THE DIET AND ECOLOGICAL ROLE OF BLACK-BACKED JACKALS, *CANIS MESOMELAS*, IN TWO CONSERVATION AREAS IN THE EASTERN CAPE PROVINCE, SOUTH AFRICA

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ABSTRACT

Mammalian predators are keystone species and can have disproportionately large impacts, relative to their abundance, on the communities and ecosystems they inhabit. In addition, predator-prey interactions (including bottom-up and top-down effects) are the fundamental linkage among species in food webs. Thus, understanding the food requirements of predators is imperative. There have been no comprehensive studies on the diet of black-backed jackals (*Canis mesomelas*) across a full seasonal cycle in the Albany Thicket Biome of the Eastern Cape Province. This biome is rich in plant diversity, is highly nutritious for herbivores and supports a large number of mammalian species, yet it is poorly conserved. The aim of the present study was to establish the diet of black-backed jackals on two conservation areas where thicket vegetation dominates (Great Fish River Reserve and Kwandwe Private Game Reserve).

The diet was assessed using scats collected monthly from June 2009 to May 2010 and a sample of 25 stomachs over the same period. At both sites and across all seasons, mammalian hair was encountered most often (93% of all scats) and a total of 23 mammal species were consumed. Of the mammals recorded in the scats, hair from several ungulate species was encountered most frequently and these were mostly hider species (offspring hidden in tall vegetation just after birth). On a seasonal basis, the proportion of mammalian hair was lowest in autumn. However, the contribution of fruits (*Carissa haematocarpa*, *Diospyros lycioides* and *Grewia robusta*) to the diet was significantly higher during this season. This suggests that black-backed jackals may employ diet switching in the Eastern Cape as a mechanism to capitalise on seasonally abundant food sources.

Based on the stomach content analysis, invertebrates were consumed as frequently as mammalian prey throughout the year but mammalian prey was recorded in greater quantity (i.e. volume and mass). Thus, scat analysis may have overestimated mammalian prey and fruits and underestimated the importance of invertebrates, particularly highly digestible species (e.g. termites). In spite of these differences, scat analysis demonstrated similar general and seasonal trends as the stomach content analysis. Thus, scat analysis can provide an efficient and relatively accurate source of information on the diet of black-backed jackals in the Eastern Cape.

Both stomach content and scat collection methods depicted the black-backed jackal as a generalist and opportunistic predator, mainly relying on mammals and invertebrates. Although the results of my study suggest that black-backed jackal may be important predators of certain ungulate species, further study on their prey preferences, actual biomass ingested and the effects on the population viability of prey species is required in order to develop a robust management plan for the species in the protected areas of the Eastern Cape.

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CHAPTER ONE

GENERAL INTRODUCTION

1.1 Description

The black-backed jackal (*Canis mesomelas* Schreber 1775; Mammalia : Canidae), also known as “silver-backed jackal”, “chacal à chabraque” (“jackal with a saddle-blanket” in French) and “rooijakkals” (“red jackal” in Afrikaans), is a slender, long-legged jackal with large ears and a pointed muzzle, reddish flanks and limbs, and a dark saddle of long (40-60 mm) black and white hair, giving it a silver appearance (Walton & Joly 2003; Loveridge & Nel 2004; Skinner & Chimimba 2005). It has a bushy tail with a distinctive black subcaudal marking (Loveridge & Nel 2004) and a small vertical stripe behind the shoulder and in front of the saddle stripe. These features may be used with the saddle markings for identification of the species or of individuals (Loveridge & Nel 2004). Although black-backed jackals show little physical or behavioural sexual dimorphism (Moehlman 1983), males are slightly larger and heavier than females (Walton & Joly 2003; Loveridge & Nel 2004). Males are approximately 15 cm longer and 0.7 kg heavier than females in the Cape region (Western Cape, Eastern Cape and Northern Cape provinces) of South Africa (Walton & Joly 2003; Loveridge & Nel 2004). Black-backed jackal males weigh on average 8.1 kg and females 7.4 kg (Loveridge & Nel 2004).

1.2 Taxonomy, distribution and habitat

There are six recognised subspecies of black-backed jackal (Loveridge & Nel 2004). However, Kingdon (1997) only recognised two geographically isolated subspecies, based on the regional variation in the species (Loveridge & Nel 2004). These two subspecies are *C. m. mesomelas* Schreber 1775, found in southern Africa and *C. m. schmidtii* Noack 1897, in East Africa (Walton & Joly 2003; Loveridge & Nel 2004) (Figure 1.1). The two populations are separated by approximately 1000 km and cover Djibouti, Eritrea, Ethiopia, Somalia, Kenya, Sudan, Uganda and Tanzania in the East and Angola, Namibia, Botswana, Zimbabwe, South Africa, Swaziland and Lesotho in the South (Walton & Joly 2003; Loveridge & Nel 2004; Ray *et al*. 2005; Skinner & Chimimba 2005). There are no black-backed jackals in Zambia or most of central and equatorial Africa. This disjunct distribution is typical of endemic African mammals which are adapted to dry conditions (Loveridge & Nel 2004; Skinner & Chimimba 2005), and suggests that at some period during the Pleistocene (1.8 million to 11 000 years ago), when conditions were more arid than at present, the savanna regions once connected south-western Africa and the Horn of Africa (Loveridge & Nel 2004; Skinner & Chimimba 2005). The absence of black-backed jackal fossils north of Ethiopia suggests that they were always restricted to sub-Saharan Africa (Loveridge & Nel 2004). Black-backed jackals have renal adaptations which allow them to survive under arid conditions; their kidneys are made up of a thick medulla which gives them the ability to concentrate urine (Macdonald *et al*. 2004). Consequently, black-backed jackals occur in a wide range of habitats, from arid coastal desert, to montane grasslands, open savanna, arid savanna and scrubland, fynbos, Nama-Karoo, succulent Karoo, woodland savanna mosaics and farmlands (Loveridge & Macdonald 2003; Loveridge & Nel 2004; Ray *et al*. 2005; Skinner & Chimimba 2005). Several studies have suggested that black-backed jackals prefer open habitats (Loveridge & Macdonald 2002; Goldenberg *et al*. 2008), such as grasslands and overgrazed areas, where smaller prey (e.g. rodents) may be more vulnerable and easier to hunt (Pienaar 1969). Open grasslands also provide open resting sites from where black-backed jackal can detect approaching predators (Loveridge & Macdonald 2002). This is supported by a study in Kruger National Park, South Africa, where stable isotope analysis confirmed that black-backed jackals are part of a C_4 grass-based food web and are thus open-savanna predators (Codron *et al*. 2007). However, black-backed jackals may not be as specialised everywhere and in south-eastern Botswana, black-backed jackals utilise areas which are more wooded and provide more cover than more open areas (Kaunda 2001). The more densely covered areas provide the black-backed jackals with increased denning and foraging opportunities and shelter from predators (Kaunda 2001).

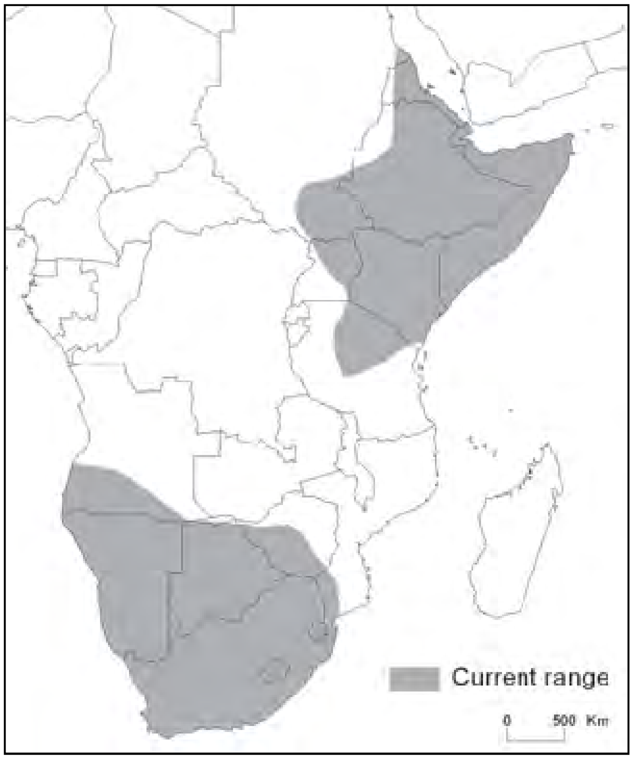

Figure 1.1 The current distribution of the black-backed jackal (*Canis mesomelas*) in Africa (from Loveridge & Nel 2004).

Of the seven species currently recognised in the genus *Canis* (Skinner & Chimimba 2005), three occur in Africa: the black-backed jackal, the side-striped jackal, (*Canis adustus*) and the golden jackal (*Canis aureus*) (Loveridge & Nel 2004); the former two diverged from a common ancestor approximately two million years ago (Macdonald *et al*. 2004). Both the side-striped and golden jackal occur in sympatry with the black-backed jackal in parts of East Africa (Van Valkenburgh & Wayne 1994; Loveridge & Nel 2004) (Figures 1.2 and 1.3). The side-striped jackal also occurs in sympatry with the black-backed jackal in parts of Zimbabwe, Botswana, Mozambique and South Africa (Van Valkenburgh & Wayne 1994; Loveridge & Nel 2004) (Figure 1.4). The black-backed jackal is a more aggressive competitor, showing hostile behaviour towards the other two jackal species and tends to displace the others from its preferred habitats in spite of its relatively smaller size (Kingdon 1997; Loveridge & Macdonald 2002; Walton & Joly 2003; Loveridge & Nel 2004; Fuller *et al*. 2008). Black-backed jackals are generally more carnivorous than the other two jackal species and thus have a well-developed carnassial shear (upper jaw) and longer premolar (lower jaw) cutting blade (Loveridge & Nel 2004) and a more robust skull (Macdonald *et al*. 2004).

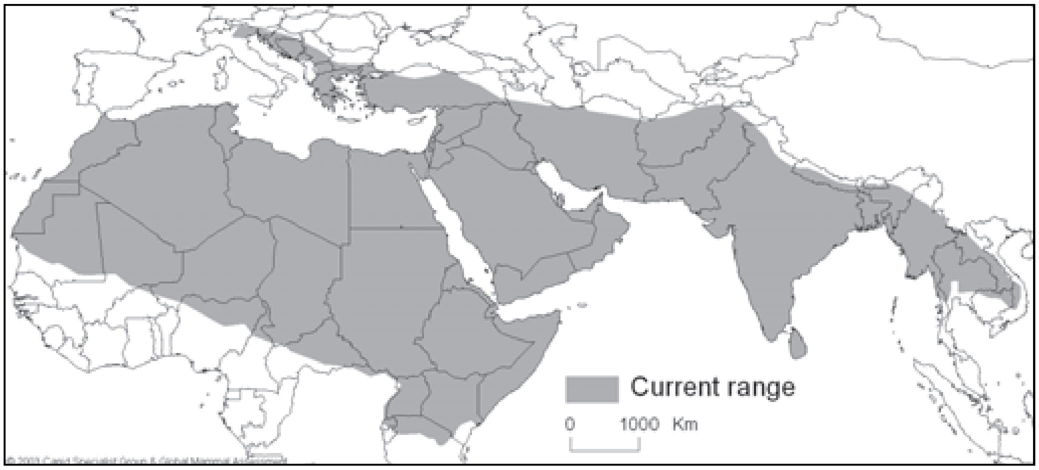

Figure 1.2 The current global distribution of the golden jackal (*Canis aureus*) (from Jhala & Moehlman 2004).

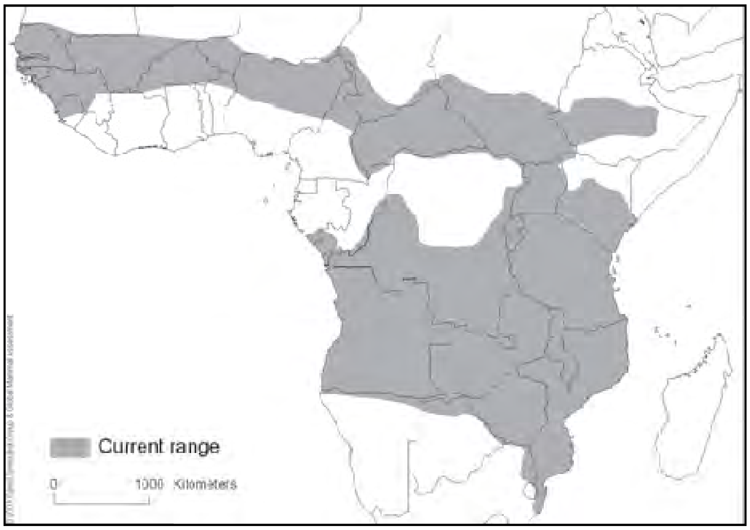

Figure 1.3 The current distribution of the side-striped jackal (*Canis adustus*) in Africa (from Atkinson & Loveridge 2004).

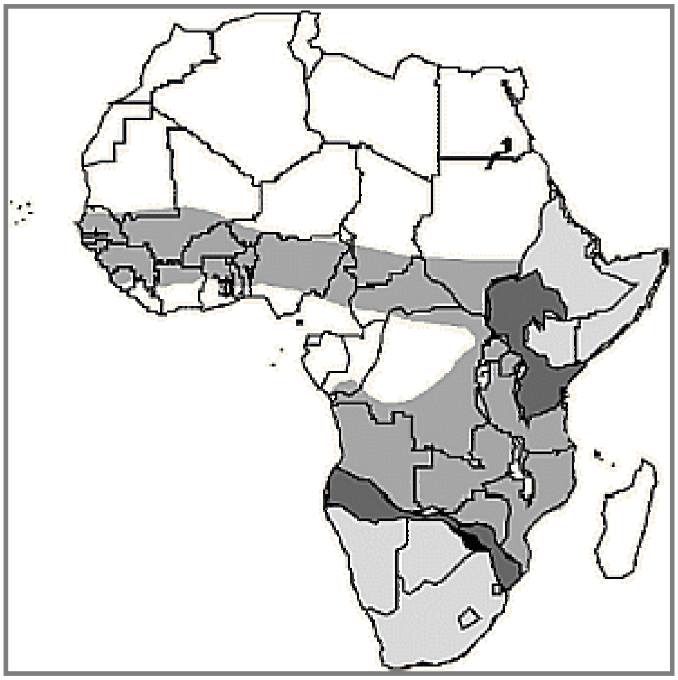

Figure 1.4 The geographic ranges of *C. mesomelas* (light grey shading) and *C. adustus* (medium grey shading), and the area where the two species of jackal are sympatric (dark grey shading) (from Macdonald *et al*. 2004).

1.3 Activity patterns, territoriality and home range size

Black-backed jackals are mostly nocturnal (Estes 1967), but their activity period may extend into the day in areas where they are not persecuted (Fox 1971; Loveridge & Nel 2004; Skinner & Chimimba 2005). They have a bigeminus (double-peaked) activity pattern (Rowe-Rowe 1983a; Ferguson *et al.* 1988; Kaunda 1998; Kaunda 2000, 2001) which closely matches the activity levels of their main prey, rodents, and is mostly influenced by light conditions during crepuscular and nocturnal periods (Ferguson *et al.* 1988; Kaunda 2001). They are territorial carnivores where territorial occupancy and the location of dominant animals is advertised through vocalisation (Kaunda 2000). A high-pitched, whining howl is used to advertise territories, to communicate with group members and to bring them together in the early evening (Moehlman 1983; Estes 1991; Loveridge & Nel 2004). Individuals are able to distinguish between family and non-family vocalisation (Moehlman 1983). Occupancy of a territory is also communicated through the use of olfactory signals (Moehlman 1983; Macdonald *et al.* 2004), including tandem (both male and female) raised leg urination and faecal deposits (Moehlman 1983). Territories are vigorously defended and intruders are attacked by a member of the pair, of the same sex (i.e. female intruders are threatened, attacked and chased by the resident female and male intruders are driven off by the male) (Moehlman 1983). The dominant animal intimidates the other one by raising the hairs on its back, made more conspicuous by the black saddle, and then swings its body, slamming its rump into the opponent whilst maintaining a face-to-face confrontation (Ferguson 1978; Kingdon 1988). However, this territorial behaviour may become less pronounced when food availability is very high, in which case large numbers (8 to 10 individuals) of black-backed jackals will congregate temporarily (Moehlman 1983; Oosthuizen *et al.* 1997; Bothma 2002; Loveridge & Nel 2004). Home range, defined as the space used by an animal where it can find resources necessary for growth, maintenance, reproduction and where it can avoid predators (Bowen 1982), varies between 2 and 8 km² in East Africa (Rowe-Rowe 1982) and 4 and 28 km² in southern Africa (Rowe-Rowe 1982; Hiscocks & Perrin 1988; Kaunda 2001). Home range size is affected by environmental factors such as variations in topography, vegetation, food supply, human presence and persecution pressure (Skinner & Chimimba 2005). Rowe-Rowe (1982) found that food distribution was a significant factor, while Hiscocks & Perrin (1988) argued that food abundance, rather than distribution, is pivotal in determining home range size. Home range size is also affected by season (Kaunda 2001), population density and competition, as well as individual characteristics, including sex, age and physiological status (Macdonald 1983), with subadults occupying larger mean home ranges (Rowe-Rowe 1982).

