White rhinoceros populations in the Eastern Cape: distribution, performance and diet

By

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ABSTRACT

White rhino populations did not occur historically in the Eastern Cape, South Africa (Skead 2007). They have, however, been introduced into a number of reserves within the Eastern Cape for reasons such as conservation, ecotourism and hunting. Based on the literature on the species, it was hypothesized that white rhinoceros would have been introduced in grass-rich habitats, as they are bulk grazers. White rhinoceros populations were further assessed in terms of population establishment by outlining their distribution and performance since introductions and this was done by extracting intercalving intervals from the literature of native populations and comparing such to the Eastern Cape intercalving intervals, extracted from data obtained from landowners. Finally, the diet of white rhinoceros was quantified, in order to identify plant species potentially at risk from white rhino herbivory using Shamwari Private Game Reserve as a study site. The distribution of white rhino in the Eastern Cape varies in terms of habitat and vegetation types. The majority (62%) of white rhino are located in grass-poor habitats and are primarily there for ecotourism purposes with only a small percentage kept for conservation purposes in the state reserves. Limited data for intercalving intervals of the white rhino in Eastern Cape are comparable to those of populations in the natural range. The *ex situ* conservation of white rhino in the Eastern Cape proved to be a success as population numbers have increased markedly since the first survey was conducted (Buijs 1999). The diet section of this study showed that white rhino are highly selective grazers even in a grass-limiting habitat which is dominated by browse. Twenty-five principal dietary items were identified in their diet, with only six being preferred in autumn. These are thus the plant species that could be the most vulnerable to white rhino herbivory. Supplementary food provision plays a big part of the feeding scheme of white rhino in Shamwari Private Game Reserve during the winter season, revealing the little confidence that the management has on natural resource availability to the animals at this time. These findings support the value of the Eastern Cape for *ex situ* conservation of white rhino, and highlight plant species potentially at risk. There is a need for further research on the population performance of these animals, and the plants identified here need to be monitored to assess white rhino impact on the vegetation.

Keywords: White rhino, population performance, *ex situ* conservation, Eastern Cape, distribution, diet, impacts

CHAPTER 1
GENERAL INTRODUCTION

1.1 Background to the southern subspecies of white rhinoceros

The white rhinoceros, also commonly known as the square-lipped rhino because of the shape of the mouth, occurs as two subspecies namely, the northern subspecies *Ceratotherium simum cottoni* and the southern subspecies *Ceratotherium simum simum* (Schwazenberger *et al*. 1998). The latter subspecies is the study animal. It was on the brink of extinction at the beginning of the 20th century, having been reduced to just one small population of about 50 individuals in KwaZulu Natal, South Africa (Owen-Smith 1988). Lang (1924) suggested that farmers had a hand in attempts to wipe out the population, this would serve their primary motives best to obtain land set aside for the animals. However, after years of protection and translocations, numbers of white rhino had grown to over 8440, about a decade ago (Emslie & Brooks 1999; Emslie *et al*. 2009). It is currently the most abundant subspecies of all rhinoceros taxa and its recovery has been recognised as one of the world's greatest international conservation successes (Emslie & Brooks 1999; Slotow *et al*. 2001).

1.2 Introduction to *ex situ* conservation

The translocation of *C. s. simum* can be seen as *ex situ* conservation or the introduction of alien species with all of the attendant problems that they bring. This dissertation addresses these issues using the white rhino into the Eastern Cape as a case study.

White rhinoceros did not occur historically in the Eastern Cape Province (Skead 2007). However, they have been introduced into the Eastern Cape in state-run reserves and on private land starting in 1967 (Shrader 2006). White rhino have been introduced into the Eastern Cape for various reasons, including conservation, ecotourism and hunting (Sims-Castley *et al*. 2004). The habitats into which these introductions have occurred range from Karoo to Thicket and include grasslands (O'Brien 2004). The Eastern Cape therefore potentially contributes towards the *ex situ* conservation of the species. As a megaherbivore and a specialist grazer (Owen-Smith 1974; 1988), it is postulated that this species will alter the dynamics of grass communities at these sites. Alternatively, the paucity of grass at most sites may be limiting to these populations, thereby compromising the contribution to *ex situ* conservation. All these Eastern Cape white rhino populations are fenced and managed, and hence although this species cannot be considered to be invasive in the conventional sense, the economic value that they represent (Sims-Castley *et al*. 2004) leads to additional white rhino populations being established, increasing the area occupied by this species.

The spread of white rhino populations can therefore be considered to be a subsidised invasive extra-limital species, with ongoing invasion achieved through human intervention. The interventions might be indirect but still result in facilitated impacts which could pose management problems (Chown *et al*. 2009). Introductions of extra-limital species are apparently mainly encouraged for tourism (Smith & Wilson 2002; Spear & Chown 2008). Tourism is a fast growing industry in many countries world wide, as well as in South Africa (Kepe 2001), and it boosts the economy of the country. The role played by tourism and the economic incentives gained through introducing extra-limital species is clearly documented in Castley *et al*. (2001) and Spear & Chown (2008). In contrast, Boshoff *et al*. (2008) showed that extra-limital species are considered undesirable by a significant portion (70%) of the visitors to a South African National Park.

Despite the ongoing conservation concerns about the low numbers of white rhino and efforts such as breeding strategies for this species, it continues to grow in numbers and distribution (IUCN 2008). The IUCN states that it is a "Near Threatened" species (IUCN 2008). Nevertheless, there is very little information on the establishment, population dynamics or impact on resources by white rhino in the Eastern Cape. This is surprising considering the fact that the species was at the brink of extinction a few decades ago (Emslie & Brooks 1999). Some surveys have been conducted to keep track of their performance since introductions took place (Buijs 2000; Castley & Hall-Martin 2003). However, there has been a paucity of such data and publications for the past 6 years. It is therefore clear that white rhino serve as an ideal model of a species that is both conserved *ex situ* and may be considered an extra-limital species, with many of the attendant concerns. Some of the questions relevant to these concepts will therefore be addressed in this dissertation.

1.3 Translocation

The success, increase of population numbers and distribution of *C*. *s*. *simum* was achieved through managed breeding strategies and translocations from the former Umfolozi Game Reserve (now Hluhluwe-iMfolozi Park) in KwaZulu Natal to various regions within South Africa and other neighbouring states (Emslie & Brooks 1999; Emslie *et al*. 2009). The first translocation of white rhinoceros took place in the early 1960s and a large number of those rhinoceroses were translocated to the Kruger National Park from Umfolozi Game Reserve (Emslie *et al*. 2009). The first introduction in the Eastern Cape of white rhinos was to a state reserve, this occurred in June 1967 (Anonymous 1967). Subsequently, introductions to the private properties picked up only in the early 1990s (current study).

Translocations in or outside natural range should occur to high quality habitats (Griffith *et al*. 1989), hence our hypothesis stating that white rhinoceros translocations should be limited to grass-rich habitats, because they are specialized bulk grazers. In addition, translocations have been widely used to establish new populations in non-native regions (Griffith *et al*. 1989; Spear & Chown 2008). Emslie (in press) documents the first indication that some white rhinos have probably been introduced into unsuitable habitats.

Translocation has been applied as a tool to conserve species (Ricciardi & Simberloff 2008; Armstrong & Seddon 2008) but it is also a tool that drives the ecotourism and hunting industry (Castley *et al*. 2001; Emslie *et al*. 2009). This amounts to translocation of species for commercial purposes (Austin 2004). It was initially developed as a tool to reintroduce species into areas of their native range from which they had been lost (Armstrong & Seddon 2008) thereby conserving them, but that is no longer the case as more species are being introduced in non-native areas, hence, the term “planned invasions” (Ricciardi & Simberloff 2008). A practical example of a “planned invasion” can be seen in the introduction of the southern white rhino into Uganda instead of the indigenous northern subspecies (Emslie *et al*. 2009). Subsequently, Ricciardi & Simberloff (2008) raised concerns of translocating organisms for the good of conservation which could result in more conservation problems than anticipated.

Moreover, a classic example of an intentional introduction of the wrong species is documented by Nyafu (2009). She showed that a non-indigenous species of warthog was introduced into the Eastern Cape, South Africa. Warthog numbers have grown and spread in the Eastern Cape and are thus regarded as invasive (Nyafu 2009). In addition, Ricciardi & Simberloff (2008) noted that a number of journals, conferences and organisations are in support of the so-called "planned invasions" as a means of responding to the threats posed on biodiversity through extinctions, despite the dangers posed by introduced species to new habitats.

Austin (2004) documented that little planning goes into many translocation programs. The impacts of introducing non-indigenous species can be economic and ecological (Rozenzweig 2001; Lodge & Shrader-Frechette 2003). Every introduction of a non-indigenous species results in some form of change to the receiving ecosystem, mostly negative impacts, therefore reducing native biodiversity (Shea & Chesson 2002). Furthermore, the quality of the habitat directly influences the success rate of the introduced species (Griffith *et al*. 1989). Consequently, the growth rate of a recently introduced population is influenced by resource quality and quantity, natural predators and the physical environment (Shea & Chesson 2002). However, some species have broad environmental tolerances (Shea & Chesson 2002), which increases their chances of survival in the new habitat. Translocation can be considered successful only if it results in the established population being self-sustaining and persisting in the new environment (Griffith *et al*. 1989).

White rhinoceroses currently have a broader range than occurred historically as a consequence of such translocations (Emslie *et al*. 2009). In the light of these events, it is disappointing that there has been little research to document the contribution of introductions and translocations, and their impacts in the respective recipient regions (Spear & Chown 2009).

1.4 *Ex situ* conservation

A whole range of terms exist describing and defining species living outside their natural range, namely exotic, introduced, non-indigenous or non-native species (D'Antonio *et al*. 2001). These can apply to both plants and animals. Ricciardi & Simberloff (2008) have however, referred to the introduction of extra-limital species as the so-called "planned invasions". Humans and their activities have been a major vector of non-indigenous species introductions (D'Antonio *et al*. 2001). Some species invasions are a natural process (Lodge & Shrader-Frechette 2003). The introduction of species beyond their natural distribution is rated as the second most important factor leading to biological diversity loss (Caughley 1994; Mettermeier & Forsyth 1997). Loss of biological diversity, species extinctions and ecosystem degradations are a consequence of invasive species. Such events have increased with increased human population (vectors of alien species) (Lodge & Shrader-Frechette 2003). Moreover, invasions do not occur overnight but, is generally a slow process which if not identified and controlled, ultimately results in large numbers of invasive species which are difficult to control, if not totally uncontrollable (Lowe *et al*. 2000). However, Rosenzweig (2001) stressed the fact that non-indigenous species may not necessarily result in species biodiversity loss or even extinction, but may have other repercussions on the ecosystem functioning that warn humans of their impacts as invasive species vectors.

Ex situ conservation strategies have been developed for the sole purpose of conserving species (Emmerson & O'Farrell 1993). Moreover, *ex situ* conservation strategies should be considered as tools that ensure the survival of wild populations of a particular species (IUCN 2002). Large mammals have benefited from this type of conservation strategy (Emmerson & O'Farrell 1993). Shortcomings have been observed nonetheless from this technique, as it is not simple due to the financial, biological and political costs which it poses (Emmerson & O'Farrell 1993). The IUCN (2002) states that the only time

ex situ conservation strategies can be considered is when the species is threatened by natural catastrophes, political and social imbalances etc., within its natural range.
The idea that white rhino populations have been established outside of their natural distribution may have negative implications for these populations, as has been reported the case with most *ex situ* conservation attempts (Novellie & Knight 1994). D'Antonio *et al*. (2001) postulated that most exotic species do not succeed in their newly established habitats, primarily because of unsuitable habitats (Griffith *et al*. 1989). Large mammals, however, have a high probability of successful invasions but as a consequence of large body size (and hence slow life-history process), it takes longer for introduction success to be scientifically assessed (Forsyth & Duncan 2001). A suite of factors contribute towards the success of introduced species, such as introduction into suitable habitat, lack of predation and competition (Griffith *et al*. 1989). Introduction success depends on the number of individuals introduced and sex ratio, thus species introduction in small numbers are unlikely to succeed (Griffith *et al*. 1989). The success of white rhino populations in the Eastern Cape might also be governed by the above mentioned factors.

South African high biodiversity regions such as the Cape Floristic Region and Maputaland-Pondoland Albany hotspots are the ones most affected by invasive species, particularly due to human influence (Richardson *et al*. 2005; Mucina & Rutherford 2006). The Eastern Cape is the most biodiverse province in South Africa at the biome level (Mucina & Rutherford 2006). A concern arises on whether white rhino can be well established and survive in their new habitats in the Eastern Cape which has a range of biomes (within which the species has been introduced). Given their specialized grazing habits, it can be inferred that grasslands and savannas would be the preferred habitats for white rhino, but the Eastern Cape is Thicket habitat dominated. Player & Feely (1960) were the first to raise conservation and management concerns and implications of moving white rhino beyond their natural environment and stressed the need for maintaining the natural habitat and basic requirements of the animals as close as possible to the natural range.

1.5 Hunting and poaching of white rhinoceros in South Africa

South Africa is by far the leading country as far as trophy hunting is concerned (Lang 1924; Damm 2005; Lindsey *et al*. 2007), with over 60 mammalian species offered for hunts (Damm 2005). Subsequently, South Africa generates a lot of revenue out of these hunting activities hence the large number of hunters from abroad coming into the country specifically for this purpose (Lang 1924; Damm 2005; Lindsey *et al*. 2007). The Eastern Cape alone contributes about 40% of the total country's wildlife revenue (Damm 2005). This type of revenue is achieved through rhino hunting and auctions which contribute much needed revenue towards state and private sectors (Emslie in press). However, such events lead to the male female ratio imbalance as males are the preferred sex to hunt (Castley & Hall-Martin 2003).

South Africa is one of two southern African countries that permit trophy hunts of both black and white rhinos (Lindsey *et al*. 2007). Both these species have high conservation status, especially the black rhino (*Diceros bicornis*) which is "Critically Endangered" according to the IUCN red list criteria and category (IUCN 2009). Permits are required for rhino ownership and hunts (Damm 2008). There are also ethics associated with trophy hunting which do not have much to do with conservation matters, but influence the way the public perceive such an activity (Lindsey *et al*. 2007).

Despite their charisma and size (Berger 1994), megaherbivores are under threat due to human predation (Richardson *et al*. 2005). One primary cause hindering the growth of rhino populations is the issue of security (Emslie in press), as it results in a decline of population numbers after attacks by poachers. In addition, if population growth is low then the chances of the population resisting poaching outbreaks would also be minimal, compromising its persistence (Emslie in press). Trading rhino for their horn is therefore a key threat to their persistence (Talukdar 2003). There has been an increase in the poaching of both black and white rhinos in southern Africa (Anonymous 2010). In addition, 248 rhinos have been poached in southern Africa between the years 2005 to 2009 (Anonymous 2010).

1.6 White rhinoceros as grazing megaherbivores

White rhinos are megaherbivores (Owen-Smith 1988) which prefer to feed in areas of short grass habitats, to which they are suited by their wide mouths and low slung heads, and in so doing also act as important ecosystem modifiers (Waldram *et al*. 2008). The change of land-use from commercial pastoralism to wildlife ventures is a common trend in southern Africa (Barnes & de Jager 1995; Smith & Wilson 2002). In the Eastern Cape a number of private reserves are situated in previously farmed land (O'Brien 2004), and accommodate a variety of wildlife. Most of these areas have been identified as unsuitable for bulk grazers such as white rhino (Emslie in press) because of their lack of grass. The impact of white rhinos on vegetation is evident (Owen-Smith 1981) because they change and maintain short grass communities and denude soil surfaces (Owen-Smith 1988; Waldram *et al*. 2008). Thus, they encourage plant species invasions (Owen-Smith 1987). Such an impact could result in a change in landscape and limiting resources.

1.7 Project hypotheses and research approach

The establishment and the distribution of white rhino populations in the Eastern Cape have not been properly documented. As an extra-limital species, it is imperative to follow up on the populations in terms of performance, distribution and dietary composition. The current project has therefore focussed on the following hypotheses:

H_1: The distribution of white rhinoceros in the Eastern Cape will be limited to grassy habitats in order to provide the forage resources.

The project firstly documented the establishment of such populations, and mapped their distribution, addressing the first hypothesis that they should be limited to grass rich habitats. This was done by approaching land owners, inspecting the permit system and getting feedback from conservation authorities and thereby locating rhino populations within the Eastern Cape. White rhino distribution was mapped in relation to the eight biomes of the Eastern Cape and the grassiness of the habitat occupied assessed.

H_2: The performance of *ex situ* white rhino populations in the Eastern Cape will be lower than that within their natural distribution range.

The project attempted to collect population records for Eastern Cape white rhino populations, such as those in state reserves, and private reserves, as well as hunting operations, in order to assess the performance of such populations in relation to such measures for the Hluhluwe-iMfolozi Park population. This addresses the second hypothesis that the population performance of white rhino in the Eastern Cape is lower than that in their natural range by extracting performance (births, deaths) data and compared it with the KwaZulu Natal populations. Hluhluwe-iMfolozi Park is well known as the place where the last of the nearly extinct population of white rhino persisted (Slotow *et al*. 2001). Furthermore, the project looked at the motives behind the introduction and management of white rhino in order to assess the role of human intervention in this population spread, as well as the possible economic incentives for them.

In addition to these hypotheses, the project asked the question:

What are the plants at risk due to white rhino grazing?

Third, the project quantified the diet of white rhino at a site within the Eastern Cape (Shamwari Private Game Reserve) in order to collect preliminary data on plants potentially at risk due to white rhino herbivory. This was done by measuring vegetation cover as a measure of availability and collecting faecal samples that were later analysed in the laboratory using the microhistological analysis technique.

CHAPTER 2
STUDY SITES AND SPECIES

2.1. Description of the study sites

2.1.1 Eastern Cape

The study was conducted on a number of private reserves, private properties and state reserves throughout the Eastern Cape Province, South Africa (Figure 2.1). The sites (N = 33) with white rhinoceros were selected on the basis of having ownership or the presence of white rhinoceros. Here an overview of the climate and vegetation of the Eastern Cape is provided, as well as a more focused description of Shamwari Private Game Reserve, which served as a study site for the diet section of the study.

2.1.2 Climate, Topography and Geology

Topographical differences and geographic variations are the cause of climatic differences and conditions experienced by the towns and cities within the Eastern Cape (DEAT 2004). Coastal areas experience average daily temperatures between 14 and 23^{o}C, while inland areas experience temperatures of -5 to 35^{o}C, depending upon season (DEAT 2004).

Bruton & Gess (1988) dealt with a part of the Eastern Cape, setting their boundaries between the Great Kei river, the Kromme-Gamtoos river and the Sneeuberg-Winterberg escarpment. Temperatures in the Eastern Cape according to Bruton & Gess (1988) range from minimum of 10^{o}C to maximum of 22^{o}C with an average of 18^{o}C. But due to climate change, temperatures and precipitation have also changed (Fairbanks & Scholes 1999). The province is generally characterized by cold winters and warm summers with the exception of coastal areas experiencing mild winters and summers (Bruton & Gess 1988). Precipitation also varies greatly with area within the Eastern Cape, from areas with late summer precipitation, through to those with most precipitation during winter, to areas with rainfall throughout the year (DEAT 2004). Bruton & Gess (1988) recorded average rainfall of the Eastern Cape as over 800 mm per year. In contrast, Low & Rebelo (1996) recorded mean annual rainfall of 850 mm.

Additionally, Bruton & Gess (1988) listed four types of rainfall that occur in the province which have different seasonal peaks with respect to area of occurrence, also documenting therein the mean monthly rainfall of the major towns of the province. Areas along the coast such as Port Elizabeth are the only regions within the province that experience significant rain during the winter months, between 500 mm and 1000 mm per year (Bruton & Gess 1988). The landscape consists of a range of mountains and undulating hills. Four major rivers occur within the boundaries of the Kei namely, Great Fish, Sundays, Mbashe and Great Kei rivers (Bruton & Gess 1988). Bruton & Gess (1988) noted that the geological formations of this region are mostly dominated by sedimentary rock types such as sandstone, limestone, mudstone, tillrite and conglomerate. The igneous rock, granite, is notably absent. However, igneous rock types such as basalt and dolerite do occur.

