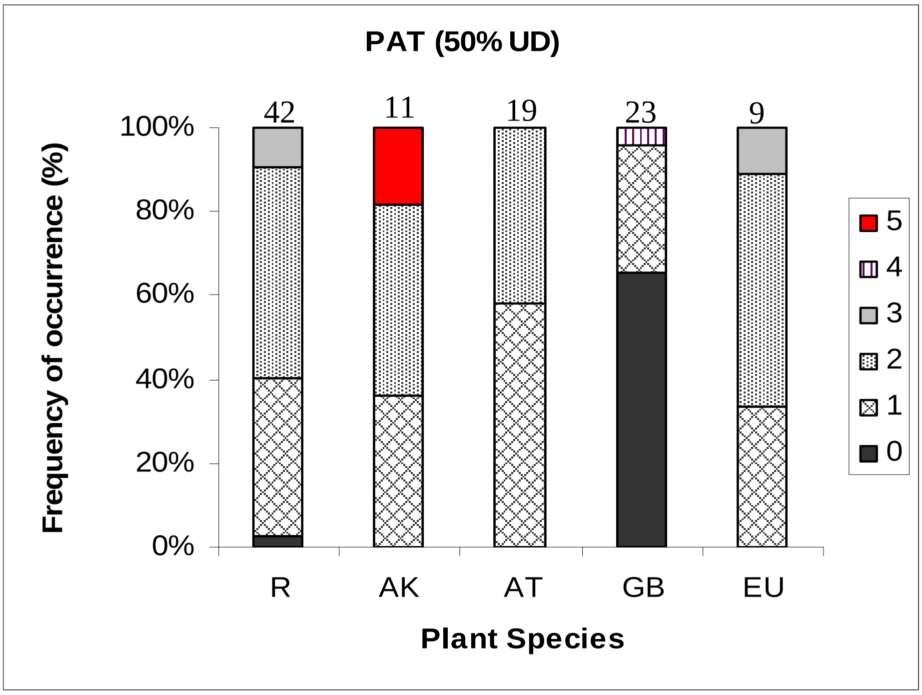


Figure 5.10: Results of a two-way ANOVA showing the effect of plant species and density on the mean damage score in subtropical thicket on Shamwari.

In primary acacia thicket, two hundred and fifteen plants were assessed, representing about 19 species. Eight percent of trees showed low levels of damage in the 50 % UD, while 69 % of trees showed low levels of damage in the 95 % UD (Figure 5.10). Nineteen percent of trees showed high levels of damage in the 50 % UD, while 8 % showed high levels of damage in the 95 % UD (Figure 5.10). Only two species occurred more than 5 times in each transect (*A. karroo* and *Rhus* spp.) and these and the next three most common species have been regarded as the most common (Figure 5.10). The effect of plant species and elephant density areas was not tested on data from PAT due to the low sample sizes. No *A. karroo*, *A. tetracantha* and *E. undulata* were left undamaged in the 50 % UD and no *E. undulata* were undamaged in the 95 % UD (Figure 5.10). In both the core area and home range, *A. karroo* was the most severely damaged (22 % of all plants had damage scores of 3–5) and *Gymnosporia* spp. were the least damaged (Figure 5.10).



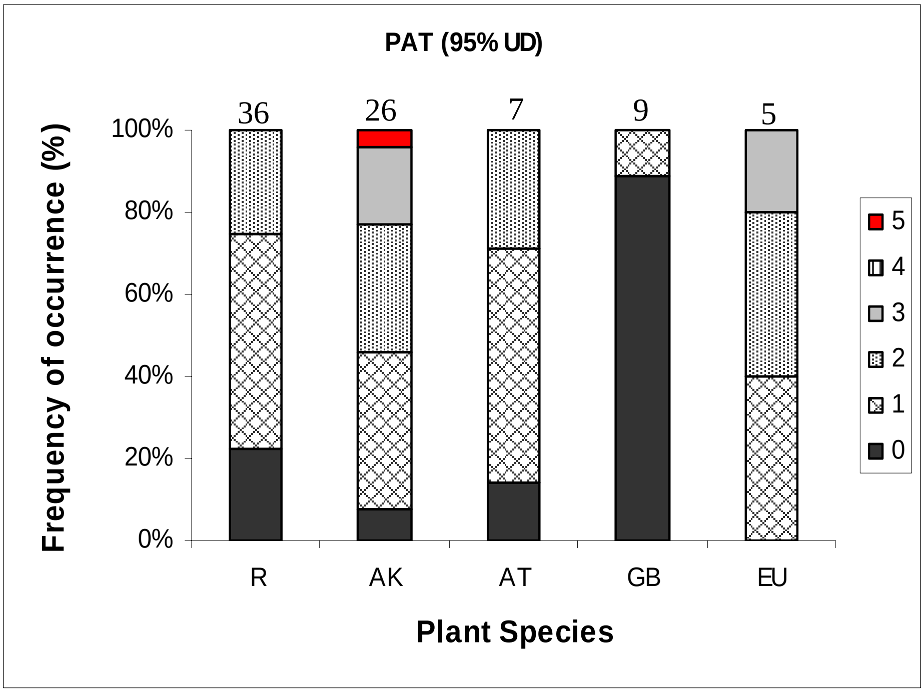


Figure 5.11: Percentage occurrence of damage levels for the most common species (n>5 number of trees per transect) in primary acacia thicket on Shamwari. R: *Rhus* spp.; AK: *Acacia karroo*; AF: *Aloe ferox*; GB: *Gymnosporia* spp.; EU: *Euclea undulata* and AT: *Azima tetracantha*. Values above bars are sample sizes (# of trees). Legend at the side of each bar chart shows the levels of damage.

Table 5.3: Total and mean damage scores for the most common species (n>5 trees per transect) in ST and PAT on Shamwari. n = total number of damaged trees (number of undamaged trees in brackets). AT: *Azima tetracantha*; AF: *Aloe ferox*; R: *Rhus* spp.; PA: *Portulacaria afra*; GB: *Gymnosporia buxifolia*; SA: *Schotia afra*; CS: *Capparis sepiaria* and AK: *Acacia karroo*.

Sp	n		Total DS*±1SD		Mean DS†±1SD	
	50% UD	95% UD	50% UD	95% UD	50%UD	95%UD
Subtropical Thicket						
AT	32(1)	16(4)	52±3.7	18±1.9	1.6±0.4	1.1±0.2
AF	42(15)	13(0)	144±17.1	59±9.8	3.5±0.6	4.1±1.4
R	9(1)	13(0)	14±1.3	17±3.7	1.7±0.4	1.1±0.2
PA	17(0)	26(4)	41±5.5	58±5.9	2.5±0.8	2.1±0.7
GB	7(39)	13(16)	11±1.5	15±1.4	1.6±0.9	1.3±0.5
SA	18(0)	27(0)	50±8.0	63±5.2	2.2±1.1	2.2±0.6
CS	13(4)	15(2)	17±1.4	23±2.4	1.3±0.4	1.6±0.4
Primary Acacia Thicket						
AK	11(0)	24(2)	24±2.1	46±4.7	2.4±1.3	1.8±0.5
R	41(1)	28(8)	70±3.2	37±1.8	1.7±0.3	1.4±0.3

* Total DS = Total damage score

† Mean DS = Total damage score per transect / total # damaged trees per transect

5.3.3 Tree height

There was no significant difference in the average height for the most common species (>5 trees per transect) in the 50 % and 95 % UDs in euphorbia portulacaria mosaic and bushclump karroid thicket on Kwandwe (Table 5.4; p>0.05). However, *P. afra* was taller in the 50 % UD than in the 95 % UD (p=0.07; Table 5.4). On Shamwari, in ST, the only significant difference in height was for *C. sepiaria*, which was significantly shorter in the 50 % UD (Table 5.4; p<0.05). *Capparis sepiaria* is a srambling shrub or small tree that is not an important food species for the elephants (see Chapter 4). Although the difference was not significant, the mean height of *A. ferox* was greater in the 50 % UD than in the 95 % UD (Table 5.4). In primary acacia thicket, there was no significant differences in the mean heights of *A. karroo* or *Rhus* spp in the 50 % and 95 % UDs however, the mean height for all trees (pooled data) was significantly greater in the 50 % UD ($p<0.05$; Table 5.4).

Table 5.4: Tree height (m) of the most common species in euphorbia portulacaria mosaic and bushclump karroid thicket on Kwandwe, and subtropical thicket and primary acacia thicket on Shamwari. Values are means ±1 S.D.