1.4 Reproductive behaviour

Black-backed jackals are monogamous and pairs may hold a territory for a lifetime with little changes in boundary demarcation (Moehlman 1983; Walton & Joly 2003). If one member of the pair dies, the remaining individual may not be able to retain the territory (Moehlman 1983). In southern Africa, mating takes place in winter, primarily between May and August and it is associated with increased vocalisation and territoriality by the pair during that time (Bernard & Stuart 1992; Kaunda 2000; Macdonald *et al.* 2004; Skinner & Chimimba 2005). The dominant individuals in the territory prevent subordinate individuals of the same sex from mating by constantly harassing them

(Moehlman 1983). Gestation is approximately 60 days long and parturition occurs between June and October (Bekoff *et al.* 1981; Bernard & Stuart 1992; Bingham & Purchase 2002). One to eight pups are born, with an average litter size of 4.6 (Bingham & Purchase 2002), in a den which is usually a modified burrow with several entrances (Moehlman 1983). Bingham & Purchase (2002) found that black-backed jackal productivity (the number of viable offspring produced per adult jackal per year) in Zimbabwe was 1.5 pups per jackal per year. The occurrence of first births in black-backed jackals during winter is however very different from other small canids such as the bat-eared fox (*Otocyon megalotis*), Cape fox (*Vulpes chama*) and side-striped jackal which all give birth during the warm, wet season (Bernard & Stuart 1992). The winter births of black-backed jackals may be timed to coincide with the higher abundance of ungulate carcasses at the end of the dry winter season (Bernard & Stuart 1992). Black-backed jackals form hierarchical family groups in which subadults or young adult helpers may assist in feeding and protecting subsequent litters (Moehlman 1979, 1983; Bernard & Stuart 1992; Kingdon 1997). Helpers also help socialise the pups, feed the lactating female by regurgitating food and defend the dominant pair's territory, but do not take part in scent marking (Moehlman 1983). In addition, helpers allow the dominant pair more time to forage together, which in turn allows more successful hunting (Moehlman 1983). Indeed, a hunting success rate of 84.7% when hunting in groups of two or three versus a 36.4% success rate when hunting alone was noted by Lamprecht (1978). Foraging in pairs also allows for a greater exploitation of carcasses as the pair is able to protect kills from intra- and interspecific competitors more effectively (Moehlman 1983). Pup survival increases with the number of helpers present. On average, one pup survives without helpers, three with one helper, four with two helpers and up to six pups with three helpers (Moehlman 1983). Pup survival also depends on parental competence and territory quality (Moehlman 1983).

Pups emerge from the den at the age of three weeks, are weaned at six to nine weeks old, become independent of the den between the ages of 12 and 14 weeks (Bekoff *et al*. 1981; Moehlman 1983) and reach sexual maturity at about 11 months (Ferguson *et al*. 1983; Loveridge & Nel 2004). However, they only start breeding at the age of two years, after having been helpers themselves (Ferguson *et al*. 1983; Bingham & Purchase 2003). The survival of helpers increases if they remain with their parents to help raise their siblings and they may gain a portion of the natal territory (Moehlman 1983; Bekoff *et al*. 1984). Helper dispersal is driven by food availability and distribution, parental behaviour, jackal density and same-age and same-sex sibling interactions (Moehlman 1983). Black-backed jackal longevity is estimated at six or seven years in the wild (Moehlman 1983).

1.5 Diet

Black-backed jackals are opportunistic and generalist feeders and their dietary habits reflect the availability of a wide range of food items and the differential vulnerability of prey (Kaunda & Skinner 2003; Walton & Joly 2003; Loveridge & Nel 2004; Ray *et al*. 2005; Skinner & Chimimba 2005). Food items include small to medium-sized mammals, amphibians, reptiles, birds, eggs, carrion, human refuse, invertebrates and plant material (Hall-Martin & Botha 1980; Walton & Joly 2003; Loveridge & Nel 2004). Mammalian prey includes species from the orders Artiodactyla (mostly young ungulates and domestic stock), Carnivora (including mongooses (Herpestidae), striped polecats (*Ictonyx striatus*), wild cats (*Felis silvestris*), bat-eared foxes, and domestic dogs (*Canis domesticus*) and cats (*Felis domesticus*)), Insectivora, Lagomorpha and Rodentia (Walton & Joly 2003; Loveridge & Nel 2004). Invertebrate prey includes species from the orders Arachnida, Coleoptera, Diplopoda, Diptera, Crustacea, Blatteria, Hymenoptera, Myriapoda, Orthoptera and Pelycopoda (Grafton 1965; Bothma 1966b Walton & Joly 2003; Loveridge & Nel 2004; Klare *et al.* 2010). Black-backed jackals consume a wide range of fruits (Grafton 1965; Bothma 1966b; Nel *et al.* 1997; Kaunda & Skinner 2003; Goldenberg *et al.* 2010; Klare *et al.* 2010) and the prevalence of individual species in the diet is dependent on local availability across their range (Hiscocks & Perrin 1987). In more arid areas, black-backed jackals consume a high proportion of insects (Rowe-Rowe 1986). For example, in the Kgalagadi Transfrontier Park, South Africa, invertebrates amounted to a volume of 68%, whilst rodents and carrion only made up 23% (Bothma 1966b). Rodents, however, form a more important part of their diet in regions with higher rainfall and where grassland dominates (Rowe-Rowe 1986). In the KwaZulu-Natal Province of South Africa, small mammals accounted for more than half (55%) of black-backed jackal diet (Rowe-Rowe 1983a). On the Skeleton Coast of Namibia, black-backed jackals also scavenge off beached marine mammals and will often follow brown hyaena (*Parahyaena brunnea*) to feed on the food remains they leave behind (Avery *et al.* 1987; Hiscocks & Perrin 1987; Oosthuizen *et al.* 1997; Walton & Joly 2003; Loveridge & Nel 2004; Kolar 2005). Fruits are more prevalent in the black-backed jackal's diet in summer and autumn, when they are readily available (Kaunda & Skinner 2003; Klare *et al.* 2010). Medium-sized mammals are more important in summer, while rodents are most important in winter (Kaunda & Skinner 2003; Klare *et al.* 2010). Most ungulate predation by black-backed jackals is limited to young animals, during the lambing season (Krofel 2008), with a strong preference for hider ungulate species. Hider species, such as impala (*Aepyceros melampus*) use a neonatal security strategy which involves leaving their offspring hidden in tall vegetation during the first few weeks after birth (Lent 1974; Estes 1991). This strategy renders them extremely vulnerable to black-backed jackals. Pairs and small groups of black-backed jackals may forage together on carcasses, while pairs or packs often cooperate to capture larger prey (Estes 1967; Kingdon 1988; Bussiahn 1997; Loveridge & Nel 2004; Krofel 2008). Groups of jackals and on rare occasions single animals have been noted to prey on several species of ungulates, including adult springbok (*Andidorcas marsupialis*) and impala (Pienaar 1969; Kamler *et al*. 2010). Kingdon (1988) suggests that most herbivores are inaccessible to black-backed jackals due to their agility and size and are thus ignored. However, when circumstances render the prey more vulnerable and accessible, such as when calves are present or when adults are wounded or old, then black-backed jackals may hunt them (Kingdon 1988).

Several cases of black-backed jackals aiding other carnivores to capture prey have been recorded, in order to benefit from scavenging opportunities (Kingdon 1988). Black-backed jackals have also been known to raid ostrich (*Struthio camelus*) nests and have learned to knock the eggs against each other, using one of the eggs as an “anvil” to break them open (Hall-Martin & Botha 1980). They are also reputed to follow the flight of vultures and raptors to carcasses and dead animals (Moehlman 1983).

These opportunistic feeding characteristics make black-backed jackals extremely successful as it increases their chances of survival during times of food shortage and allows them to have wider distributions than specialist predators (Atkinson *et al*. 2002). Black-backed jackals have been known to cache parts of mammalian prey remains in shallow holes and concealed places (Kaunda 1998). Domestic prey species include predominantly sheep (*Ovis aries*), as well as goats (*Capra hircus*), pigs (*Sus scrofa*) and poultry (Walton & Joly 2003). In conservation areas, domestic prey makes up a very small fraction (<10%) of the diet (Grafton 1965; Kaunda & Skinner 2003; Klare *et al*. 2010) of all mammalian remains.

1.6 The black-backed jackal as a problem animal

In South Africa, intensive hunting for food, sport and to reduce competition with livestock, led to a drastic decrease in the number of indigenous large mammalian species by the mid-nineteenth century (Beinart 2003). This decrease in natural prey, combined with the increase in domesticated animals, caused predators to turn towards livestock as a food source (MacKenzie 1988; Beinart 2003). Predators have been a major problem for livestock farmers in South Africa since the late nineteenth century, particularly for sheep farmers (Beinart 2003). The black-backed jackal has the greatest ability to adapt to changing circumstances in its habitat as a result of its physiological adaptations and broad diet. This has made the black-backed jackal one of the most problematic of predators (Bekoff *et al*. 1984; Beinart 2003). The black-backed jackal's reputation as a livestock killer means that it is considered a pest in many of the countries in its range, and it is presently declared a problem animal in South Africa (Hall-Martin & Botha 1980;

Loveridge & Nel 2004). Problem animals are defined by the National Environmental Management Biodiversity Act, Act 10 of 2004 (NEMBA), as any animal that causes losses to livestock or wildlife specimens, damage to crops or property, presents a threat to human life or is present in such numbers that agricultural livelihoods are materially depleted (Anon. 2010). However, predation on livestock by black-backed jackals is generally not widespread (Loveridge & Nel 2004; Ray *et al*. 2005). In East Africa, around the Serengeti National Park, the black-backed jackal is only the fifth most important problem animal, being responsible for only 0.1% of livestock depredation (Holmern *et al*. 2007). By contrast, the spotted hyaena (*Crocuta crocuta*) is responsible for the majority (97.7%) of the livestock depredation (Holmern *et al*. 2007). Most of the livestock farmed in this area is cattle (*Bos* spp.) (63.8%) and goats (26%), while only a small number of farmers keep sheep, pigs and donkeys (*Equus africanus asinus*). In southern Africa, black-backed jackal predation on livestock is more prevalent than in East Africa, with annual livestock losses ranging from 0.05% (Rowe-Rowe 1975) to 29% (Lawson 1989) in the KwaZulu-Natal Province. Greatest losses are experienced during the winter and spring (June-October), which coincides with the lambing season and black-backed jackal births (Rowe-Rowe 1975; Lawson 1989). Black-backed jackals kill livestock by biting the throat and then open the carcass on the flank between the hip and lower ribs, eating small amounts (up to approximately 500 g) (Rowe-Rowe 1975, 1983b, 1986). Some authors contend that black-backed jackals may actually be beneficial to farmers by playing a role in controlling crop pests such as rodents and invertebrates and may benefit reserve managers by feeding on harvester termites (such as *Hodotermes* spp.) (Kaunda 2001; Kaunda & Skinner 2003). Furthermore, black-backed jackals have been suggested to play an important role as intra-guild predators by preying on potentially more problematic predators such as caracal (*Caracal caracal*) (Kaunda 2001). Pringle & Pringle (1979) noted that the elimination of black-backed jackals may cause an increase in the caracal population as they prey on caracal kittens. More recently, black-backed jackals have been blamed for loss of antelope in the game farming industry, particularly during the lambing season, with serious impacts on the population viability of these species (Wyman 1967; Schaller 1972; Rowe-Rowe 1976). A study of blesbok, *Damaliscus dorcas phillipsi*, conducted on a nature reserve near Pretoria, South Africa, found that black-backed jackals may have decreased blesbok population viability (Du Plessis 1972). Thirty-three percent of all lambs born were still alive several months after birth prior to any predator control measures being implemented (Du Plessis 1972). However, following an intensive black-backed jackal control campaign (a total of 21 jackals were killed using coyote getters) prior to the lambing season the following year, a significant (~85%) increase in the survival of blesbok lambs was observed (Du Plessis 1972). Therefore, predation on juveniles (pre-breeders) can have a significant impact on ungulate population dynamics as the variation in juvenile survival, together with stable high adult survival, may influence population fluctuations (Barber-Meyer & Mech 2008). In fact, recruitment is often considered to be more important than adult survival in determining population size (Gaillard *et al.* 1998).

Nature reserves may act as refugia for black-backed jackals in some regions (Kaunda 2001). Many farmers believe that black-backed jackals and other problem animals cross reserve boundaries into the neighbouring farmlands where they prey on livestock (Van

Rensburg 1991). This belief is supported by studies which have found sheep remains in black-backed jackal stomachs obtained from black-backed jackals killed in reserves (Beinart 2003). The reverse has also been observed where black-backed jackals entered a nature reserve from surrounding farmlands in order to prey on blesbok lambs (Du Plessis 1972).

Black-backed jackals are also culled in some instances because they are viewed as vectors for numerous diseases (McKenzie 1993; Walton & Joly 2003; Ray *et al*. 2005). Importantly, however, it was noted that the incidence of rabies is relatively low in undisturbed populations and that, ironically, disruption of the hierarchy of complex packs through persecution results in an increase of rabies outbreaks (McKenzie 1993). Rapid population turnover results in increased movement of individuals and thus increased aggression and contact between individual black-backed jackals (Bothma 2002; Ray *et al*. 2005).

In spite of the use of numerous control measures in many of the farming areas of southern Africa, the black-backed jackal is still relatively abundant in both livestock producing and protected areas (Loveridge & Nel 2004; Blaum *et al*. 2009). Numbers may have, in fact, increased over the years on farmlands (Beinart 2003; Blaum *et al*. 2009). A study carried out in the Drakensberg Mountains, South Africa, calculated densities of 0.4 jackal/km² (Loveridge & Nel 2004). Removal of dominant black-backed jackals in agricultural areas results in population gaps which are filled by the expansion of neighbouring territories or the dispersal of sub-adults from neighbouring areas (Bothma

2002; Ray *et al*. 2005). The resultant increase in the number of jackals in the area can result in over-exploitation of the natural prey base of the region (Emmett 2006). This forces black-backed jackals and other predators to find alternative prey, usually livestock (Emmett 2006). Moreover, it is often believed that the incoming subadult black-backed jackals are less efficient hunters than the adults, take longer to catch their prey and tend to choose prey that is easier to kill (Linnell *et al*. 1999).

Conflicts between humans and carnivores pose a serious management issue as they often counter conservation efforts (Linnell *et al*. 1999), particularly outside protected areas. Thus, conflicts need to be taken into consideration and dealt with accordingly in order to minimise economic losses to humans, whilst ensuring the protection of predator species (Holmern *et al*. 2007). Whether this is done by separating predators from livestock (zoning) or conserving both in the same area, both solutions will probably need to run in parallel with lethal or non-lethal predator control methods of individual carnivores (Linnell *et al*. 1999).

1.7 Conservation status

The black-backed jackal has one of the lowest threat and vulnerability scores of any African predators and is listed in the category “least concern” in the IUCN Red List of threatened species (Loveridge & Nel 2004; Ray *et al*. 2005). Vulnerability is defined as natural biological and ecological features which cause the species to become less resilient to changes in their environment and/or reduces their ability to recover from population declines (Ray *et al*. 2005). Threats include mostly external ones and are primarily disease and human conflict (Ray *et al*. 2005). Thus, in most countries within their range, black-backed jackals have no legal protection outside of protected areas (Ray *et al*. 2005). Although the industry is not extensive, black-backed jackals are also hunted for the local fur trade to make karosses (rugs) made of multiple skins sold to tourists, especially in South Africa and Namibia (Loveridge & Nel 2004; Ray *et al*. 2005). The main predators of black-backed jackals, excluding humans, are lions and leopards (Estes 1967; Walton & Joly 2003), wild dogs (*Lycaon pictus*) (Kamler *et al*. 2007), cheetahs (*Acinonyx jubatus*) (Bissett 2004) and some eagles (Loveridge & Nel 2004). In spite of these threats, black-backed jackals are abundant and widespread in southern Africa, mostly due to their ability to adapt to a wide range of conditions and environmental changes, which allows them to expand their ranges and sustain high and stable population sizes in areas where other large predators succumbed to changes in their habitats (Kaunda 2001).

1.8 Previous studies and motivation

Numerous studies have been conducted on black-backed jackals (for example: Ferguson *et al*. 1988; McKenzie 1993; Brand *et al*. 1995; Bussiahn 1997; Oosthuizen *et al*. 1997; Kaunda & Skinner 2003; Loveridge & Macdonald 2003), including aspects of their diet (see Bothma 1971; Rowe-Rowe 1976; Hall-Martin & Botha 1980; Rowe-Rowe 1983a; Bussiahn 1997; Kaunda & Skinner 2003). However, there have not been any comprehensive studies on the diet of black-backed jackals across a full seasonal cycle in the Eastern Cape Province and its associated biome, the Albany Thicket. Three studies (Hall-Martin & Botha 1980; Bussiahn 1997; Do Linh San *et al*. 2009) have been published on the diet of the black-backed jackal in this biome; two studies only covered the autumn season, while the third (Bussiahn 1997) only separated the diet into two seasons: summer and winter. Hall-Martin & Botha's (1980) study was based on analysis of five stomachs obtained between February and June 1977, while Bussiahn's (1997) study made use of 100 black-backed jackal stomachs. Do Linh San *et al.*'s (2009) study used faecal analysis to determine the diet of black-backed jackals from scats collected between April and May 2005. The Albany Thicket Biome consists of a very dense, closed shrubland to low forest dominated by evergreen, often spinescent, sclerophyllous or succulent trees, shrubs and vines, with little herbaceous cover (Mucina & Rutherford 2006). It is only found in the Eastern Cape Province (Mucina & Rutherford 2006) and although it only covers 2.2 % of the total surface of South Africa, representing 26820 km², it has the greatest diversity of all the biomes it borders (Mucina & Rutherford 2006). The Albany Thicket Biome also exhibits high levels of endemism for Karroid succulent flora and succulent *Euphorbia* species, is highly nutritious (Stuart-Hill 1992) and supports a large number of mammalian species, yet it is poorly conserved (Knight & Cowling 2006; Mucina & Rutherford 2006). The high plant species richness of this biome is a result of its location; the Albany Thicket Biome lies across several phytochoria (areas with a relatively uniform plant species composition), where species are at the end of their distribution ranges (Mucina & Rutherford 2006). Indeed, the biome's perimeter covers more than 15 000 km, allowing for potentially high species diversity along this ecotone (Mucina & Rutherford 2006). Therefore, this study will be significant in terms of determining the importance of fruits and other plant matter to the diet of the black-backed jackal in this biome.