2.1.3 Vegetation

The Eastern Cape is viewed as an area with the greatest biome level diversity in South Africa, as it encompasses areas of the most biomes in South Africa (eight of nine) (Figure 2.1) and a vast number of vegetation types (Low & Rebelo 1996; Mucina & Rutherford 2006). The eight biomes which occur in the Eastern Cape are described below:

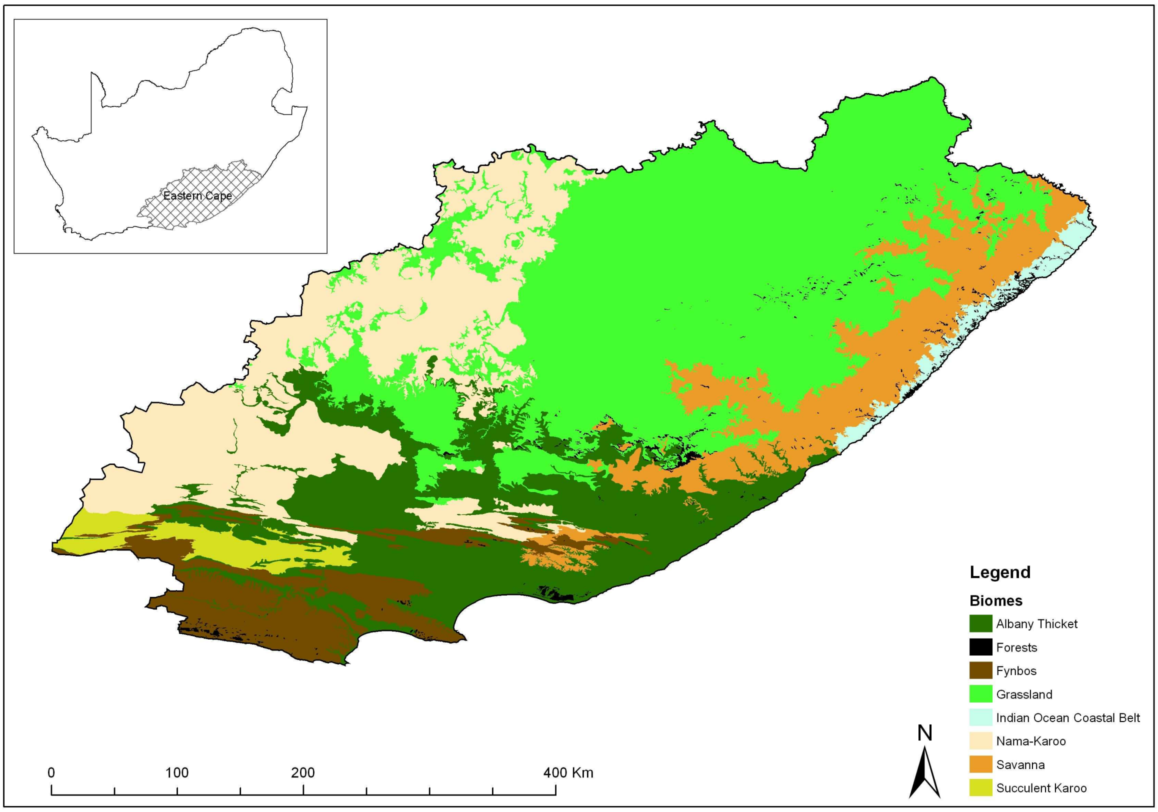


Figure 2.1: Map showing the eight different biomes of the Eastern Cape, South Africa (from Mucina and Rutherford 2006). Insert shows the location of the Province in South Africa.

2.1.3.1 Savanna biome

Savanna is the largest biome in southern Africa. It is characterized by grass and woody plants (which vary according to growth form and height, these may be 1-20 m high) (Scholes & Archer 1997; Mucina & Rutherford 2006). The altitude of this particular biome ranges from sea level to 2000 m above sea level and rainfall varies between 235 and 1000 mm per year. Almost all rock and soil types occur within this biome (Mucina & Rutherford 2006). Factors acting upon this system are rainfall, fire and grazing (Scholes & Archer 1997; Mucina & Rutherford 2006). Insufficient rain is, furthermore, a major constraint in the development and growth of plant life in this particular biome (Low & Rebelo 1996). C_4 grasses dominate in summer (November to January) and C_3 grass types dominate in winter (May to July) (Mucina & Rutherford 2006). The large herbivore community of the savanna biome is characterized by a mixture of browsers, such as black rhino, giraffe (*Giraffa camelopardalis*), and kudu (*Tragelaphus strepsiceros*) and grazers such as buffalo (*Syncerus caffer*) (Mucina & Rutherford 2006).

2.1.3.2 Grassland biome

The topography of this biome is characterised by flat ground and rolling slopes (Mucina & Rutherford 2006). Altitude is from near sea level to 2 850 m above sea level. The vegetation is dominated by a layer of grasses and, unlike the savanna biome, it seldom has the presence of trees. It is also affected by fire, rainfall and grazing pressure (O'Connor & Roux 1995; Roques *et al*. 2001; Mucina & Rutherford 2006; Waldram *et al*. 2008). C_4 grasses dominate within the biome, although C_3 grass types dominate at high altitude (Mucina & Rutherford 2006). Forbs are also an important component of the plant community in this biome (Mucina & Rutherford 2006). Grasslands are inhabited by domestic stock such as cattle, and indigenous ungulates such as black wildebeest (*Connochaetes gnou*), and blesbok (*Damaliscus pygargus phyllipsi*) (Roques *et al*. 2001; Mucina & Rutherford 2006).

2.1.3.3 Forest biome

The forest biome is characterised by a continuous canopy of evergreen trees (Low & Rebelo 1996). Altitude is from near sea level to over 2 100 m above sea level. Herbaceous plants such as lianas and epiphytes are common. Mean annual rainfall is typically more than 525 mm in the winter rainfall regions, and more than 725 mm in the summer rainfall regions (Low & Rebelo 1996). Forests are threatened by plant invaders such as *Acacia melanoxylon*. Fire may only occur under dry and hot conditions (Low & Rebelo 1996). There is typically very little grass cover in forests, this being restricted to clearings and forest edges. Bushbuck (*Tragelaphus scriptus*), and bush pig (*Potamochoerus porcus*) are common species occurring in the Forest biome (Hayward *et al*. 2005; Mucina & Rutherford 2006; Skead 2007).

2.1.3.4 Nama-Karoo biome

The vegetation of this biome is characterised by grass and dwarf shrubs with trees restricted to drainage lines (Low & Rebelo 1996). Altitudes range between 500 and 2

000 m above sea level. Rainfall is only experienced in summer and varies between 100 and 520 mm per year (Low & Rebelo 1996). It is used for grazing purposes of domestic livestock and invaders such as *Prosopis glandulosa* occur (Mucina & Rutherford 2006). Grass cover varies annually as a function of rainfall, and also declines westwards. Springbok (*Antidorcas marsupialis*), zebra (*Equus burchelli*), gemsbok (*Oryx gazelle*) and eland (*Tragelaphus oryx*) are typical Nama-Karoo ungulates (Venter & Watson 2008; Mucina & Rutherford 2006). Domestic stock of goats and sheep has replaced indigenous ungulates in this biome (Mucina & Rutherford 2006).

2.1.3.5 Fynbos biome

The Fynbos biome is characterised by small-leaved sclerophyllous shrubs (Low & Rebelo 1996). Mean annual rainfall averages approximately 480 mm and mainly occurs in winter (Mucina & Rutherford 2006). This biome, which is florally diverse, consists of two vegetation groups, namely, Fynbos and Renosterveld (Low & Rebelo 1996). Centres of endemism and other plant species in the biome are threatened by urban expansion. Alien species also threaten this biome (Low & Rebelo 1996). Grass cover is typically low in the Fynbos biome and also characteristically C_3 grass (Low & Rebelo 1996). Bontebok (*Damaliscus pyrgargus pyrgargus*), grysbok (*Raphicerus melanotis*) and eland typically occur in Fynbos (Mucina & Rutherford 2006).

2.1.3.6 Succulent Karoo biome

The vegetation is dominated by dwarf, succulent shrubs (Low & Rebelo 1996). Grasses are rare, when present they are of C_3 type. The altitude is between 800 and 1 500 m above sea level with flat to gentle undulating plains (Low & Rebelo 1996). Rainfall varies between 20 and 290 mm per year with this low rainfall experienced in winter, and a dry summer season. Temperatures in excess of 40^{o}C are common in this biome (Low & Rebelo 1996). Climate and the growing human population are a threat to this vegetation type (Mucina & Rutherford 2006). Typical herbivores include gemsbok, springbok, steenbok (Raphicerus campestris) and red hartebeest (*Alcelaphus buselaphus*) (Skead 2007; Mucina & Rutherford 2006).

2.1.3.7 Indian Ocean Coastal Belt biome

The Indian Ocean Coastal Belt along the sea contains a remarkable display of coastal dunes and coastal grassy plains (Mucina & Rutherford 2006). This biome according to Mucina & Rutherford (2006) only occurs in KwaZulu Natal and the Eastern Cape in South Africa at an altitude of between 0 to 600 m above sea level. Rain is experienced throughout the year with peaks in summer, mean annual rainfall ranges between 819 to 1272 mm per year (Mucina & Rutherford 2006). The biome is primarily used for subsistence and sugarcane farming (Mucina & Rutherford 2006). Alien invasive species such as *Chromolaena odorata* pose a threat to this biome (Mucina & Rutherford 2006). Grass dominated habitats can be well developed. Oribi (*Ourebia ourebi*), red hartebeest and eland are typical ungulates (Mucina & Rutherford 2006).

2.1.3.8 Albany Thicket biome

Lubke (1996) defined the subtropical thicket as a closed shrubland to low forest which is almost impenetrable and dominated by evergreen, sclerophyllous or succulent trees, shrubs and vines, many of which have spines. Grasses, lianas, forbs and geophytes also occur in this habitat (Low & Rebelo 1996). The closed canopy can reach a height of 6 m (Lubke 1996). The vegetation is highly diverse in terms of floristic endemism, specifically shrubs, geophytes and succulent forbs (Hoffman & Cowling 1991). This biome is found in the semi-arid areas of the Eastern Cape (Mucina & Rutherford 2006). Rainfall in this vegetation type ranges from 400 to 800 mm per annum with mild temperatures (Lubke 1996), rainfall peaks are experienced in March and October (Mucina & Rutherford 2006). Historically, this biome used to be home to indigenous browsers such as kudu, elephant (*Loxodonta africana*), bushbuck and black rhinoceros (Lubke 1996; Skead 2007). Moreover, Sigwela (2004) postulated that megaherbivores amongst other organisms play a vital role in the seed dispersal in thicket habitat. It is thus a herbivory driven system (Kerley *et al*. 1999), which is resilient to drought (Kerley *et al*. 1995). The thicket biome in the Eastern Cape is used mainly for farming, where pastoralism is practiced and ecotourism (Kerley *et al*. 1999). This system is therefore being degraded through grazing pressure (Kerley *et al*. 1995).

2.2 Land-use and trends in the Eastern Cape

Private ownership of land is characterized mostly by pastoral farms at the ecotourism industry based on private nature reserves in the Eastern Cape (Sims-Castley *et al*. 2004). These reserves are located on the western part of the Eastern Cape (see Chapter 4). It is a growing industry that contributes to the economy of the country and creates job and empowerment, and community development opportunities (Kerley *et al*. 1995). Previous land ownership utilized the land for livestock farming (Sims-Castley *et al*. 2004; O'Brien 2004). Thus an extensive change from stock farming to game farming has occurred (Smith & Wilson 2002; Castley & Hall-Martin 2003). Land is also used primarily for conservation purposes i.e. Addo Elephant National Park, where numerous reintroductions of indigenous animals have taken place (Hayward *et al*. 2006). The Transkei region within the Eastern Cape is largely used for communal farming and is also used for conservation purposes including the protection of indigenous forests (Hayward *et al*. 2005), with the Wild Coast attracting a lot of tourists (Kepe 2001).

2.3. Shamwari Private Game Reserve

Shamwari Private Game Reserve (Figure 2.2) was the study site used to quantify the diet of white rhinoceros in the Eastern Cape. The reserve is situated on land previously used for farming purposes and as a result a number of farms were purchased to form what is currently known as Shamwari Private Game Reserve (O'Brien 2004). It lies between 33^{o}20'S, 26^{o}10'E, 65 km along the N2 road from Port Elizabeth to Grahamstown. The reserve was established in 1992 and is used for wildlife conservation.

2.3.1 Climate, Geology and Topography of Shamwari

Shamwari receives rainfall throughout the year (Figure 2.3) as it is located between the summer and winter rainfall areas (O'Brien 2004). Peak rainfall is experienced in March, April and August (Figure 2.3). Annual rainfall for the years 1999 to 2008 averaged 492 mm (Shamwari Wildlife Department 2009). Temperature data were not available for the reserve or Paterson (a town 11 km west of the reserve) and temperature data for Addo Elephant National Park (approximately 40 km south-west of Shamwari) were therefore used. Mean monthly temperatures reach a maximum of 31^{o}C and minimum of 20^{o}C (in summer) and a maximum of 25^{o}C and a minimum of 4^{o}C (in winter) (Roux 2006).

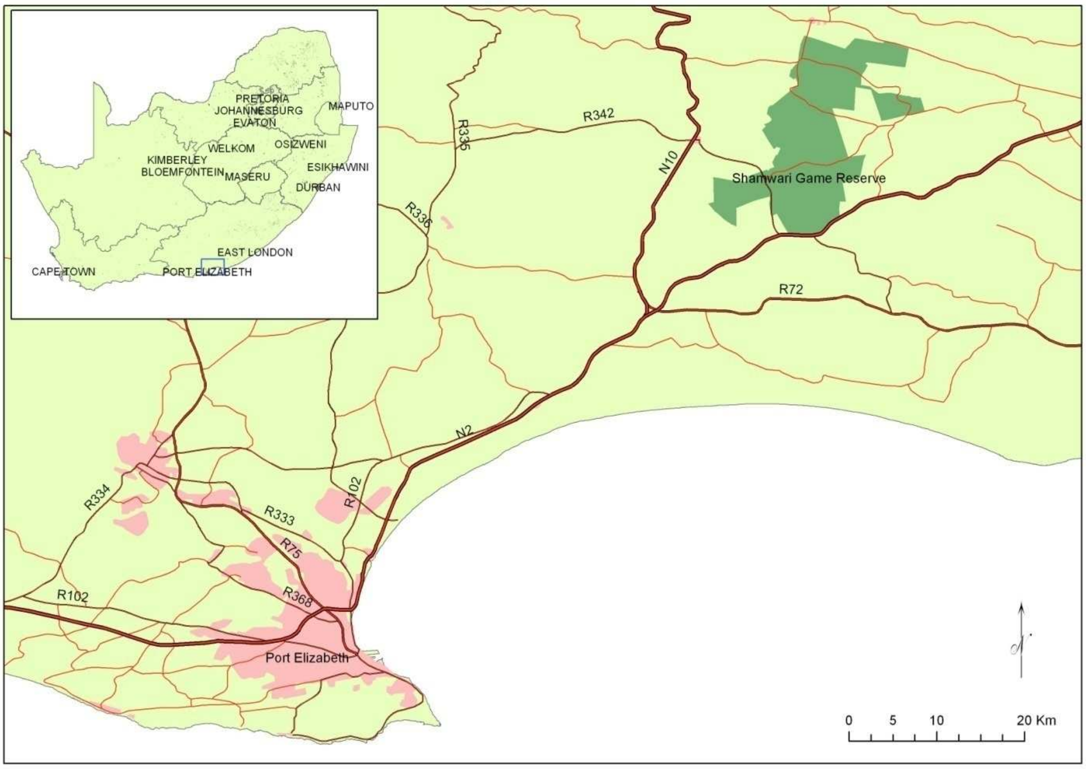


Figure 2.2: Map showing the location of the study site at Shamwari Private Game Reserve.

The dominant geological formations occurring in Shamwari are Bokkeveld Series Shale, Witteberg Quartzite, Karroo Sandstone and Sunday's River Formations (O'Brien 2004). The Sundays and Bushman's rivers form part of the reserve with the latter flowing through the reserve for some 27.6 km. The elevation of the reserve ranges from 196 m above sea level to 628 m above sea level, with undulating hills and deep valleys.

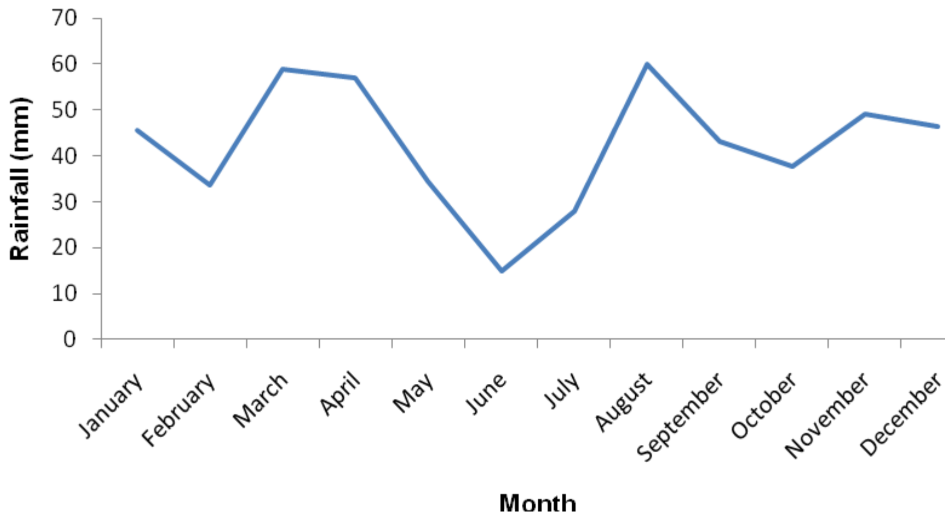


Figure 2.3: Average monthly rainfall for the years 1999-2008 in Shamwari Private Game Reserve (Shamwari Wildlife Department 2009).

2.3.2 Vegetation

Shamwari Private Game Reserve comprises 5 vegetation types as per Mucina & Rutherford's (2006) classification, namely, Kowie Thicket, Zuurberg Quartzite Fynbos, Bisho Thornveld, Albany Coastal Belt and Suurberg Shale Fynbos. Kowie Thicket is the dominant vegetation type, representing 64.6% of the area (Figure 2.4) (O'Brien 2004). Bontveld habitat type was identified i addition to those identified by Mucina & Rutherford (2006). Burning and manual clearing is employed as a tool to manage alien enchroachers such as *Acacia cyclops*, *Opuntia-ficus indica* (this being the most dominant species) and *Pinus spp*. These are either managed through containment or possibly eradication (O'Brien 2004). Considerable grass cover is found in the following vegetation types within the reserve:

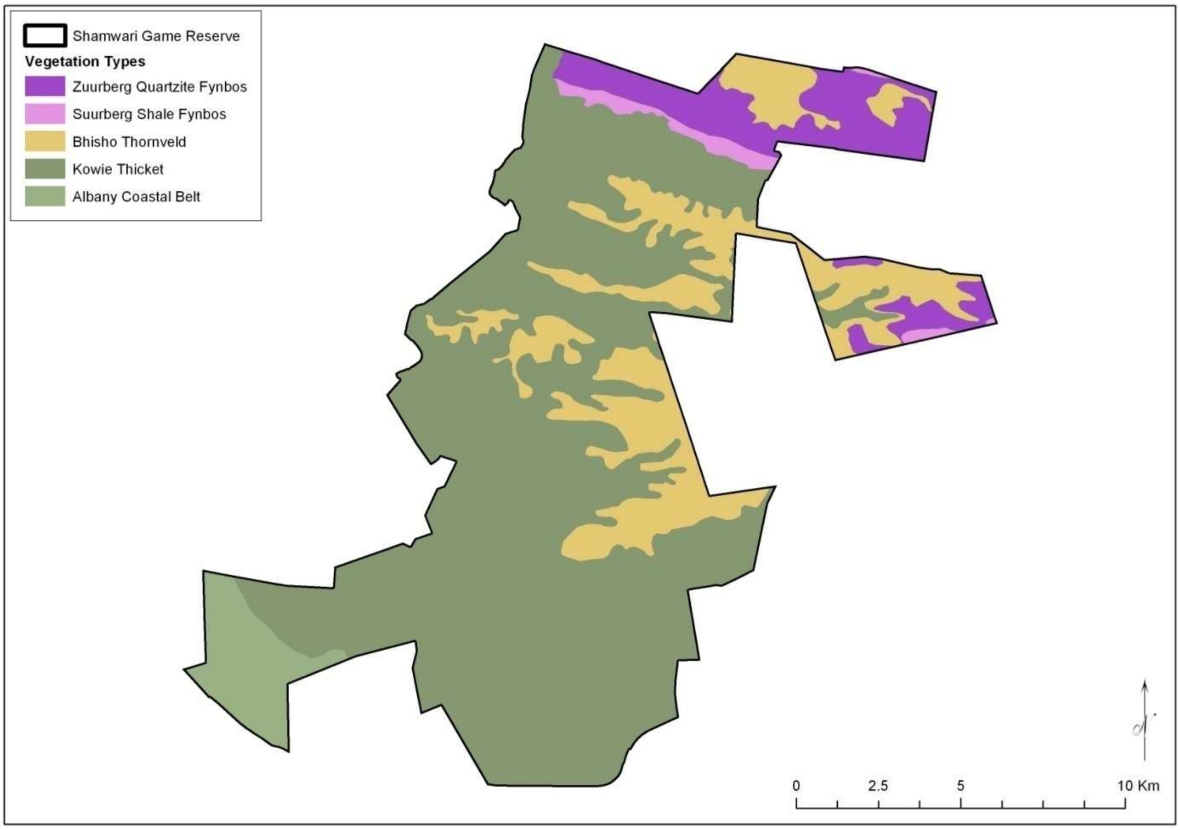


Figure 2.4: Vegetation map of Shamwari Private Game Reserve, showing the dominant thicket (from Mucina and Rutherford 2006) habitats.