Plant species	50%UD	95%UD	50%UD	95%UD
Kwandwe	**EPM**		**BKT**	
P.capensis	2.1±1.1	2.5±1.2		
P. afra	1.8±0.5	1.4±0.3		
Grewia spp.	1.0±0.4	0.8±0.3		
E. undulata	1.2±0.7	1.2±0.7		
Gymnosporia spp.	1.3±0.2	1.3±0.5	1.1±0.6	1.2±0.6
A. tetracantha			1.8±0.5	1.4±0.6
Rhus spp.			2.3±0.6	2.6±1.4
Mean	**1.2±0.8**	**1.1±0.7**	**1.6±0.9**	**1.6±1.2**
Shamwari	**ST**		**PAT**	
A. ferox	0.7±0.4	0.4±0.4		
A. tetracantha	1.5±0.6	1.6±0.6		
P. afra	2.0±0.8	2.0±0.6		
Gymnosporia spp.	1.3±0.4	1.2±0.5		
C. sepiara[*]	1.2±0.2	1.6±0.5		
S. afra	2.7±0.9	3.0±0.7		
Rhus spp.	1.9±1.1	1.9±0.5	3.2±0.8	2.9±1.2
A. karroo			1.7±1.1	1.9±0.9
Mean	**1.7±1.4**	**2.0±1.2**	**1.7±1.1**	**1.6±1.4**

5.4 DISCUSSION

Total damage scores were significantly higher in the subtropical thicket vegetation compared to the savanna vegetation on both reserves however this was because the density of trees was approximately two times higher in subtropical thicket vegetation. Consequently, mean damage scores provide a better reflection of the effect of

[*] $t=-2.47$; $df=11$; $p=0.03$

elephants on the vegetation. There was no significant difference in the mean damage between subtropical thicket and bushclump savanna vegetation or between the 50 % and 95 % UDs and the two hypotheses set out in the introduction were not supported. Although the differences were not statistically significant, in the subtropical thicket vegetation on both reserves, mean damage was slightly lower in the core area than the home range. This is counter intuitive, but Anderson & Walker (1974) found similar results in the Sengwa Wildlife Research Area and suggested that elephants might utilise their core areas for light browsing and for activities other than feeding. By contrast, in the bushclump vegetation on both reserves, mean damage to vegetation was slightly greater in the core area than the home range. These results suggest that the relationships between elephant density and damage are not simple and may be affected by the nature of the vegetation. For example, in the Luangwa Valley, Zambia, responses of *Colophospermum mopane* to elephant browsing varied with the woodland structure (Lewis 1991). In the Venetia-Limpopo Nature Reserve (Limpopo Province), MacGregor & O'Connor (2004) found that the removal of the canopy in a riparian woodland did not cause mortality of trees while the same process in an acacia woodland (mainly *Acacia tortiliis*) did. It is also likely that the relatively short period of time for which elephants have been in the reserves has reduced the likelihood of there being significant differences in levels of damage. Penzhorn *et al*. (1974) found that after 17-18 years of continuous utilization by elephant and a density of 2.7 elephants/km^2, the total biomass of plant species in Addo Elephant National Park had decreased (mean biomass decrease from 360 kg outside the elephant camp to 170 kg inside the camp). Whyte (1996; cited in Hofmeyr & Eckardt 2004) found that after 10 years, approximately 1000 baobab trees had died due to elephant utilization in the Kruger National Park. It has been found that where elephants have occurred in confined areas for a few decades, biodiversity can be reduced (Cumming *et al*. 1997). Elephants have been in Shamwari for 13 years and Kwandwe for four years and at densities of 0.4 per km^2 for Shamwari and 0.2 per km^2 for Kwandwe, it is likely that this combination of relatively low densities and short periods of time partly explains the failure to detect significant differences in damage between core areas and home ranges.

Analysis of total and mean levels of damage for the two vegetation types masks species-specific differences and on both reserves some species were utilized more than others. In the subtropical thicket vegetation on Kwandwe, mean damage was greatest for *Portulacaria afra*, a succulent element of the subtropical thicket, and *Pappea capensis*, a woody tree species. About 20 % of all *P. afra* in the core area showed high damage (levels 3-5) that was attributable to elephants, while no *Pappea capensis* were severely damaged. A similar trend was seen on Shamwari where, in the subtropical thicket, two succulent species (*Aloe ferox and P. afra*) had the highest mean damage levels. *A. ferox* was the most damaged species (40 %, core area and 92 % home range with damage levels between 3 & 5) and levels of damage were slightly lower for *P. afra* (50 % core area; approximately 35 % home range). As on Kwandwe, damage was lowest for *Gymnosporia* spp. and *Rhus* spp., which are woody shrubs and trees. These results suggest that within the subtropical thicket, feeding pressure is concentrated on succulent elements and, although large trees are used, they are not severely damaged. On Kwandwe, this could be due to the high densities of succulent species in the subtropical thicket vegetation (54 % of all plant species per hectare, Chapter 4) and the elephants are simply using an abundant and palatable food source. Comparable results have been reported in valley bushveld (subtropical thicket) in Addo Elephant National Park where *P. afra*, *Aloe africana*, *Schotia afra*, *Euclea* *undulata* and *Azima tetracantha* are the most utilized species (Penzhorn *et al*. 1974). Similarly, in the Songimvelo Game Reserve (south eastern part of Mpumalanga), *Aloe marlothii* is ranked as the 2nd most utilised woody plant species (Steyn & Stalmans 2001). O'Connor *et al.* (2004) has suggested that, in order to reduce searching time and increase intake rate, elephants should select plants with succulent stems or woody plants where leaves can be selected without having to harvest stems. This could explain what is happening in both these reserves, where elephants are selecting succulent species in preference to woody species. In addition, most, if not all of the succulent species on Kwandwe and Shamwari are evergreen and are higher in moisture than the woody plant species, which are mostly deciduous, and this may play a role in their selection. A different pattern is seen in the savanna-like vegetations on the two reserves. On Kwandwe, damage was greatest to *Rhus* spp. and on Shamwari, to *A. karroo.* On both reserves there was very little damage to *Gymnosporia* spp. The absence of succulent species from the list of damaged species simply reflects the absence, or very low abundance, of succulents in these vegetation types. The preference for *A. karroo* could be due to its high palatability because of the high protein and water content present in the leaves (Cooper *et al*. 1988, Sauer 1983). A preference for *Acacia nilotica* and *A. gerrardii* has been reported in Ithala Game Reserve by Wiseman *et al*. (2004). Similarly, Steyn and Stalmans (2001) reported a high utilisation of *A. davyi, A. ataxacantha* and *A. caffra*. The utilisation of *Rhus* spp. on Kwandwe was not common and in the Maputo Elephant Reserve and Ithala Game Reserve, *Rhus* spp. were utilised little (De Boer *et al*. 2000, Wiseman *et al*. 2004). The extent to which *Acacia* spp. are deciduous varies with the climate of the region (Parker *et al*. 2003) and in the Eastern Cape Province; *A. karroo* loses its leaves in winter. Giraffe, which utilise *A. karroo* through summer, switch to the evergreen members of the *Rhus* genus in winter (Parker *et al*. 2003) and it is possible that the elephants in the Eastern Cape Province are feeding from *Rhus* spp. for the same reasons. In the subtropical thicket, mean damage on Shamwari (mean damage score approximately 2.1) was about twice that on Kwandwe (damage score ≈ 1.5). This substantial difference could be due to the higher density of *Aloe ferox* in subtropical thicket on Shamwari (21.9/ha) than on Kwandwe (5.6/ha; Chapter 4). This, combined with the high levels of damage to *A. ferox* would increase the overall damage score. The increased damage on Shamwari could also be due to the fact that the vegetation has been subjected to elephant utilization for 9 years longer than the vegetation on Kwandwe. To a certain extent, species differences in levels of damage are supported by observations of the diet of the elephants. On Kwandwe, *Pappea capensis* and *P. afra* made up 36 % (see Chapter 4) of the elephant's diet. On Shamwari, *A. karroo* made up 36 % of the elephant's diet (see Chapter 4).