The Eastern Cape Province is also an important area for ecotourism in South Africa, where the number of conservation areas and game reserves has recently increased at a fast pace (Sims-Castley 2002; Smith & Wilson 2002), increasing the potential for human-wildlife conflict. Indeed, as both conservation areas and human populations increase, direct competition for a shrinking resource base increases between humans and wildlife. As predator persecution and the removal of apex predators increases, "mesopredator release" can occur, resulting in further conflict (Lloyd 2007; Prugh *et al*. 2009; Ritchie & Johnson 2009). Most studies on the diet of black-backed jackal in southern Africa have only made use of faecal remains to infer diet (Rowe-Rowe 1983a; Bothma *et al*. 1984; Avery *et al*. 1987; Hiscocks & Perrin 1987; Kaunda & Skinner 2003; Do Linh San *et al*. 2009; Goldenberg *et al*. 2010; Klare *et al*. 2010). A few studies have used stomach contents (Bothma 1966b; Rowe-Rowe 1976; Hall-Martin & Botha 1980; Bussiahn 1997) and only very few have used direct observations (Hiscocks & Perrin 1987; Kaunda 1998). The efficacy of the latter method depends on the wariness of black-backed jackals and visibility of the vegetation. Furthermore, it is not reliable to determine small prey at the species/ order level. This project will thus involve the study of black-backed jackal diet over a full seasonal cycle, using two methods.

1.9 Objectives

The main objectives of this study were:

1. To compare the diet of the black-backed jackal in two conservation areas, with respect to ungulate density and differences in presence of large predators.
2. To identify any seasonal variation in the diet.
3. To compare two methods of diet analysis: scat analysis and stomach content analysis.

CHAPTER TWO

STUDY SITES

2.1 Choice of study sites

The Great Fish River Reserve (hereafter referred to as GFRR) and Kwandwe Private Game Reserve (hereafter referred to as Kwandwe) were selected as the two study sites for this research (Figure 2.1). They were selected based on their proximity to each other (< 1km at the closest point) so as to mirror abiotic and biotic conditions (i.e. vegetation, rainfall, geology, aspect, past land-use and history of fire) as closely as possible. Although care was taken to reduce potentially confounding factors (e.g. past land-use, fire, etc.), it was recognised that it would be impossible to completely control for their effects.

Despite the two reserves sharing similar abiotic conditions, several distinct biotic differences existed and it was my intention in this study to compare the diet of black-backed jackals in light of these differences. Large predators (viz. lions, leopards, cheetahs and brown hyaenas) are present at Kwandwe in relatively high numbers (brown hyaenas: 0.06/km² (Marlton 2009), lions: 0.10/km², leopards: unknown, cheetahs: 0.04/km²), but not at GFRR. This was particularly significant in terms of the quantification of the importance of scavenging to the black-backed jackal diet (Estes 1991). In addition, Kwandwe tends to have a higher density of ungulates (mammals in the orders Artiodactyla) (0.22 ungulates/ha) compared to GFRR (0.10 ungulates/ha) (calculated from census data; Peinke & Peinke 2009). Food availability affects mammalian diet selection and preference (Norbury & Sanson 1992) as predators tend to feed on the most abundant prey species (Chesson & Rosenzweig 1991) depending on the flexibility of their diet and how opportunistic they are (Ramakrishnan *et al.* 1999). As opportunistic and generalist predators, black-backed jackals (Kaunda & Skinner 2003; Walton & Joly 2003; Loveridge & Nel 2004; Ray *et al.* 2005; Skinner & Chimimba 2005) are likely to be particularly affected by differences in prey abundance.

In areas where black-backed jackals are subjected to hunting pressure, their temporal and spatial utilisation and general social organisation will be different from areas where they are not persecuted, and this in turn will affect diet (Fox 1971; Loveridge & Nel 2004; Skinner & Chimimba 2005). Jackals thus tend to limit their activity to particular areas and times when they find adequate resources for growth, maintenance and reproduction (Bowen 1982) and to evade predators (Kaunda 2000; Pedlar *et al.* 1997). The high hunting pressure outside reserves is known to induce a nocturnal pattern of activity in black-backed jackals (Kaunda 2000). Kaunda (2000) found that jackals encountered outside reserves ran off for cover when they noticed humans, irrespective of the time of day, and this disrupted their feeding patterns. Most studies of black-backed jackals have been done in relatively undisturbed areas such as nature reserves where they are not persecuted (Kaunda 2001). However, Kwandwe employs a regular jackal culling programme and GFRR does not. Culling at Kwandwe usually takes place at times when jackals are encountered more frequently and when time permits active hunting. This study will thus allow a comparison between two reserves that employ different predator management techniques. The resulting changes in temporal activity patterns may affect the diet of black-backed jackals (Fox 1971; Loveridge & Nel 2004; Skinner & Chimimba 2005). This may result in an increase in the number of nocturnal prey species in their diet, a decrease in the number of prey which require chasing over long distances (i.e. larger prey such as ungulates) and a change in the number of prey species from different habitats.

It was recognised that by comparing only two reserves, there was effectively one replicate per "treatment" (e.g. with or without predators etc.). Consequently, the statistical power of the inferences is likely to be low and caution will need to be exercised when it comes to the generality of the results (Zar 1996). The remainder of this chapter includes a brief description of each study site, including vegetation types, topography and geology, climate and mammalian fauna.

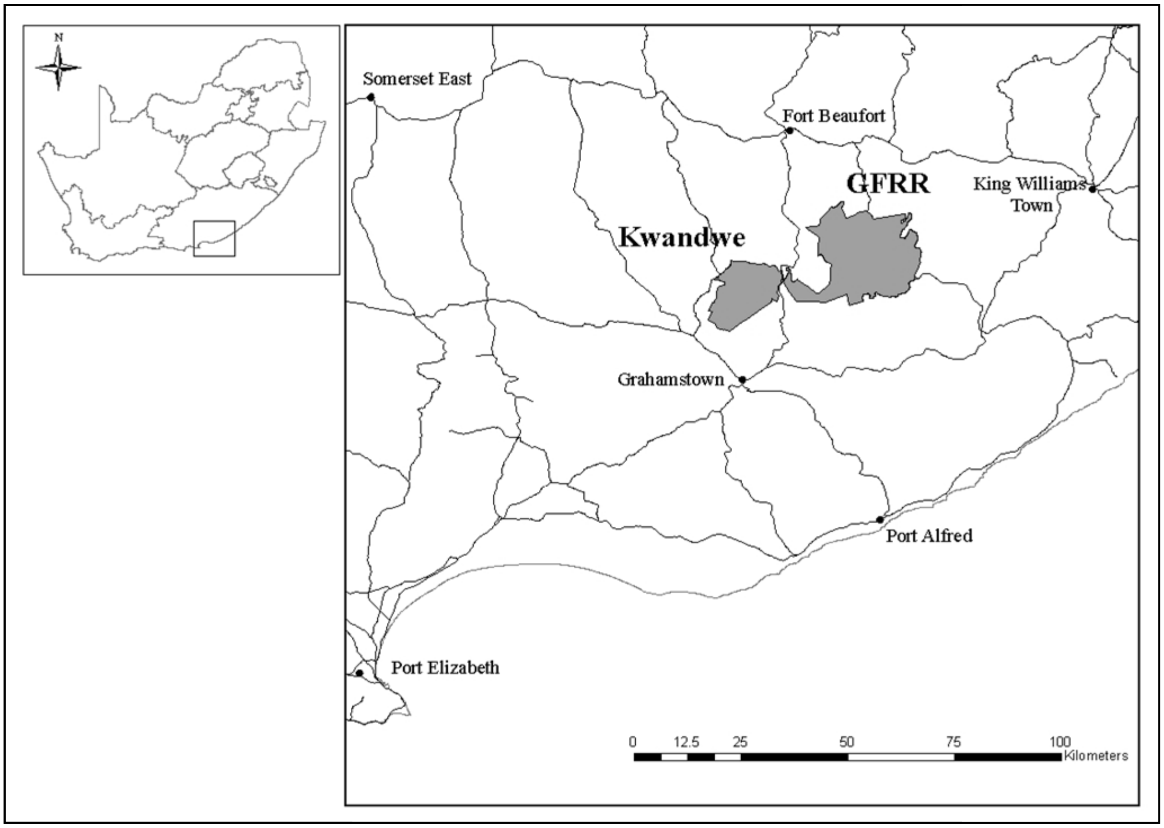

Figure 2.1 A map of the Eastern Cape Province, South Africa (inset), showing the location of the two study sites (shaded areas).

2.2 The Great Fish River Reserve

2.2.1 Location and history

The GFRR lies between Grahamstown and Fort Beaufort, stretching eastwards to the Keiskamma River (33º11'S, 26º38'E) (Figure 2.1). The GFRR consists of three reserves: the Double Drift Game Reserve (DDGR; 23 500 ha), east of the Great Fish and Kat Rivers; the Sam Knott Nature Reserve (SKNR; 15 500 ha) and Andries Vosloo Kudu Reserve (AVKR; 6 500 ha), both of which lie to the west of the Great Fish River. The area was previously used for cattle farming. The AVKR was established in 1973 after the state bought the Kentucky, Double Drift Outspan and Grasslands farms. The area was then further enlarged and designated as a reserve in 1976 by the purchasing of Lowestof Farm, bringing the total reserve area to its current size. The western part of the complex was enlarged by the addition of SKNR in 1983. In 1982 the then L. L. Sebe Game Reserve was established, to be renamed to DDGR in 1990. The GFRR complex now covers a total of 45 500 ha. To the east of the reserve, the surrounding areas are densely populated (70 people/km²) by Xhosa-speaking communities living on communally owned land and relying on subsistence agriculture, natural resources and government grants (Kostauli *et al*. 2006). In contrast, the areas west of the reserve have relatively low population densities (3 people/km²) and the land is generally privately owned (Kostauli *et al*. 2006). This study focused on the western section of the reserve, namely the AVKR, as this section was sufficiently large to provide a 20 km stretch of road and lies closest to the other study site. Furthermore, AVKR does not contain extralimital mammalian species.

2.2.2 Climate

2.2.2.1 Temperature

The GFRR has a semi-arid climate with temperatures ranging between 39ºC in the summer (December to February) to -1ºC at night in winter (June to August). During the year of study, temperatures ranged between 43ºC and -1ºC, as measured at the Kamadolo weather recording station (33º08’05S, 26º39’02E) (Figure 2.2). Extensive frost is only experienced approximately five days per annum between the months of July and August (Stone *et al.* 1998).

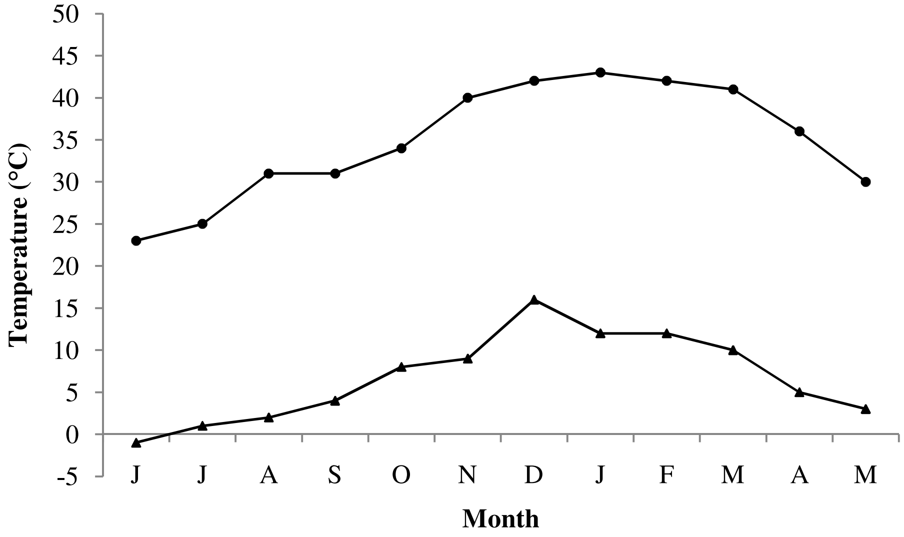

Figure 2.2 Mean daily maximum (circles) and minimum (triangles) temperatures for each month of the study, from June 2009 to May 2010 at Great Fish River Reserve (Kamadolo weather station).

2.2.2.2 Rainfall

The GFRR lies between the spring and autumn-dominant rainfall regions of the Eastern Cape Province and thus experiences distinct bimodal rainfall, with highest occurrence between the months of September to November and January to April (Figure 2.3) (Stone *et al.* 1998). Annual rainfall at GFRR ranges between 400 and 500 mm, with an average of 404 mm (1983-2008). During the year of study (June 2009 to May 2010), GFRR experienced a total of 398 mm. Rainfall in the Eastern Cape Province is not as seasonal as other provinces in South Africa. This is because the Eastern Cape Province is in a transition zone of climatic types, lying directly between the subtropical conditions with associated summer rains of the KwaZulu-Natal Province and the Mediterranean conditions, with associated winter rains, of the Western Cape Province (Stone *et al.* 1998). Highest rainfall at GFRR occurred in October and January (Figure 2.3; Mucina & Rutherford 2006). Altitude, aspect and slope all affect rainfall, resulting in localised variation within the reserve. The southern slopes experience cooler and moister conditions, while the northern slopes experience warmer, drier conditions. Areas below 300 m receive a mean of 434 mm p.a. and areas above 300 m receive approximately 618 mm p.a. (Kostauli *et al.* 2006).

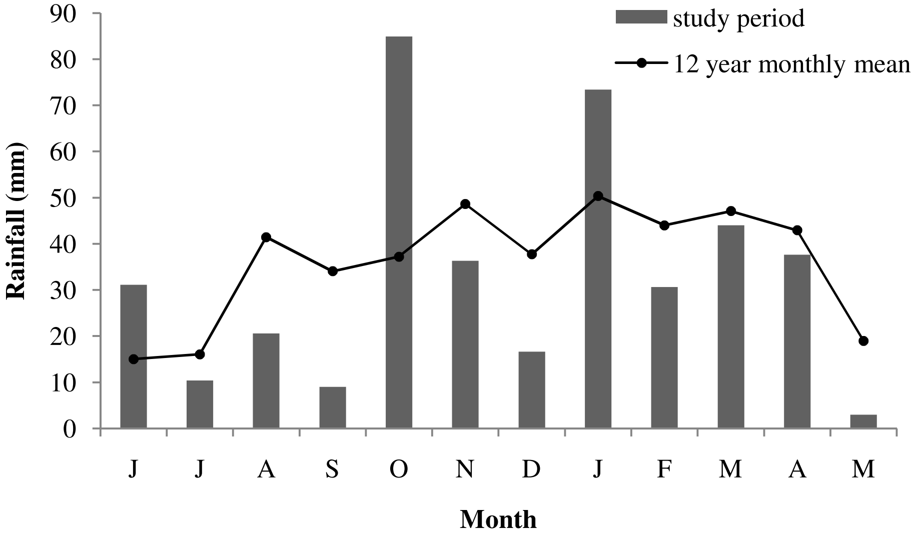

Figure 2.3 Total monthly rainfall for the study period, from June 2009 to May 2010 at the Great Fish River Reserve. Mean monthly rainfall for the last 12 years (1999-2010) is also included.

2.2.3 Topography and geology

The landscape consists of undulating terrain, with steep river valleys and inter-basin ridges. Elevation ranges from 95 to 561 m above sea level. The majority of the GFRR (except the south-western tip), consists primarily of mudstone, arenite and sandstone and shallow clay soils (Glenrosa and Mispah) derived from the Adelaide and Estcourt Formations (Beaufort Group, Karoo Supergroup) (Mucina & Rutherford 2006). The south-western tip of the complex consists of finely laminated clastic sediments of the Ecca Group supporting skeletal shallow soils (Glenrosa and Mispah). The river valleys contain the highly erodible, nutrient-rich mudstones, while the more resistant sandstones are found on the inter-basin ridges.