2.3.2.1 Vegetation types within Shamwari Private Game Reserve

Bisho Thornveld

This occurs as a series of patches on the higher elevation portions. *Themeda triandra* is the dominant grass species under good conditions, with a diversity of other woody tree species also occurring (Mucina & Rutherford 2006). It is described as a Least Threatened vegetation type within South Africa by Mucina & Rutherford (2006).

Albany Coastal Belt

Mucina & Rutherford (2006) also describe it as a Least Threatened vegetation type. Growth forms in this vegetation type ranges from trees, shrubs to woody climbers and grasses like *Panicum deustum*, *Cynodon dactylon* and *T*. *triandra* (Mucina & Rutherford 2006).

Bontveld

The depth of the topsoil in bontveld is cut off at 10 cm on very shallow calcrete (O'Brien 2004). The vegetation here is characterized by a mixture of bushclumps and grasses. O'Brien (2004) recorded the dominant grasses occurring on the bontveld as *T*. *triandra*, *Digitaria eriantha*, *Eragrostis curvula*, *Sporobolus africanus* and *Brachiaria serrata*. The bushclumps are characterized by species like *Rhus pterota*, *Grewia occidentalis* and *Aloe ferox* (O'Brien 2004).

There are two types of grasslands in the reserves, namely montane grassland and lowland grassland (O'Brien 2004). The montane grassland type is located on top of quartzite ridges. Grasses found here range from *T*. *triandra*, *E*. *curvula*, *B*. *serrata*, *Heteropogon contortus* and the dominant *Sporobolus fimbriatus*. The area is however prone to woody plant species invasions such as *Pteronia incana* (O'Brien 2004). Lowland grassland is located south of the reserve at low latitudes of 220 to 230 m above sea level (O'Brien 2004). Dominant grasses are *T*. *triandra*, *E*. *curvula* and *D*. *eriantha* (O'Brien 2004).

Kowie Thicket

The vegetation is dominated by succulent Euphorbias and aloes with thick thorny shrubs (*Azima spp*.), woody shrubs (*Capparis spp*.) and shrubby succulents (Crussulaceae). Grasses in this vegetation type include *C*. *dactylon*, *Karoochloa curva, E*. *curvula* and *P*. *deustum* (Mucina & Rutherford 2006). Shamwari Private Game Reserve plays a role in conserving this Least Threatened vegetation type (Mucina & Rutherford 2006).

Suurberg Shale Fynbos

Important taxa in this vegetation type include tall shrubs (*Rhus spp*.), low shrubs (*Selago corymbosa*) and succulent shrubs (*Cotyledon orbiculata*) (Mucina & Rutherford 2006). Grasses such as *T. triandra* also occur (Mucina & Rutherford 2006). It is Least Threatened with approximately 40% conserved in the Greater Addo National Park

(Mucina & Rutherford 2006). It is however prone to transformation and alien species invasions (Mucina & Rutherford 2006).

Zuurberg Quartzite Fynbos

The vegetation here ranges from small trees such as *Loxostylis alata*, succulent trees like *Aloe ferox*, and tall shrubs like *Euryops latifolius*. Grasses include *T*. *triandra*, *E*. *curvula*, and *Hyparrhenia hirta* (Mucina & Rutherford 2006). It is also a Least Threatened vegetation type with the Greater Addo National Park conserving 15% of it (Mucina & Rutherford 2006). Transformation occurs when frequent fires result in the conversion of Fynbos to grassland (Mucina & Rutherford 2006).

2.3.2.2 Disturbed lands

Disturbed lands created through human intervention have been classified into two categories, namely, cleared and cultivated lands (O'Brien 2004). Cultivated lands have been seeded with *Panicum maximum*, *D*. *eriantha* and *Cenchrus ciliaris* by the conservation department of the study area (O'Brien 2004). O'Brien (2004) pointed out that the vegetation has thus been transformed due to human impacts (cultivation, burning etc.).

2.3.2.3 Large mammal fauna of Shamwari

Shamwari Private Game Reserve is a Big Five reserve that supports a wide range of mammalian fauna, a mixture of grazers such as buffalo, hippopotamus (*Hippopotamus amphibius*), red hartebeest, white rhino (N = 24), black wildebeest, blue wildebeest (*Connochaetes taurinus*), zebra and gemsbok, browsers such as black rhino, giraffe, bushbuck, blue duiker (*Cephalopus monticola*), steenbok (*Raphicerus campestris*) and kudu and mixed feeders such as eland, springbok, impala (*Aepyceros melampus*) and elephant (O'Brien 2004). Of these, white rhino, gemsbok, giraffe, blue wildebeest, black wildebeest and impala did not occur historically in the Eastern Cape (Skead 2007) and have been introduced.

2.4 Ecology of the study animal

A brief summary of the biology and ecology of white rhino is provided here to provide a context for the rest of this dissertation.

2.4.1 Taxonomy of the white rhinoceros

The white rhinoceros is represented by two subspecies namely, the northern *C. s. cottoni* and the southern race *C. s. simum* (Schwazenberger *et al*. 1998; van der Goot 2009). The latter is the study animal. There is no extensive literature describing the differences between the two subspecies (Alexander & Player 1965). Nonetheless, the two extant white rhinoceros subspecies can be separated from each other through differences in the skull and size (Groves 1972). Additionally, the northern race lose their body hair in the adult stage of life, the southern race does not (Alexander & Player 1965). The study animal is larger than its sister subspecies (Groves 1972). The northern subspecies is Critically Endangered with only 4 individuals remaining as a representative of the species in the wild in Garamba National Park, in the Democratic Republic of Congo (Brooks 2006). There is however, another population in the Czech Republic kept in the zoo (Brooks 2009).

2.4.2 Description

The white rhinoceros, *C. s. simum* (Figure 2.5) is ranked as the world's 3rd largest extant terrestrial mammal, after the two species of elephants (Owen-Smith 1988). It is thus the largest pure grazer. Adult males weigh a maximum of 2 400 kg, and females weigh up to 1 600 kg (Owen-Smith 1987). Player & Feely (1960) listed a number of physical characteristics by which the animal can be distinguished from the black rhino. The colour of the skin depends upon that of the surrounding soil (Player & Feely 1960). White rhino walk slowly with their heads held closely to the ground, an adaptation for short grass feeding (Shrader 2006).

Figure 2.5: White rhinoceros (*Ceratotherium simum simum*) in a typical grass-rich habitat.

2.4.3 Distribution

White rhinoceros historically had a much more restricted distribution as compared to the black rhino (Figure 2.6). White rhino were widely distributed over the southern part of Africa (Emslie *et al*. 2009). It has remained an inhabitant and dweller of the savanna woodlands and grasslands. However, fossil records and paintings in caves indicate the fact that white rhinos possibly had a more continuous range in Central and Eastern Africa until they separated due to changes in climate and vegetation during the last ice age (Emslie & Brooks 1999). Skeletal remains are evidence that white rhinos once occurred in the Eastern parts of Africa, Northern Africa and South Africa. They also occurred in the Western Cape region of South Africa during the Pleistocene (Shrader 2006). There are no historical records of white rhinoceros in the Eastern Cape (Skead 2007). Due to overhunting the species range was constricted to the Hluhluwe-iMfolozi Game Reserve in KwaZulu Natal by the 1920s. The Natal Parks Board launched

Operation Rhino in 1961 which comprised the removal of about 4 000 white rhinos by 1997 from its reserves to state-run reserves and private land throughout their former range and beyond (Shrader 2006). Translocations have contributed greatly to the current increase in range and distribution of the species (Emslie *et al*. 2009). *C. s. simum* is extensively distributed in the Republic of South Africa. The southern white rhino is currently found in Zimbabwe, Namibia, Swaziland, Botswana, Zambia, South Africa (Figure 2.7), Ivory Coast and Kenya. South Africa constitutes 94.2% of the population (Emslie & Brooks 1999; Emslie 2000; Leader-Williams *et al*. 2005; Shrader 2006). Extra-limital population of the southern subspecies of the white rhino have been established in the Ivory Coast (Emslie & Brooks 1999) and the Eastern and Western Cape Province of South Africa (Buijs 1999; Castley & Hall-Martin 2003).

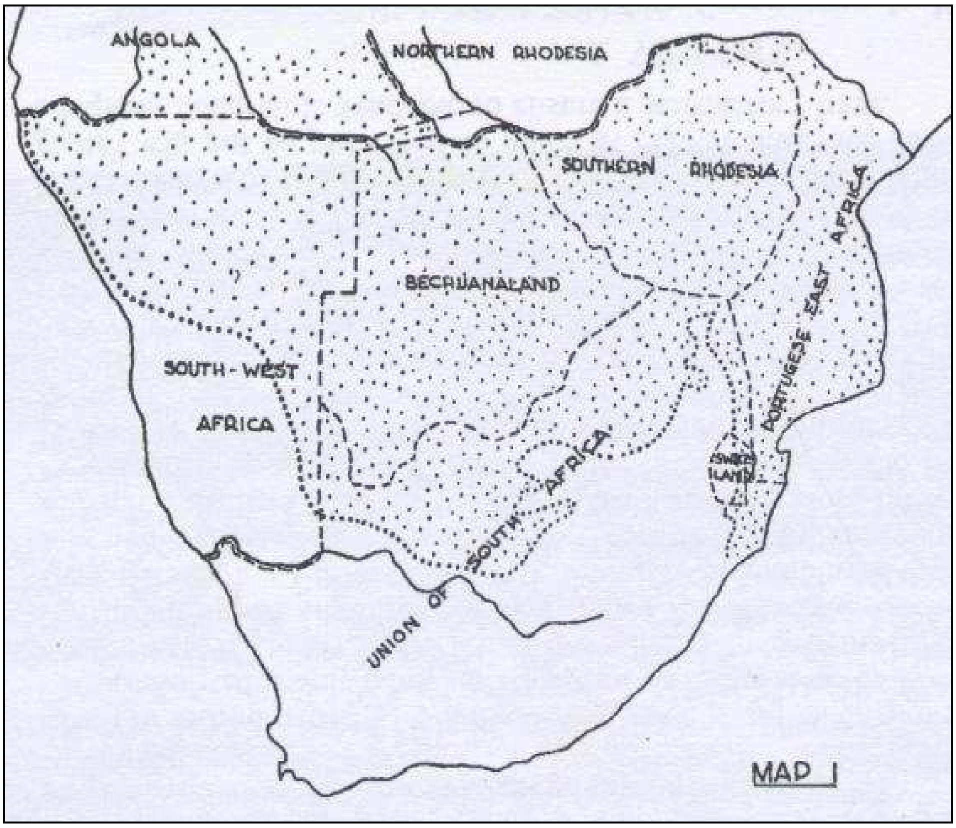


Figure 2.6: Map showing the former distribution of the study animal in the 1800s in the southern African subregion (from Player & Feely 1960).

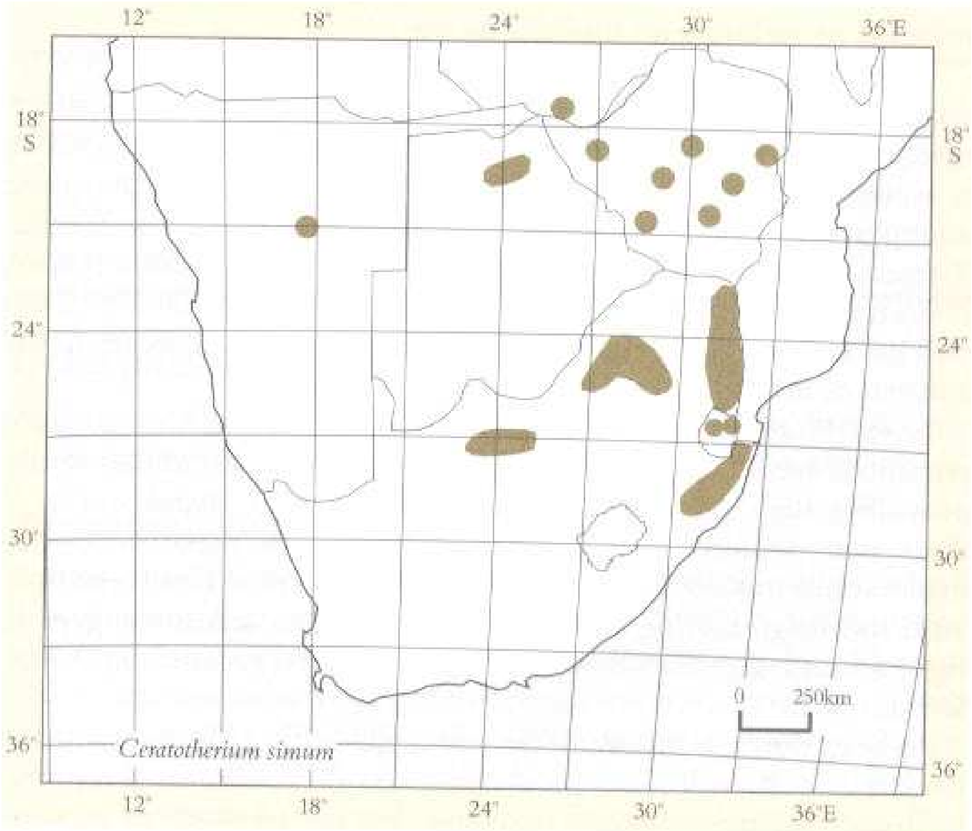


Figure 2.7: Map outlining the current distribution of *C. s. simum* (Skinner & Chimimba 2005). Note that the extra-limital populations in the Eastern Cape are not featured.

2.4.4 Conservation status

C. s. simum is rated as "Near Threatened" in the red list criteria and category of the IUCN (IUCN 2008), though their population trend is recorded to be increasing. The species is vulnerable to the continued threat of poaching due to the illegal trade of the rhino horn. It is therefore of high conservation priority (Gordon *et al*. 2004). Data on white rhino locations has over the years become a sensitive matter and as a result, detailed information about their whereabouts is seldom published (IUCN 2008). The same applies to rhinos in some of the Eastern Cape private reserves, as the reserves employ expensive security measures to ensure the safety of the rhinos and provide protection against poaching (Dr. William Fowlds pers. comm. 2009). Thus information pertaining to white rhino numbers and location was also not disclosed in the current study for security reasons.

2.4.5 Behaviour

2.4.5.1 Territoriality

White rhinoceros are territorial, hence their tendency to occur in specific areas (Owen-Smith 1974; Rachlow *et al*. 1999; Shrader 2006). Territorial males display marking behaviours such as spray urination and scattering of dung immediately after defecation. Non-territorial males, however, do not express themselves in this manner (Owen-Smith 1974; Rachlow *et al.* 1999). Territorial males were recorded to have higher testosterone levels than non-territorial males (Rachlow *et al*. 1998). Territorial males generally express interest in females that were willing to mate (Rachlow *et al*. 1998). Furthermore, territorial bulls have the chance to mate (Kretzschmar *et al*. 2004). The sense of smell is the main medium of communication between individuals and they also have an acute sense of hearing as they have relatively poor eyesight (Player & Feely 1960). They also communicate through vocal displays, males are generally louder than females (Groves 1972). Sound is made when mating, fighting, females seeking their calf and while drinking or threatened (Player & Feely 1960).

2.4.5.2 Home range use

Social behaviour and space use in white rhino differ between sexes (Horne *et al*. 2008). Their social groups frequently comprise of two individuals but larger groups of up to six individuals may also occur, ranging from cow-calf pairs to cow-adolescent groups (Owen-Smith 1974). Bulls on the other hand are generally solitary and associate with cows during courtship or mating (Owen-Smith 1974). The subordinate bulls stay in the territory of a territorial male but unlike the territory owner, may leave the home range (Owen-Smith 1974). Owen-Smith (1974) noted that each adult cow has a home range and these may overlap with each other, although the females move independently. Moreover, these home ranges are adhered to at all times, except during the dry season when movements to seek water have to be made (Owen-Smith 1974). Home ranges thus contain resources utilized by the owner such as food and shelter (Seaman & Powell 1990). Adult cows occupy home ranges that cover 10 to 12 km^2 (Owen-Smith 1974) and territorial bulls occupy 6.2 to 13.8 km^2 (Pienaar 1994) while adolescent groups remain in home ranges of 4 to10 km^2 (Owen-Smith 1974).

2.4.5.3 Diet and feeding behaviour

The white rhino is the largest entirely grass feeding animal (Groves 1972; Owen-Smith 1974; Schwarzenberger *et al.* 1998) which shows a strong preference for short grasses (Shrader & Perrin 2006). Lips are used to pluck the grass (Groves 1972). Field observations have shown that white rhinos feed by preference in the morning on shade-loving grass such as *P*. *maximum,* that mostly grow on river banks (Pienaar *et al.* 1992). During mild or cloudy weather white rhinos were found to be active at all times of the day unlike sunny days. They rest lying or standing for approximately 6 hours throughout the midday period (Owen-Smith 1975). Large herbivores in general are less selective in their foraging behaviour (Venter & Watson 2008). Herbivores, particularly during the dry period have a tendency of shifting their use of the habitat from the more open plains usually utilized during the rainy season to use of the available habitats (Melton 1987). Venter & Watson (2008) pointed out that typically large herbivores come across a range of food items while feeding and therefore need to select what they ingest, white rhino therefore exhibited diet selectivity among grass species and their use of grass also varied seasonally (Owen-Smith 1973; 1988; Shrader *et al*. 2006; Shrader & Perrin 2006; Shipley 2007). In addition, the size of the mouth has an influence on the bite size (Spalinger *et al*. 1988; Shipley 1999).

2.4.6 Habitat requirements

White rhinoceros show preference and avoidance in their usage of habitats (Pienaar *et al.* 1992). Player & Feely (1960) listed four basic habitat requirements of white rhinos, these being, areas of short grass, water for drinking purposes as well as for mud wallowing as a means of thermoregulation, adequate bush cover for relief from weather extremes, as well as cover and shelter for females giving birth and relatively flat terrain (topography). Habitat use differs for white rhinos as demonstrated by their feeding behaviour as seasons change. Subsequently, white rhinos feed on areas of short green grass during the wet season and shift their attention from medium to tall grasses such as *T. triandra* during the dry season (Owen-Smith 1988). Water is important for drinking purposes, which occurs twice daily while water is abundant (Owen-Smith 1974). It has been estimated that an adult white rhino can drink up to 40-50 litres of water per day, although they can go without water for two to three days when water resources become limited. Journeys during water-scarcity are made at 2-4 day intervals to available water resources (Owen-Smith 1974; Rogers 1993). During the summer period, white rhinos indulge in mud wallowing which is done in pans especially for ridding themselves of ectoparasites (Owen-Smith 1988; Shrader 2006). White rhinos also rub themselves against trees to remove mud on their skin (Shrader 2006). Pienaar *et al.* (1993) described the landscape preferred by white rhinos in the Kruger National Park as one having sodic soils and poor internal drainage, with small pans commonly occurring with trees and sparsely distributed shrubs.