One of the hypotheses set out in this chapter was that damage would be greater in the 50 %UD than in the home range because elephant activity is concentrated in this area. The measurement of tree height did not support this and, for most species, there was no significant difference between mean height in the core area and in the home range. The exception was *Capparis sepiaria* on Shamwari which was significantly shorter in the core area than the home range. However, *C. sepiaria* is a shrub or small tree and damage, or any reduction in height, cannot be solely attributed to elephants. The absence of any significant reduction in tree height in the 50 % UD, compared to the home range could be due to the short time period that elephants have been on these reserves. It might also reflect the fact that elephants may use the core area for light browsing (Anderson & Walker 1974).

A second hypothesis was that damage would be greater in more open vegetation types. If this was the case, then one might expect to have seen a greater reduction in tree height in the core areas of the open vegetation types (PAT and BKT) than in the thicket vegetations. This was not the case and on Shamwari the trend was the opposite and tree height was significantly greater in PAT in the 50 % UD. It is in fact unlikely that this difference is the result of elephant browsing and more likely that it is a consequence of the positioning of the core area. The core area on Shamwari was close to the Bushmans River and because of the proximity to water, the trees were generally taller.

There is some correlation between levels of damage reported earlier in this chapter and height reduction. On Kwandwe, in EPM, damage was greatest to *P. afra* and this is reflected in the height reduction in the home range. Although this is counter intuitive, it supports the suggestion that the core area is used for activities other than feeding (Anderson & Walker 1974). In EPM, although *Pappea capensis* is a preferred species, levels of damage were never high (3-5) and there was no significant difference in height. On Kwandwe, in BKT, damage was greatest to *Rhus* spp. and only the *Rhus* spp. showed a reduction in mean height in the 50 % UD. No *Gymnosporia* spp were severely damaged and there was no difference in mean height in the 50 % UD or 95 % UD. On Shamwari, in ST. *A. ferox* was most damaged but this species did not appear in the transects and height data were not available. However, in PAT, damage was greatest to *A .karroo* and, although the differences were not significant, trees were shorter in the 50 % UD than the home range. In considering the ecological consequences of elephant feeding, it is important to remember that, depending on the type of utilisation and the tree’s growth response, certain plant species are more resistant to elephant damage than other species

(Anderson & Walker 1974, MacGregor & O'Connor 2004). For example, *P. afra* is able to coppice (extensive lateral vegetative expansion using creeping shoots; Vlok *et al*. 2003) and coppicing produces a larger biomass and creates an improved forage source for elephants and other herbivores (MacGregor & O'Connor 2004). Stuart-Hill (1992) has shown that *P. afra* is tolerant of heavy browsing by elephants and Vlok *et al*. (2003) suggest that *P. afra* is an important pioneer species for subtropical thicket establishment because of its unique biology and ability to withstand heavy damage. Ben-Shahar (1996) found that elephants preferred to browse on shrubs and coppiced trees. By contrast, *A. ferox* is unable to coppice (*pers. obs.*) and therefore vulnerable to elephant damage. This is best seen on Shamwari where damage in the core area was either low (0) or high (5) and in transects in the home range, 70% of specimens were dead. This suggests that a single feeding episode on *A. ferox* will often result in destruction of the plant and is supported by the way elephants feed on *A. ferox*; knocking the head off and feeding from the inner pith downwards until there is nothing left standing (*pers. obs*.). Utilisation of *Acacia karroo* usually takes the form of bark stripping (*pers. obs.*), which could lead to the death of the specimen due to the resultant vulnerability to fire, wood-boring beetles (Anderson & Walker 1974) and secondary infections (Campbell *et al*. 1996). Beuchner & Dawkins (1961) found that elephants sought out trees that had been previously damaged by bark stripping. This would result in differential utilisation of specimens of the same species and might explain the variation around the mean damage scores observed in this study.

The apparent discrepancies between results presented in Chapter's 4 & 5 probably reflect an effect of different time scales. Measurements of damage reported in Chapter 5 are cumulative and have built up over months or years, while feeding observations in Chapter 4 are instantaneous. Hence, while there were very few observations of elephants feeding on *A. ferox* (Table 4.2; Chapter 4) it is one of the most damaged species.

An important question facing reserve managers is whether to control elephant numbers in order to conserve vegetation (Wiseman *et al*. 2004). There is evidence that elephants may drive major changes in vegetation from woodland to wooded grassland and ultimately to grassland (Beuchner & Dawkins 1961, Dublin *et al*. 1990, Hofmeyr & Eckardt 2004). It has also been suggested that the change from woodland to open grassland that is occurring in many of the larger parks and reserves (and is envisioned to occur in Kwandwe and Shamwari) might be a restoration of conditions ‘that were prevalent a few centuries ago’ (Owen-Smith 2004). Similarly, there is conflicting evidence as to whether “damage” by elephants results in a decline in biodiversity or an increase in biodiversity through the creation of environmental heterogeneity (Huntly 1991, Pamo & Tchamba 2001, Mapaure & Campbell 2002, Wiseman *et al*. 2004). What is clear is that elephants, as megaherbivores, can drive habitat change and that this will be exaggerated in small reserves where long range movement is not possible.

CHAPTER 6

GENERAL DISCUSSION

The growth of private ecotourism ventures in the Eastern Cape Province has led to the development of a number of small, fully fenced reserves. In order to compete with similar game reserves in the region, many of these reserves have re-introduced elephants, and other large mammals. While such re-introductions can be seen as a positive step towards conservation by returning parts of the Eastern Cape Province to a more natural condition, they pose a number of problems. The size of the reserve and the space available to elephants is an important issue. Elephants have large home ranges (54 km^2 in AENP – 2179 km^2 in Etosha NP; Whitehouse & Schoeman 2003, Jackson & Erasmus 2005) which are typically larger than the space available in many of the smaller reserves and the restriction of elephants to small reserves may exaggerate the affect of elephants, through feeding and trampling, on the vegetation. With four phytogeographical regions amalgamating in the Eastern Cape Province, it is botanically diverse, with subtropical thicket covering 25% (Kerley *et al*. 1995, Cowling & Hilton-Taylor 1997) and occurring only in this province (Everard 1987, Vlok *et al*. 2003). Subtropical thicket is characterised by high levels of endemism (Lubke *et al*. 1986), is easily damaged by small livestock (Hoffman & Cowling 1990, Stuart-Hill 1992, Kerley *et al*. 1995) and regarded as being of high conservation priority (Kerley *et al.* 1995). Thus, the change from traditional agriculture to ecotourism could be seen as contributing to the conservation of subtropical thicket. However, if elephants select this vegetation type and feed heavily from components in it, then any benefit could be negated. The feeding biology of elephants in subtropical thicket has only been studied in Addo Elephant National Park where the elephants are at a relatively high density (≈ 3 per km^2), and there is a need for further studies in subtropical thicket at substantially lower elephant densities.

Results from Kwandwe and Shamwari support the suggestion that in small reserves (i.e. reserves of about 200 km^2) movement of elephants is restricted. The home ranges of the elephants took up the majority of the reserve and in some cases, areas that were not used were not accessible to elephants. This was supported by the broad analysis of home range size in reserves or systems of different sizes which suggested that home range size increased with increasing reserve size, up to a reserve size of 1000 km^2. While this analysis may be simplistic because it does not consider, and could not easily have considered, the various other factors that can affect space use by elephants (access to water, seasonality of the climate, food quality), it seems likely that in the small reserves, elephant movement is limited. The small home range size of elephants in Addo Elephant National Park, which is substantially less than the size of the reserve, is probably a result of limited access to water, concentrating elephants in one or two areas, and the topography making some regions of the reserve inaccessible. The core areas of the elephants on Kwandwe and Shamwari were much smaller than the home ranges and it is assumed that the positioning of these core areas represented habitat selection. On both reserves the core areas were close to water, highlighting the reliance of elephants on water (Leuthold 1977, Ottichilo 1986, Lindeque & Lindeque 1991, Tufto *et al*. 2005). Although the results are not conclusive, it is felt that the elephants did not select vegetation types but rather used those vegetation types that occurred close to the water. This was particularly apparent on Shamwari (see Chapter 3).