2.2.4 Vegetation

The GFRR falls within the Albany Thicket Biome; a closed impenetrable shrubland, with indistinguishable strata and no herbaceous cover, dominated by evergreen, sclerophyllous, spiny or succulent trees and shrubs (Mucina & Rutherford 2006). Most of these woody species produce seeds contained within edible fruits (Mucina & Rutherford 2006), providing a rich source of nutrients to birds and mammals. The vegetation of this biome shows little seasonal fluctuation in its perennial cover or biomass, due to its high resistance to drought, a result of several mechanisms including underground storage organs, sclerophylly, CAM photosynthesis and succulence (Mucina & Rutherford 2006). The dominant vegetation categories within this Biome are the Great Fish Thicket and Great Fish Noorsveld (Mucina & Rutherford 2006) (Figure 2.5). The Great Fish Thicket is made up of short, medium and tall thicket types with numerous spinescent shrubs (Mucina & Rutherford 2006). It is dominated by *Portulacaria afra*, which is replaced by *Euphorbia bothae* in more arid areas or by woody elements and tall emergent *Euphorbia tetragona* and *E. triangularis* in moister areas (Mucina & Rutherford 2006). Areas rich in nutrients and moisture (due to zoogenic activity forming mounds) support long-lived woody shrubs and trees (e.g. *Pappea capensis* and *Boscia oleoides*) (Mucina & Rutherford 2006). The rest of the complex falls under the Great Fish Noorsveld vegetation, which consists of *P. afra*, particularly on rocky outcrops, while the sloping flanks and plateaus support low to medium height succulent thicket dominated by *E. bothae* and other *Euphorbia* species, sclerophylous bush clumps (*Euclea undulata*, *Grewia robusta*, *Gymnosporia polyacantha*, *Putterlickia pyracantha* and *Schotia latifolia*), succulent shrubs (*Crassula perfoliata*, *Cotyledon orbiculata*, *Pelargonium sidoides* and *P. reniforme*), rhizomatous herbs (*Sansevieria hyacinthoides*, *Strelitzia reginae*) and numerous grass species (Mucina & Rutherford 2006). A small portion in the far north part of GFRR falls under Bhisho Thornveld, which falls under the Sub-Escarpment Savanna Bioregion. This vegetation category consists mostly of open savanna with small *Acacia natalitia* trees and dense, grassy undergrowth dominated by *Themeda triandra* (Mucina & Rutherford 2006). Trollope *et al.* (2004) suggested that the GFRR vegetation can be further categorised into ten recognisable homogeneous vegetation units (HVU's) (Figures 2.6 and 2.7), based on structure and dominant species. *Acacia* Savanna is characterised by open thornveld dominated by *Acacia karroo* trees and shrubs. Bushclump Karroid Thicket (or Doubledrift Karroid Thicket) is characterised by *Rhus* spp., *E. undulata*, and *G. polyacantha* tree species, *Pentzia incana* and *Scutia* *myrtina* bushclumps, and a karroid herbaceous layer made up of characteristic grass species such as *Setaria neglecta* and *Digitaria eriantha* (Figure 2.8). Bushclump Savanna Thicket is found on flatter areas at high altitudes. It is characterised by dense thornveld dominated by *Chrysocoma ciliata*, *Rhus* spp, *Olea europaea*, *Cussonia spicata*, *Fluggea verucossa*, *Psydrax ovata*, *Ptaeroxylon obliquum* and *S. myrtina* bushclumps, interspersed with patches of grassland, with characteristic grass species including *D. eriantha*, *S. neglecta* and *Eustachys paspaloides* (Figure 2.9). Dry Forest (or Fish Thicket), characterised by tall growing *S. latifolia, Hippobromus pauciflora, Viperus undulata* and *Harpephylum caffrum* trees and shrubs, occurs on southern aspects. Grassland is characterised by open grassland dominated by one of the following species: *T. triandra, Sporobolus fimbriatus* and *D. eriantha* grass species. Medium *Portulacaria* Thicket (or Fish Spekboom Thicket) is characterised by *P. afra*, has a bare under storey and is interspersed with *P. capensis* trees (Figure 2.10). Riverine *Acacia* Thicket is characterised by dense *A. karroo* tree communities growing on river banks (Figure 2.11). Short *Euphorbia* Thicket (or Fish Noorsveld) is dominated by *E. bothae* and *E. corulescens* in some areas, woody species include *P. afra*, *P. capensis*, *Rhigozum obovatum* and *Maytenus capitata*, and grass species include *D. eriantha*, *T. triandra* and *Aristida* spp. (Figure 2.12). Tall *Euphorbia* Thicket (or Fish Valley Thicket) is dominated by a continuous assemblage of *E. tetragona* and *E. triangularis*, with *Maytenus undata*, *Elaeodendron zeyheri* and *C. spicata* tree species, and an under storey dominated by *Panicum deustem* and *P. maximum* grass species. This vegetation type usually grows on steep slopes (Figure 2.13). A further vegetation type, known as Riverine *Combretum* Thicket, occurs on the reserve and is characterised by stands of Cape bush willows, *C.*

caffrum, and other tree species including *A. karroo*, *Acalypha glabrata*, *O. europaea*, *Ziziphus mucronata*, and *Schotia afra*, and undergrowth species, including *Azima tetracantha*, *S. myrtina*, *Ehretia regida*, *Carissa bispinosa*, and *Maytenus heterophylla* (Madikiza *et al*. 2010) (Figure 2.14). Finally, Succulent aloe Shrub land is characterised by *Aloe* spp. and is mostly found in the northern sector of the reserve (Figure 2.15). Areas labeled as degraded/bare soil consist of previously cultivated fields.

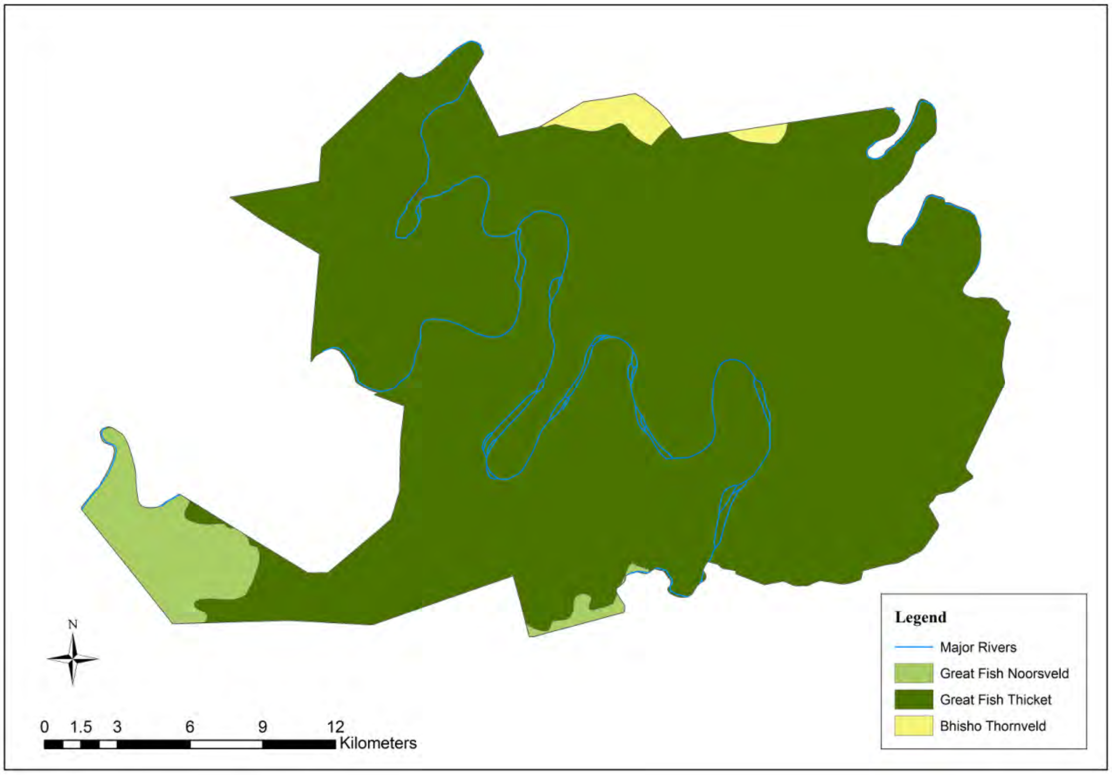

Figure 2.5 A vegetation map of Great Fish River Reserve, Eastern Cape Province, South Africa, according to Mucina & Rutherford (2006). (ArcGIS 9 map units: decimal degrees; not projected).

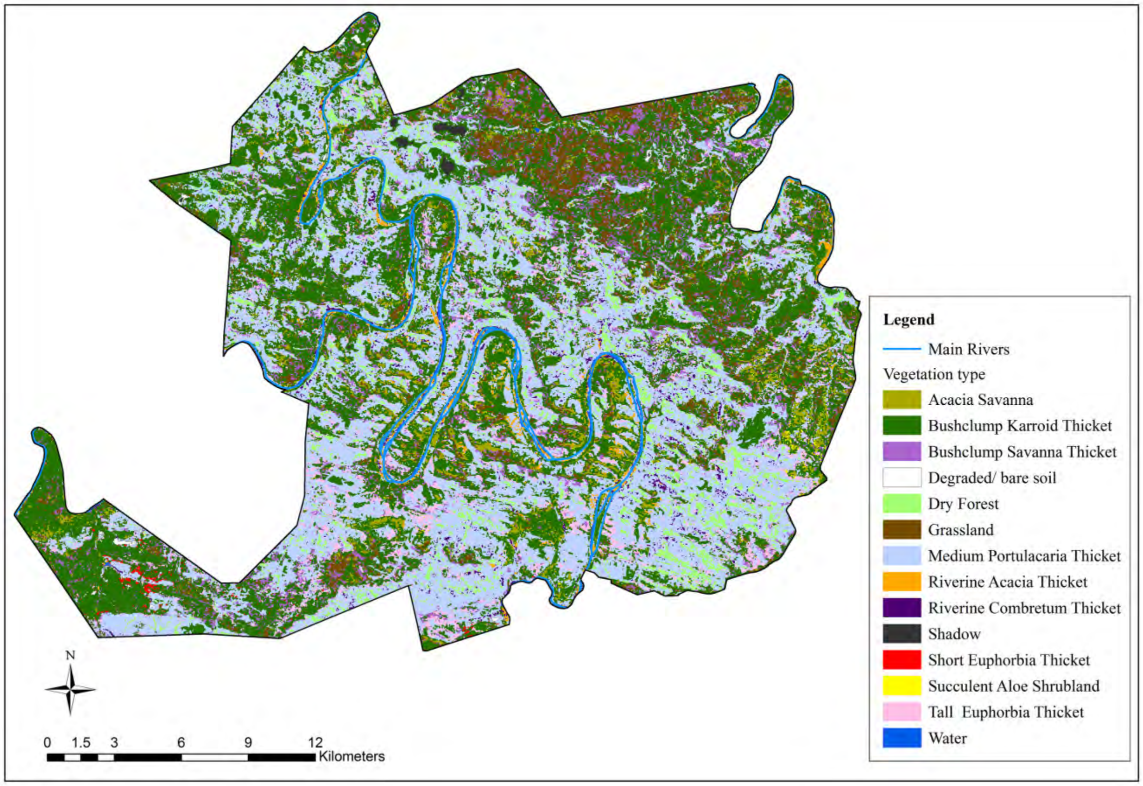

Figure 2.6 Distribution of the 12 vegetation types on the Great Fish River Reserve, Eastern Cape, South Africa, according to Trollope *et al*. (2004). (ArcGIS 9; map units: decimal degrees; not projected).

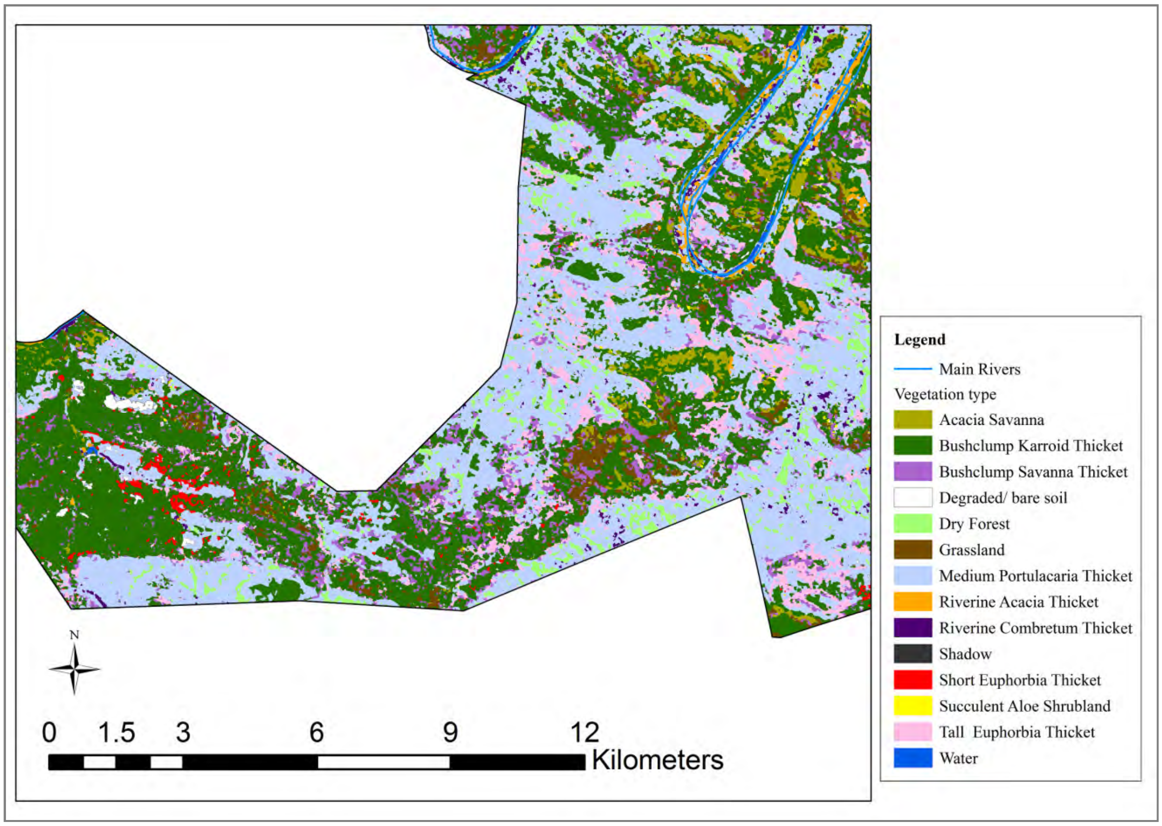

Figure 2.7 Distribution of vegetation types within the Andries Vosloo Kudu Reserve sector of the Great Fish River Reserve, Eastern Cape, South Africa, according to Trollope *et al*. (2004). (ArcGIS 9; map units: decimal degrees; not projected).

Figure 2.8 Bushclump Karroid Thicket, dominated by *Rhus* spp. bushclumps and showing the characteristic karroid herbaceous layer.

Figure 2.9 Bushclump Savanna, found on flat hilltops and characterised by dense thornveld dominated by *Rhus* spp. and *S. myrtina* bushclumps interspersed with patches of grassland.

Figure 2.10 Medium *Portulacaria* Thicket, which is mainly found on slopes, and is dominated by *P. afra*, with very little under storey vegetation.

Figure 2.11 Riverine *Acacia* Thicket, characterised by dense *A. karroo* tree communities growing on sandy river banks.

Figure 2.12 Short *Euphorbia* Thicket (in flower) dominated by *Euphorbia* spp.

Figure 2.13 Tall *Euphorbia* Thicket showing *E. tetragona* growing on steep slopes.

Figure 2.14 Riverine *Combretum* Thicket showing characteristic *C. caffrum* trees.

Figure 2.15 Succulent aloe Shrubland with *Aloe ferox* and *Euphorbia* spp. present.

2.2.5 Mammalian Fauna

A mammal list for SKNR/AVKR includes 73 species, including, aardvark (*Orycteropus afer*), honey badger (*Mellivora capensis*), black-backed jackal, brown hyaena, caracal, leopard and Cape clawless otter (*Aonyx capensis*). Large and medium-sized herbivores include, among others, hippopotamus (*Hippopotamus amphibious*), black rhinoceros (*Diceros bicornis*), elephant (*Loxodonta africana*), bushpig (*Potamochoerus porcus*), Cape buffalo (*Syncerus caffer*), Burchell's zebra (*Equus zebra*), blesbok (*Damaliscus pygargus phillipsi*), red hartebeest (*Alcelaphus buselaphus caama*), springbok (*Antidorcas marsupialis*), waterbuck (*Kobus ellipsiprymnus*), steenbok (*Raphicerus campestris*), Cape grysbok (*Raphicerus melanotis*), mountain reedbuck (*Redunca fulvorufula*), bushbuck (*Tragelaphus scriptus*), grey duiker (*Sylvicapra grimmia*), kudu (*Tragelaphus strepsiceros*) and eland (*Tragelaphus oryx*). Large predators are absent from the GFRR, with the exception of a few transient brown hyaenas and leopards (Brad Fike, pers. comm). Several extralimital species were introduced into the DDGR part of GFRR including warthog (*Phacochoerus africanus*), blue wildebeest (*Connochaetes taurinus)*, nyala (*Tragelaphus angasii*), giraffe (*Giraffa camelopardalis*), and white rhinoceros (*Ceratotherium simum*).

Aerial game counts for GFRR were done in 2009, using a four seater Robinson R44 helicopter with two counters, a recorder and a pilot, flying along transects at a speed of 60 km/hr, 30 m above ground (Peinke & Peinke 2009). One full count with transects 300 m apart, and two 50 % sample counts with transects 600 m apart, were completed (Peinke & Peinke 2009). Animals 150 m either side of the helicopter were counted and their location recorded using a GPS (Geographical Positioning System) (Peinke & Peinke 2009). A third 50 % sample count was then extracted from the full count data-set using the observations made from the same flight path used for the first two 50 % counts (Peinke & Peinke 2009). Data from the sample counts were converted to density estimates to estimate total population size for the whole of GFRR.

Aerial game counts of black-backed jackals for the years 2003, 2004, 2005 and 2006 fluctuated with totals of 71, 85, 52 and 87, respectively. The census for 2009 totalled 86 at GFRR and 18 on AVKR. See Appendix A for a full list of the mammalian fauna and Appendix B for the 2009 game count at GRRR. It should be noted, however, that this study focused on the AVKR section of GFRR, which does not contain all of the mammalian prey found in the whole of the GFRR, including blesbok, blue wildebeest, African elephant, giraffe, impala, mountain reedbuck, nyala, waterbuck and Burchell's zebra.

2.3 Kwandwe Private Game Reserve

2.3.1 Location

Kwandwe lies in the Great Fish River Valley, less than a kilometre west of GFRR, approximately 35 km north-east of Grahamstown (33º09'S, 26º37'E). Kwandwe was established as a conservation area in 1999, when it first occupied an area of approximately 16 000 ha. In 2005, it was further enlarged by purchasing adjacent land and the reserve now covers approximately 21 000 ha. It was previously used for ostrich (*Struthio camelus*) and small stock farming and is surrounded by privately-owned farmland and state-owned land. The Great Fish River is the main river and bisects the reserve into a northern and southern section. The other significant watercourse, Botha's River, is found in the southern section of the reserve and fills three large man-made dams (Figure 2.19).

2.3.2 Climate

2.3.2.1 Temperature

Kwandwe experiences a warm temperate climate, with temperatures that range between 35ºC in summer (December to February) and below 5ºC in winter, with widespread frost at night (June to August) (Stone *et al.* 1998) (Figure 2.16). During the year of study, temperatures fluctuated between 45ºC and -2ºC, as measured at the Krantzdrift weather station (33°09'15S, 26°29'37E). Temperatures at Kwandwe exceeded 35ºC for 33 days of the study year. As at GFRR, low-lying areas are hot and semi-arid, whilst higher areas are cooler and wetter.