2.4.7 Reproduction

Rachlow *et al.* (1998) found that territorial males tended to be older and spent most of their time with females of high reproductive value. Females are attracted to territorial males because of the resources contained in the territory (White *et al*. 2007a). Reproduction in white rhinos is not restricted seasonally, births had been recorded in every single month of the year by Owen-Smith (1987). However, oestrus is apparently stimulated by a flush of green grass during the wet season (Owen-Smith 1974). White rhino cows generally give birth to their first calf between the ages 6.5-7 years (Owen-Smith 1975). The gestation period is estimated to be some 16 months (480 days) by Owen-Smith (1974), whereas 547 days was documented by Player & Feely (1960). Female white rhinos generally give birth to offspring at an interval of 2-3 years withi their natural range (Owen-Smith 1974; Shrader & Owen-Smith 2002). Calves begin to graze at an age of about 2 months, and by the time they reach 3-4 months, the calves spend most of their time grazing (Owen-Smith 1974). In contrast, Player & Feely (1960) recorded that the calf starts grazing at about a week old. Suckling may continue up until the calf is well over a year old.

2.4.8 Predation

The horns of white rhinoceros are said to be direct functional weapons (Owen-Smith 1974), but are also the primary reason why they are susceptible to human poaching (Player & Feely 1960; Owen-Smith 1974). Fighting among males is believed to be the leading cause of natural mortality for male white rhinos in Kruger National Park (Pienaar *et al.* 1992)**.** Although serious fights are seldom observed, defence of a territory is a risky venture (Rachlow *et al.* 1998). Horns act as defense points when threat is posed through predation or clashes within species (Berger 1994). White rhinos pay little or no attention to other mammalian species at close range or far off. They are however, vulnerable to attacks by elephants in certain situations and a number of white rhinos have been killed in this manner in Hluhluwe-iMfolozi Park (Slotow *et al.* 2001). Furthermore, lions and hyenas may kill calves on occasion (Shrader 2006).

CHAPTER 3
DIET AND IDENTIFICATION OF PLANTS AT RISK

3.1 Introduction

This diet study on white rhino residing in thicket environment was done to determine the composition of their diet. The diet of predominantly grazing indigenous herbivores has been studied before in the Eastern Cape thicket vegetation (De Graaf *et al*.1973; Sigwela 1999; Landman & Kerley 2001; Schlebusch 2002), including that of introduced species (Koekemoer 2001; Gerber 2008; Jacobs 2008). These studies all used the microhistological approach followed here. The white rhino is a grazer (Owen-Smith 1974) and it is not known how this species will respond to being introduced into habitats like thicket that are not characterized by an abundance of grass. De Graaf *et al*. (1973) showed that buffalo, also typically grazers, increased their browse intake in thicket habitat and this was later confirmed by Landman & Kerley (2001). In contrast, zebra, another grazer, maintained a very high proportion of grass (92%) in their diet in thicket. Given the degree of specialization as a grazer shown by the white rhino (Owen-Smith 1988; Shrader *et al*. 2006), it was hypothesized that they would maintain a diet dominated by grass when introduced into thicket habitats.

Resource utilization by animals is important to understand as it should give an insight to their general behaviour, and management needs and opportunities (Chapius *et al*. 2001; Shrestha & Wegge 2006; Bradley *et al*. 2007). The behaviour and distribution of animals within a habitat are influenced by the availability and distribution of food. Thus, different parts of the habitat present varying quality in terms of resources (Melton 1987) and terrestrial herbivores exhibit marked habitat preferences (Einsenberg & Seidensticker 1976). Food resources are therefore key features in terms of how animals use landscapes. Through their consumption of these food resources, herbivores can potentially influence the distribution and abundance of plants on the landscapes (Melton 1987). An understanding of the diet of a species is therefore important in order to understand not only what forage species are eaten, but also how habitats can vary in quality across the landscape and what plant species are vulnerable to the effects of herbivory of the herbivore.

White rhinos feed on short grass species such as *P. maximum* when available but will feed on the medium to tall grass species, *T. triandra* during the dry season (Owen-Smith 1988). No studies have been done to date in the Eastern Cape to investigate the diet of white rhinos.

3.2 Techniques used to determine herbivore diet

There are a variety of techniques available to assess the diet of a species, each with its own advantages and disadvantages (Henley *et al*. 2001). These techniques are briefly reviewed below to place the chosen technique in perspective.

3.2.1 Direct observations

Previous studies on the white rhinoceros have used direct observations to describe their diet (Player & Feely 1960; Pienaar *et al*. 1992; Pienaar *et al*. 1993; Shrader *et al*. 2006). This was achieved through the bite-count method which involves the close observation of animals and recording of bite numbers and plant species consumed (Shrestha & Wegge 2006). Direct observations are time consuming and require animals to be habituated to the proximity of the observer. This needs one to be very close so that they can see the plant species being fed upon by the animals (Holechek *et al*. 1982a). Moreover, this technique is not feasible for application in aggressive, nocturnal or shy animals. This method also requires an observer to be familiar with the plant species found in the study area (Shrestha & Wegge 2006). This technique was therefore not feasible in the present study.

3.2.2 Fistulation and oesophageal extrusa

The valve fistula technique was found to be the most precise technique when comparing faecal analysis and direct observations of diet (Henley *et al*. 2001). Both fistulation and oesophageal extrusa assume that diet selection of plants remain constant throughout the day (Henley *et al*. 2001). Though oesophageal extrusa does not entail slaughtering of the animal, it involves surgical implants (Henley *et al*. 2001). This technique was therefore not feasible in the present study.

3.2.3 Stomach content analysis

The diets of many species have been described from stomach or rumen contents analysis (McElroy & Goss1940; Tirasin & Jørgensen 1999; Chapius *et al*. 2001) and this is presumably comparable to fistulation in terms of precision. However, this does require the killing of the study animals and was therefore not feasible for use in the present study.

3.2.4 DNA extacts from faecal samples

The diet of herbivores can also be assessed indirectly through DNA extracts from faecal samples (Valentini *et al*. 2009). It is non-invasive and a good method to be applied when dealing with endangered or elusive animals (Valentini *et al*. 2009). This technique has also been applied on primate diets (Bradley *et al*. 2007). DNA techniques and equipment are however expensive and require a well-established genetic reference collection of potential diet species. Such a collection has yet to be established for the study area. This approach was therefore not feasible in the present study.

3.2.5 Microhistological faecal analysis

Microhistological analysis has become the most commonly used method for determining herbivore diets in recent years (Dearden *et al*. 1975; Holechek *et al*. 1982a) because of its simplicity in terms of labour during sample collection and it involves no form of disturbance incurred by animals (MacLeod *et al*. 1996). As with any other method, it is also not without its own shortcomings (Holechek 1982). This method is time consuming and requires skill and patience in identifying plants in faecal samples to species level (Shrestha & Wegge 2006). Another disadvantage with regards to the technique is the risk of misidentifying the plant consumed (Shrestha & Wegge 2006). These shortcomings are however largely overcome by use of photomicrographs of a reference collection (Shrestha & Wegge 2006). Holechek *et al*. (1982b) listed the advantages, and showed that the stage of maturity of any plant does not have an impact on the results of analysis. In addition, Vavra & Holechek (1980) outlined some factors that affect the technique and made a few suggestions to refine the method.

Microhistological analysis is a relatively easy technique that does not interfere with the general behaviour of animals or result in death thereof (Holechek *et al*. 1982a; MacLeod, Kerley & Gayland 1996). An advantage of this technique is that it can be applied to any herbivore in any habitat (McAllister & Bornman 1972). Faecal analysis appears to be the most accurate method to measure and describe diet of herbivores (Shrestha & Wegge 2006). In addition, Chapuis *et al*. (2001) found similar results between faecal and rumen analysis. Henley *et al*. (2001) reported the same results between faecal analysis and oesophageal extrusa. This method was therefore used in the present study.

The aim of this section was to therefore describe the diet of white rhino by identifying principal dietary items and preferred plant species in Shamwari Private Game Reserve. The introduced white rhino currently co-exists with other indigenous and non-indigenous herbivores in this location (O'Brien 2004), where indigenous species could be at potential risk due to intensive herbivory by white rhinos. I hypothesized, based on published accounts of white rhino diet and feeding (Owen-Smith 1988; Shrader & Perrin 2006), that white rhino at Shamwari Private Game Reserve would be grazers and would exhibit preference for specific grass species.

3.3 Methods

3.3.1 Study site

Shamwari Private Game Reserve (Figure 2.2) was used as a site to quantify the diet of white rhinoceros in the Eastern Cape. The site was selected because it has the largest white rhino population (N = 24) in the province. See previous section for a full description of the reserve.

3.3.2 Microhistological analysis

Fifteen fresh faecal samples of white rhinoceros from different individuals, mostly from white rhino middens, were collected at the study site for each of the four seasons i.e. winter (July 2008), spring (September 2008), summer (February 2009) and autumn (April 2009). I requested rainfall data for the duration of the study from the Wildlife Department of Shamwari (see Figure 3.1).

All faecal material was dried at 55^{o}C for a week and stored until analysis. The dried material was then ground through a mill with a 2 mm sieve prior to treatment. A 5 g portion of each sample was boiled for two minutes in 20 ml 55% nitric acid. Then 100 ml of water was added to the mixture and the mixture was diluted to a 10% solution, and it was shaken and boiled for a further five minutes, following McAllister & Bornman (1972) as modified by Landman *et al*. (2008). The mixture was then rinsed with tap water over a 250 µm sieve to remove the remaining acid in the mixture (MacLeod *et al*. 1996). Samples were stored in Formalin Acetic Acid (FAA; 25% water, 60% absolute alcohol, 10% formalin and 5 % glacial acetic acid) until further analysis.

Microscope slides were prepared using the procedure followed by Sparks & Malechek (1968). Two subsamples of each sample were placed on a gridded slide from which 100 fragments were identified and recorded to species level under the microscope at 400 X magnification (50 fragments per slide). Identification was achieved with the use of a plant photographic reference collection belonging to Centre for African Conservation Ecology at the Nelson Mandela Metropolitan University, which has been prepared by various authors (Sigwela 1999; Landman 2000; Koekemoer 2001; Davis 2004). Failure to identify a fragment led to it being recorded as unidentified and it was further given a specific name/code relating to its growth form.

The plant species encountered at the study site that were not present in the reference collection were added to the collection by cutting the leaves into squares of about 15 mm that were boiled for 2 to 5 minutes (depending on the hardness of the leaf) in 10 ml of 10 % nitric acid to separate the epidermis and the mesophyll. The leaves were then flushed under running water to remove the remaining acid. The epidermal fragments were then put onto a slide, the cuticle layer stained with Ruthenium Red and permanently mounted (McAllister & Bornman 1972). Adaxial and abaxial plant cuticles were photographed at 400 X magnification (Sparks & Malechek 1968). The photographs were then printed and added to the reference collection (Appendix 1).

3.3.3 Food availability

Relative forage availability was measured to allow determination of preference by white rhino. Odo *et al*. (2001) put an emphasis on the importance of measuring and knowing available food types in a habitat that is utilised the most by the study animal in order to understand their general behaviour. Food availability was measured in Autumn 2009 by setting out 15 x 50 m transects which were in grassland, thicket and bontveld habitats in Shamwari Private Game Reserve. These habitats represent a subset of the Mucina & Rutherford (2006) vegetation types and are described by O'Brien (2004). They largely correspond to Mucina & Rutherford's (2006) Kowie Thicket (Figure 2.5). These habitats were chosen on the basis of the presence of white rhinoceros dung in them during the sampling period (July 2008 to April 2009). It was assumed that the habitats were homogenous and that the results from the transects would be a good representation of the whole habitat. All the plant species, occurring at 20 cm intervals along the line for the 50 m transect were recorded. Those plants that could not be identified in the field were clipped off, marked and pressed, to be identified later in the Nelson Mandela Metropolitan University herbarium. All plant species that were a metre and above were ignored as the mean height normally grazed upon by white rhino in the dry season was recorded to be 20 cm (Owen-Smith 1988). In addition, Shrader *et al*. (2006) categorized grasses > 30 cm in Hluhluwe- iMfolozi Park as too tall for white rhino to feed on. All transects were at least a kilometre apart in order to cover as much of the particular habitat as possible.

Although lucerne (*Medicago sativa*) was provided as a supplementary feed for white rhino at Shamwari Private Game Reserve (John O'Brien pers. comm. 2009) during winter, the availability was not recorded. Thus, preferences for this species are likely to be over-estimated.

3.3.4 Data analyses

EstiMateS Version 7.5 was used to determine whether white rhinoceros diet could be confidently described with the number of samples analysed. An accumulation curve (mean ± 1 SD; 50 randomised iterations) was produced of the recorded plant species per faecal sample (Collwell 2005). The asymptote, characterised by flattening or stabilizing of the curve and a decrease in SD, is used to assess sampling efficiency. Total species richness was determined using the non-parametric incidence-based coverage estimator within *EstiMateS* version 7.5 (Foggo *et al*. 2003), assuming that the accumulation curves did not reach an asymptote. This particular test is essential in detecting the number of plant species possibly missed during analysis.

Analysis of similarities (ANOSIM; 5000 permutations) calculated in PRIMER 6 (Clarke & Warwick 2001) was used to determine whether there was a significant difference in diet composition between seasons. R values range between +1 and zero. R values > 0 indicate increasing dissimilarity between seasons and zero values indicate that the null hypothesis of similarity is true. Values close to 1 show that all replicates within season are more similar to each other than replicates from other seasons. Furthermore, SIMPER analysis was performed on the diet to determine the percentage similarities between seasons and the contribution of plant species to that similarity. Finally, using the non-Metric Multidimensional Scaling (n-MDS) ordination (1000 permutations), occurrence of seasonal changes or variations in the diet was determined on square-root transformed data. A stress value of less than 0.2 is considered as useful 2D ordination plot (Quinn & Keough 2002).

Animals prefer and avoid food items on the basis of availability, nutritional value and variety of such factors (Krebs 1989). Neu *et al*. (1974) pointed out the importance of determining preferred and avoided habitats as well as plant species by animals. Preferred plant species were those that occurred more frequently in the diet than were available in the environment (Petrides 1975). Preference of dietary items was estimated only for food items used in autumn using Jacob's index (Jacob 1974):

$$D = (u\text{-}a).(u+a\text{-}2ua)^{-1}$$

Where, D is the index which ranges from +1 (maximum preference) to -1 (maximum avoidance). Furthermore, *u* represents the proportional utilization of a food item and *a* is the proportional availability of the same food item (Jacobs 1974). It is also essential to measure errors associated with preference index values of animal diets and food availability data sets and such errors should be included in the calculations for statistical validity (Hobbs & Bowden 1982). The 95% confidence interval was therefore assessed for the utilization of each plant species (Neu *et al.* 1975). Preferences were considered significant if the confidence interval did not overlap the mean relative availability (Neu *et al*. 1975). All the plant species that contributed > 2% to the diet of white rhinos were classified as Principal Dietary Items (PDI) (Petrides 1975) and were determined per season.

Plant species in the diet were classified into the following growth form categories: forbs, grasses, geophytes, succulents, sedges and woody shrubs. Utilization and the contribution of different growth forms to the diet across seasons was assessed by calculating mean percentage of growth form. A χ^2 goodness of fit test was used to test the hypothesis that growth forms were utilized in proportion to their availability (Zar 1999). Differences between relative availability and utilization of growth forms during the dry season were determined by calculating 95% confidence interval for the utilization of each growth form (Neu *et al*. 1975). The dry season (winter and autumn) is defined as the period experiencing minimal rainfall and scarce food resources. Normality tests were ran before the analysis was performed. All percentage data had to be arcsine-transformed as it did not satisfy the assumptions of normality (Zar 1999).

3.4 Results

During the study period Shamwari Private Game Reserve receives rainfall throughout the year with peaks in summer and notable declines in winter (Figure 3.1).

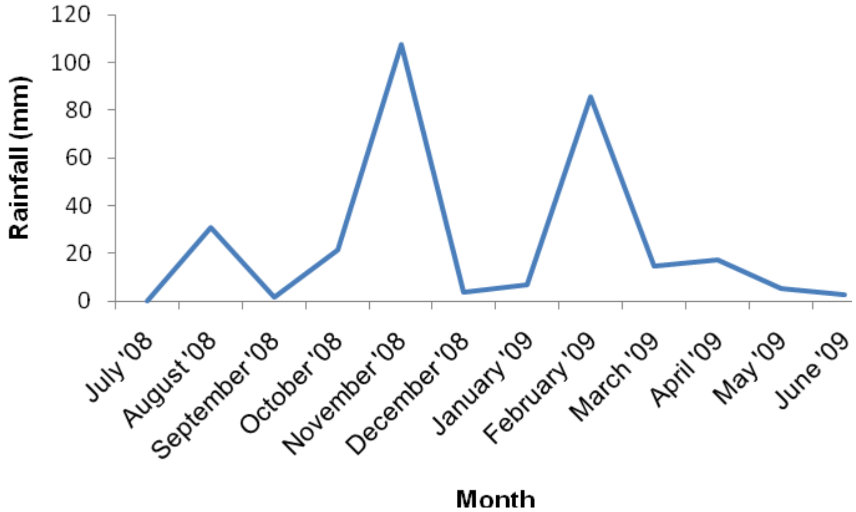
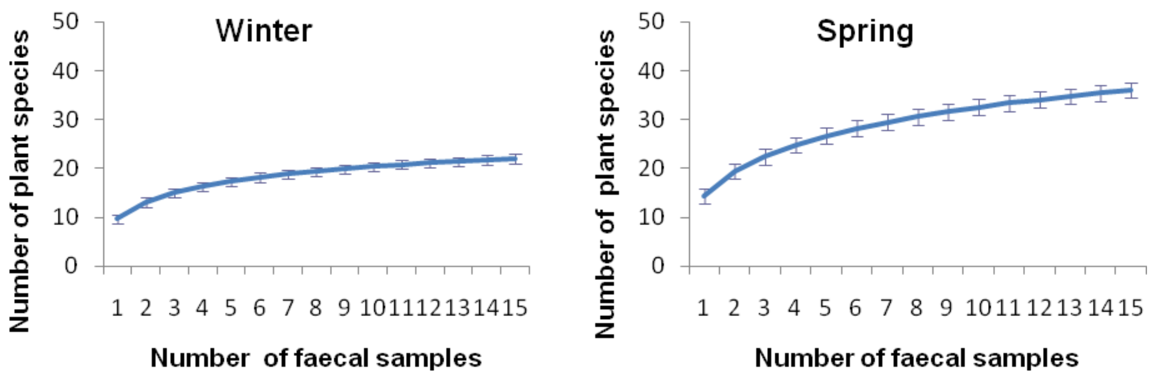


Figure 3.1: Rainfall pattern in Shamwari Private Game Reserve for the duration of the study (Shamwari Wildlife Department 2009).

3.4.1. Forage availability

A total of 114 plant species of varying growth forms were recorded on the point transect method when determining forage availability during autumn. The available potential forage was dominated by woody shrubs (57.6%) followed by forbs (14.4%), succulents (11.9%), grasses (10.1%), geophytes (5.1%) and sedges (0.9%) (Appendix 2).



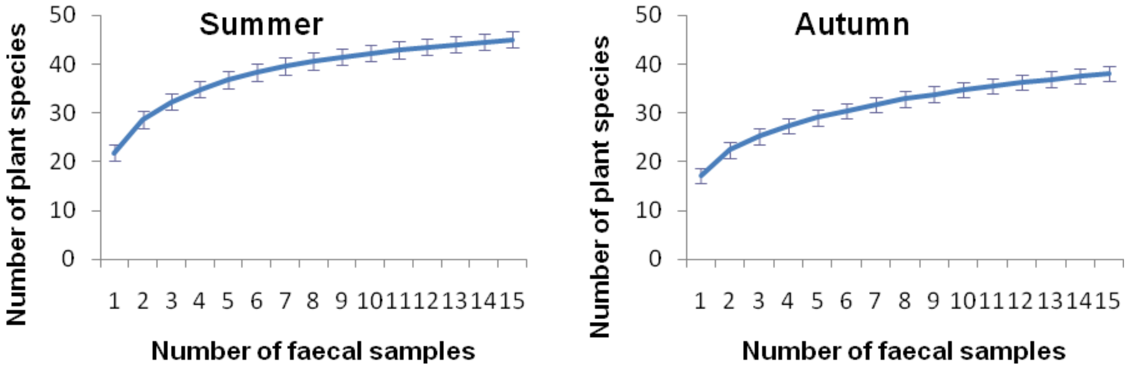


Figure 3.2: Accumulation curves (mean ± 1 SD; 50 randomised iterations) for all seasons of plant species recorded per white rhino faecal sample.

Table 3.1 Number of plant species observed in diet of white rhino across all four seasons and estimators of species richness (ICE).