Studies of the diet of the elephants were difficult and the small sample size has made interpretation problematic. By contrast, studies of the effect of elephants on the woody vegetation were more easily controlled. Results from this study showed a significant decrease in time spent grazing from summer (wet season) to winter (dry season), as has been reported in several previous studies (Wyatt & Eltringham 1974, Laws *et al*. 1975, Williamson 1975, Osborn 2004). The importance of grass in summer (≈25% of all feeding records on both reserves) suggests that the prolonged droughts that characterise the Eastern Cape Province could result in periods of nutritional stress. On both reserves, the elephants utilized succulent and woody components of the subtropical thicket. On Kwandwe, *Portulacaria afra* and *Pappea capensis* were important species in the diet and on Shamwari *Aloe ferox* and *P. afra* had the highest mean damage levels. Levels of utilization and damage have to be interpreted in relation to the growth form of the plant species and its resistance to browsing. *P. afra*, which is a characteristic species of subtropical thicket, will coppice and is resistant to browsing. Persistent browsing, particularly top down browsing by elephants, may alter the growth form or reduce the height of individual plants, but the plant will respond by producing new lateral growth (Stuart-Hill 1992). By contrast, *Aloe ferox* and *Pappea capensis* will not coppice and have no resistance to browsing. This is exacerbated in *A. ferox*, where it appears that a single feeding episode in which the elephants break off the flowering and leaf head and feed from a succulent region just below the head, kills the plant. Thus, while some components of the subtropical thicket will survive browsing by elephants, others may not. The high levels of severe damage to *A. ferox* (40 – 90 % of all plants with damage levels 3-5) in Shamwari suggest that, with time, the occurrence of this species in subtropical thicket will decline and that it may only survive in regions that are inaccessible to elephants. On Shamwari, where the core area of the elephants was in a region characterized by primary and secondary acacia thickets, woody trees of the genera *Acacia* and *Rhus* were regularly fed from and 22 % of *A. karroo* were severely damaged. A preference by elephants for members of the genus *Acacia* has been widely reported (Field & Ross 1976, Kabigumila 1993, De Boer *et al*. 2000, Steyn & Stalmans 2001, MacGregor & O'Connor 2004) and elephants can cause an increase in mortality of acacia (MacGregor & O'Connor 2004). However, *A. karroo* is an invasive, pioneer species that tends to form monocultures at high densities, and an increase in mortality would be seen as desirable by the managers. This raises the challenging question of how to assess and if, when and how to limit change and this is briefly discussed later. Although substantial damage was recorded for *A. ferox* and significant damage was recorded for some other species (*Pappea capensis, Acacia karroo, Azima tetracantha* and *Schotia afra*) the study failed to detect significant differences in damage between the home range and core area and between the different vegetation types. It is most likely that this is due to the relatively low elephant densities (≈ 0.3 per km^2) compared to much higher densities in the Addo Elephant National Park (3 per km^2) and the relatively short period of time for which elephants have been present on the private reserves (13 years on Shamwari, 4 years on Kwandwe and 51 years on Addo Elephant National Park). This is supported by the greater levels of damage on Shamwari, where elephants have been present for longer, than on Kwandwe.

As mentioned in the introduction to Chapter 5, there is considerable debate over what represents natural, reasonable or acceptable habitat change and this is a question that has to be considered by all owners and mangers of reserves. Using examples from this study, the levels of damage to *A. ferox* and its lack of resistance to elephant browsing suggest that it will undergo a substantial reduction in density and may disappear from some reserves. This raises two immediate questions. Firstly, since elephants occurred historically at quite high densities in the area (Boshoff *et al.* 2002), are the large stands of *A. ferox* that are a characteristic of the region natural, or a consequence of the removal of elephants? Secondly, irrespective of the answer to the first question, *A. ferox* is an important resource for a range of nectar feeding birds and insects and the dried flower heads are used by a group of bumble bees (D. Parker *pers. comm.*). Thus the elephant-driven change to the abundance of *A. ferox* will affect other facets of the system. Similar debates as to whether elephant driven change to the vegetation represents a return to a more natural state have occurred for the Kruger National Park (Kay 2004, Owen-Smith 2004) and on the Chobe River (Skarpe *et al*. 2004). Because of the visual appeal of stands of flowering *A. ferox*, and the sunbirds and sugarbirds that visit them, loss of the species is widely seen as unfortunate. The dense stands of *A. karroo* that characterise secondary acacia thicket are (possibly like the stands of *A. ferox*) an artefact of Man's activities but, the possibility that elephants may control *A. karroo* through selective browsing is seen as positive. Clearly, deciding what represents natural change is made more difficult by the absence of a historical records of, for example *A. ferox*, from 100 years ago and managers and ecologists have to make pragmatic decisions based on the best available information and the aims of the reserve.

In conclusion, the results of this study indicate that in reserves <300 km^2, elephant movement is restricted. At a core area level, habitat selection occurs but this is probably driven more by the need for water than a preference for a particular vegetation type. The importance of grass in the diet (time spent grazing compared to browsing) changes seasonally and is more important in the wet summer months than in winter. The diet includes a range of woody and succulent species some of which have a greater resistance to browsing than others. It is clear from published studies and from this study that elephants can drive habitat change and that this will be exaggerated in reserves where movement is restricted. Changes to the relative abundance of species such as *A. ferox*, *Pappea capensis* and *A. karroo*, and to the growth form of others such as *P. afra* should be anticipated and the cascade effect of these changes on the system should be considered. Fortunately, elephants are easily located and observed by tourists and thus densities need not be high and an important management approach is to control elephant numbers. In addition, botanical enclosures that protect regions of subtropical thicket with key species such as *A. ferox*, should be created within reserves. Finally, since change is inevitable, monitoring is essential to quantify that change and all reserves with elephants should undertake regular and rigorous monitoring of the vegetation.

CHAPTER 7

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APPENDIX A

DETAILS OF HABITAT USE BY ELEPHANTS ON KWANDWE

Table A1.1: Habitat use at a home range and core area level during summer by elephant herd 5 in Kwandwe Private Game Reserve. BKT: bushclump karroid thicket; BS: bushclump savanna; DLT: drainage line thicket; EPM: euporbia portulacaria mosaic; KS: karroid shrubland; MPT: medium portulacaria thicket; OL: old lands; RT: riverine thicket; SET: short euphorbia thicket and TET: tall euphorbia thicket.

Veg type	Total area (ha)	Proportion of total area	Observed	Expected	Observed proportion	Expected proportion	Lower CI	Upper CI	P
ELH 5									
SUMMER 95 UD									
BKT	1460	0.120	18	18.626	0.116	0.120	0.019	0.044	-
BS	147	0.012	0	1.875	0.000	0.012			
DLT	179	0.015	2	2.284	0.013	0.015	-0.013	0.038	
EPM	3351	0.276	45	42.749	0.290	0.276	0.188	0.393	
KS	2099	0.173	14	26.777	0.090	0.173	0.026	0.155	-
MPT	847	0.070	24	10.805	0.155	0.070	0.073	0.236	+
OL	266	0.022	8	3.393	0.052	0.022	0.002	0.101	
RT	695	0.057	17	8.866	0.110	0.057	0.039	0.180	
SET	2822	0.232	26	36.001	0.168	0.232	0.083	0.252	
TET	284	0.023	1	3.623	0.006	0.023	-0.012	0.025	
SUMMER 50 UD									
BKT	76	0.064	6	2.935	0.130	0.064	0.055	0.206	
BS	0	0.000	0	0.000	0.000	0.000			
DLT	3	0.003	1	0.116	0.022	0.003	-0.011	0.055	
EPM	375	0.315	14	14.484	0.304	0.315	0.201	0.408	
KS	223	0.187	1	8.613	0.022	0.187	-0.011	0.055	-
MPT	144	0.121	4	5.562	0.087	0.121	0.023	0.150	
OL	56	0.047	1	2.163	0.022	0.047	-0.011	0.055	
RT	118	0.099	8	4.558	0.174	0.099	0.088	0.259	
SET	196	0.165	11	7.570	0.239	0.165	0.143	0.335	
TET	0	0.000	0	0.000	0.000	0.000			

Veg. type = vegetation type
observed = number of elephant fixes
lower and upper CI = lower and upper Bonferroni confidence intervals
P = Preference.

Table A1.2: Habitat use at a home range and core area level during winter by elephant herd 5 in Kwandwe Private Game Reserve. BKT: bushclump karroid thicket; BS: bushclump savanna; DLT: drainage line thicket; EPM: euporbia portulacaria mosaic; KS: karroid shrubland; MPT: medium portulacaria thicket; OL: old lands; RT: riverine thicket; SET: short euphorbia thicket and TET: tall euphorbia thicket.