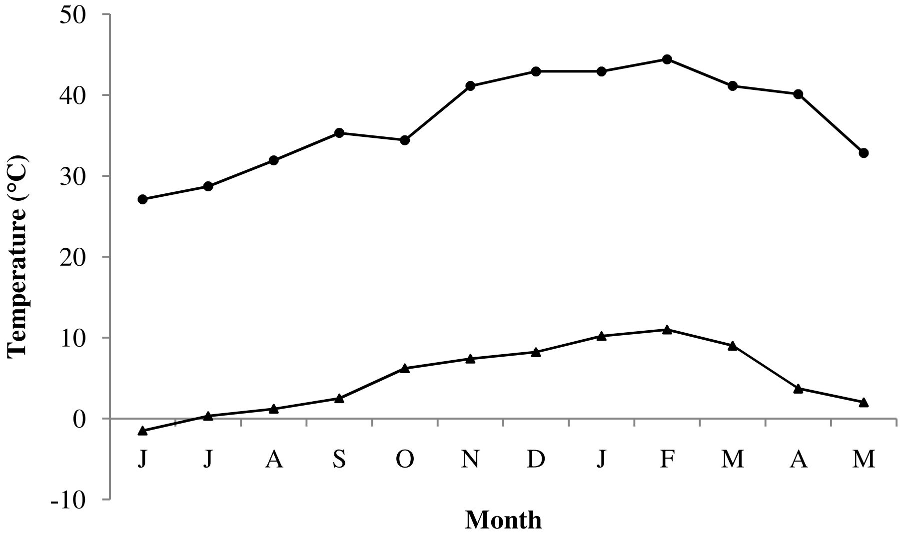

Figure 2.16 Mean daily maximum (circles) and minimum (triangles) temperatures for each month of the study, from June 2009 to May 2010 at Kwandwe Private Game Reserve (Krantzdrift weather station).

2.3.2.2 Rainfall

Kwandwe also experiences distinct bimodal rainfall, with the highest occurrence between the months of November and December and March and April (Figure 2.17) (Stone *et al.* 1998). Annual rainfall ranges between 400-500 mm, with an annual mean of 425 mm. The mean annual between 1983 and 2008 was 417 mm. During the year of study (June 2009 to May 2010), Kwandwe experienced a total of 340 mm. Due to the lack of long-term climatic data for Kwandwe, data from a nearby farm (Markwood Farm; 33°02’10S, 26°24’42E) were used for the period 1983-2002. For the period 2003-2010, data from Krantzdrift weather station on Kwandwe were used. Altitude, aspect and slope, as at GFRR, also affect rainfall, resulting in variation within the reserve. The southern slopes experience cooler and moister conditions and northern slopes experience warmer, drier conditions. The low-lying areas receive a mean of approximately 400 mm and the higher ground receives about 600 mm. Kwandwe experienced distinct bimodal peaks with highest rainfall in the months of October and January for the study period (June 2009 - May 2010) (Figures 2.3 & 2.17).

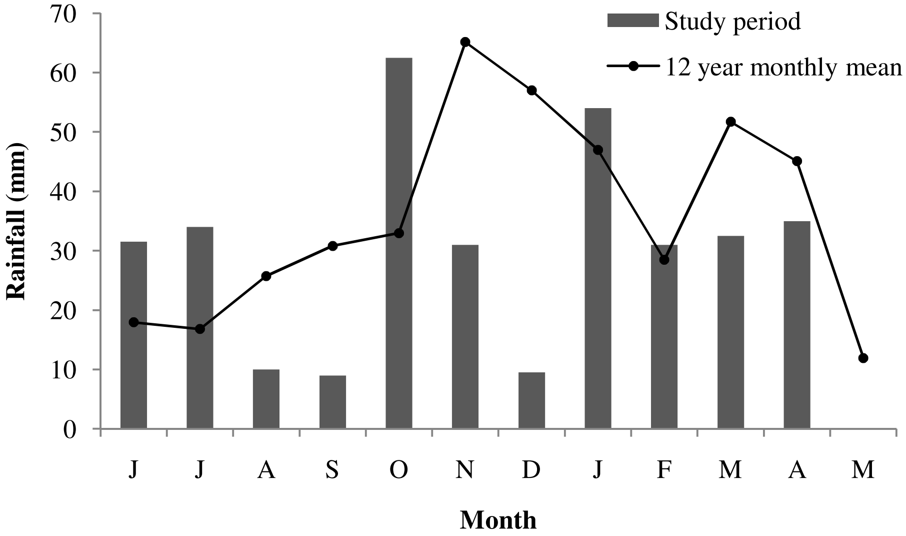

Figure 2.17 Total monthly rainfall for the study period, from June 2009 to May 2010 at Kwandwe Private Game Reserve. Mean monthly rainfall for 12 years (1992-2003) is also included.

2.3.3 Topography and geology

Elevation ranges from 170 m in the Great Fish River valley to over 600 m above sea level. A succession of sandstone ridges with an east-west orientation are found in the southern part of the reserve, forming steep valleys and gorges. Wide plains and low hills can be found in the centre of the reserve. In the northern part of the reserve the ground rises steeply from the Great Fish River to the top of the Fish River Rand. The northern sector consists primarily of shallow clay soils (Glenrosa and Mispah) derived from the Adelaide and Estcourt Formations (Beaufort Group, Karoo Supergroup) (Mucina & Rutherford 2006). The southern sector consists of finely laminated clastic sediments of the Ecca Group (particularly the Fort Brown Formation), which supports skeletal shallow soils (Glenrosa and Mispah) (Mucina & Rutherford 2006). The highly erodible, nutrient-rich mudstones are found in the river valleys, while the more resistant sandstones are found on the ridges.

2.3.4 Vegetation

Kwandwe also falls within the Albany Thicket Biome. The dominant vegetation categories, like GFRR, are Great Fish Thicket and Great Fish Noorsveld (Mucina & Rutherford 2006) (Figure 2.18). The Great Fish Thicket covers the northern sector of the reserve (north of the Great Fish River) as well as a narrow band in the southern part of the reserve. The southern sector of the reserve falls under the Great Fish Noorsveld vegetation. A further two narrow bands of vegetation occur in the southern sector of the reserve: the Kowie Thicket and the Albany Broken Veld (Mucina & Rutherford 2006). Kowie thicket, is found on the steep north-facing slopes and is dominated by succulent euphorbias and aloes and has a thick under storey made up of thorny shrubs, woody lianas and shrubby succulents, and a poorly developed herbaceous layer (Mucina & Rutherford 2006). Albany Broken Veld, which falls under the Lower Karoo Bioregion vegetation, consists of an open grassy karroid dwarf shrubland on hills, with *Eragrostis obtusa* grasses, dwarf shrubs, and scattered low trees, such as *P. capensis* (Mucina & Rutherford 2006). Similar homogenous vegetation units (HVU’s) as those present on

GFRR can be recognised on Kwandwe (Figure 2.19). Bushclump Karroid Thicket occurs on the red, sandy colluvial slopes neighbouring the alluvial plains of the major rivers. Bushclump Savanna Thicket is found on flatter areas at high altitudes, particularly in the northern section of the reserve. Dry Forest (or Fish Thicket) occurs in steep valleys in the northern section of Kwandwe. It is characterised by 5-10 m tall trees such as *Harpephyllum caffrum, Mystroxylon aethiopicum, C. spicata, S. latifolia, Clanedendron copense* and *O. europea*, it has a distinct shrub layer of *M. heterophylla, S. myrtina*, *C. bispinosa* and *Rhoicissus tridentata*, and an herbaceous layer dominated by the grasses *P. deustem* and *P. maximum*. The Grassland vegetation part is only found in a small area in the north western part of the reserve. Medium *Portulacaria* Thicket is found mostly on steep slopes in the northern and the western sections of the reserve. In the western section it has a bare under storey, whilst in the northern section it has a herbaceous layer dominated by *T. triandra*, *Digitaria eriantha* and *P. maximum*. Riverine *Acacia* Thicket, which occurs on alluvial slopes and banks of the Great Fish and Botha's Rivers, is characterised by *Rhus lancea*, *A. karroo* and *C. caffrum* tree species, while the herbaceous layer is dominated by *P. maximum.* Short *Euphorbia* Thicket is dominated by *E. bothae* and *E. corulescens* in some areas, woody species, which are dominant over the *Euphorbia* spp. in the northern section of the reserve, include *P. afra*, *P. capensis*, *R. obovatum* and *M. capitata*, and grass species include *T. triandra*, *P. maximum, D. eriantha* and *Aristida* spp. Tall *Euphorbia* Thicket usually grows on steep slopes in the northern section of the reserve.

An additional three vegetation types can be found on Kwandwe. Drainage Line thicket is found in drainage lines and consists of dense clumps of *Rhus refracta* and an under storey of *Plumbago auriculata* and the grass species *P. maximum*. *Euphorbia*/ *Portulacaria* Mosaic (Figure 2.20) is a transitional vegetation type between Short *Euphorbia* thicket and Medium *Portulacaria* thicket. It is characterised by a combination of clusters of woody species such as *P. afra*, *P. capensis*, *M. capitata* and *S. afra* and grass species such as *Sporobolis fimbriatus* and *P. maximum*, and more open areas characterised by the woody species *E. bothae* and *R. obovatum*, and the grass species *T. triandra* and *D. eriantha*. Karroid *Cynodon* Shrubland, found mostly in the low-lying areas of the centre of the reserve, is characterised by tree species such as *P. capensis* and *R. refracta*, short growing karroid shrublets and a stoloniferous grass cover of *Cynodon dactylon*, *D. eriantha* and *Aristida congesta*. Areas labeled as degraded old lands (Figure 2.21) consist of previously cultivated fields, primarily located on alluvial sections of the Great Fish and Botha's Rivers, dominated by *Pennisetum clandestinum*, *Cenchrus ciliaris* or *Cynodon dactylon*.

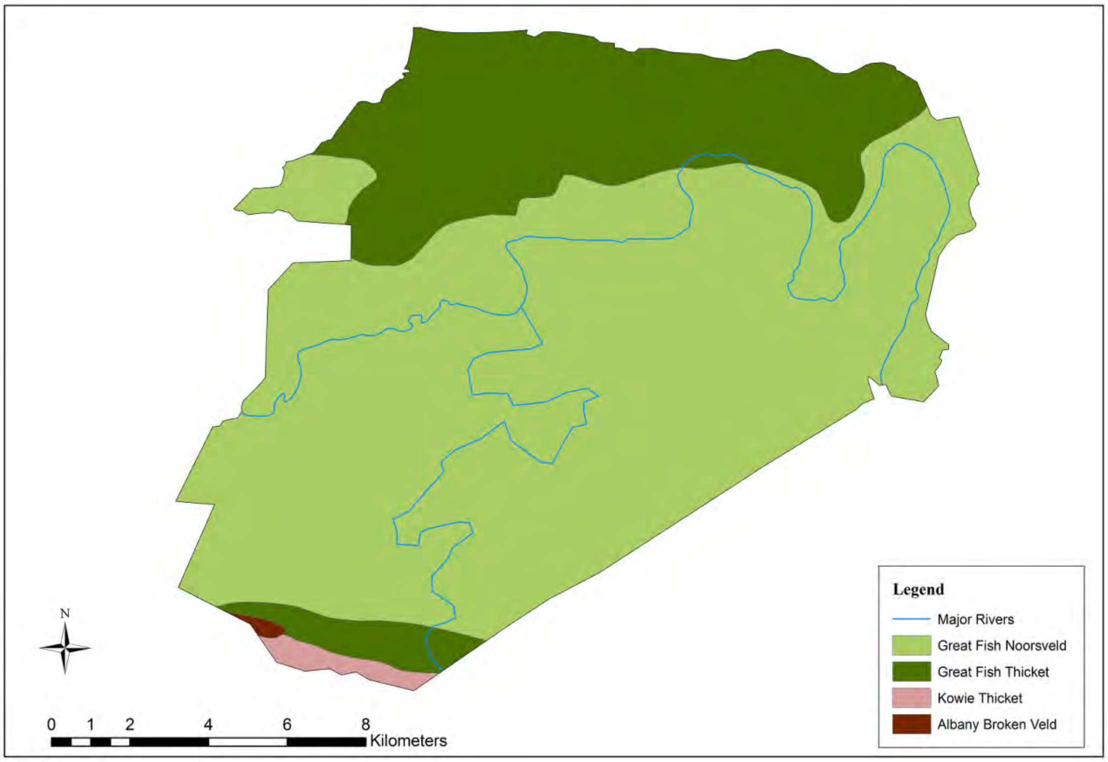

Figure 2.18 A vegetation map of Kwandwe Private Game Reserve, Eastern Cape Province, South Africa, according to Mucina & Rutherford (2006). (ArcGIS 9 map units: decimal degrees; not projected).

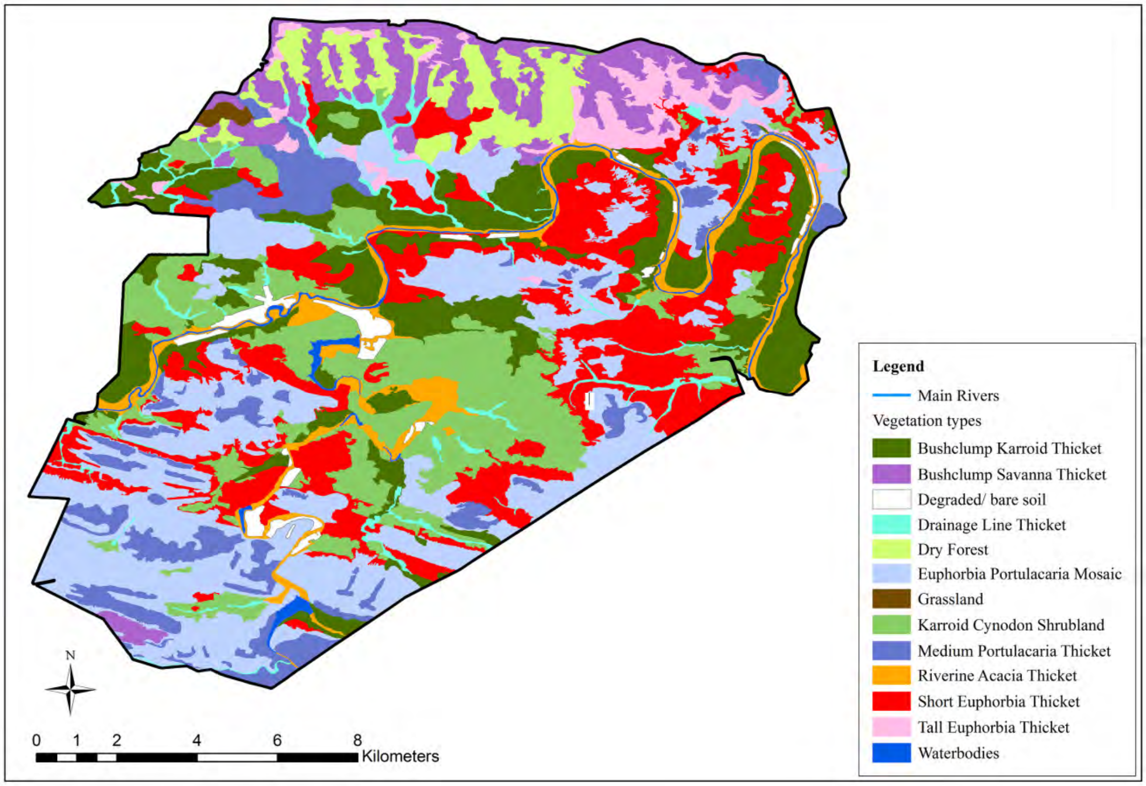

Figure 2.19 Distribution of the 10 vegetation types present at Kwandwe Private Game Reserve, Eastern Cape, South Africa, according to Trollope *et al*. (2004). (ArcGIS 9; map units: decimal degrees; not projected).

Figure 2.20 *Euphorbia*/*Portulacaria* Mosaic showing *E. bothae* in the right foreground, *P. afra* on the left and the characteristic grassy under storey.

Figure 2.21 Degraded old land at Kwandwe Private Game Reserve. The old land is the lighter green in the background.

2.3.5 Mammalian Fauna

When the reserve was established in 1999, indigenous fauna included greater kudu, bushbuck, grey duiker, steenbok, Cape grysbok, grey rhebuck (*Pelea capreolus*), mountain reedbuck, bushpig and warthog. Between 1999 and 2001, more than 7 000 animals were reintroduced, including over 2 000 head of ungulates, such as buffalo, gemsbok (*Oryx gazella*), Burchell's zebra, eland, blue wildebeest, black wildebeest (*Connochaetes gnou*), hippopotamus, giraffe, white rhinoceros, black rhinoceros and African elephants. Carnivore reintroductions included lions, cheetahs, African wild dogs, leopards, brown hyenas and servals (*Leptailurus serval*). Other small predators present on the reserve, other than black-backed jackal, include caracal and Cape fox. The latest aerial game counts were completed in 2007, using a Jet Ranger III, ZS-HSV helicopter with two counters, a recorder and a pilot, flying along transects 250 m apart, at a speed of 60-90 km/hr, 30-50 m above ground (Bissett 2004). Animals 125 m on either side of the helicopter were counted and their localities recorded using a GPS (Bissett 2004). Aerial game counts of black-backed jackals for the years 2003, 2004, 2005 and 2007 fluctuated on an annual basis, with totals of 41, 74, 80 and 34 respectively (Bissett 2007). See Appendix C for a full list of mammals and Appendix D for the 2007 game count at Kwandwe.