Season	Observed species	ICE	Estimated number of species missed
Winter	22	25	3
Spring	36	44	8
Summer	45	50	5
Autumn	39	46	7

3.4.2. Diet composition

None of the accumulation curves performed on the data reached an asymptote (Figure 3.2) indicating that there were some missing plant species due to under sampling or rarity of the species (Table 3.1). The lowest number of species recorded in the diet was in winter when only 22 species were observed, followed by 36 in spring, 39 in autumn and 45 in summer.

Table 3.2: The overall plant species observed in the diet of white rhino in Shamwari Private Game Reserve and their growth forms for all seasons, a dash represents an unknown family of a species. Contribution of growth forms also recorded.

Growth form	Family	Plant species	Mean consumption (%)	Growth form (%)
Grass	Poaceae	*Karoochloa curva*	18.77	Grasses = 77.6
Grass	Poaceae	*Panicum deustum*	10.87	Forbs = 17.2
Forb	Fabaceae	*Medicago sativa*	7.38	Succulent = 0.02
Sedge	Lasiocampoiaea	*Androcymbium longipes*	6.78	Sedge = 5.2
Grass	Poaceae	*Themeda triandra*	6.12	Geophyte = 0.02
Grass	Poaceae	*Stenotaphrum secundatum*	5.67	
Grass	Poaceae	*Eragrostis obtusa*	5.55	
Forb	_	Unidentified forb 1	5.10	
Grass	Poaceae	*Eustachys paspaloides*	4.92	
Grass	Poaceae	*Panicum maximum*	4.22	
Grass	Poaceae	*Cynodon spp.*	3.80	
Grass	Poaceae	*Scirpus dioecus*	2.55	
Grass	Poaceae	Unidentified grass 5	2.33	
Grass	Poaceae	*Cynodon dactylon*	1.96	
Grass	Poaceae	*Melinis repens*	1.81	
Forb	Aizoaceae	*Aizoon rigidum*	1.52	
Grass	Poaceae	*Eragrostis curvula*	1.47	
Grass	Poaceae	Unidentified grass 1	1.47	
Grass	Poaceae	*Hyparrhenia hirta*	1.44	
Grass	Poaceae	*Eragrostis sp.*	1.24	
Grass	Poaceae	*Eragrostis capensis*	1.11	
Forb	Commelinaceae	*Commelina africana*	0.97	
Grass	Poaceae	*Digitaria eriantha*	0.97	
Forb	Aizoaceae	*Galenia pubescens*	0.90	
Forb	Asteraceae	*Senecio linifolius*	0.90	
Grass	Poaceae	*Ehrharta calcina*	0.89	
Forb	Aizoaceae	*Lampranthus productus*	0.67	
Forb	Solanaceae	*Solanum lineanum*	0.67	
Forb	Solanaceae	*Solanum tomentosum*	0.67	
Forb	_	Unidentified forb 3	0.67	
Forb	Asteraceae	*Senecio inaequidens*	0.65	
Grass	Poaceae	*Ehrharta capensis*	0.62	
Grass	Poaceae	*Fingerhuthia africana*	0.56	
Forb	_	Unidentified forb 6	0.47	
Grass	Poaceae	*Eragrostis plana*	0.37	
Forb	Asteraceae	*Cineraria lobata*	0.33	
Forb	Asteraceae	*Senecio spp.*	0.33	
Forb	_	Unidentified forb 5	0.33	
Grass	Poaceae	*Digitaria spp.*	0.33	
Grass	Poaceae	Unidentified grass 3	0.33	
Forb	_	Unidentified forb 2	0.31	
Forb	Solanaceae	*Solanum sp.*	0.27	
Forb	Aizoaceae	*Tetragonia decumbens*	0.27	
Forb	_	Unidentified forb 4	0.27	
Grass	Poacea	Unidentified grass 2	0.27	
Forb	_	Unidentified forb 7	0.27	
Grass	Poaceae	*Stipa dregeana*	0.24	
Grass	Poaceae	*Melica racemosa*	0.20	
Forb	Commelinaceae	*Commelina spp.*	0.20	
Grass	Poaceae	Unidentified grass 4	0.13	
Forb	Campanulaceae	*Wahlenbergia uitenhagensis*	0.13	
Grass	Poaceae	*Brachiaria serrata*	0.07	
Grass	Poaceae	*Eragrostis aethiopica*	0.07	
Geophyte	Hyacinthaceae	*Eucomis autumnalis*	0.07	
Succulent	Liliaceae	*Aloe ferox*	0.03	

Fifty-five (including unidentified plants that were classified according to respective growth form) plants were identified as occurring in the diet of white rhino, of those 77.6% of the species were grasses, 17.2% forbs, 5.2% sedges with succulents and geophytes each making up only 0.02% of the species in the diet (Table 3.2). Forb consumption peaked during the winter season (14 forb species, 31.8%). Woody shrubs were not utilized by white rhino for the duration of the current study.

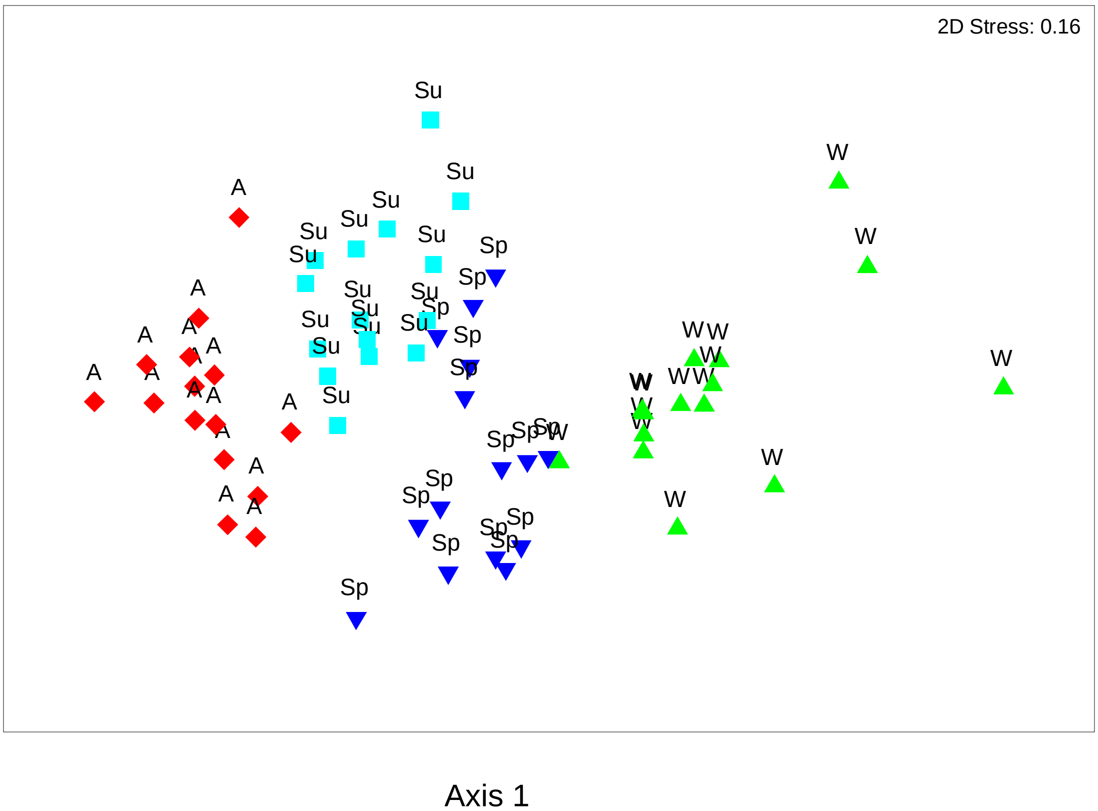


Figure 3.3: An n-Multidimensional Scaling ordination (1000 permutations) of white rhino diet at Shamwari Private Game Reserve across all seasons (A = autumn, Su = summer, Sp = spring and W = winter).

The MDS plots stress factor was 0.16 (Figure 3.3) showing that use of the 2D dimensional plot was appropriate to illustrate the comparison between dietary species and seasons (Quinn & Keough 2002). The MDS plot (Figure 3.3) further showed that there was a difference between seasons, as overlaps were minimal between seasons, particularly along the Axis 1, and samples from of the seasons were clustered together.

ANOSIM statistics test followed a similar trend, showing a significant difference between seasons, where $p < 0.001$, thus a similar p value for all seasons. The difference between seasons was noted and is arranged in ascending order, the difference between spring and summer was ($R = 0.599$, $p < 0.001$), winter and spring (R 0.622, $p < 0.001$), summer and autumn ($R = 0.702$, $p < 0.001$), spring and autumn ($R = 0.869$, $p < 0.001$), winter and summer ($R = 0.869$, $p < 0.001$) and lastly, winter and autumn ($R = 0.968$, $p < 0.001$).

Table 3.3: Consumption of growth forms by white rhino at Shamwari Private Game Reserve for four seasons.

Growth form	Winter (%)	Autumn (%)	Summer (%)	Growth form	Spring (%)
Grass	47.5	95.0	84.7	Grass	84.6
Forb	42.5	3.9	12.8	Sedge	8.1
Sedge	9.9	0.1	2.3	Forb	7.3
Succulent	0.0	0.0	0.1	Succulent	0.0
Geophyte	0.0	0.0	0.1	Geophyte	0.0

Grasses were the most utilized food types through all the seasons, but a lot of forbs were consumed during the winter season (Table 3.3). Succulents and geophytes made minimal contribution towards the diet of white rhino with each contributing 0.1% only in summer. Grasses contributed the most (95.0%) to the diet of white rhino in autumn and their least (47.5%) contribution was in winter. Forbs also formed an important component of the diet of white rhino with the most (42.5%) contribution recorded in winter and the least (3.9%) in autumn. Sedges were eaten the most (9.9%) in winter and least (0.1%) in autumn.

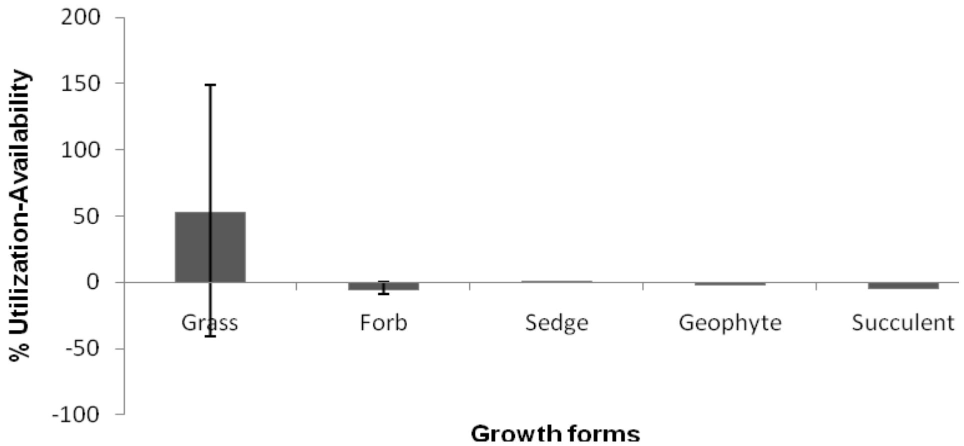


Figure 3.4: Difference between the availability and use of growth forms by white rhino (± 95% confidence interval) during autumn. Growth forms > 0 are used more than expected based on availability. Woody shrub data not featured as they were recorded as present but not eaten.

The overall use of grasses was significantly greater than that of other growth forms followed by forbs (Table 3.3 and Figure 3.4). Use of succulents and geophytes was minimal and woody shrubs were not used (Table 3.3 and Figure 3.4). There was no significant difference in the use of grasses and forbs compared to available forage, but sedges were more significantly used during autumn than was available (Figure 3.4). In autumn growth forms were not utilised in proportion to their availability (χ^2 = 25.687 df = 2, p < 0.001). Growth forms were used more than was available. Geophytes and succulents were significantly avoided.

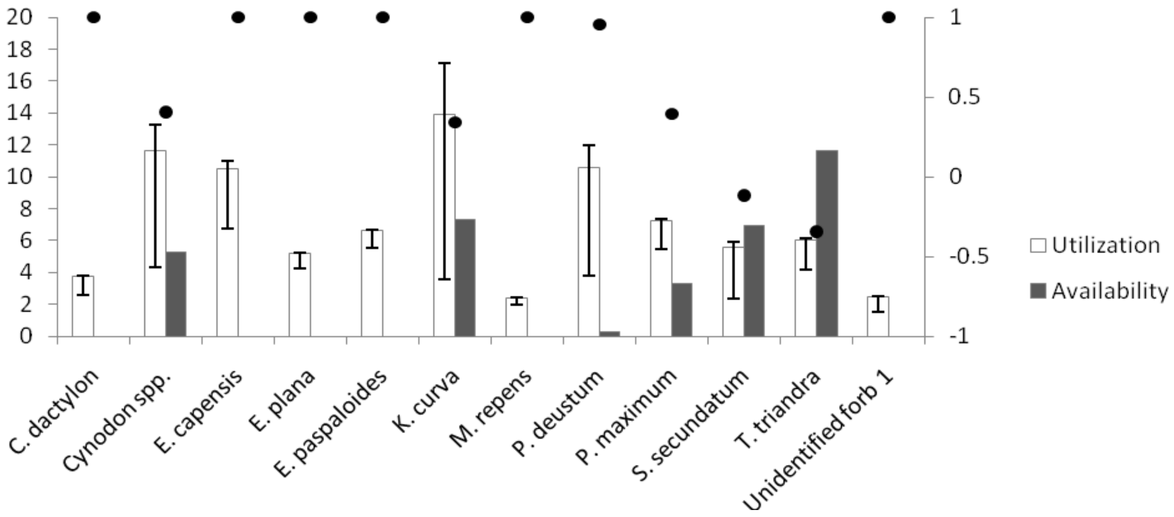


Figure 3.5: Utilization of principal dietary items by white rhino (± 95% confidence interval) during autumn. Jacob's index (black dots) indicates preference (D>0) and avoidance (D<0).

The confidence intervals (± 95%) in Figure 3.5 indicate which species were significantly preferred and avoided in autumn by white rhino. *K. curva* (D = 0.34), *M. repens* (D = 1.00), *Cynodon spp.* (D = 0.41), *E. plana* (D = 1.00), *P. deustum* (D = 0.96) and the unidentified forb 1 (D = 1.00) were significantly preferred. *S. secundatum* (D = -0.12) is the only grass species which was significantly avoided. There was no significant difference in the use of *C. dactylon* (D = 1.00), *Ehrharta capensis* (D = 1.00), *E. paspaloides* (D = 1) *P. maximum* (D = 0.40) and *T. triandra* (D = -0.34) than was available.

Principal dietary items were also identified totalling 25 species, which varied with season (Table 3.4). *C. dactylon*, *Cynodon spp., Ehrharta capensis*, *E. plana*, *E. paspaloides*, *K. curva*, *M. repens*, *P. deustum*, *P. maximum*, *S. secundatum*, *T. triandra* and unidentified forb 1 were the PDI's for autumn (Figure 3.5).

Table 3.4 Percentages (± SD) of principal dietary items observed per season in white rhino diet. Blank spaces denote the absence of a species for the season.

Plant species	Winter	SD	Spring	SD	Summer	SD	Autumn	SD
Karoochloa curva	18.9	9.4	23.5	7.7	18.8	7.7	13.9	5.8
Medicago sativa	27.4	9.0	<2		<2		<2	
Unidentified forb 1	10.1	12.3	2.1	3.7	5.7	2.7	2.5	2.1
Panicum deustum	10.1	7.9	11.3	4.2	11.5	6.6	10.6	6.3
Androcymbium longipes	9.9	5.4	8.1	4.6	2.3	2.4	<2	
Eragrostis obtusa	7.3	5.4	4.9	4.6	3.5	3.3		
Eustachys paspaloides	2.1	3.5	7.0	6.8	3.9	4.5	6.7	8.4
Stenotaphrum secundatum	2.3	2.7	5.6	3.2	9.1	4.1	5.6	2.9
Themeda triandra			11.6	5.0	5.4	3.6	6.1	8.7
Panicum maximum			3.5	4.2	6.0	5.1	7.3	7.7
Scirpus dioecus			3.9	4.2	4.8	3.4	<2	
Cynodon dactylon			<2		2.2	1.7	3.7	3.3
Unidentified grass 1	2.5	4.0	2.7	2.9	<2		<2	
Cynodon spp.	<2		2.2	1.9	<2		11.7	6.3
Melinis repens	<2		<2		3.4	3.0	2.4	2.6
Ehrharta capensis			<2		<2		10.5	8.3
Hyparrhenia hirta			<2		3.1	4.1	<2	
Commelina Africana	2.2	4.7	<2		<2		<2	
Ehrharta calcina			<2		2.4	2.3	<2	
Eragrostis curvula			<2		2.0	1.4	<2	
Eragrostis racemosa			<2		2.0	2.6	<2	
Eragrostis capensis			2.1	2.5	<2		<2	
Aizoon rigidum	<2		<2	2.3	2.0	<2		
Eragrostis spp.					<2		4.1	2.5
Unidentified grass 5					<2		5.2	6.1

The species contributing the most to the overall diet were *K. curva*, *P. maximum*, *S. secundatum*, *P. deustum*, *E. obtusa*, *E. paspaloides*, *T. triandra*, *A. longipes* and unidentified forb 1. *K. curva* was the main dietary item for all seasons except winter when *M. sativa* dominated (Table 3.4). 84% of PDI were grasses, forbs (12%) and sedges (4%). Thus, PDI were predominantly grasses.

3.5 Discussion

3.5.1 Diet composition

The accumulation curves approached an asymptote with very little variation in standard deviation. A total of 55 plants species were identified in the diet of white rhino although ICE indicated that there could have been 60 species. These were not recorded because they were particularly rare. The data is therefore sufficient to describe the diet of the species at this site. The microhistological technique is not only reliable but convenient to measure free ranging herbivore diets (MacLeod *et al*. 1996). Diet sampling was adequate therefore to describe the diet of white rhino in the Eastern Cape. Many studies have previously used this method to describe herbivore diet with sample sizes ranging between seven, nine and fifteen (as was the case in the current study) that give reliable results (Sigwela 1999; Koekemoer 2001; Nyafu 2009).

The diet of white rhinos, though comprising mostly of grasses, also included some forbs. Elsewhere however their diet has been more narrowly described, with only grasses being primarily consumed (Player & Feely 1960; Owen-Smith 1988; Pienaar *et al*. 1992; Pienaar *et al*. 1993; Shrader & Perrin 2006). It was interesting to find that even during the wet season animals seem to use *T. triandra* just as much as the dry season, even more so, which could be due to the high availability of the plant species in the reserve. Elsewhere, *T. triandra* has been recorded to be fed upon only during the dry season as animals avoid it when other grasses are available (Owen-Smith 1988; Shrader *et al*. 2006). It is thus used in great quantities during the dry season in the natural range (Owen-Smith 1988; Shrader *et al*. 2006). The relative availability of *T. triandra* was 9.8% in Shamwari Private Game Reserve (Appendix 1). The availability data confirmed the low levels of grass (10%) availability, with browse dominating the system. This further suggests that the quality of grass in Shamwari is poor.

The occurrence of *M. sativa* in the diet reflects the management intervention of feeding white rhino at Shamwari Private Game Reserve in winter. The heavy reliance on this species (27.4%) suggests that other resources are limiting at this time. Verification of the importance of this supplementary feeding is beyond the scope of this study, but it has profound implication for diet strategies of this species at this site.

During summer *P. deustum* was the grass species eaten the most (16.0%) and the most preferred by impala in Shamwari (Gerber 2008). During summer *K. curva* was the grass species consumed the most (18.8%) in this study with *P. deustum* comprising 11.5%. But in winter *E. curvula* (42.5%) and *C. dactylon* (16.1%) contributed the most to the diet of impala in Shamwari (Gerber 2008). *E. curvula* was thus an important dietary item for impala during winter season, with a mean percentage of 42.5%. *E. curvula* was not utilized at all in winter but 2.1% was used in summer in the current study. This species is thus not under threat due to white rhino herbivory as its use is low. Plant species overlap occurs between impala and white rhino with regards to the use of *P*. *deustum*. There seems to be an alternate use of *C. dactylon* and *E. curvula* in seasons between these herbivores. *K. curva* (18.9%)*, M*. *sativa L.* (27.4%), *P*. *deustum* (10.1%), were the PDIs during the dry season for this study and is possibly at risk of herbivory by white rhino. Of 12 PDI's, six (50%) were preferred by white rhino in autumn.