Veg type	Total area	Proportion of total area	Observed	Expected	Observed proportion	Expected proportion	Lower CI	Upper CI	P
ELH 5									
WINTER 95% UD									
BKT	1221	0.135	0	17.197	0.000	0.135			
BS	280	0.031	0	3.944	0.000	0.031			
DLT	115	0.013	6	1.620	0.047	0.013	-0.006	0.100	
EPM	2042	0.226	40	28.761	0.315	0.226	0.199	0.431	
KS	1459	0.162	5	20.549	0.039	0.162	-0.009	0.087	-
MPT	458	0.051	14	6.451	0.110	0.051	0.032	0.188	
OL	215	0.024	5	3.028	0.039	0.024	-0.009	0.087	
RT	589	0.065	17	8.296	0.134	0.065	0.049	0.219	
SET	2257	0.250	33	31.789	0.260	0.250	0.151	0.369	
TET	381	0.042	7	5.366	0.055	0.042	-0.002	0.112	
WINTER 50% UD									
BKT	277	0.127	7	11.457	0.078	0.127	-0.001	0.157	
BS	23	0.011	1	0.951	0.011	0.011	-0.020	0.042	
DLT	20	0.009	4	0.827	0.044	0.009	-0.017	0.105	
EPM	653	0.300	32	27.008	0.356	0.300	0.214	0.498	
KS	194	0.089	3	8.024	0.033	0.089	-0.020	0.086	-
MPT	90	0.041	8	3.722	0.089	0.041	0.005	0.173	
OL	82	0.038	3	3.392	0.033	0.038	-0.020	0.086	
RT	140	0.064	12	5.790	0.133	0.064	0.033	0.233	
SET	612	0.281	18	25.313	0.200	0.281	0.082	0.318	
TET	85	0.039	2	3.516	0.022	0.039	-0.021	0.065	

Veg. type = vegetation type
observed = number of elephant fixes
lower and upper CI = lower and upper Bonferroni confidence intervals
P = Preference.

Table A1.3: Habitat use at a home range and core area level during summer by elephant herd 6 in Kwandwe Private Game Reserve. BKT: bushclump karroid thicket; BS: bushclump savanna; DLT: drainage line thicket; EPM: euporbia portulacaria mosaic; KS: karroid shrubland; MPT: medium portulacaria thicket; OL: old lands; RT: riverine thicket; SET: short euphorbia thicket and TET: tall euphorbia thicket.

Veg type	Total area (ha)	Proportion of total area	Observed	Expected	Observed proportion	Expected proportion	Lower CI	Upper CI	P
ELH 6									
SUMMER 95% UD									
BKT	1476	0.118	15	21.868	0.081	0.118	0.020	0.143	
BS	291	0.023	2	4.311	0.011	0.023	-0.013	0.034	
DLT	180	0.014	1	2.667	0.005	0.014	-0.011	0.022	
EPM	3374	0.270	59	49.987	0.319	0.270	0.214	0.424	
KS	2110	0.169	15	31.261	0.081	0.169	0.020	0.143	-
MPT	882	0.071	14	13.067	0.076	0.071	0.016	0.135	
OL	266	0.021	10	3.941	0.054	0.021	0.003	0.105	
RT	698	0.056	10	10.341	0.054	0.056	0.003	0.105	
SET	2838	0.227	52	42.046	0.281	0.227	0.180	0.382	
TET	372	0.030	7	5.511	0.038	0.030	-0.005	0.081	
SUMMER 50% UD									
BKT	222	0.091	6	7.702	0.071	0.091	-0.007	0.149	
BS	21	0.009	1	0.729	0.012	0.009	-0.021	0.045	
DLT	41	0.017	0	1.422	0.000	0.017			
EPM	834	0.340	35	28.935	0.412	0.340	0.262	0.562	
KS	179	0.073	2	6.210	0.024	0.073	-0.023	0.071	-
MPT	147	0.060	4	5.100	0.047	0.060	-0.017	0.111	
OL	19	0.008	0	0.659	0.000	0.008			
RT	79	0.032	3	2.741	0.035	0.032	-0.021	0.091	
SET	823	0.336	31	28.553	0.365	0.336	0.218	0.512	
TET	85	0.035	3	2.949	0.035	0.035	-0.021	0.091	

Veg. type = vegetation type
observed = number of elephant fixes
lower and upper CI = lower and upper Bonferroni confidence intervals
P = Preference.

Table A1.4: Habitat use at a home range and core area level during winter by elephant herd 6 in Kwandwe Private Game Reserve. BKT: bushclump karroid thicket; BS: bushclump savanna; DLT: drainage line thicket; EPM: euporbia portulacaria mosaic; KS: karroid shrubland; MPT: medium portulacaria thicket; OL: old lands; RT: riverine thicket; SET: short euphorbia thicket and TET: tall euphorbia thicket.

Veg type	Total area (ha)	Proportion of total area	Observed	Expected	Observed proportion	Expected proportion	Lower CI	Upper CI	P
ELH 6									
WINTER 95% UD									
BKT	1352	0.171	12	24.607	0.083	0.171	0.018	0.148	-
BS	280	0.035	8	5.096	0.056	0.035	0.002	0.110	
DLT	81	0.010	7	1.474	0.049	0.010	-0.002	0.099	
EPM	1630	0.206	41	29.666	0.285	0.206	0.179	0.391	
KS	1007	0.127	3	18.328	0.021	0.127	-0.013	0.055	-
MPT	349	0.044	11	6.352	0.076	0.044	0.014	0.138	
OL	184	0.023	5	3.349	0.035	0.023	-0.008	0.078	
RT	554	0.070	10	10.083	0.069	0.070	0.010	0.128	
SET	2094	0.265	31	38.111	0.215	0.265	0.119	0.311	
TET	381	0.048	16	6.934	0.111	0.048	0.038	0.184	
WINTER 50% UD									
BKT	141	0.106	2	7.304	0.029	0.106	-0.028	0.086	-
BS	138	0.104	4	7.149	0.058	0.104	-0.021	0.137	
DLT	14	0.011	5	0.725	0.072	0.011	-0.015	0.159	
EPM	341	0.256	27	17.664	0.391	0.256	0.226	0.556	
KS	14	0.011	0	0.725	0.000	0.011	0.000	0.000	-
MPT	85	0.064	6	4.403	0.087	0.064	-0.008	0.102	
OL	4	0.003	0	0.207	0.000	0.003			
RT	59	0.044	0	3.056	0.000	0.044			
SET	318	0.239	11	16.473	0.159	0.239	0.035	0.283	
TET	218	0.164	14	11.293	0.203	0.164	0.067	0.339	

Veg. type = vegetation type
observed = number of elephant fixes
lower and upper CI = lower and upper Bonferroni confidence intervals
P = Preference.

Table A1.5: Habitat use at a home range and core area level during summer by elephant male 1 in Kwandwe Private Game Reserve. BKT: bushclump karroid thicket; BS: bushclump savanna; DLT: drainage line thicket; EPM: euporbia portulacaria mosaic; KS: karroid shrubland; MPT: medium portulacaria thicket; OL: old lands; RT: riverine thicket; SET: short euphorbia thicket and TET: tall euphorbia thicket.

Veg type	total area (ha)	proportion of total area	observed	expected	observed proportion	expected proportion	lower CI	upper CI	P
				ELM 1					
				SUMMER 95% UD					
BKT	2003	0.075	17	8.067	0.159	0.075	0.060	0.258	
BS	555	0.021	2	2.235	0.019	0.021	-0.018	0.056	
DLT	184	0.007	0	0.741	0.000	0.007			
EPM	13089	0.493	21	52.713	0.196	0.493	0.088	0.304	-
KS	2140	0.081	16	8.618	0.150	0.081	0.053	0.247	
MPT	1248	0.047	3	5.026	0.028	0.047	-0.017	0.073	
OL	262	0.010	13	1.055	0.121	0.010	0.033	0.209	+
RT	1603	0.060	6	6.456	0.056	0.060	-0.006	0.118	
SET	3346	0.126	29	13.475	0.271	0.126	0.150	0.392	+
TET	2139	0.081	0	8.614	0.000	0.081			
				SUMMER 50% UD					
BKT	404	0.043	8	1.604	0.216	0.043	0.034	0.398	
BS	0	0.000	0	0.000	0.000	0.000			
DLT	57	0.006	0	0.226	0.000	0.006			
EPM	3828	0.411	5	15.199	0.135	0.411	-0.016	0.286	-
KS	1547	0.166	4	6.142	0.108	0.166	-0.029	0.245	
MPT	143	0.015	1	0.568	0.027	0.015	-0.045	0.099	
OL	81	0.009	6	0.322	0.162	0.009	-0.001	0.325	
RT	374	0.040	3	1.485	0.081	0.040	-0.040	0.202	
SET	2879	0.309	10	11.431	0.270	0.309	0.074	0.466	
TET	6	0.001	0	0.024	0.000	0.001			

Veg. type = vegetation type
observed = number of elephant fixes
lower and upper CI = lower and upper Bonferroni confidence intervals
P = Preference.