CHAPTER THREE

SEASONAL VARIATION IN THE DIET OF BLACK-BACKED JACKALS, *CANIS MESOMELAS*, IN TWO CONSERVATION AREAS IN THE EASTERN CAPE PROVINCE, SOUTH AFRICA

3.1 Introduction

Gaining insight into the relationship between predators and their prey is essential for their management, as well as to better understand their role in the ecosystems they inhabit (Adams *et al*. 2010). The diet of a carnivore reflects both the availability of its potential prey items and a suite of morphological, behavioural and physiological adaptations that allow the individual to locate, capture, ingest and digest a variety of prey taxa (Kok & Nel 2004). The availability and the nature of the available food, such as the quality, quantity and spatial distribution, of various food resources influence a carnivore's demographics, including density, reproduction, survival and behaviour (Bekoff *et al*. 1984; Fuller & Sievert 2001). Additionally, the way food resources are exploited, such as how they are located, defended and whether they are hunted or scavenged, strongly influence interspecific relationships of predators and result in considerable intraspecific variations in social organisation (Bekoff *et al*. 1984). In turn, predation is believed to have important effects on prey behaviour, population size and viability and on a community's species diversity (Sih *et al.* 1985). Dietary studies are necessary for reserve managers in order to provide insight into these fundamental aspects of an animal's ecology, habitat utilisation, daily consumption, predator-prey interactions and competitive interactions (Korschgen 1980; Litvaitis 2000; Rapson & Bernard 2007). These data are necessary for the effective management and conservation of predators and are thus important for the development of the ecotourism industry (Rapson & Bernard 2007).

As large predators (lions, leopards, cheetahs and spotted hyaenas) became more problematic as livestock killers in the 19th and 20th century they were locally extirpated from many parts of their range in South Africa (Beinart 2003). It is likely that this extirpation of the superior predators resulted in "mesopredator release", where middle-ranked predators such as the black-backed jackal were freed from top-down control of apex predators (Estes 1996; Lloyd 2007; Prugh *et al*. 2009; Ritchie & Johnson 2009). Without the limiting effects of the larger predators, populations of mesopredators tend to increase (Lloyd 2007; Prugh *et al*. 2009). This increases predation pressure on the mesopredator prey species (Lloyd 2007), which may in turn destabilise communities and result in species extinctions (Prugh *et al*. 2009). The prediction and management of mesopredator release is therefore crucial to reduce the ecological, economic and social costs associated with mesopredators (Prugh *et al*. 2009).

Several characteristics make the role of black-backed jackals important in ecosystems and thus necessitate further study. Firstly, as generalist and opportunistic predators, their diet will depend on the abundance and availability of their prey species (Pyke *et al*. 1977), thus resulting in a wide variation in their diet across their range. However, few studies (Hall-Martin & Botha 1980; Bussiahn 1997; Do Linh San *et al*. 2009) have been conducted on their diet in the Eastern Cape and its associated biome, the Albany thicket Biome. Of these three, only one study (Do Linh San *et al*. 2009) was based on scat analysis. Since black-backed jackal diet depends on the availability and abundance of their prey species, prey composition will show seasonal variation (Pyke *et al*. 1977), rendering seasonal diet studies crucial to understanding the overall use of food resources by the black-backed jackal. There have, however, been no comprehensive studies on the diet of black-backed jackals across a full seasonal cycle in reserves in the Eastern Cape Province. This is particularly important in light of the increase in private game reserves in the region (Smith & Wilson 2002; Sims-Castley *et al*. 2005).

Black-backed jackals are often viewed as problem animals, both on livestock farms (Hey 1964; Rowe-Rowe 1975; Van Sittert 1998; Beinart 2003; Davies-Mostert *et al*. 2007) and on nature reserves (Bussiahn 1997). On nature reserves or game farms, their predation on ungulates (Rowe-Rowe 1976; Bussiahn 1997; Kaunda & Skinner 2003; Klare *et al*. 2010) may be a threat to the population viabilities of these animals. Slight increases in mortality brought about by predation can have significant effects on the recovery potential of a population (McLoughlin & Owen-Smith 2003). Through top-down effects, predators affect ungulate populations, and herbivore abundance in turn determines the consequences of herbivory for ecosystems (Estes 1996).

The main objectives of this chapter were:

1. To determine the diet of the black-backed jackal in two conservation areas in the Eastern Cape.
2. To identify any seasonal variation in the black-backed jackal diet in these two conservation areas.
3. To determine whether the diet of the black-backed jackal is different on a reserve with large predators compared to one without.

3.2 Methods

Scat (faecal) analysis was selected as a means of analysing the black-backed jackal diet because of the species' elusive and nocturnal nature (Brand & Nel 1997). The dense vegetation of the Eastern Cape Province (Mucina & Rutherford 2006) also rendered the use of direct observations impractical. Scat analysis is defined as the identification and quantification of individual components which have passed through the digestive systems of mammalian carnivores (Trites & Joy 2005). The method is commonly used to study the feeding ecology of elusive predators (e.g. Ciucci *et al*. 1996; Kaunda & Skinner 2003; Ott *et al*. 2006) as it is non-destructive and scats are easy to collect (Norbury & Sanson 1992; Mukherjee *et al*. 1994; Chame 2003; Trites & Joy 2005). Scat analysis can be used as a primary or additional source of information on the feeding habits of predators. Scat analysis can be used to estimate prey individual numbers of certain prey types in order to study prey preferences, overlap in prey species of sympatric carnivores and can describe the functional responses of carnivores to changing prey densities (Korschgen 1980; Krüger *et al*. 1999; Rühe *et al*. 2008). However, the method suffers from the differential passage rate of ingesta through the gut and the presence of material which has become unidentifiable through the process of digestion, such as highly digestible meat from large prey (Bowland & Bowland 1991; Norbury & Sanson 1992; Krüger *et al*. 1999).

When using scat analysis, the analytical approach most commonly used is based on presence/absence data and entails calculating the percentage occurrence (PO) and relative percentage occurrence (RPO) (Corbett 1989; Ciucci *et al*. 1996; Loveridge & Macdonald 2003; Ciucci *et al*. 2004; Lanszki *et al*. 2009; Giannatos *et al*. 2010; Klare *et al*. 2010; Balestrieri *et al*. 2011). The PO of prey items indicates how often a carnivore feeds on a certain type of food and is defined as the number of times a food type is encountered in the scats as a percentage of the total number of scats (Corbett 1989; Hidalgo-Mihart *et al*. 2001; Capitani *et al*. 2003; Kübarsepp & Valdmann 2003; Loveridge & Macdonald 2003; Trites & Joy 2005; Van der Merwe *et al*. 2009; Do Linh San *et al*. 2009; Giannatos *et al*. 2010; Herbst & Mills 2010; Liu *et al*. 2010). The RPO, defined as the number of times a food type is encountered in a sample of scats expressed as a percentage of total occurrences of all food items, allows one to determine the importance of each food item to the overall diet of the carnivore (Hidalgo-Mihart *et al*. 2001; Loveridge & Macdonald 2003; Ciucci *et al*. 2004; Van der Merwe *et al*. 2009; Do Linh San *et al*. 2009; Herbst & Mills 2010; Klare *et al*. 2011). The PO and RPO method are comparatively simple to apply and, because of their wide application, they can be compared with results from other diet studies (Corbett 1989).

It is often assumed that each occurrence of a prey species in different scats represents a different prey individual (Sheperd & Leman 1983). However, some individual prey items take longer to digest relative to other prey items and can be found in more than one scat (Murie 1946), resulting in scats containing multiple parts of a single large meal (Floyd *et al*. 1978). Thus, the contribution of certain prey items may be overestimated. For example, small mammals can be over-estimated in carnivore scats because they have a relatively high surface area to volume ratio (Lockie 1959; Floyd *et al*. 1978; Bowland & Bowland 1991; Weaver 1993; Klare *et al*. 2011). This means that they are covered with proportionally more hair (which is used to identify mammalian prey in scat analyses) than other mammals (Floyd *et al*. 1978; Bowland & Bowland 1991; Weaver 1993). However, black-backed jackal produce approximately one scat/day (24 hours) and the majority of remains are passed in the first two scats following ingestion (Bowland & Bowland 1991). As individual prey types are scored on a presence or absence basis, the frequency of small, commonly eaten items (e.g. invertebrates or fruit) may be overemphasised (Corbett 1989; Atkinson *et al*. 2002; Klare *et al*. 2011) while larger prey may be underestimated in terms of relative importance (Do Linh San *et al*. 2009). Underestimation of large prey (e.g. large ungulates) may further arise as little indigestible material is ingested when the predator feeds on the softer parts of the animal and avoids the hide and bones (Gamberg & Atkinson 1988; Bowland & Bowland 1991). Frequency of occurrence also has a tendency to overestimate vegetative food items, particularly fruits, which result in increased scat deposition rate (Andelt & Andelt 1984).

The PO and RPO methods allow one to account for rare food items and very small prey items which are frequently consumed but may not be significant in terms of biomass (Klare *et al*. 2010, 2011). Additionally, PO provides insight into the breadth of a carnivore's diet (i.e. whether it is an opportunist or a specialist) (Klare *et al*. 2011). Other approaches commonly used to quantify the importance of prey items include estimating the relative amount (mass and/or volume) of prey remains in carnivore faeces (Corbett 1989; Atkinson *et al*. 2002; Capitani *et al*. 2003; Ciucci *et al*. 2004; Van Dijk *et al*. 2007; Do Linh San *et al*. 2009; Giannatos *et al*. 2010; Klare *et al*. 2010, 2011) and the use of estimations of ingested biomass based on the number of prey items detected multiplied by the weight of the prey (Floyd *et al*. 1978; Kruuk & Parish 1981; Klare *et al*. 2011), or using conversion factors determined from feeding trials (Putman 1984; Corbett 1989; Atkinson *et al*. 2002; Giannatos *et al*. 2010; Klare *et al*. 2010, 2011). However, correction factors are not extensively used because they are affected by inaccuracies when extrapolating from faecal remains to foods consumed (Atkinson *et al*. 2002, Van Dijk *et al*. 2007).

3.2.1 Scat collection

Black-backed jackal scats were identified in the field based on distinctive features such as colour, shape, smell, dimensions and position (Do Linh San *et al*. 2009). These scats are usually found in conspicuous sites, generally near roads, paths or at track junctions (Hayward & Hayward 2010) and on prominent features such as tufts of grass, where they can be easily detected by other jackals for territoriality purposes (Walker 1996; Stuart & Stuart 2000; Hayward & Hayward 2010). Black-backed jackal scats also typically contain a mixture of grass and other components such as mammalian hairs, seeds and parts of insects (Walker 1996; Stuart & Stuart 2000) and are characteristically long with pointed ends (Walker 1996). Furthermore, collection sites, being inside nature reserves, were isolated from domestic canids, thus excluding the likelihood of accidentally collecting faeces from the latter.

Based on prey occurrence, Trites and Joy (2005) demonstrated that for an animal with a diet of 15 or more prey species, a minimum sample size of between 23 and 51 scats is necessary to identify principal prey remains which occur in >5% of the scats. A study conducted by Do Linh San *et al.* (2009) on the autumn diet of black-backed jackals in the Eastern Cape Province estimated that over 17 species are consumed. Thus, I aimed to collect 51 scats per season per site (i.e. a minimum of 17 scats/ site/ month) along a pre-determined route at each site (Figures 3.1 and 3.2). The length of the route was determined by the minimum number of scats necessary per month per site. Approximately one scat could be found per kilometre of route (*pers. obs.*), resulting in a route of approximately 20 km (i.e. 20 scats/ site/ month). Black-backed jackal scats were collected opportunistically along these routes between June 2009 and May 2010. The majority of the route at GFRR passed through Great Fish Thicket, whilst the route at Kwandwe lay in Great Fish Noorsveld vegetation (Figures 2.5 and 2.18). To remove sampling bias, similar vegetation types were sampled within the two broader vegetation categories and were based on Trollope *et al.* (2004)'s vegetation types within the reserves (Figures 2.6, 2.7 and 2.19). The scats were spotted from a vehicle, driving at a constant speed (<15km/h) and with the driver and passenger looking on either side of the road.

Any old scats which appeared to have been deposited in the previous month, and any scats which could not be positively identified in the field were not collected (Korschgen 1980). An average of 25 (± 4) scats per month and 17 (± 6) scats per month were collected at GFRR and Kwandwe, respectively. The spring (n=42) and summer (n=38) samples at Kwandwe were below the required 51 scats per season, but still above the minimum sample size of 23 scats per season (Trites & Joy 2005). A total of 496 black-backed jackal scats were collected; 295 from GFRR and 201 from Kwandwe. The scats were placed in sealable plastic Ziploc^{TM} bags (17.7 cm x 20.3 cm) and labelled with individual scat numbers, date, site of collection, defecation site (side or middle of the road) and substrate (shrub, grass or ground), and preserved in a deep freeze (-20ºC) until analysis.

Figure 3.1 Collection route along which black-backed jackal scats were collected at the Great Fish River Reserve, Eastern Cape, South Africa.

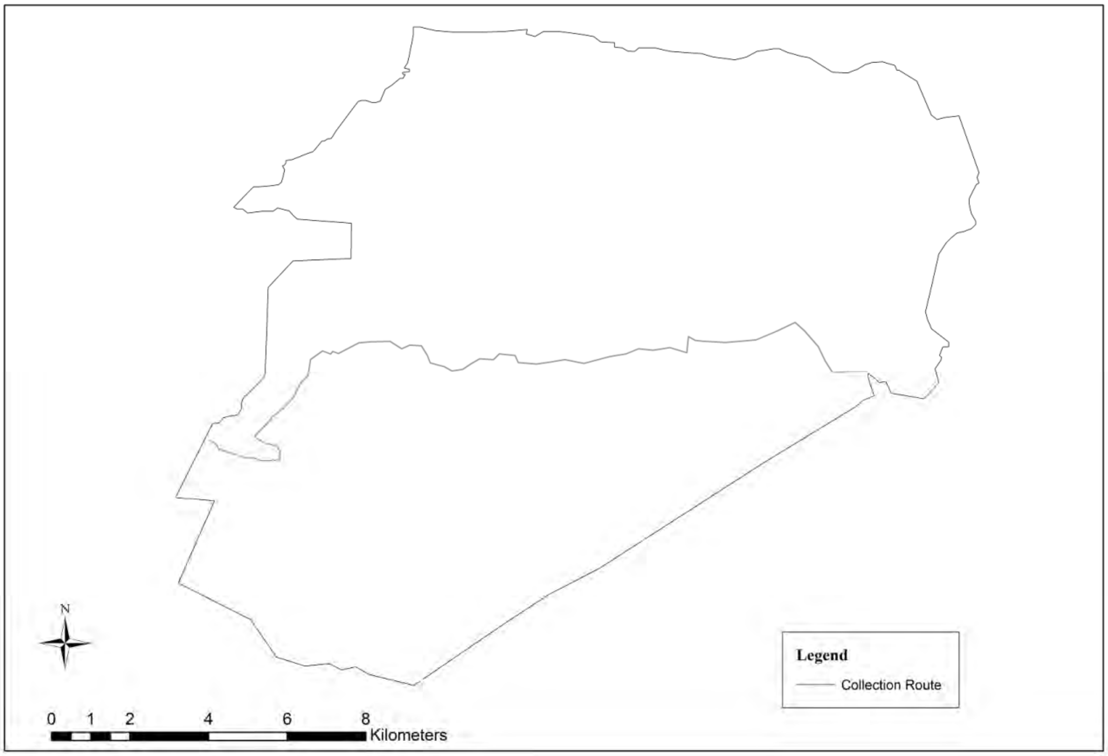

Figure 3.2 Collection route along which black-backed jackal scats were collected at Kwandwe Private Game Reserve, Eastern Cape, South Africa.

3.2.2 Scat analysis

Scat contents were examined by macerating scats overnight in separate 500 ml glass beakers containing warm tap water (Hiscocks & Perrin 1987; Bowland & Bowland 1991). After maceration, scats were spread evenly in white plastic sorting trays (50 cm x 35 cm x 4 cm), with sufficient water to cover the bottom, and visually examined (Hiscocks & Perrin 1987; Bowland & Bowland 1991; Loveridge & Macdonald 2003). Different dietary components were sorted out (see section 3.2.2.1 Overall Diet) and a sample of randomly selected mammalian hairs were removed from each scat using fine forceps for later identification (Bissett 2004).

3.2.3 Overall diet

Data were grouped according to i) site and ii) season, in order to investigate local and time-related variation in black-backed jackal diet. The overall diet was determined by macroscopically identifying the scat contents and separating them into seven broad categories: mammals, birds, reptiles, invertebrates, fruit, plant matter (other than fruit) and anthropogenic items (Kaunda & Skinner 2003; Ciucci *et al*. 2004; Van der Merwe *et al*. 2009; Herbst & Mills 2010). Mammals were identified by the presence of hair, bone and teeth (Kaunda & Skinner 2003). Bird remains were identified by the presence of feathers (Kaunda & Skinner 2003). Reptilian remains were identified by the presence of scales and other body parts (e.g. legs and tails) (Kaunda & Skinner 2003). Invertebrates were recognised by the presence of exoskeletons and were identified down to order using Picker *et al*. (2004). Fruits and seeds were identified to species by comparison with known specimens held at the Selmar Schönland Herbarium at the Albany Museum, Grahamstown, South Africa. The species level identification of fruits and seeds was completed using the autumn data only as this was when they were most prevalent in the scats. Birds and reptiles were not classified to finer taxonomic levels as remains in the scats were usually too fragmented to permit identification (Grafton 1965; Kaunda 1998; Klare *et al*. 2011). Anthropogenic items were identified by the presence of unusual objects (plastic, rubber and metal). Non-food items such as stones were recorded but not included in the PO and RPO analysis (Klare *et al*. 2011).

3.2.4 Mammalian prey component

Mammalian prey species within the scats were identified to species level from macro- and microscopic hair morphology (Keogh 1983). Diet was quantified using presence or absence of prey, thus equal value was given to hairs ingested in different amounts (Kaunda & Skinner 2003). The hairs retrieved from scats were identified using a reference collection of hairs of local mammals and the use of two keys: the key on the microstructure of the hair of southern African bovids (Keogh 1983) and the key to mammals of the Andries Vosloo Kudu Reserve (Perrin & Campbell 1979). The reference collection consisted of hairs from the mammalian prey species (a total of 81 species) present on both reserves (see Appendix C). The hair samples were obtained from museum specimens at the Amathole Museum in King Williams Town, Eastern Cape, South Africa. Guard, dorsal and ventral hairs were collected for each species (Keogh 1983). Imprints and cross-sections were prepared for each hair type (guard, dorsal and ventral) for each species, following the methods described below (section 3.2.4.1) (Perrin & Campbell 1979; Keogh 1983; Bissett 2004). Dorsal hairs were taken from the mid-dorsal line between the shoulders of the specimens; ventral hairs were obtained from the mid-ventral line (Keogh 1983). Guard hairs, which are longer and coarser than other hair types (Keogh 1983), were obtained from the dorsal side of the specimens. Three photographs were taken of each hair imprint: of the base, mid- and tip-region of each hair to ensure cataloguing of the entire range in pattern differences for each hair (Keogh 1983). Cross sections of three different hairs were photographed for each hair type (guard, dorsal and ventral) and for all species except the smaller rodents and bats as the hairs were too fine to obtain suitable cross-sections (Douglas 1989). The full collection, slides and remaining hairs are held in the Wildlife and Reserve Management Research Group laboratory at Rhodes University.