3.5.2. The impact of the dry season on feeding behaviour

Plants lose their nutrients during the dry season, and for a megaherbivore the scenario is exacerbated as they need a lot of such nutrients to meet their daily metabolic needs (Shrader *et al. 2006*). To compensate for this loss, herbivores employ a number of strategies outlined by Shrader *et al.* (2006). Herbivores generally increase their time spent foraging during the dry season (Owen-Smith 1994). If white rhino were to increase the time spent foraging in the Eastern Cape thicket which is limiting in grasses, this would put more pressure on the resource and animals as they would lack a resource which they depend upon for survival and nutritional needs. Thus, other activities would be delayed. However, Shrader *et al*. (2006) showed that white rhinos fed less than previously recorded during such a period. Unlike the scenario described by Owen-Smith (1994) that white rhino widen their diet, showing low selectivity (Melton 1987) to incorporate dietary items with less nutritional value in terms of species grazed upon, the opposite was true for the present study with only 12 PDI's recorded in their diet during autumn. This reflects the heavy use of lucerne provided as a supplementary feed. Thus, white rhino were expected to broaden their diet during the dry season but instead showed high selectivity. Similarly, Venter & Watson (2008) found that more grass species were incorporated in the diet of buffalo in summer than they were in winter in Nama-Karoo which is characterized by low grass availability. This pattern was related to habitat use by buffalo (Venter & Watson 2008).

3.5.3 Possible impacts on plants and herbivores in thicket

This is the first study to date that describes the diet of the megaherbivore, white rhino, in the Eastern Cape thicket and comparisons will therefore be made between white rhino, other extra-limital herbivores such as impala and giraffe, and indigenous herbivores such as buffalo and elephant, occurring in this habitat. The diets of these herbivores may overlap as a result of similar feeding behaviour in the same habitat.

Grasses eaten the most have been identified in this section of the study. In addition, preferred food resources are likely to be under grazing pressure (Jacobs 2008) and these are probably the most at risk by white rhino grazing, which could lead to ultimate loss of the food resource if nothing is done about the management and distribution of the animals (Landman *et al*. 2008). Megaherbivores are partially responsible for the disappearance of endemic and rare species in the thicket habitat (Landman *et al*. 2008). Extensive grazing by white rhino has resulted in the creation of bare ground in the Hluhluwe-iMfolozi Park (Owen-Smith 1981). The same could also apply in Eastern Cape properties with white rhino especially because grass availability is low in most of these areas (see Chapter 4 and results of this chapter). How does a megaherbivore remain a pure grazer in a grass-limiting environment?

Buffalo and zebras, which are predominantly grazers were found to have a small percentage (28.1% and 8.5%, respectively) of browse in their diet in the Eastern Cape thicket habitat (Landman & Kerley 2001). They therefore showed that specialist grazers are not likely to shift their diet even in a grass-limiting environment (Landman & Kerley 2001). White rhino have also consistently shown to be grazers despite (Current study) the low availability of grass and their high selectivity shows that they could impact on their forage resources. There is a high likelihood that competition for resources between predominant grazers such as buffalo, zebra, hippopotamus, gemsbok and white rhino exist in Shamwari Private Game Reserve.

There was an overlap in grass species (*P*. *deustum*, *E. curvula* and *C*. *dactylon*) eaten by impala which, are mixed feeders and white rhino in Shamwari Private Game Reserve (Gerber 2008; Current study). This is indicative of possible competition for grass resources between mixed feeders and white rhino. Nyafu (2009) also showed that warthogs, although, predominantly grazers (79%) included browse but white rhino in the current study did not include any browse in their diet. In addition, introduced giraffe have been shown to have a potential negative impact on preferred plant species in Eastern Cape thicket, this result is exacerbated where resources are limiting and the animals exist at high densities (Jacobs 2008).

3.5.4 Supplementary feeding

None of the populations occurring in the natural range were reported to be supplementary fed at any time over the duration of the studies, implying that there was a sufficient supply of natural resources available to white rhino within their natural range (Owen-Smith 1988; Shrader & Perrin 2006). Supplementary feeding was reported to be applied in three Eastern Cape populations during the winter season as a tool to combat limiting natural forage resources. Additionally, supplementary feeding is commonly used on animals kept in captivity (Galpine 2006). Supplementary feeding in the Eastern Cape is a result of the management’s lack of confidence that the white rhinos will persist in the habitat due to obviously limiting resources. The implications of the supplementary feeding on diet choice and feeding impacts are currently unknown as only one population was studied here. It may be hypothesized that in the short term this would reduce rhino impacts on the natural vegetation, although in the long term this would maintain artificially high populations of white rhino on these properties.

3.6 Conclusions

White rhino are predominantly grazers despite relatively low grass cover in the Shamwari Private Game Reserve, and also include forbs and sedges in their diet. Twenty-five PDI by white rhino were recorded. Additionally, dietary overlaps were recorded which could result in possible competitive behaviour between white rhino and other herbivores in the Shamwari Private Game Reserve and because of this, plant species could be depleted faster than would normally be the case if one species was acting upon it. White rhino therefore, potentially heavily impact plant species in the reserve, and the preferred species and PDI species identified here should be used as the basis for a monitoring programme to assess any such impacts.

CHAPTER 4
DISTRIBUTION AND PERFORMANCE OF WHITE RHINO IN THE EASTERN CAPE

4.1 Introduction

D'Antonio *et al*. (2001) postulated that most exotic species do not succeed in their newly established habitats. White rhino introductions in Eastern Cape were deliberate and meant to serve ecotourism, conservation and hunting objectives. Translocation has thus led to the establishment of new non-native populations in a variety of locations. A concern however arises as to whether white rhinos can establish successfully and prosper in their new habitats in the Eastern Cape which has a range of biomes, some of which are grass poor (Mucina & Rutherford 2006). This concern reflects both their status as an introduced species and their specialized food requirements as the largest grazers (Owen-Smith 1974). It can therefore be hypothesized that white rhino introductions, and subsequently persisting populations, should be focussed on the more grass-rich habitats in the Eastern Cape. Such habitats can be mapped as vegetation types or biomes, as defined by Mucina & Rutherford (2006).

The performance of the white rhino in the present study was determined through the reproductive success of females in terms of intercalving intervals (ICI) in relation to other populations in suitable habitats where white rhino occur naturally. ICI is defined as the interval between births of calves by a female (Rachlow & Berger 1998) or simply how long a female takes between births. A number of studies have looked at the general overview of ICI of rhino cows but some have been more specific (Owen-Smith 1988; Rachlow & Berger 1998; Shrader & Owen-Smith 2002; Emslie in press; White *et al*. 2007a). The average gestation period for cows within the natural range is 16 months for white rhino cows (Owen-Smith 1988; Pienaar 1994). Rachlow & Berger (1998) estimated that the ICI for white rhinos is 2-4 years. In contrast, Shrader & Owen-Smith (2002) documented ICI to be between 2 to 3 years. More precisely, Owen-Smith (1981) recorded it to be 2.4 years on average, with the shortest observed being 1.8 years.

Species may show variation in phenotypic features ranging in variation in morphology, physiology and life history traits as a function of environmental pressures. Variation in life history traits can include features such as age at first reproduction, litter size, interbirth intervals etc. as a function of resource availability (Rachlow & Berger 1998; Biela *et al*. 2009). These can then serve as useful indicators of performance of populations as these features ultimately influence the demographics of a population (Caughley 1977).

Various factors influence white rhino female reproductive success and hence population growth. These include extrinsic factors such as drought (as grass availability declines with drought, Groves 1972), or intrinsic factors such as age of rhino cows, older females taking longer to produce a calf compared to younger females (Owen-Smith 1988; Rachlow & Berger 1998). Moreover, it is imperative that there are sufficient resources to support a population, as this ensures fitness in terms of growth and reproductive success. Limited resource availability could lead to animals delaying age at first reproduction, with carrying capacity and density also featuring as factors acting upon a population (Biela *et al*. 2009). Not surprisingly, age at first reproduction was found to be significantly lower for low density females than high density females by Rachlow & Berger (1998). Presumably the former had less competition for resources. Body condition in relation to population density and resource availability reflects resource availability and also influences reproductive success (Rachlow & Berger 1998).

The current study was therefore carried out to determine the current distribution of white rhino in the Eastern Cape in relation to the different biomes. I wanted to test the hypothesis that introduced white rhino populations in the Eastern Cape should be limited to grass-rich habitats. Furthermore, if resources are limiting, the reproductive performance should be lower in the Eastern Cape compared to white rhino occurring in areas of their natural range. The performance of white rhino through birth data in the Eastern Cape was therefore assessed.

Surveys to assess the status of white and black rhino on private land have previously been conducted in the Eastern Cape (Buijs 2000; Castley & Hall-Martin 2003; Hall-Martin & Castley 2003) suggesting that attempts have been made in the past to determine reproductive performance of the species in the Eastern Cape. Such surveys are seldom successful, due to lack of responses from the respondents (Castley & Hall-Martin 2003), due to concerns over the security of the rhino. Information pertaining to white rhino populations was treated with confidentiality by the researchers in these surveys due to the understanding reached with the land owners who at the beginning were very reluctant to assist and contribute to the current study. A similar approach was therefore adopted here. The property names have therefore not been revealed for security reasons and will henceforth be referred to according to alphabetic coding or otherwise. Similarly, mapping is at a scale comparable with the scale represented on the websites of the landowners reporting white rhino on their websites.

4.2 Methods

4.2.1 Distribution

The internet was used as an initial step in discovering the total number of properties in terms of state reserves, private reserves and hunting operations that have white rhino in the Eastern Cape. The search engine Google (www.google.com) was used with 'white rhino in the Eastern Cape' as a search string to locate white rhino supporting properties in the Eastern Cape. Land owners who indicated that they had white rhino were then contacted for confirmation of the internet data and detailed data on deaths, births, and translocations of their white rhino populations was requested. A letter of support from the Rhino Management Group (Dr. Michael Knight, pers. comm. 2008) and a brief background of the current study was also provided to the landowners. Eastern Cape Parks was approached to obtain information pertaining to white rhinos kept in the state reserves. Follow-up telephone calls were made in cases where responses were delayed or for clarity purposes. A map was constructed using GIS, which outlined the distribution of white rhino in the Eastern Cape. The total number of properties that have white rhino in the Eastern Cape for primarily conservation, ecotourism or hunting purposes was calculated.

ArcGIS version 9.2 was used to map grassy *vs.* non-grassy habitats at the biome level in the Eastern Cape. These were defined according to the biomes described by Mucina & Rutherford (2006). Savanna and Grassland were considered to have high grass cover, and the rest of the biomes which include Thicket, Fynbos, Indian Ocean Coastal belt, Nama-Karoo and Succulent Karoo were categorized as low grass cover. A map was thus constructed identifying the white rhino populations located in grassy versus non-grassy habitats. Many sites supporting white rhino included more than one biome. Therefore at a finer scale, the proportion of grassy habitats (defined above) was estimated for each property in relation to the area of the property.

4.2.2 Population performance

Information regarding births and deaths and possible causes of death was sought from white rhino managers in the Eastern Cape. In order to compare the information obtained from the Eastern Cape, an application was made to the Ezemvelo KwaZulu Natal Wildlife to obtain relevant information on the Hluhluwe-iMfolozi Park white rhino population. Other avenues in terms of data from private properties elsewhere in natural species range were consulted to meet the objectives of the study but failed. Thus, due to insufficient information available, the only other alternative was to extract data from the literature on white rhino performance from a range of habitats within its natural range (Owen-Smith 1988; Rachlow & Berger 1998; White *et al*. 2007b). Not all the data from Eastern Cape properties surveyed could be used in the analysis, mainly because of insufficient information. Managers were also requested to provide information on any special management of white rhino, such as supplementary feeding.

4.2.3 Data analyses

The area for each property supporting white rhino was calculated. The number and proportion of white rhino populations in grassy *vs*. non-grassy habitats was calculated. A χ^2 test was used to test whether white rhino were randomly distributed across different properties in relation to the proportion of grassy habitats. Properties were classified as having 0-20, 21-40, 41-60, 61-80 and 81-100% of grassy habitat.

The estimated ICI of white rhino from previous studies (Owen-Smith 1988; Rachlow & Berger 1998; White *et al*. 2007b) in natural range including Kruger National Park, Hluhluwe-iMfolozi Park and Zimbabwe were used to compare with the average population ICI for two Eastern Cape populations for which I had sufficient data for and confidence intervals were calculated (Zar 1999). Confidence interval is for the ICI using individual females as replicates. If the estimated ICI of white rhinos within their natural range were within the confidence interval of white rhinos in the Eastern Cape, there was no difference in ICI between populations. In the case of white rhino from the Eastern Cape, the offspring of a female that was introduced to a site when she was already pregnant was ignored when calculating ICI. The χ^2 analysis was used to test if there was a sex bias in calves born in the Eastern Cape. Calves of which the sexes were unknown were ignored.

4.3 Results

4.3.1. Distribution

A total of at least 35 properties (Figure 4.1) were found to have white rhino in Eastern Cape. The majority of these are privately owned, operating as ecotourism and hunting reserves. Ecotourism reserves constitute about 66%, hunting 20% and state reserves contributing 14% of the number of populations of white rhino in the Eastern Cape. These data may under-represent the situation, as some populations may not be reported.

4.3.2 Hunting operations

None of the hunting operations (Figure 4.1) provided data for the survey and as such I have not presented their data. Websites of most hunting operations indicated opportunities of white rhino hunts but, upon contact for further information stated that they do not have such a species on their properties. Thus no data are available on hunting of white rhino in the Eastern Cape. Those illustrated in Figure 4.1 did have white rhino on their properties.

White rhino distribution in the Eastern Cape varies in terms of habitat, with 62% of the populations located in non-grassy habitats (Figure 4.1 & 4.2). White rhinos are mainly located in the Albany Thicket biome (67%), with the Savanna and Grassland biomes constituting only 25% of 21 properties that we had size and shape file data for. The χ^2 analysis revealed the distribution of white rhino across properties differed in terms of the proportion of grassy habitat (χ^2 = 1253.2, df = 4, p < 0.00). Inspection of Figure 4.2 shows that most of these were properties with less than 20% grassy habitat.

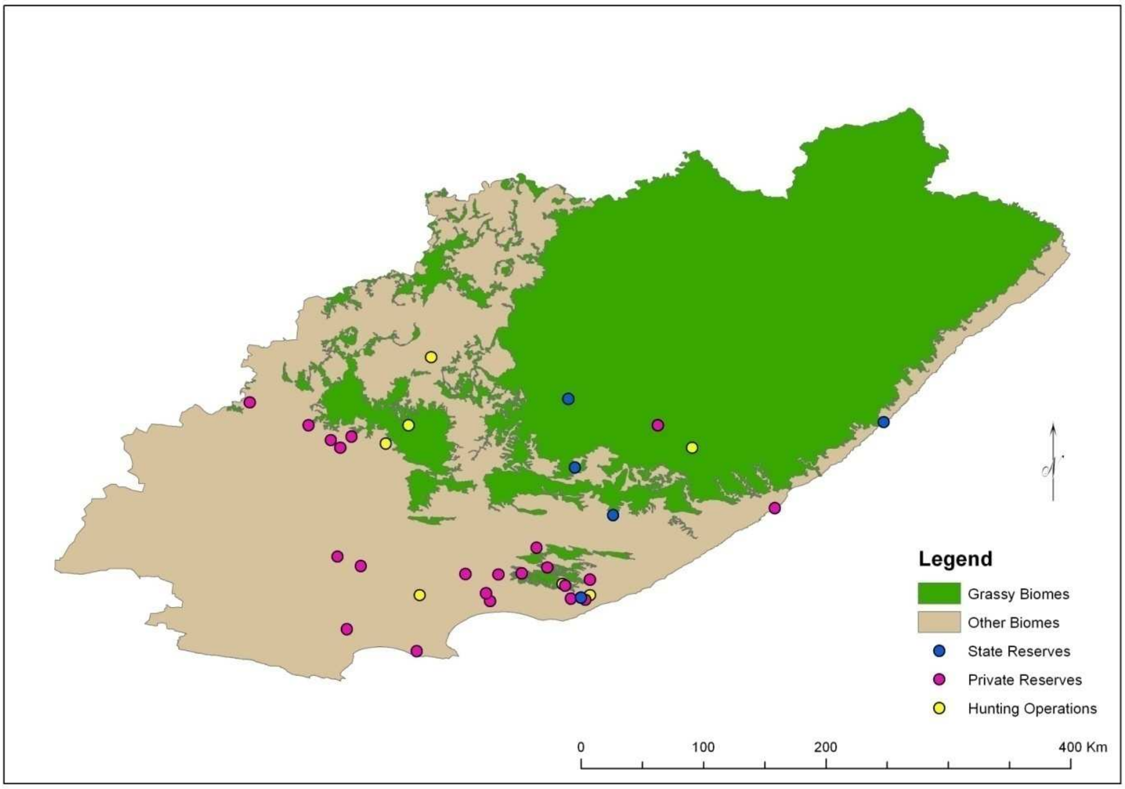


Figure 4.1: Map showing the distribution of white rhino in the Eastern Cape in relation to the relative amount of grass cover (see text for clarification of grassy *vs*. other biomes).

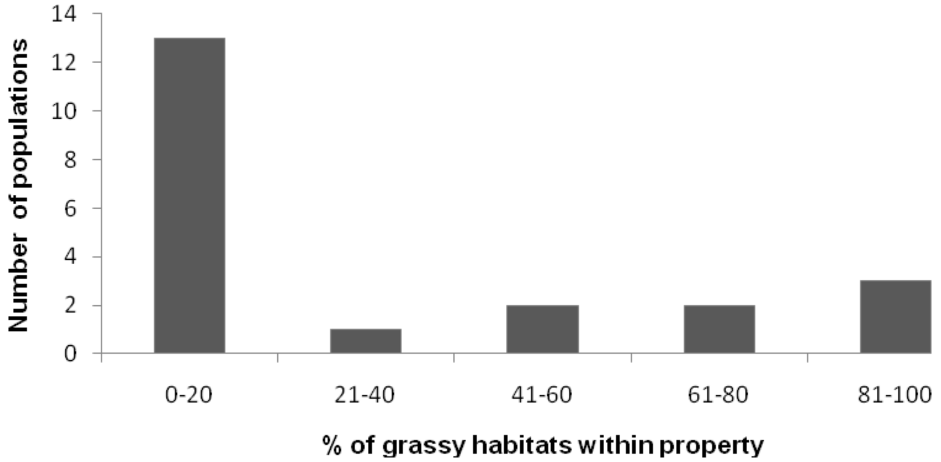


Figure 4.2: The majority (62%) of white rhino populations are located in low grass cover habitats (n = 21).

There are currently at least 135 white rhinos in the 15 private and state reserves for which data were provided in the Eastern Cape, with a ratio of male:female being 57:70 individuals, respectively, and the rest is either unknown or unsexed. A total of 108 calves have been born on all 15 reserves, 51 males and 35 females, the rest are not sexed. The χ^2 analysis of available data revealed that male calves contribute more to the offspring born to white rhino in the Eastern Cape than females (χ^2 = 19.8, df = 9, p < 0.02).

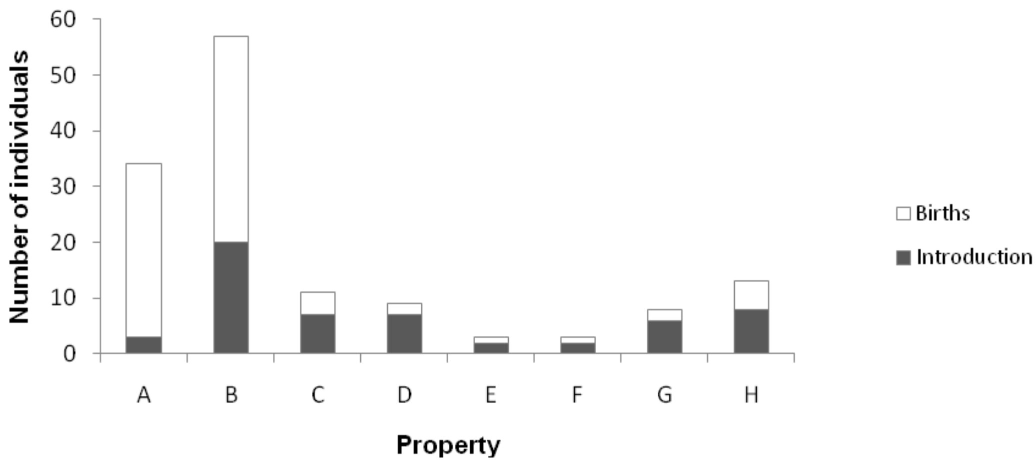


Figure 4.3: Stacked bar graph showing the contribution of birth *vs.* introduction to the growth of eight populations since the establishment of the white rhino populations in various properties until the year 2009.