Table A1.6: Habitat use at a home range and core area level during winter by elephant male 1 in Kwandwe Private Game Reserve. BKT: bushclump karroid thicket; BS: bushclump savanna; DLT: drainage line thicket; EPM: euporbia portulacaria mosaic; KS: karroid shrubland; MPT: medium portulacaria thicket; OL: old lands; RT: riverine thicket; SET: short euphorbia thicket and TET: tall euphorbia thicket.

Veg type	total area (ha)	proportion of total area	observed	expected	observed proportion	expected proportion	lower CI	upper CI	P
ELM 1									
WINTER 95% UD									
BKT	1965	0.077	16	7.883	0.155	0.077	0.059	0.251	
BS	58	0.002	0	0.233	0.000	0.002			
DLT	189	0.007	4	0.758	0.039	0.007	-0.012	0.090	
EPM	10058	0.392	16	40.351	0.155	0.392	0.059	0.251	-
KS	3525	0.137	27	14.142	0.262	0.137	0.145	0.379	+
MPT	909	0.035	3	3.647	0.029	0.035	-0.015	0.073	
OL	251	0.010	13	1.007	0.126	0.010	0.038	0.214	+
RT	1294	0.050	7	5.191	0.068	0.050	0.001	0.135	
SET	7064	0.275	17	28.340	0.165	0.275	0.067	0.263	-
TET	361	0.014	0	1.448	0.000	0.014			
WINTER 50% UD									
BKT	77	0.009	8	0.266	0.267	0.009	0.054	0.480	+
BS	0	0.000	0	0.000	0.000	0.000			
DLT	0	0.000	0	0.000	0.000	0.000			
EPM	3701	0.426	1	12.787	0.033	0.426	-0.053	0.119	-
KS	2928	0.337	8	10.116	0.267	0.337	0.054	0.480	
MPT	58	0.007	0	0.200	0.000	0.007			
OL	84	0.010	6	0.290	0.200	0.010	0.007	0.393	
RT	1007	0.116	4	3.479	0.133	0.116	-0.031	0.297	
SET	828	0.095	3	2.861	0.100	0.095	-0.045	0.245	
TET	0	0.000	0	0.000	0.000	0.000			

Veg. type = vegetation type
observed = number of elephant fixes
lower and upper CI = lower and upper Bonferroni confidence intervals
P = Preference.

Table A1.7: Habitat use at a home range and core area level during summer by elephant male 2 in Kwandwe Private Game Reserve. BKT: bushclump karroid thicket; BS: bushclump savanna; DLT: drainage line thicket; EPM: euporbia portulacaria mosaic; KS: karroid shrubland; MPT: medium portulacaria thicket; OL: old lands; RT: riverine thicket; SET: short euphorbia thicket and TET: tall euphorbia thicket.

Veg type	total area (ha)	proportion of total area	observed	expected	observed proportion	expected proportion	lower CI	upper CI	P
ELM 2									
SUMMER 95% UD									
BKT	1869	0.101	22	11.990	0.185	0.101	0.085	0.285	
BS	576	0.031	3	3.695	0.025	0.031	-0.015	0.065	
DLT	240	0.013	0	1.540	0.000	0.013			
EPM	7889	0.425	21	50.609	0.176	0.425	0.078	0.274	-
KS	2213	0.119	23	14.197	0.193	0.119	0.091	0.295	
MPT	1173	0.063	6	7.525	0.050	0.063	-0.006	0.106	
OL	266	0.014	4	1.706	0.034	0.014	-0.013	0.081	
RT	863	0.047	8	5.536	0.067	0.047	0.003	0.131	
SET	3071	0.166	31	19.701	0.261	0.166	0.148	0.374	
TET	390	0.021	1	2.502	0.008	0.021	-0.015	0.031	
SUMMER 50% UD									
BKT	1344	0.092	6	3.508	0.158	0.092	-0.006	0.322	
BS	0	0.000	0	0.000	0.000	0.000			
DLT	14	0.001	0	0.037	0.000	0.001			
EPM	5134	0.353	7	13.401	0.184	0.353	0.010	0.358	
KS	5501	0.378	5	14.359	0.132	0.378	-0.020	0.284	-
MPT	102	0.007	0	0.266	0.000	0.007			
OL	221	0.015	1	0.577	0.026	0.015	-0.046	0.098	
RT	633	0.043	3	1.652	0.079	0.043	-0.042	0.200	
SET	1603	0.110	16	4.184	0.421	0.110	0.199	0.643	+
TET	6	0.000	0	0.016	0.000	0.000			

Veg. type = vegetation type
observed = number of elephant fixes
lower and upper CI = lower and upper Bonferroni confidence intervals
P = Preference.

Table A1.8: Habitat use at a home range and core area level during winter by elephant male 2 in Kwandwe Private Game Reserve. BKT: bushclump karroid thicket; BS: bushclump savanna; DLT: drainage line thicket; EPM: euporbia portulacaria mosaic; KS: karroid shrubland; MPT: medium portulacaria thicket; OL: old lands; RT: riverine thicket; SET: short euphorbia thicket and TET: tall euphorbia thicket.

Veg type	total area (ha)	proportion of total area	observed	expected	observed proportion	expected proportion	lower CI	upper CI	P
ELM 2									
WINTER 95% UD									
BKT	1390	0.034	32	4.446	0.248	0.034	0.141	0.355	+
BS	850	0.021	1	2.719	0.008	0.021	-0.014	0.030	
DLT	202	0.005	6	0.646	0.047	0.005	-0.005	0.099	
EPM	17078	0.423	20	54.620	0.155	0.423	0.066	0.244	-
KS	12753	0.316	17	40.788	0.132	0.316	0.048	0.216	-
MPT	1060	0.026	3	3.390	0.023	0.026	-0.014	0.060	
OL	140	0.003	3	0.448	0.023	0.003	-0.014	0.060	
RT	1669	0.041	13	5.338	0.101	0.041	0.027	0.175	
SET	4802	0.119	30	15.358	0.233	0.119	0.129	0.337	+
TET	390	0.010	4	1.247	0.031	0.010	-0.012	0.074	
WINTER 50% UD									
BKT	761	0.228	15	10.731	0.319	0.228	0.136	0.502	
BS	0	0.000	0	0.000	0.000	0.000			
DLT	0	0.000	0	0.000	0.000	0.000			
EPM	282	0.085	8	3.977	0.170	0.085	0.023	0.317	
KS	55	0.017	3	0.776	0.064	0.017	-0.032	0.160	
MPT	15	0.005	0	0.212	0.000	0.005			
OL	8	0.002	1	0.113	0.021	0.002	-0.035	0.077	
RT	723	0.217	3	10.195	0.064	0.217	-0.032	0.160	-
SET	1489	0.447	17	20.997	0.362	0.447	0.173	0.551	
TET	0	0.000	0	0.000	0.000	0.000			

Veg. type = vegetation type
observed = number of elephant fixes
lower and upper CI = lower and upper Bonferroni confidence intervals
P = Preference.

Table A1.9: Habitat use at a home range and core area level during summer by elephant male 3 in Kwandwe Private Game Reserve. BKT: bushclump karroid thicket; BS: bushclump savanna; DLT: drainage line thicket; EPM: euporbia portulacaria mosaic; KS: karroid shrubland; MPT: medium portulacaria thicket; OL: old lands; RT: riverine thicket; SET: short euphorbia thicket and TET: tall euphorbia thicket.