3.2.4.1 Mammalian hair identification

The use of hair characteristics and morphology for identification purposes is a widely accepted technique in several fields, including forensics, taxonomy, predator feeding habits and ecological and epidemiological studies (Perrin & Campbell 1979; Keogh 1983). The hair of prey species has a characteristic shape, length, colour, cross-section and scale pattern (Krüger *et al*. 1999). Each hair consists of a cuticle, cortex and medulla which differ in shape and size and are visible in a sample cross section (Perrin & Campbell 1979; Keogh 1983). The cuticle is made up of keratinized overlapping scales which differ in shape, size and type, forming patterns that are used for identification purposes (Perrin & Campbell 1979; Keogh 1983). The main advantage of using hair from faecal and stomach content is that, unlike other ingested material, it remains largely undamaged by digestion (Keogh 1983; Gamberg & Atkinson 1988; Bowland & Bowland 1991; Reynolds & Aebischer 1991). However, identification based on hair structure and morphology presents a problem linked to variations in the structure of the hair along its length and across different hair types (e.g. underhair and guard hairs) found on a single individual (Keogh 1983). In order to overcome this problem it was decided that the reference hair libraries used should include guard, dorsal and ventral hair for all species. The sex and age of the individual species does not have a significant effect on cuticular scale patterns (Keogh 1983).

Obscurity produced by the transparency of the scale-like structures of hair allows interference from the pigments below the scales, and has thus led to the use of hair impressions (cuticular imprints) for identification rather than the hairs themselves (Keogh 1983). Hairs of the mammalian prey species were washed with distilled water and air-dried using standard methods (Perrin & Campbell 1979; Bissett 2004) and cuticular imprints were made using methods similar to those described by Keogh (1983). Gelatin (Royal) was mixed with hot water and heated in a water bath at boiling point to produce a solution with a final concentration of 5% (Perrin & Campbell 1979). This mixture was used to thinly coat clean slides, before placing five hairs on each slide using fine forceps (Keogh 1983; Bissett 2004). The slides were then dried for approximately 24 hours before the hairs were delicately removed using fine forceps, leaving negative imprints on the slides (Bissett 2004). Photographs were taken of the cuticular imprints under medium power (magnification: 40X) using a Canon Power Shot A640 digital camera (10.0 megapixel) attached to a Carl Zeiss PrimoStar Upright Microscope by a 52 mm wide adaptor tube. The final magnification was included in each photograph. The different types of cuticular scale patterns include coronal, chevron, mosaic, pectinate and petal (Keogh 1983). Other characteristics used to identify the species from cuticular imprints included the distance between and the form of the scale margins (Keogh 1983). Cuticular imprints alone are not sufficient to accurately identify prey species (Keogh 1983; Mukherjee *et al*. 1994; Wilson 2005) and transverse sections were used in combination with the cuticular imprints (Douglas 1989). Cross sections were made using the method proposed by Douglas (1989). This method is considered to be ideal for the hairs of large mammals compared to the thin sections obtained using a microtome (Douglas 1989). Profile or serial cross-sections entail cutting cross-sections along the length of the hair, revealing grooves and the shape and size of the medulla (Douglas 1989). The different types of most commonly found cross-sectional shapes included circular, oval, oblong and concavo-convex (Douglas 1989). Each hair used in the cuticular imprints was placed in a labelled 3 ml disposable pipette (with a 2 mm internal diameter) and the tube filled with molten wax (Paraplast Plus, Sherwood Medical Co. St Louis) (Douglas 1989). The 2 mm internal diameter pipettes were found to be ideal as they were small enough to reduce the angle at which the hair lay in the tube, thus reducing the cross-sectional angle (Douglas 1989). The tubes were cooled rapidly in a beaker with cold water (Douglas 1989) before a sharp razor blade was used to cut the pipette into 0.5-1 mm sections. The three best sections were selected and fixed onto microscope slides, using molten wax, for further examination (Bissett 2004). Photographs were taken of the cross-sections, under medium power (magnification: 40 X) and a scale bar included. Cuticular imprints and their matching transverse sections were analysed microscopically and compared with the reference collection and the two keys (Perrin & Campbell 1979; Keogh 1983). Hairs that were too damaged or were otherwise unidentifiable were recorded as “unidentified”.

3.2.4.2 Sampling efficiency for mammalian species identification

Due to the large number of scats collected, enumerating all mammalian species from all the hairs in all the scats collected would have been impractical, thus sub-sampling of hairs was necessary. In order to establish the number of hairs required to accurately determine sampling representivity, sample-based accumulation curves were constructed

(Colwell *et al*. 2004). Species accumulation curves illustrate the number of observed species as a function of sampling effort (Colwell *et al*. 2004). This was completed using 20 black-backed jackal scats collected at GFRR at the end of May 2009. The scats were processed as described above and all hairs extracted. Each scat was assigned a number and individual hairs were randomly selected from these scats using a random number generator in Microsoft Excel (2007). A total of 345 hairs were selected and separated into gradually increasing sample sizes: 5, 10, 15, 20, 25, 30, 40, 50, 60, 80 and 100. Cuticular imprints were then produced for these hairs and they were identified to species level (Figure 3.3). The sample-based curves were produced using the analytically calculated Sobs (Mao Tau) (number of species expected) at a 95% confidence level (Colwell *et al*. 2004). The incidence-based coverage estimator (ICE) and the abundance-based coverage estimator (ACE) (Chazdon *et al*. 1998) (Figure 3.4) were produced using the program EstimateS V 7.5.2^{TM} (Colwell 2005). The richness estimates were considered representative when the observed sample-based species accumulation curves and estimators converged at the highest observed species richness (Longino *et al*. 2002). The estimators converged between 30 and 40 hairs, thus a sample of 35 hairs per site per month was considered sufficient. However, a Repeated Measures ANOVA (Statistica 9; StatSoft, Inc. 2009) indicated that the 5-10 hairs category was the only category where significantly fewer species were observed than in the other categories (Figure 3.5; $p<0.01$, $F_{(4,5)} = 24.23$). There were no significant differences ($p>0.05$) among the remaining categories (Figure 3.5). Thus, a minimum of 25 hairs was deemed sufficient (Figure 3.5).

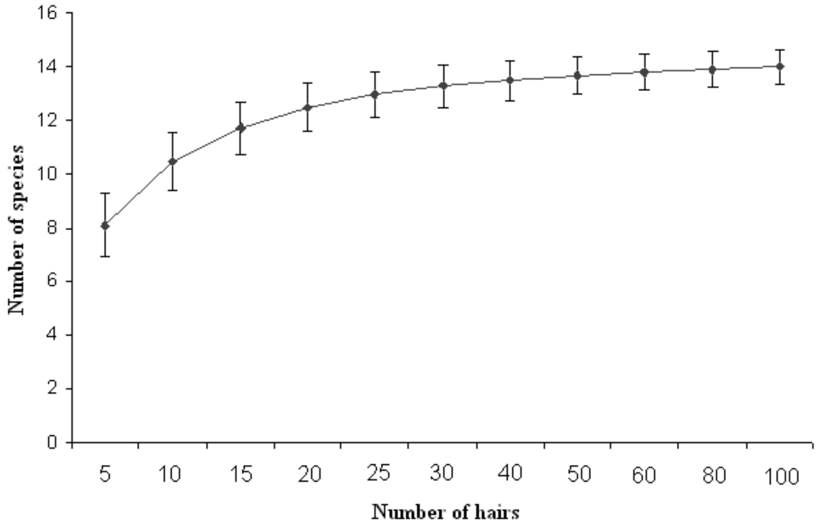

Figure 3.3 Sample-based rarefaction (species accumulation) curve (Sobs- Mao Tau), based on Colwell *et al*. (2004). Error bars represent standard deviation from the means.

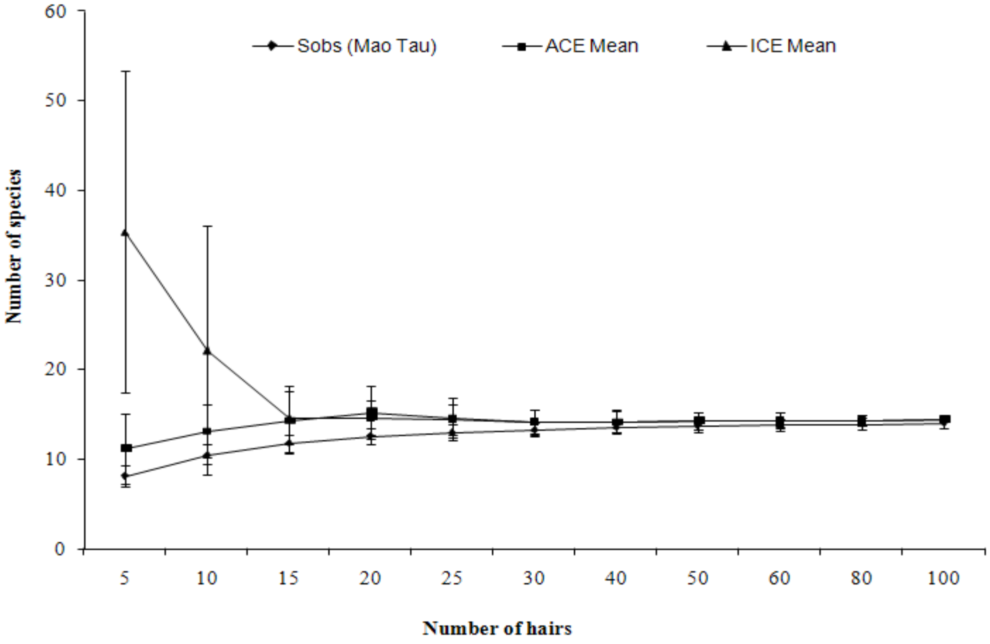

Figure 3.4 Sobs (Mao Tau), abundance-based coverage estimator (ACE) and incidence-based coverage estimator (ICE).

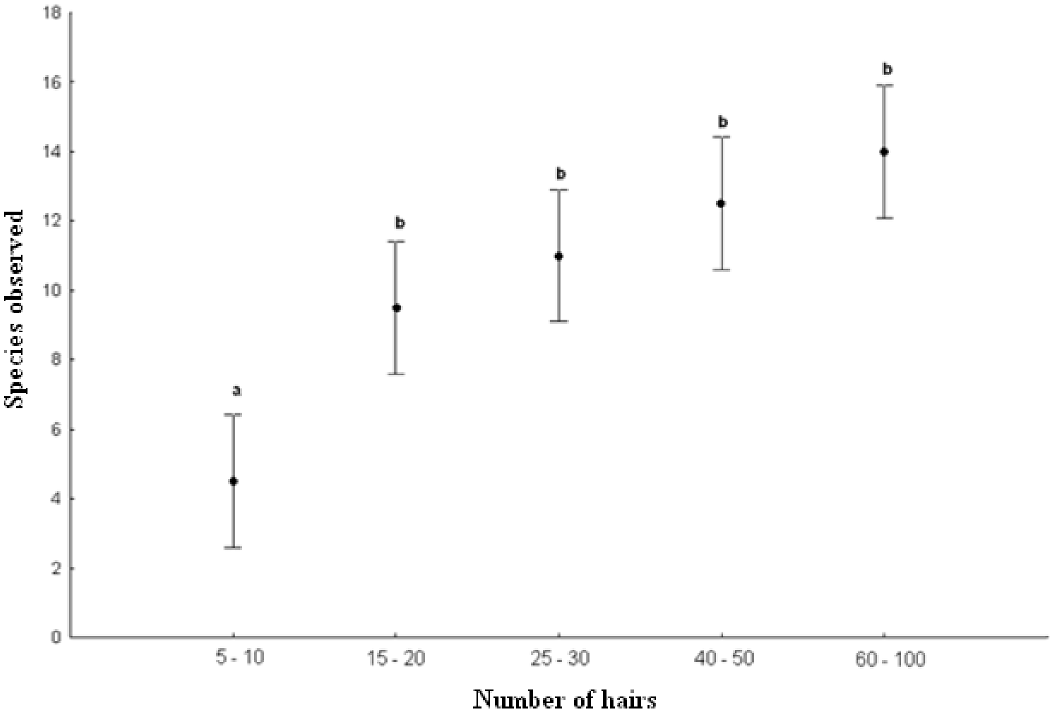

Figure 3.5 The mean number of species (± 95% confidence intervals) observed in each of five sample categories. Significant ($p<0.05$) differences among categories are represented by lower case letters.

3.2.5 Data analysis

The PO and RPO were calculated for each prey category. For seasonal comparisons of the PO and RPO values, months were pooled as follows: June - August = winter, September - November = spring, December - February = summer, March - May = autumn (Bissett 2004; Parker & Bernard 2005; Klare *et al*. 2010).

The order Diptera was omitted from the PO and RPO analysis as it was assumed that fly larvae (*Sarcophaga* sp.) were ingested unintentionally when the black-backed jackals fed on carrion (Ellis & Shemnitz 1957). However, the presence of fly larvae (> 10 mm) was used as an indicator of the black-backed jackal having fed on carrion (Grafton 1965; Rowe-Rowe 1976). All ticks (Acarina: Ixodida) were also excluded as they were assumed to have been ingested with mammalian prey (Kok & Petney 1993).

All proportions were arcsine transformed before analysis (Zar 1996). A one-way ANOVA was used to assess the PO data of mammalian hair, invertebrates and plant matter from GFRR because the data met the assumptions of the test (Zar 1996). The rest of the food items failed the assumption of a normal distribution ($p<0.05$), therefore, the non-parametric Kruskal-Wallis test was conducted to compare seasonal changes in PO. Similarly, a one-way ANOVA was conducted to assess the PO data of fruits, invertebrates and plant matter at Kwandwe because the data met the associated assumptions. The remaining food items failed the assumption of a normal distribution and a Kruskal-Wallis test was conducted to compare seasonal changes in the PO (Zar 1996). A one-way ANOVA was performed on the data for the PO of invertebrate orders. In terms of the mammalian prey consumption, the results were normally distributed thus one-way ANOVAs were used. The results for the Rodentia were not normally distributed, thus a Mann-Whitney *U*-test was used to determine statistical difference between the two sites (Siegel & Castellan 1988) and a Kruskal-Wallis test was conducted for seasonal differences. All statistical tests were carried out using Statistica 9 (StatSoft, Inc. 2009).

Data for the RPO of food items in the scats failed the assumption of a normal distribution ($p<0.05$), consequently Kruskal-Wallis and Mann-Whitney *U*-tests were conducted to compare seasonal and site differences, respectively, in the RPO of the different dietary components. These analyses examined presence/absence matrix tables for each season at the two sites to determine significant difference between the two sites and among seasons (Gotelli & Graves 1996; Manly & Sanderson 2002). Results for the RPO of each fruit species encountered in the scats in autumn were not normally distributed. Thus, a Mann-Whitney *U*-test was used to determine statistical difference between the two sites (Siegel & Castellan 1988).

3.3 Results

The majority of the scats collected were found on shrubs at both GFRR (76% of all scats) and Kwandwe (74%), and the remainder were found on grass clumps (GFRR: 9%; Kwandwe: 14%), bare ground (GFRR: 14%; Kwandwe: 11%) and only a few on rhino middens and termite mounds. The vast majority of the scats (GFRR: 98%; Kwandwe: 91%) were found on the side of the road. Very few (GFRR: 2%; Kwandwe: 9%) were located in the centre of the roads and latrines were located more regularly (GFRR: 67%; Kwandwe: 52%) than single scats at both sites. Only the freshest scat was collected from each latrine.

3.3.1 Overall diet composition of black-backed jackals

At both sites, mammalian prey was recorded most frequently in the scats of black-backed jackals (Table 3.1). A total of 23 mammal species were recorded in the scats, with even-toed ungulates (Artiodactyla) and jackal hair comprising the majority (Table 3.1). Plant matter and invertebrate remains were the second most abundant food items in the scats at both sites (Table 3.1). Beetles and termites were recorded more frequently than any other insect group (Table 3.1). Fruits and seeds (nine species in autumn) also made up a substantial portion of food remains in the scats at both sites (Table 3.1). Birds, reptiles and anthropogenic items were comparatively rare in the scats (Table 3.1).

Table 3.1 The frequency of occurrence (PO in %) and relative frequency of occurrence (RFO in %) of the different food categories found in the scats of black-backed jackals at Great Fish River Reserve (GFRR) and Kwandwe Private Game Reserve (Kwandwe), Eastern Cape, South Africa, June 2009 to May 2010 (*n* = no. of scats analysed).