The population composition data for eight properties for which adequate data were provided (Figure 4.3) show that most of the white rhinos were introduced rather than locally born. This was particularly so for the smaller populations (Figure 4.3).

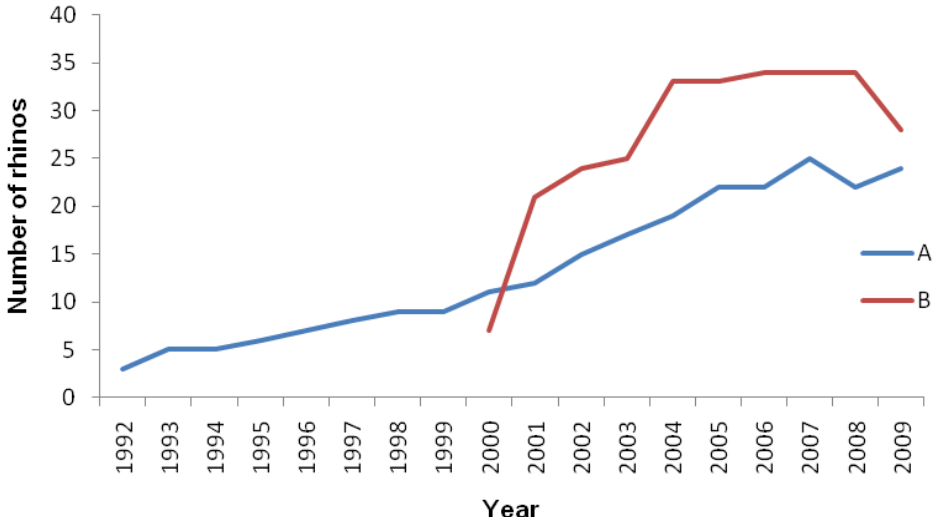


Figure 4.4: Graph depicting population trend of white rhino in two white rhino supporting reserves since the introductions.

Available data for two white rhino populations that have been established for a reasonably long period (> 8 years) clearly indicates growth of these populations (Figure 4.4), although the rate of introductions is not clear. The recent decreases in white rhino numbers in this figure represent recent removals of animals from property B. These have apparently been used to stock other areas in the Eastern Cape.

4.3.3 White rhino properties and population density

State and private reserves currently supporting white rhinos have a mean area of 9506 ha in the Eastern Cape (N = 21). The minimal area in which rhino occur in is 201 ha supporting only 2 rhinos, and the maximum area being 26307 ha with 5 rhinos. The density of rhinos for properties (N = 15) providing data averaged 0.26 km^{-2} with a range of 0.03 to 0.48 km^{-2}.

Table 4.1: Published intercalving intervals (ICI) of different white rhino populations in southern Africa. Note that the Zimbabwe populations are different populations.

Population	ICI (years)	Authors
Hluhluwe-iMfolozi Park	2.6	Owen-Smith (1988)
Kruger National Park	2.7	Owen-Smith (1988)
Zimbabwe (1)	2.9	Owen-Smith (1988)
Zimbabwe (2)	3.5	Owen-Smith (1988)
Zimbabwe (3)	2.7	Rachlow & Berger (1998)
Hluhluwe-iMfolozi Park	2.7	White *et al*. (2007a)

Table 4.2: ICI for two Eastern Cape populations together with the range represented by the 95% confidence intervals. Population A was supplementary fed during winter and B was not.

Population	ICI (years)	Number of females used to derive data	Births	-95%	+95%
A	2.6	6	29	2.2	3.0
B	2.3	12	38	1.7	3.0
C (all data for Eastern Cape combined)	2.5	27	81	2.2	2.9

One state reserve and 2 private reserves supplementary fed (lucerne) their rhinos in the Eastern Cape. Some reserves failed to respond to this question, so these data are incomplete.

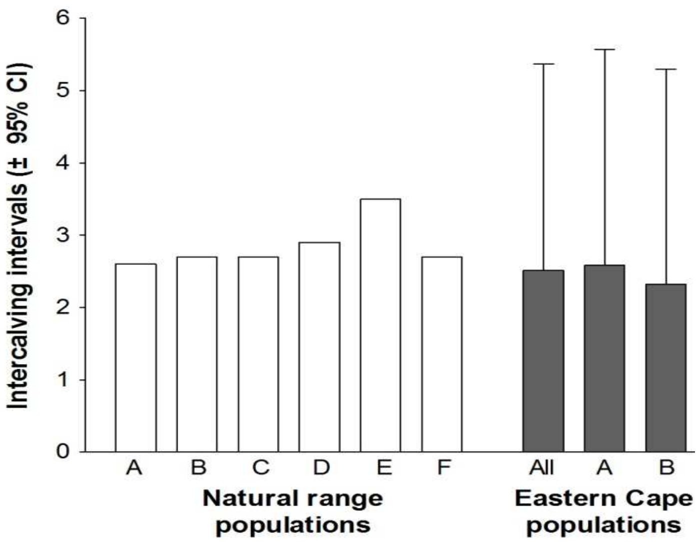


Figure 4.5: Intercalving interval data for white rhinos in their natural range (see Table 4.1 for sources) in relation to data for Eastern Cape white rhino (see Table 4.2). The error bars reflect 95% confidence intervals, and indicate the lack of difference in the data.

Intercalving intervals of white rhino for 6 data sets within the natural range varied from 2.6-3.5 years (Table 4.2). ICI data for the Eastern Cape population could be calculated for two populations and a further 9 individuals. These mean ICI values range from 2.3-2.6 years, with 95% confidence intervals including extremes of 1.7-3.0 years (Table 4.2). There is no significant difference (based on the confidence intervals) in the ICI of the Eastern Cape populations against the other populations in the natural range of the species (Tables 4.1 and 4.2).

4.4 Discussion

4.4.1 Data quality

A number of limitations in the nature and quality of available and collected data were encountered during this study. The information from Hluhluwe-iMfolozi Park was not what was initially anticipated with only census data conducted every two years but no information that goes down to individual level, especially for female-calf relations. The objective of clearly outlining population performance in terms of individual female ICI was therefore not achieved in this study. None of the hunting operations contacted participated in the study and as a consequence their rhino numbers are not reflected here. Furthermore, individual managers did not necessarily know the exact details pertaining to the history of the population. Information was therefore sometimes provided from rangers that had been with the reserve for at least a decade and thus had better personal understanding and knowledge of the population in question. For many populations the records of the year of release, birth, death or translocations did not exist. In contrast, data capturing and monitoring of white rhino is an ongoing process for some private reserves. This made it easier in terms of data extraction for these properties. Some Eastern Cape populations have proved to be too young to assess, with minimal data available because rhinos have recently been introduced. Information on KwaZulu Natal rhino is just as poor as that in state reserves in Eastern Cape with respect to monitoring and record keeping down to individual level. In summary, performance and data keeping is generally good in most private reserves but this does not apply to all white rhino properties (state and otherwise) in the Eastern Cape. A consequence of this is that the ability to comprehensively analyse and interpret the role of Eastern Cape white rhino populations in the conservation of this species was compromised. It is clear that there is an urgent need to ensure that such data collection and monitoring is initiated, and the data effectively managed.

There was great difficulty in an attempt to collect data on white rhino because of security concerns. These are a result of poaching. This phenomenon is a major issue for all rhino owners' country wide and beyond, as it threatens the safety and existence of the animals (Talukdar 2003). Therefore, a species that is of conservation concern will be poorly studied and managed if security of information regarding the species is an issue. Mechanisms should thus be put into place to securely collect and analyse data on white rhino, especially as internet-derived data cannot be trusted.

4.4.2 Distribution

Most white rhino populations in the Eastern Cape are located in the western portion of the province which reflects the focus of ecotourism industry (Langholz & Kerley 2006) and private landownership. In addition, these areas are grass-poor. These findings clearly refute the hypothesis that white rhino would be located in grass-rich habitats in the Eastern Cape. Some of these populations are also located on very small properties. These two factors suggest that white rhino in the Eastern Cape may be resource limited. The conservation and management of white rhino in the Eastern Cape is not therefore focussing on the optimal habitat or resource availability. Numerous authors (Player & Feely 1960; Griffith *et al*. 1989; Caughley 1994) have emphasized the need to manage species of conservation concern within appropriate habitats, whether these are *ex situ* or not. This calls into question whether these populations are sustainable or not. Furthermore, the need for supplementary feeding of some white rhino populations in the Eastern Cape would suggest insufficient natural forage for the survival of the animals especially during winter or drier months. So, although this study has demonstrated the presence of a number of white rhino populations representing a relatively large number of animals (> 135), it is not clear what the long-term prospects for this species in the Eastern Cape are.

4.4.3 Intercalving intervals

Emslie (in press) listed criteria to be used when assessing reproductive performance in terms of ICI. Thus, ICI of 4 years and above was described as poor, conversely, 2-3 years was described as excellent, but 3 years and more was described as relatively good (Emslie in press). In addition, a cow that is over 7 years and already at the time has a calf is an indicator of good reproductive performance (Emslie in press). A few such cases were recorded in some of the Eastern Cape private populations. However, more such cases might exist, the limiting factor is that the age at introduction of many animals is unknown, thus making it impossible to extract any information pertaining to age at first birth. ICI as recorded on Table 4.2 fall within the 'excellent' range description and are also not different to other populations in their native range. There is a high level of phenotypic plasticity (Biela *et al*. 2009) in the species as demonstrated by the variation in ICI. Hence, there is a need for a more comprehensive data set to directly compare populations across the range of ICI values.

Nutrition and food availability plays an essential role in reproductive performance (Owen-Smith 1988; Rachlow & Berger 1998). Female rhinos that are nutritionally challenged are not in good condition to either conceive or raise calves (Emslie in press). Subsequently, it has been suggested that white rhino cows in poor condition invest more in female calves because low quality daughters produce more offspring as compared to low quality sons (White *et al*. 2007b). Interestingly, there is a sex bias in the young produced in the Eastern Cape reserves i.e. 51:35 in the favour of males. This issue needs further investigation. This was not expected based on the scenario described by White *et al*. (2007b) that females in poor conditions invest in low quality female calves that produce more offspring than low quality males. This suggests that females in the Eastern Cape are in a better nutritional condition to produce quality sons. This male bias in the calf production may reflect translocation and other stresses on these animals (Linklater 2007; Cameron & Linklater 2007). The issue of the drivers of biased birth sex ratios are complex, as only recently have the proximal mechanism been explored (Cameron *et al*. 1999; Cameron 2004; Linklater 2007). The data in the present study are not adequate to explore these drivers, but it is possible that stress associated with nutritional limits (e.g. Cameron *et al*. 1999) may bring about the observed biased birth sex ratios. Given that a large proportion of the individual white rhinos have been recently translocated and the demonstration by Linklater (2007) that translocation leads to biased birth sex ratios, this may be a real cost of establishing *ex situ* populations. The demographic consequences of these biased birth sex ratios will be felt for many years (Law & Linklater 2007) and need to be understood and managed.

According to Buijs & Anderson (1989) the Pilanesburg National Park is noted as the most successful location for white rhino conservation, after KwaZulu Natal and the Kruger National Park. Moreover, populations in some private reserves in the Eastern Cape are successful as per the definition by Griffith *et al*. (1989) which states that a translocation is successful if it results in a self-sustaining population. Many populations of ungulates introduced beyond their historic range failed to persist (Novellie & Knight 1994). Failures such as these signify the importance of using historic information to plan translocations to appropriate habitats (Novellie & Knight 1994). In addition, reproductive success of white rhinos in captivity has been low although mating behaviour is normal (Swaisgood *et al*. 2006). Some privately owned white rhino populations in the Eastern Cape were successful in terms of population growth, even though the habitat was not optimal. The suspected explanation for this apparent contradiction could be supplementary feeding. In contrast, Griffith *et al*. (1989) stated that the chances of success of introduced species in poor habitats are low. The role of supplementary feeding of white rhino in the Eastern Cape appears to be critical and needs further investigation. Furthermore, the role of ongoing introductions in growing and sustainable white rhino populations may be substantial, especially as the population has increased by more than four times since Buijs (1999) recorded 35 white rhino in the Eastern Cape in 1999.

Population growth in the Eastern Cape cannot be used to assess the effectiveness of the Eastern Cape in conserving the species. This is because these populations are supplemented by ongoing introductions. The ICI of white rhino populations in the Eastern Cape have been shown to be comparable to those of white rhino populations in the native range, despite the quality of habitats in the Eastern Cape. This then provides one objective measure of this conservation value of the Eastern Cape white rhino population.

4.5 Conclusions

Despite the historical absence of white rhino in Eastern Cape, many populations have been established, mostly in grass-poor habitats. Eastern Cape populations of white rhino show comparable population performance with populations occurring in the natural range. Private reserves play a pivotal role in conservation of white rhino in the Eastern Cape, as they constitute 67% of the number of populations. Only the state reserve kept rhinos solely for conservation purposes, although plans to remove them are being made because they are extra-limital species. Monitoring is a challenge for many Eastern Cape populations that provided their information to the current study. Lack of monitoring programs in place resulted in a number of demographic events being unaccounted for, for several years depending on the reserve in question. Conversely, good monitoring provides up to date information or data allowing for well informed conservation decisions to be made (Emslie in press) and should be implemented to better contribute to the conservation of white rhino in the Eastern Cape.

CHAPTER 5
GENERAL DISCUSSION

5.1 White rhino in the Eastern Cape

This project aimed at collecting and synthesizing data on the distribution and population performance of white rhino populations introduced into the Eastern Cape. This was done in order to assess crude habitat suitability and population performance after introductions to various areas within the Eastern Cape, using locally-collected data and comparing this with data from populations in the natural distribution range. The idea behind introductions is often that species can be conserved and flourish in terms of population growth and sustainability (Armstrong & Seddon 2008). Habitat quality is the key factor that determines success or failure of population introductions that take place (Novellie & Knight 1994; Armstrong & Seddon 2008). This factor is critical when a species is introduced beyond its natural range. This was done as an approach to answer the two hypotheses and the one question asked:

H_1: The distribution of white rhinoceros in the Eastern Cape will be limited to grassy habitats in order to provide the forage resources.
H_2: The performance of *ex situ* white rhino populations in the Eastern Cape will be lower than that within their natural distribution range.
What are the plants at risk due to white rhino grazing?

Both hypotheses were rejected, as white rhino populations were mostly introduced into non-grassy habitats, but still showed demographic performance comparable to those within grassy habitats, within white rhino natural range. Caution should however be applied as only a small data set was used. The diet question was answered as the dietary species, PDI and preferred forage items were described. This study therefore represents the most comprehensive study of white rhino in the Eastern Cape. The lack of previous attention to this species in the Eastern Cape is surprising, given their conservation status, the fact that they have been introduced and their economic value.

A shortcoming of the current study is that despite the efforts made to acquire the data, there were gaps in the data I had in terms of the distribution and performance chapter (Chapter 4). Difficulties were encountered when collecting the data because landowners were reluctant to give out any information with regards to the species because of poaching concerns. The limited population data resulted in limits to the achievements of the current study, and clearly highlight the need to better monitor and critically evaluate the distribution and performance of white rhino in the Eastern Cape.

It was however possible to conclude that most of the sites within which white rhino are introduced to in the Eastern Cape, are probably highly unsuitable (grass-poor) for a mega-grazer (Owen-Smith 1988) like the white rhino. The fact that they still persist in these habitats raises the need to understand how this is achieved. The reliance on supplementary feeding is obviously important, but poorly understood.

5.2 Implications of having specialized grazers in an unsuitable habitat

Dietary items consumed by white rhino have been identified. White rhinos are clearly predominant grazers, showing preferences for grasses even in the browse-dominated thicket habitat of Shamwari Private Game Reserve. These white rhino have not shifted to become browsers in this browse-dominated habitat. This is similar to the demonstration by Landman & Kerley (2001) that buffalo and zebra maintain a grass-dominated diet in thicket. De Graaf *et al*. (1973) showed that buffalo that died in a drought had consumed mainly browse, presumably reflecting the absence of grass (Stuart-Hill & Aucamp 1993). This suggests that observation of white rhino switching to browse should serve as a warning of forage limitation.

They rely heavily on the forb lucerne during the winter season in Shamwari Private Game Reserve. It is not known what would happen in the absence of supplementary feeding of the population in this reserve. The principal dietary items and preferred plant species that are at possible risk of disappearing through white rhino herbivory have also been identified in this study. Such impacts through megaherbivory have been shown by elephants in Eastern Cape thickets (Moolman & Cowling 1994; Lombard *et al*. 2001;

Kerley & Landman 2006). If the grasses are eaten at a rate that exceeds their production, then these grass species are rendered vulnerable to high grazing pressure exerted on them, especially at high white rhino densities and if there are few other plant species to graze upon. Such grass species are *Cynodon spp.*, *K*. *curva*, *M*. *repens*, *P*. *deustum,* and *E*. *plana,* (and the unidentified forb 1) which were found to be significantly preferred by white rhino. This is supported by Lombard *et al*. (2001), who showed that the elephant as a megaherbivore at high densities has negative impacts on the plant community, as well as other herbivore species (Kerley & Landman 2006; Valeix *et al*. 2007). Grazing pressure and impacts by white rhino can therefore be detected by focusing monitoring on these plant species.

5.3 Effects of introduced megaherbivores in the Eastern Cape

The introduction of any non-indigenous species may have detrimental consequences for native species (Adler 2002). This is exacerbated in the case of megaherbivores as they have the ability to transform landscapes (Owen-Smith 1981; 1988; Kerley *et al*. 2008). The dry season is typically the most limiting in terms of resource availability (Melton 1975, Owen-Smith 1988; Shrader & Perrin 2006) and the impacts on resources and competing species are greatest at this time (Sinclair 1985). The issue of competition with indigenous grazers in a limiting environment in terms of resource availability therefore needs to be addressed. Competition of white rhino with other grazers in a grass resource limiting habitat is highly likely to happen, and needs to be investigated and is expanded on below. Many studies previously conducted in thicket have raised concerns regarding land-use practices and the introduction of non-indigenous species in this habitat (Kerley *et al*. 1999; Sigwela 1999; Gerber 2006; Jacobs 2008). Thus, white rhino are not the only herbivores to be introduced into the Eastern Cape, but they appear to be the only species that has been shown to rely on supplementary feeding (at least at some locations). This calls into question the sustainability of the population.

A wide range of herbivores co-occur with white rhino in Shamwari Private Game Reserve (O'Brien 2004) as well as more broadly in the Eastern Cape (Castley *et al*. 2001). O'Brien (2004) classified these herbivores according to feeding habits that consists of bulk grazers with buffalo, hippopotamus and Burchell's zebra, falling in the same category with white rhino (O'Brien 2004). Other categories include selective grazers like the black and blue wildebeest, gemsbok, red hartebeest, waterbuck and warthogs, and mixed feeders, like eland, impala, nyala and elephant (O'Brien 2004). Browsers include kudu, bush buck, common duiker and blue duiker). Note that not all species are indigenous.

Competition for overlapping resources is inevitable in habitats where white rhino co-occur with other herbivores. Extra-limital impala in Shamwari Private Game Reserve, for instance, were found to be more grazers, making use of the open plains, than browsers (thicket) in summer in the Eastern Cape thicket habitat (Koekemoer 2001; Gerber 2008). There is potential for competition between the herbivores mentioned above and white rhino especially because of lack of grass at these landscapes (Stuart-Hill & Aucamp 1993).

5.4 Other possible impacts of white rhino in the Eastern Cape

Grazing pressure by white rhino may result in denuded landscapes that promote run-off during the rainy season (Owen-Smith 1981; Owen-Smith 1987; Roques *et al*. 2001). White rhino have the ability to modify savanna ecosystems in Hluhluwe-iMfolozi Park by maintaining the sward height of grasses and by so doing keeping the grasses short (Waldram *et al*. 2008). White rhino may also influence fire dynamics through consumption of fuel (Waldram *et al*. 2008). Fire is infrequent in the thicket biome (Kerley *et al*. 1995) but white rhino herbivory may influence fire dynamics in other fire-influenced biomes where they have been introduced. Furthermore, alien plant species encroachers establish in disturbed landscapes where grasses have been removed and start invading such areas (Owen-Smith 1981). Thus, white rhino herbivory can therefore make way for soil erosion and woody species invasions (Owen-Smith 1987; Roques *et al*. 2001). It may thus be hypothesized that white rhino may affect ecosystem level processes significantly in terms of loss of grass species and cover, soil erosion and possibly invasion by woody shrubs. These ideas are similar to findings by Hoffman & Cowling (1990) who showed that domestic livestock brought about desertification in the Sundays

River Valley. It would be ironic if attempts to conserve white rhino *ex situ* were to lead such effects. This highlights the need to effectively study these possible impacts by white rhino.