Veg type	total area (ha)	proportion of total area	observed	expected	observed proportion	expected proportion	lower CI	upper CI	P
ELM 3									
SUMMER 95% UD									
BKT	1941	0.075	12	6.789	0.133	0.075	0.034	0.232	
BS	302	0.012	4	1.056	0.044	0.012	-0.016	0.104	
DLT	325	0.013	0	1.137	0.000	0.013			
EPM	13436	0.522	21	46.997	0.233	0.522	0.109	0.357	-
KS	2570	0.100	12	8.990	0.133	0.100	0.034	0.232	
MPT	1053	0.041	6	3.683	0.067	0.041	-0.006	0.140	
OL	266	0.010	2	0.930	0.022	0.010	-0.021	0.065	
RT	1244	0.048	10	4.351	0.111	0.048	0.019	0.203	
SET	4210	0.164	20	14.726	0.222	0.164	0.101	0.343	
TET	383	0.015	3	1.340	0.033	0.015	-0.019	0.085	
SUMMER 50% UD									
BKT	1085	0.152	10	6.537	0.233	0.152	0.067	0.399	
BS	0	0.000	0	0.000	0.000	0.000			
DLT	4	0.001	0	0.024	0.000	0.001			
EPM	1932	0.271	10	11.640	0.233	0.271	0.067	0.399	
KS	214	0.030	0	1.289	0.000	0.030			
MPT	83	0.012	4	0.500	0.093	0.012	-0.021	0.207	
OL	145	0.020	0	0.874	0.000	0.020			
RT	729	0.102	5	4.392	0.116	0.102	-0.010	0.242	
SET	2940	0.412	14	17.713	0.326	0.412	0.142	0.510	
TET	5	0.001	0	0.030	0.000	0.001			

Veg. type = vegetation type
observed = number of elephant fixes
lower and upper CI = lower and upper Bonferroni confidence intervals
P = Preference.

Table A1.10: Habitat use at a home range and core area level during winter by elephant male 3 in Kwandwe Private Game Reserve. BKT: bushclump karroid thicket; BS: bushclump savanna; DLT: drainage line thicket; EPM: euporbia portulacaria mosaic; KS: karroid shrubland; MPT: medium portulacaria thicket; OL: old lands; RT: riverine thicket; SET: short euphorbia thicket and TET: tall euphorbia thicket.

Veg type	total area (ha)	proportion of total area	observed	expected	observed proportion	expected proportion	lower CI	upper CI	P
ELM 3									
WINTER 95% UD									
BKT	1664	0.066	32	9.568	0.219	0.066	0.123	0.315	+
BS	915	0.036	2	5.261	0.014	0.036	-0.013	0.041	
DLT	140	0.006	5	0.805	0.034	0.006	-0.008	0.076	
EPM	6108	0.241	21	35.121	0.144	0.241	0.062	0.226	-
KS	6332	0.249	19	36.409	0.130	0.249	0.052	0.208	-
MPT	978	0.039	9	5.624	0.062	0.039	0.006	0.118	
OL	260	0.010	11	1.495	0.075	0.010	0.014	0.136	+
RT	1762	0.069	20	10.132	0.137	0.069	0.057	0.217	
SET	6486	0.255	26	37.295	0.178	0.255	0.089	0.267	
TET	746	0.029	1	4.290	0.007	0.029	-0.012	0.026	-
WINTER 50% UD									
BKT	1031	0.091	18	7.092	0.231	0.091	0.103	0.359	+
BS	0	0.000	0	0.000	0.000	0.000			
DLT	23	0.002	0	0.158	0.000	0.002			
EPM	4895	0.432	3	33.672	0.038	0.432	-0.020	0.096	-
KS	2498	0.220	16	17.184	0.205	0.220	0.082	0.328	
MPT	250	0.022	5	1.720	0.064	0.022	-0.011	0.139	
OL	202	0.018	6	1.390	0.077	0.018	-0.004	0.158	
RT	1090	0.096	17	7.498	0.218	0.096	0.092	0.344	
SET	1350	0.119	13	9.287	0.167	0.119	0.053	0.281	
TET	0	0.000	0	0.000	0.000	0.000			

Veg. type = vegetation type
observed = number of elephant fixes
lower and upper CI = lower and upper Bonferroni confidence intervals
P = Preference.

Table A1.11: Habitat use at a home range and core area level during summer by elephant male 4 in Kwandwe Private Game Reserve. BKT: bushclump karroid thicket; BS: bushclump savanna; DLT: drainage line thicket; EPM: euporbia portulacaria mosaic; KS: karroid shrubland; MPT: medium portulacaria thicket; OL: old lands; RT: riverine thicket; SET: short euphorbia thicket and TET: tall euphorbia thicket.

Veg type	total area (ha)	proportion of total area	observed	expected	observed proportion	expected proportion	lower CI	upper CI	P
ELM 4									
SUMMER 95% UD									
BKT	1708	0.099	6	6.457	0.092	0.099	-0.007	0.191	
BS	359	0.021	1	1.357	0.015	0.021	-0.027	0.057	
DLT	327	0.019	0	1.236	0.000	0.019			
EPM	5491	0.319	17	20.759	0.262	0.319	0.111	0.413	
KS	2156	0.125	6	8.151	0.092	0.125	-0.007	0.191	
MPT	1192	0.069	4	4.506	0.062	0.069	-0.021	0.145	
OL	235	0.014	3	0.888	0.046	0.014	-0.026	0.118	
RT	1633	0.095	9	6.174	0.138	0.095	0.019	0.257	
SET	3714	0.216	18	14.041	0.277	0.216	0.123	0.431	
TET	378	0.022	1	1.429	0.015	0.022	-0.027	0.057	
SUMMER 50% UD									
BKT	1589	0.142	3	3.841	0.111	0.142	-0.052	0.274	
BS	0	0.000	0	0.000	0.000	0.000			
DLT	4	0.000	0	0.010	0.000	0.000			
EPM	2976	0.266	6	7.193	0.222	0.266	0.007	0.437	
KS	1286	0.115	3	3.108	0.111	0.115	-0.052	0.274	
MPT	166	0.015	2	0.401	0.074	0.015	-0.062	0.210	
OL	97	0.009	1	0.234	0.037	0.009	-0.061	0.135	
RT	840	0.075	2	2.030	0.074	0.075	-0.062	0.210	
SET	4208	0.377	10	10.171	0.370	0.377	0.120	0.620	
TET	5	0.000	0	0.012	0.000	0.000			

Veg. type = vegetation type
observed = number of elephant fixes
lower and upper CI = lower and upper Bonferroni confidence intervals
P = Preference.

Table A1.12: Habitat use at a home range and core area level during winter by elephant male 4 in Kwandwe Private Game Reserve. BKT: bushclump karroid thicket; BS: bushclump savanna; DLT: drainage line thicket; EPM: euporbia portulacaria mosaic; KS: karroid shrubland; MPT: medium portulacaria thicket; OL: old lands; RT: riverine thicket; SET: short euphorbia thicket and TET: tall euphorbia thicket.

Veg type	total area	proportion of total area	observed	expected	observed proportion	expected proportion	lower CI	upper CI	P
ELM 4									
WINTER 95% UD									
BKT	2551	0.116	20	8.787	0.263	0.116	0.121	0.405	+
BS	302	0.014	2	1.040	0.026	0.014	-0.025	0.077	
DLT	240	0.011	3	0.827	0.039	0.011	-0.023	0.101	
EPM	6416	0.291	14	22.101	0.184	0.291	0.059	0.309	
KS	6261	0.284	11	21.567	0.145	0.284	0.032	0.258	-
MPT	555	0.025	5	1.912	0.066	0.025	-0.014	0.146	
OL	235	0.011	3	0.810	0.039	0.011	-0.023	0.101	
RT	1642	0.074	4	5.656	0.053	0.074	-0.019	0.125	
SET	3471	0.157	12	11.956	0.158	0.157	0.041	0.275	
TET	390	0.018	2	1.343	0.026	0.018	-0.025	0.077	
WINTER 50% UD									
BKT	1190	0.157	5	3.937	0.200	0.157	-0.015	0.415	
BS	0	0.000	0	0.000	0.000	0.000			
DLT	35	0.005	1	0.116	0.040	0.005	-0.065	0.145	
EPM	3189	0.422	4	10.550	0.160	0.422	-0.037	0.357	-
KS	446	0.059	7	1.475	0.280	0.059	0.038	0.522	
MPT	180	0.024	4	0.595	0.160	0.024	-0.037	0.357	
OL	0	0.000	0	0.000	0.000	0.000			
RT	238	0.031	2	0.787	0.080	0.031	-0.066	0.226	
SET	2279	0.302	2	7.539	0.080	0.302	-0.066	0.226	-
TET	0	0.000	0	0.000	0.000	0.000			

Veg. type = vegetation type
observed = number of elephant fixes
lower and upper CI = lower and upper Bonferroni confidence intervals
P = Preference.