5.5 Future research

This study, the most comprehensive study of white rhino in the Eastern Cape to date, has clearly been unable to address all the issues around this species in this region, and has in fact identified a number of research questions. These can be addressed as a number of hypotheses, some of which are developed below.

It may be hypothesized that the diet of white rhino varies with habitat within which introductions have taken place in the Eastern Cape, and overtime, as grass availability varies as a function of rainfall (Stuart-Hill & Aucamp 1993; Hoffman & Cowling 1990). There is therefore a need to investigate if the diet of white rhino in the Eastern Cape is uniform through properties and overtime.

It may also be hypothesized that those white rhino populations in the Eastern Cape relying on supplementary feeding may suffer high mortalities in the absence of supplementary feed. Hence the need to also expand on the understanding of populations and their resource use that are supplementary fed and compare them to populations that are not supplementary fed.

The dynamics associated with the plant species identified as preferred in the diet in the current study need to be studied. It may therefore be hypothesized that white rhino will have differential impacts on different grass species. Given this, it may also be hypothesized that white rhino depletion of preferred grass species may lead them to switching their diet to less preferred species, as shown by Davis (2004) for elephant and Simard *et al*. (2008) for white-tailed deer (*Odocoileus virginianus*). Thus monitoring diet and grass availability will serve to monitor both impacts, as well as possible periods of resource limitation.

There is also a need for better population data so as to better understand and further test the hypothesis that white rhino will perform less successfully in the Eastern Cape than populations in the natural range. This can ideally be focussed at the individual population level and be assessed as a function of resource availability. The growing number of white rhino populations in the Eastern Cape therefore allows expanded opportunities to investigate this idea. Ideally this should provide opportunities to detect fine detailed shifts such as growth rates, longevity, life-time reproductive outputs and sex ratio of offspring. An unexpected result in this study was the demonstration of male-biased birth-sex ratios of white rhino in the Eastern Cape. This finding raises the issue as to what the causes and consequences of this birth sex ratio bias may be. Many studies have highlighted the role of stress in birth sex ratio bias (Cameron 2004; Cameron & Linklater 2007; Linklater 2007) and it would therefore be important to further investigate whether this birth sex ratio bias is a function of stress around translocation or possible nutritional stress. Furthermore, the consequence of this biased birth sex ratio for population growth needs to be explored, as sex ratios have profound effects on population performance (Law & Linklater 2007).

Competition between white rhino and other indigenous herbivores needs to be studied in areas where white rhinos occur in the Eastern Cape, especially the interactions they have with indigenous grazers and plant species. Other ecological processes that white rhino carry with them as mega-grazers such as accelerating soil erosion should also be looked into. Thus, the hypothesis that white rhino carry with them ecological processes that may impact on other animals and plants should be tested.

The security concerns surrounding the rhino species in the Eastern Cape could lead to a species of conservation concern not being properly studied as information regarding them remains concealed. The private sector, including the hunting industry, needs to assist researchers with white rhino population data. Ongoing monitoring programs of the current and future populations are imperative in developing and meeting long term conservation objectives (Emslie & Brooks 1999; Castley & Hall-Martin 2003). I therefore recommend that a monitoring system should thus be applied that will focus on securely and effectively collecting and analysing data on the population dynamics after introductions of white rhinos and keeping track of populations as they grow. It is only when we are equipped with this level of information and understanding that we will be able to make conclusive statements regarding the rate of *ex situ* conservation of white rhino in the Eastern Cape.

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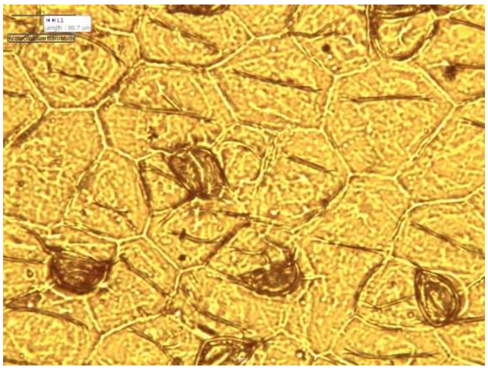
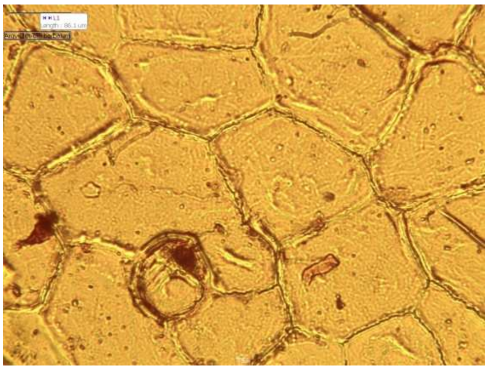
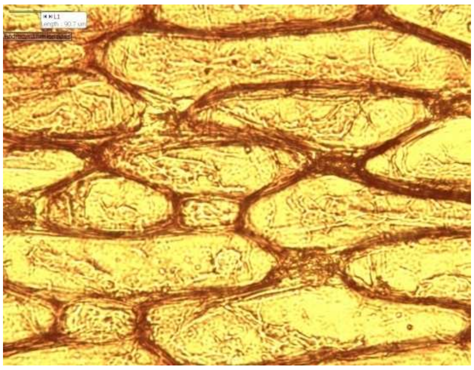
Appendix 1: Photomicrographs of plant cuticle of plant species added to the Centre for African Conservation Ecology reference collection for the purpose of this study. The adaxial leaf surface is represented by the label (a) and (b) represents the abaxial surface. Only one photomicrograph is provided when there is no difference between the leaf surfaces.



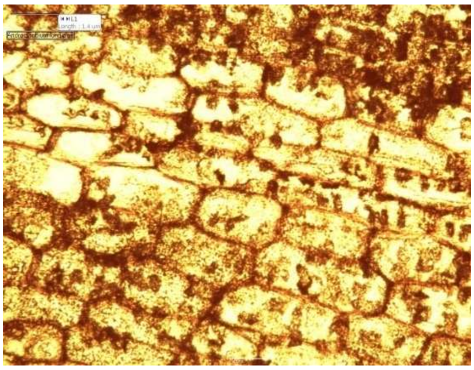
1(a) *Agyrolobium barbatum*



(b) *Agyrolobium barbatum*



2(a) *Androcymbium longipes*



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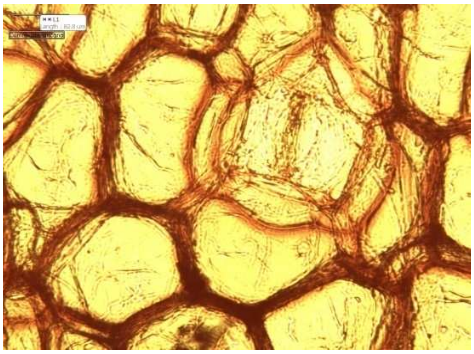
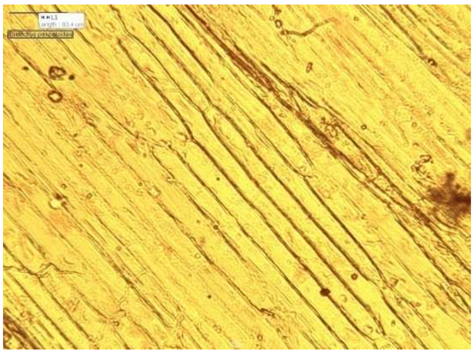
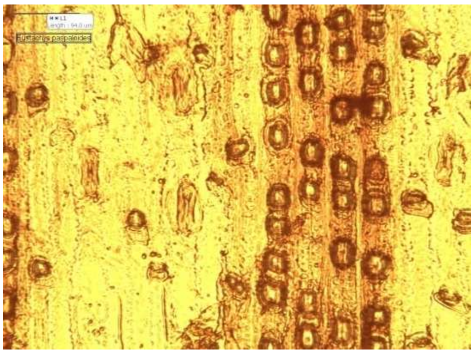


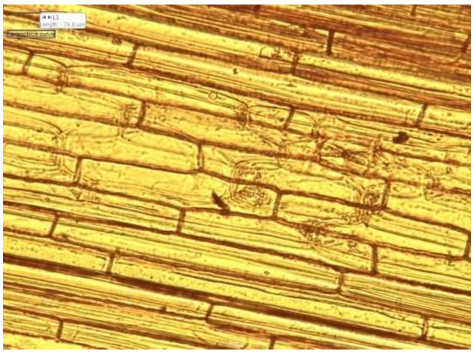
3. *Commelina africana*



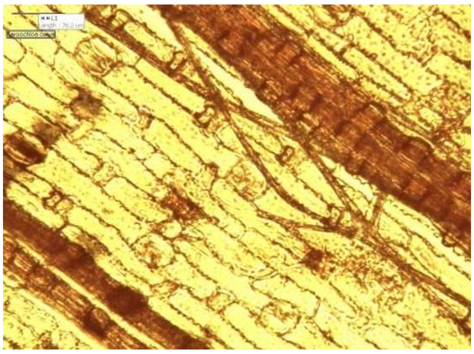
4(a) *Eustachys paspaloides*



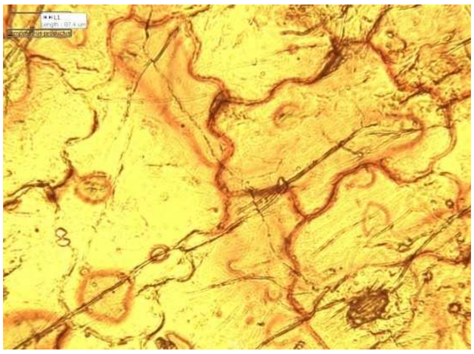
(b) *Eustachys paspaloides*



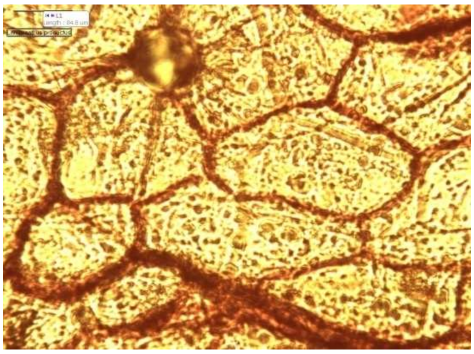
5(a) *Karoochloa curva*



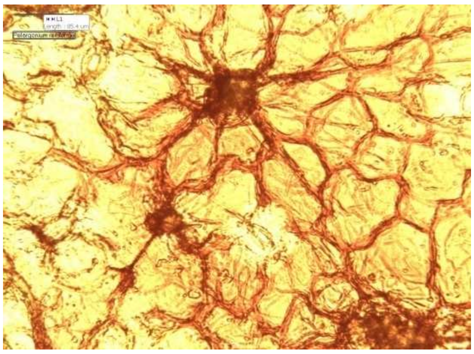
(b) *Karoochloa curva*



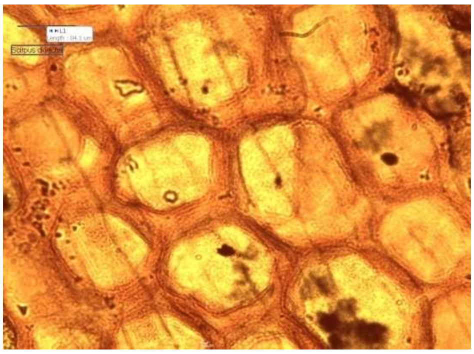
6(a) Lampranthus productus



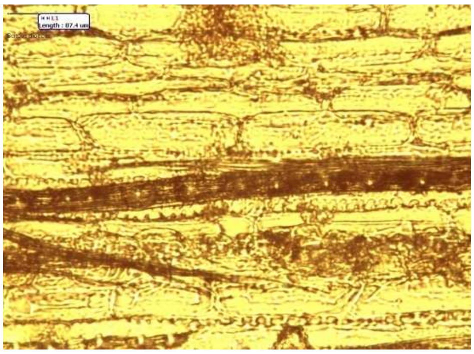
(b) Lampranthus productus



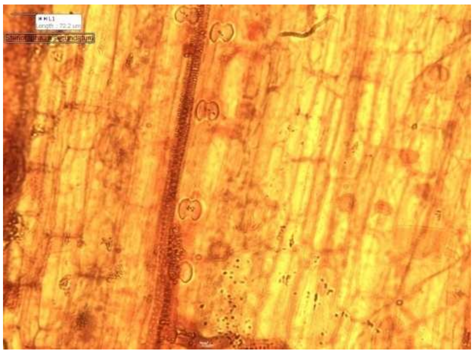
7. *Perlagonium reniforme*



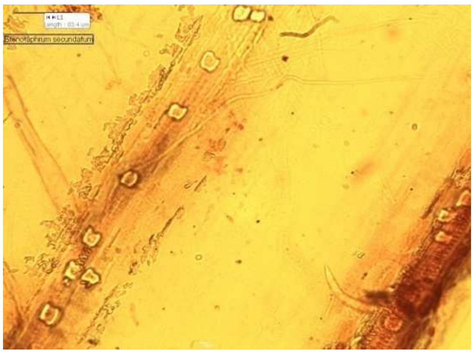
8(a) *Scirpus dioecus*



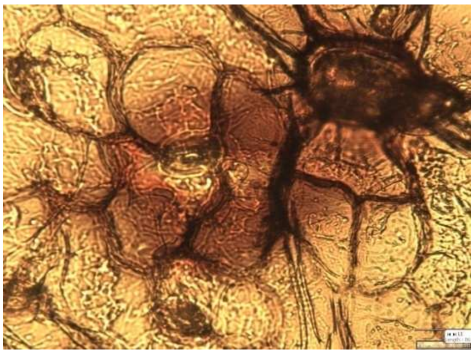
(b) *Scirpus dioecus*



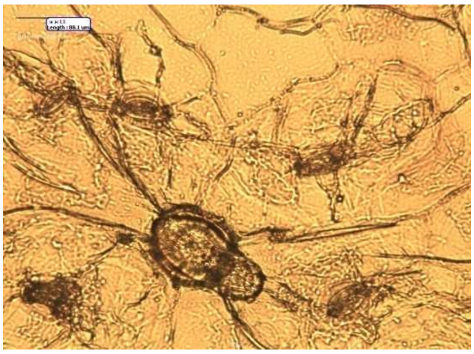
9(a) *Stenotaphrum secundatum*



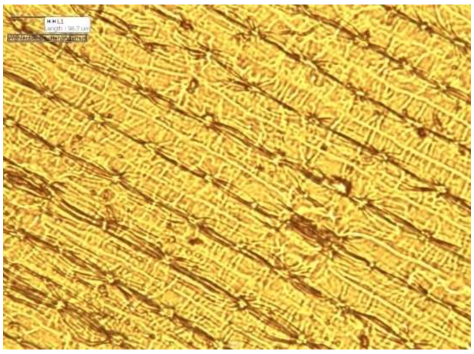
(b) *Stenotaphrum secundatum*



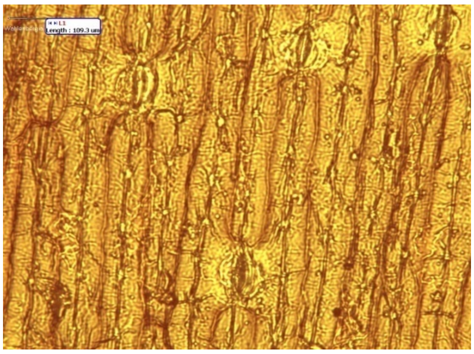
10(a)*Tephrosia capensis*



(b)*Tephrosia capensis*



11(a) *Wahlenbergia uitenhagensis*



(b) *Wahlenbergia uitenhagensis*

Appendix 2: Relative growth form percentage and plant species recorded as available in Shamwari Private Game Reserve and their relative availability (%). Grasses are underlined.

Growth forms (%)	Species	Relative availability (%)	Species	Relative availability (%)
Woody shrubs = 57.6	*Themeda triandra*	11.66	*Sansevieria sp.*	0.17
	Jamesbrittenia microphylla	7.35	*Chelianthus viridis*	0.17
Forbs = 14.4	Stenotaphrum secundatum	6.96	*Felicia fascicularis*	0.17
Succulents = 11.9	*Cynanchum obtuse-folium*	5.29	*Crassula muscosa*	0.15
Grasses = 10.1	*Indigofera disticha*	4.88	*Linum africanum*	0.15
Geophytes = 5.1	*Euryops euryopoides*	4.16	*Rhus longispina*	0.15
Sedges = 0.9	*Elaeodendron croceum*	4.14	*Tephrosia capensis*	0.15
	Panicum maximum	3.28	*Atriplex sp.*	0.12
	Delosperma algoense	3.16	*Crassula perforata*	0.12
	Commelina africana	2.96	*Crassula tetragona*	0.12
	Sporobolus sp.	2.94	*Muraltia ericaefolia*	0.12
	Chaetacanthus setiger	2.84	*Mystoxylon aethiopicum*	0.10
	Portulacaria afra	2.67	*Dimorphotheca ecklonis*	0.10
	Pteronia incana	2.47	*Senecio radicans*	0.10
	Crassula mollis	2.21	*Selago corymbosa*	0.10
	Digitaria eriantha	2.19	*Selago decipiens*	0.10
	Azima tetracantha	2.06	*Tecoma capensis*	0.10
	Eragrostis curvula	1.72	*Asparagus suaveolens*	0.10
	Aizoon rigidum	1.42	*Bulbine fruitescens*	0.10
	Putterlickia pyracantha	1.40	*Hypoestes aristata*	0.10
	Pelargonium reniforme	1.25	*Adromischus sphenophyllus*	0.07
	Plumbago auriculata	1.25	*Argyrolobium barbatum*	0.07
	Crassula ovata	0.96	*Asparagus selaceus*	0.07
	Hypoestes aristata	1.23	*Disparago ericoides*	0.07
	Schotia afra	0.81	*Ehretia rigida*	0.07
	Gazania krebsiana	0.78	*Passerina corymbosa*	0.07
	Gasteria bicolor	0.71	*Rhus glauca*	0.07
	Eragrostis obtusa	0.66	*Asparagus subulatus*	0.05
	Asparagus racemosus	0.64	*Carpobrotus sp.*	0.05
	Capparis sepiaria	0.59	*Cynanchum natalitium*	0.05
	Galenia pubescens	0.56	*Microloma tenufolium*	0.05
	Chrysocoma ciliata	0.51	*Ruschia tenella*	0.05
	Rhus incisa	0.49	*Sarcostemma viminale*	0.05
	Felicia filifolia	0.49	*Senecio glutinosus*	0.05
	Gladiolus sp.	0.47	*Senegalia karroo*	0.05
	Pelargonium peltatum	0.47	*Sporobolus africanus*	0.05
	Sideroxylon inerme	0.47	*Androcymbium longipes*	0.04
	Wahlenbergia uitenhagensis	0.44	*Rhoicissus tridentata*	0.03
	Selago glomerula	0.39	*Trichodiadema barbatum*	0.03
	Rhus pterota	0.37	*Anthospermum aethiopicum*	0.02
	Psilicaun cariarium	0.32	*Cassine tetrogona*	0.02
	Rhoicissus digitata	0.29	*Cynodon sp.*	0.02
	Panicum deustum	0.27	*Cyphotemme currorii*	0.02
	Hermannia hyssopifolia	0.27	*Euclea undulata*	0.02
	Hibiscus pusillus	0.27	*Euphorbia rhombifolia*	0.02
	Cadaba aphylla	0.27	Hermania flammea	0.02
	Karoochloa curva	0.27	*Psoralea vepens*	0.02
	Crussula mesembryanthoides	0.25	*Senecio inaquidens*	0.02
	Crassula pellucida	0.25	*Setana sphacelata*	0.02
	Hermannia althaeoides	0.25	*Amaranthus deflexus*	0.01
	Ruschia sp.	0.22		
	Solanum rigescens	0.22		
	Dimorphotheca ecklonis	0.22		
	Aspalagus subtigens	0.22		
	Cotyledon velutina	0.22		
	Euphorbia mauritanica	0.22		
	Ficinia sp.	0.22		
	Gibboria scabra	0.22		
	Lampranthus productus	0.20		
	Dipogon lignosus	0.20		
	Asparagus africanus	0.17		