APPENDIX B

DETAILS OF HABITAT USE BY ELEPHANTS ON SHAMWARI

Table B1.1: Habitat use at a home range and core area level during summer by the elephant herds on Shamwari Private Game Reserve. AF: afromontane forest; B: bontveld; BS: bushclump savanna; CL: cleared lands; CUL: cultivated lands; MG: montane grassland; OG: open grassland; PAT: primary acacia thicket; RT: riverine thicket; SAT: secondary acacia thicket; ST: subtropical thicket.

Veg type	Total area (ha)	Proportion of total area	Observed	Expected	Observed proportion	Expected proportion	Lower CI	Upper CI	P
				SUMMER 95% UD					
AF	5	0.000	1	0.164	0.002	0.000	-0.004	0.008	
B	486	0.041	4	17.660	0.009	0.041	-0.004	0.022	-
BS	227	0.019	4	8.236	0.009	0.019	-0.004	0.022	
CL	134	0.011	15	4.879	0.035	0.011	0.010	0.060	
CUL	1476	0.126	71	53.648	0.167	0.126	0.116	0.218	
MG	1279	0.109	15	46.495	0.035	0.109	0.010	0.060	-
OG	572	0.049	1	20.792	0.002	0.049	-0.004	0.008	-
PAT	774	0.066	56	28.129	0.131	0.066	0.085	0.177	
RT	361	0.031	33	13.121	0.077	0.031	0.040	0.114	+
SAT	238	0.020	42	8.636	0.099	0.020	0.058	0.140	+
ST	6169	0.526	184	224.241	0.432	0.526	0.364	0.500	-
				SUMMER 50% UD					
AF	0	0.000	0	0.000	0.000	0.000			
B	0	0.000	0	0.000	0.000	0.000			
BS	0	0.000	0	0.000	0.000	0.000			
CL	0	0.000	0	0.000	0.000	0.000			
CUL	1198	0.143	1	21.580	0.007	0.143	-0.011	0.025	-
MG	48	0.006	0	0.860	0.000	0.006	0.000	0.000	
OG	0	0.000	0	0.000	0.000	0.000			
PAT	789	0.094	45	14.205	0.298	0.094	0.200	0.396	
RT	361	0.043	27	6.502	0.179	0.043	0.097	0.261	
SAT	292	0.035	30	5.254	0.199	0.035	0.113	0.285	
ST	5695	0.679	48	102.598	0.318	0.679	0.218	0.418	

Veg. type = vegetation type
observed = number of elephant fixes
lower and upper CI = lower and upper Bonferroni confidence intervals
P = Preference.

Table B1.2: Habitat use at a home range and core area level during winter by the elephant herds on Shamwari Private Game Reserve. AF: afromontane forest; B: bontveld; BS: bushclump savanna; CL: cleared lands; CUL: cultivated lands; MG: montane grassland; OG: open grassland; PAT: primary acacia thicket; RT: riverine thicket; SAT: secondary acacia thicket; ST: subtropical thicket.

Veg type	Total area (ha)	Proportion of total area	Observed	Expected	Observed proportion	Expected proportion	Lower CI	Upper CI	P
				WINTER 95% UD					
AF	0	0.000	0	0.000	0.000	0.000			
B	486	0.045	6	13.735	0.020	0.045	-0.002	0.042	-
BS	102	0.010	3	2.890	0.010	0.010	-0.006	0.026	
CL	121	0.011	7	3.415	0.023	0.011	-0.001	0.047	
CUL	1328	0.123	62	37.534	0.204	0.123	0.140	0.268	+
MG	1576	0.147	16	44.567	0.053	0.147	0.017	0.089	-
OG	0	0.000	0	0.000	0.000	0.000			
PAT	765	0.071	39	21.625	0.128	0.071	0.075	0.181	+
RT	375	0.035	14	10.612	0.046	0.035	0.013	0.079	
SAT	244	0.023	35	6.897	0.115	0.023	0.064	0.166	+
ST	5755	0.535	122	162.724	0.401	0.535	0.323	0.479	-
				WINTER 50% UD					
AF	0	0.000	0	0.000	0.000				
B	0	0.000	0	0.000	0.000				
BS	0	0.000	0	0.000	0.000				
CL	107	0.013	8	1.601	0.067	0.013	0.006	0.128	
CUL	1025	0.128	17	15.379	0.142	0.128	0.056	0.228	
MG	48	0.006	0	0.716	0.000	0.006			
OG	0	0.000	0	0.000	0.000				
PAT	550	0.069	27	8.256	0.225	0.069	0.122	0.328	+
RT	361	0.045	8	5.413	0.067	0.045	0.006	0.128	
SAT	215	0.027	26	3.219	0.217	0.027	0.116	0.318	+
ST	5695	0.712	34	85.416	0.283	0.712	0.172	0.394	-

Veg. type = vegetation type
observed = number of elephant fixes
lower and upper CI = lower and upper Bonferroni confidence intervals
P = Preference.

APPENDIX C

DETAILS OF THE TUKEY'S HSD TEST ON THE EFFECT OF PLANT SPECIES AND ELEPHANT DENSITY IN SHAMWARI

Table C1.1: The effect of plant species and elephant density areas on mean damage scores in subtropical thicket on Shamwari. AF: *Aloe ferox*, PA: *Portulacaria afra*, SA: *Schotia afra*, AT: *Azima tetracantha*, R: *Rhus* spp., GB: *Gymnosporia* spp., CS: *Capparis sepiaria*.

#	Spp.	Density	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	AF	50% UD		0.1322	***0.0001***	***0.0002***	***0.0001***	***0.0001***	***0.0001***	***0.0001***	***0.0001***	***0.0001***	***0.0001***	***0.0001***	***0.0001***	***0.0001***
2		95% UD			***0.0039***	0.2021	***0.0091***	***0.0302***	***0.0001***	***0.0002***	***0.0001***	***0.0003***	***0.0001***	***0.0003***	***0.0002***	***0.0001***
3	PA	50% UD	***0.0001***	***0.0039***		0.9904	1.0000	1.0000	0.2043	0.9448	0.1380	0.9938	0.2757	0.9840	0.9579	0.5072
4		95% UD	***0.0002***	0.2021	0.9904		0.9996	0.9999	***0.0137***	0.2605	***0.0081***	0.5324	***0.0177***	0.4769	0.3414	0.0518
5	SA	50% UD	***0.0001***	***0.0090***	1.0000	0.9996		1.0000	0.0709	0.7319	***0.0434***	0.9345	0.0939	0.8954	0.7990	0.2332
6		95% UD	***0.0001***	***0.0301***	1.0000	0.9999	1.0000		0.1217	0.8110	0.0807	0.9514	0.1669	0.9187	0.8478	0.3332
7	AT	50% UD	***0.0001***	***0.0001***	0.2043	***0.0137***	0.0709	0.1217		0.9631	1.0000	0.9500	1.0000	0.9888	0.9907	0.9999
8		95% UD	***0.0001***	***0.0001***	0.9448	0.2605	0.7319	0.8110	0.9631		0.9156	1.0000	0.9929	1.0000	1.0000	0.9996
9	R	50% UD	***0.0001***	***0.0001***	0.1381	***0.0081***	***0.0435***	0.0807	1.0000	0.9156		0.8991	0.9999	0.9707	0.9737	0.9999
10		95% UD	***0.0001***	***0.0003***	0.9938	0.5324	0.9345	0.9514	0.9500	1.0000	0.8991		0.9874	1.0000	1.0000	0.9989
11	GB	50% UD	***0.0001***	***0.0001***	0.2757	***0.0177***	0.0939	0.1669	1.0000	0.9929	0.9999	0.9874		0.9986	0.9990	1.0000
12		95% UD	***0.0001***	***0.0003***	0.9841	0.4769	0.8955	0.9187	0.9888	1.0000	0.9707	1.0000	0.9986		1.0000	0.9999
13	CS	50% UD	***0.0001***	***0.0001***	0.9579	0.3414	0.7990	0.8478	0.9907	1.0000	0.9737	1.0000	0.9990	1.0000		0.9999
14		95% UD	***0.0001***	***0.0001***	0.5072	0.0518	0.2333	0.3332	0.9999	0.9996	0.9999	0.9989	1.0000	0.9999	0.9999	