	GFRR										**Kwandwe**									
	Winter (*n* = 83)		**Spring (*n* = 69)**		**Summer (*n* = 71)**		**Autumn (*n* = 72)**		**All year (*n* = 295)**		**Winter (*n* = 55)**		**Spring (*n* = 42)**		**Summer (*n* = 38)**		**Autumn (*n* = 66)**		**All year (*n* = 201)**	
Prey Category	**PO**	**RPO**	**PO**	**RPO**	**PO**	**RPO**	**PO**	**RPO**	**PO**	**RPO**	**PO**	**RPO**	**PO**	**RPO**	**PO**	**RPO**	**PO**	**RPO**	**PO**	**RPO**
Mammals	**95.0**	**39.3**	**97.3**	**41.5**	**89.9**	**34.4**	**90.0**	**33.5**	**93.0**	**37.2**	**95.2**	**43.6**	**95.5**	**44.9**	**97.4**	**42.1**	**84.0**	**30.2**	**93.1**	**40.2**
Artiodactyla	57.0	23.6	54.5	23.2	50.3	19.3	54.0	20.1	54.0	21.5	53.3	24.4	19.1	9.0	39.0	16.8	47.0	16.9	39.6	16.8
Alcelaphus buselaphus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	1.8	0.0	0.0	0.0	0.0	1.0	0.4
Antidorcas marsupialis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	1.8	0.0	0.0	3.4	1.2	1.8	0.8
Oryx gazella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	1.8	3.9	1.7	0.0	0.0	1.9	0.9
Phacochoerus africanus	0.0	0.0	3.9	1.7	3.6	1.4	7.2	2.7	3.7	1.4	0.0	0.0	0.0	0.0	7.8	3.4	6.7	2.4	3.6	1.4
Raphicerus campestris	7.6	3.1	7.8	3.3	7.2	2.8	0.0	0.0	5.6	2.3	3.8	1.7	0.0	0.0	3.9	1.7	0.0	0.0	1.9	0.9
Sylvicapra grimmia	7.6	3.1	0.0	0.0	3.6	1.4	0.0	0.0	2.8	1.1	0.0	0.0	0.0	0.0	15.6	6.7	6.7	2.4	5.6	2.3
Syncerus caffer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	1.8	0.0	0.0	0.0	0.0	1.0	0.4
Tragelaphus oryx	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	1.7	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.4
Tragelaphus scriptus	11.4	4.7	11.7	5.0	28.8	11.0	43.2	16.1	23.8	9.2	38.1	17.4	0.0	0.0	3.9	1.7	16.8	6.0	14.7	6.3
Tragelaphus strepsiceros	30.4	12.6	31.1	13.3	7.2	2.8	3.6	1.3	18.1	7.5	7.6	3.5	3.8	1.8	3.9	1.7	13.4	4.8	7.2	3.0
Carnivora																				
Proteles cristatus	0.0	0.0	3.9	1.7	0.0	0.0	0.0	0.0	1.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hyracoidea																				
Procavia capensis	0.0	0.0	0.0	0.0	3.6	1.4	0.0	0.0	0.9	0.3	3.8	1.7	0.0	0.0	3.9	1.7	0.0	0.0	1.9	0.9
Lagomorpha	0.0	0.0	3.9	1.7	0.0	0.0	0.0	0.0	1.0	0.4	0.0	0.0	0.0	0.0	7.8	3.4	3.4	1.2	2.8	1.1
Lepus saxatilis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4	1.2	0.8	0.3
Pronolagus rupestris	0.0	0.0	3.9	1.7	0.0	0.0	0.0	0.0	1.0	0.4	0.0	0.0	0.0	0.0	7.8	3.4	0.0	0.0	1.9	0.8
Rodentia	11.4	4.7	3.9	1.7	7.2	2.8	14.4	5.4	9.2	3.6	15.2	7.0	11.5	5.4	23.4	10.1	13.4	4.8	15.9	6.8
Graphiurus murinus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	1.8	0.0	0.0	0.0	0.0	1.0	0.4
Hystrix africaeaustralis	3.8	1.6	0.0	0.0	0.0	0.0	3.6	1.3	1.9	0.7	0.0	0.0	0.0	0.0	15.6	6.7	3.4	1.2	4.7	2.0
Mastomys coucha	0.0	0.0	0.0	0.0	3.6	1.4	3.6	1.3	1.8	0.7	0.0	0.0	0.0	0.0	3.9	1.7	3.4	1.2	1.8	0.7

Table 3.1 (continued) The frequency of occurrence (PO in %) and relative frequency of occurrence (RPO in %) of the different food categories found in the scats of black-backed jackals at Great Fish River Reserve (GFRR) and Kwandwe Private Game Reserve (Kwandwe), Eastern Cape, South Africa, June 2009 to May 2010 (*n* = no. of scats analysed).

	GFRR										**Kwandwe**									
	Winter (*n* = 83)		**Spring (*n* = 69)**		**Summer (*n* = 71)**		**Autumn (*n* = 72)**		**All year (*n* = 295)**		**Winter (*n* = 55)**		**Spring (*n* = 42)**		**Summer (*n* = 38)**		**Autumn (*n* = 66)**		**All year (*n* = 201)**	
Prey Category	**PO**	**RPO**	**PO**	**RPO**	**PO**	**RPO**	**PO**	**RPO**	**PO**	**RPO**	**PO**	**RPO**	**PO**	**RPO**	**PO**	**RPO**	**PO**	**RPO**	**PO**	**RPO**
Otomys irroratus	7.6	3.1	0.0	0.0	3.6	1.4	0.0	0.0	2.8	1.1	11.4	5.2	7.6	3.6	3.9	1.7	6.7	2.4	7.4	3.2
Pedetes capensis	0.0	0.0	3.9	1.7	0.0	0.0	3.6	1.3	1.9	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rattus rattus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	1.7	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.4
Rhabdomys pumilio	0.0	0.0	0.0	0.0	0.0	0.0	3.6	1.3	0.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eulipotyphla	3.8	1.6	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.4	0.0	0.0	0.0	0.0	3.9	1.7	0.0	0.0	1.0	0.4
Crocidura flavescens	3.8	1.6	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Myosorex varius	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.9	1.7	0.0	0.0	1.0	0.4
unidentified	3.8	1.6	11.7	5.0	0.0	0.0	7.2	2.7	5.7	2.3	7.6	3.5	11.5	5.4	0.0	0.0	3.4	1.2	5.6	2.5
Canis mesomelas	19.0	7.9	19.5	8.3	28.8	11.0	14.4	5.4	20.4	8.1	15.2	7.0	53.5	25.1	19.5	8.4	16.8	6.0	26.2	11.6
Invertebrates	**54.2**	**21.6**	**65.4**	**27.9**	**67.1**	**25.1**	**55.1**	**20.3**	**60.4**	**23.7**	**30.3**	**14.0**	**49.8**	**23.5**	**60.5**	**25.4**	**57.4**	**20.3**	**49.5**	**20.8**
Insecta	31.8	12.7	58.7	25.0	65.8	24.6	53.0	19.5	52.3	20.5	13.5	6.2	47.5	22.4	58.5	24.6	57.6	19.8	44.3	18.2
Blattaria	23.6	9.4	28.2	12.0	16.1	6.0	16.6	6.1	21.1	8.4	10.1	4.7	24.9	11.8	20.2	8.5	18.2	6.2	18.3	7.8
Coleoptera	3.5	1.4	25.9	11.1	42.2	15.8	23.9	8.8	23.9	9.3	3.4	1.6	22.6	10.7	34.3	14.4	27.3	9.4	21.9	9.0
Orthoptera	4.7	1.9	4.5	1.9	7.5	2.8	12.5	4.6	7.3	2.8	0.0	0.0	0.0	0.0	4.0	1.7	12.1	4.2	4.0	1.5
Arachnida																				
Scorpionida	0.0	0.0	2.3	1.0	0.0	0.0	0.0	0.0	0.6	0.2	0.0	0.0	0.0	0.0	2.0	0.8	0.0	0.0	0.5	0.2
Diplopoda																				
Spirostreptida	0.0	0.0	3.4	1.4	1.2	0.5	2.1	0.8	1.7	0.7	0.0	0.0	2.3	1.1	0.0	0.0	0.0	0.0	0.6	0.3
unidentified	22.4	8.9	1.1	0.5	0.0	0.0	0.0	0.0	5.9	2.4	16.8	7.8	0.0	0.0	0.0	0.0	0.0	0.5	4.2	2.1
Fruits/seeds	**19.8**	**7.6**	**2.6**	**1.1**	**16.8**	**6.5**	**46.0**	**16.4**	**21.3**	**7.9**	**19.6**	**8.3**	**2.4**	**1.1**	**10.0**	**3.3**	**76.2**	**27.6**	**27.0**	**10.1**
Plant matter	**72.1**	**29.4**	**65.1**	**27.6**	**85.4**	**32.0**	**73.1**	**27.2**	**73.9**	**29.1**	**75.8**	**34.1**	**58.1**	**26.6**	**67.6**	**28.1**	**52.2**	**18.5**	**63.4**	**26.8**
Birds	**2.4**	**1.1**	**3.1**	**1.3**	**1.3**	**0.5**	**3.0**	**1.1**	**2.4**	**1.0**	**0.0**	**0.0**	**6.8**	**3.1**	**0.0**	**0.0**	**5.0**	**1.8**	**3.0**	**1.2**
Reptiles	**2.2**	**0.9**	**1.3**	**0.6**	**2.9**	**1.1**	**3.9**	**1.4**	**2.6**	**1.0**	**0.0**	**0.0**	**2.1**	**0.9**	**0.0**	**0.0**	**2.1**	**0.8**	**1.0**	**0.4**
Anthropogenic Items	**0.0**	**0.0**	**0.0**	**0.0**	**1.7**	**0.6**	**0.0**	**0.0**	**0.4**	**0.1**	**0.0**	**0.0**	**0.0**	**0.0**	**2.2**	**1.0**	**2.1**	**0.8**	**1.1**	**0.5**

3.3.2 Diet composition at Great Fish River Reserve

Across all seasons, mammal hair was the most common item in the scats (PO 93%), followed by plant matter (74%), invertebrates (60%) and fruits (21%) (Figure 3.6). Reptiles (3%), bird remains (2%) and anthropogenic items (0.4%) were much less prevalent in the scats (Figure 3.6). The PO of mammalian hair remained relatively stable across all seasons (p>0.05) (Figure 3.6). Season had no significant effect (p>0.05) on the prevalence of fruits, invertebrates, birds, reptiles or anthropogenic items in black-backed jackal scats.

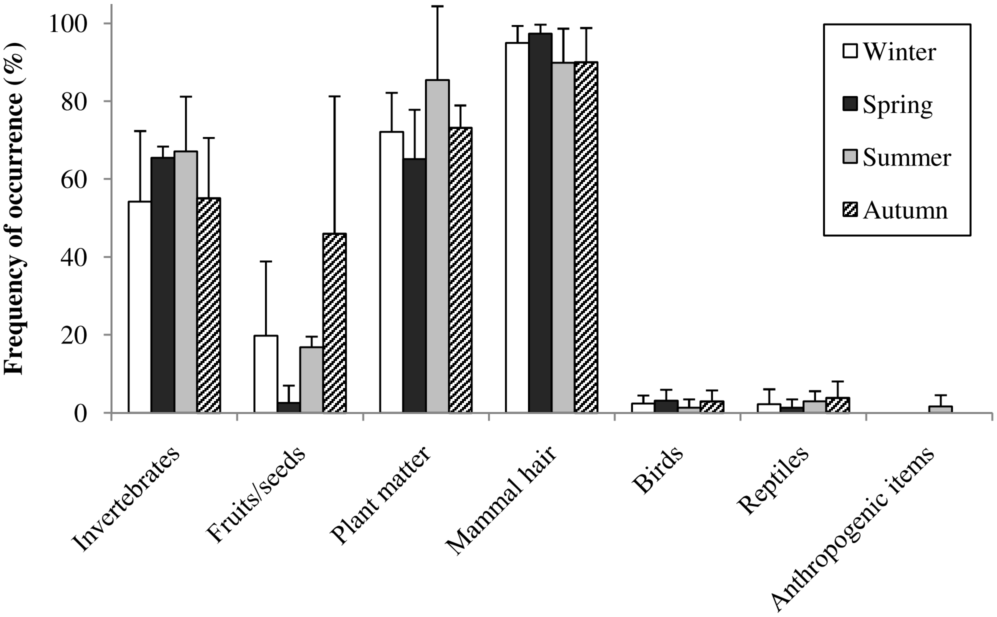

Figure 3.6 A comparison of the mean frequency of occurrence (± SD) of the seven food categories found in black-backed jackal scats at GFRR for the full year of study (June 2009 - May 2010).

In terms of RPO, mammal hair accounted for most of the remains found in the scats (37%) across all seasons, followed by plant matter (29%), invertebrates (24%) and fruits (8%)

(Figure 3.7). Bird remains, reptiles and anthropogenic items only made up a very small proportion of all food items found in the scats (Figure 3.7). Mammalian prey items and fruits showed signs of seasonality (Figure 3.7). There was a significant decrease in the importance of the mammalian prey component during autumn compared to spring ($p<0.01$, $H_{(3,295)} = 14.31$) (Table 3.1; Figure 3.7). By contrast, fruits constituted a larger part of the diet in autumn than in any other season ($p<0.005$, $H_{(3,295)} = 52.95$) (Figure 3.7). There was no seasonal difference ($p>0.05$) in the importance of invertebrates, plant matter, birds, reptiles, or anthropogenic items.

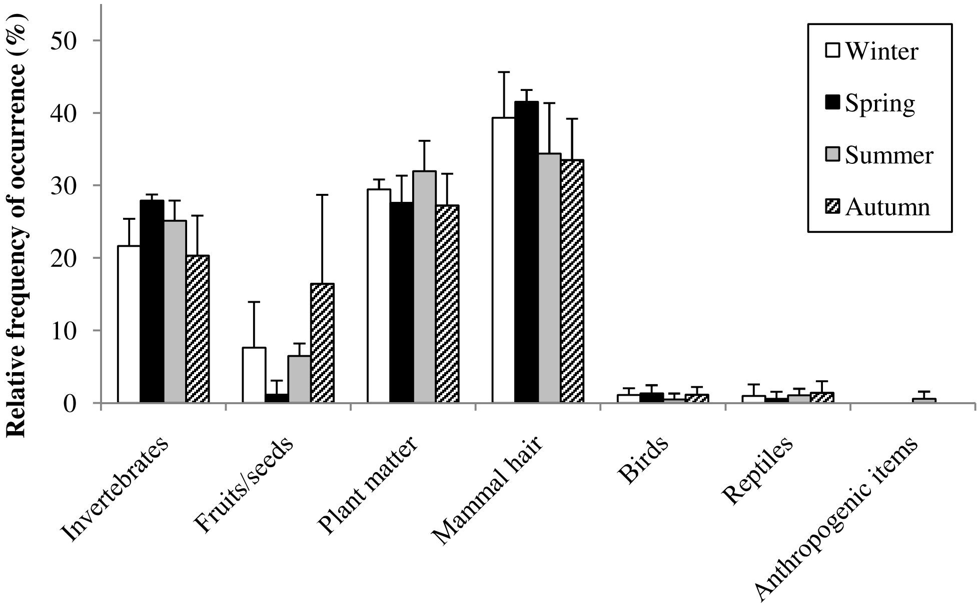

Figure 3.7 A comparison of the mean relative frequency of occurrence (± SD) of the seven food categories found in black-backed jackal scats at GFRR for the full year of study (June 2009 - May 2010).

3.3.3 Diet composition at Kwandwe Private Game Reserve

As at GFRR, mammalian hair was the most common item in the scats across seasons (93%), followed by plant matter (63%), invertebrates (50%) and fruits (27%) (Figure 3.8). Bird remains (3%), anthropogenic items (1%) and reptiles (1%) were much less prevalent in the scats (Figure 3.8). Frequency of occurrence of mammalian hair in the scats remained relatively stable across all seasons at Kwandwe ($p>0.05$) (Figure 3.8). Fruit consumption increased significantly ($p<0.05$, $F_{(3,8)}= 11.94$) in autumn compared to the other seasons (Figure 3.8). Consumption of invertebrates, plant matter, birds, reptiles and anthropogenic items showed no significant change ($p>0.05$) across seasons (Figure 3.8).

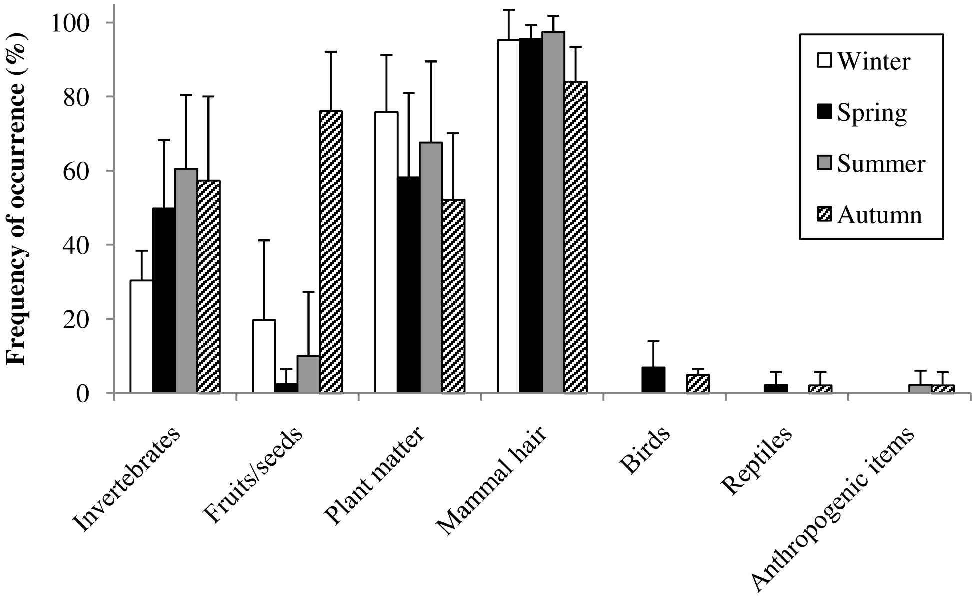

Figure 3.8 A comparison of the mean frequency of occurrence (± SD) of the seven food categories found in black-backed jackal scats at Kwandwe in winter, spring, summer and autumn, for the full year of study (June 2009 - May 2010).

In terms of RPO, mammal hair accounted for 40% of all food items found in scats, followed by plant matter (27%), invertebrates (21%) and fruits (10%) (Figure 3.9). Bird remains (1%), reptiles (0.4%) and anthropogenic items (0.5%) only made up a very small proportion of the food items in the scats (Figure 3.9). A seasonal trend was visible in terms of RPO, with a significant decrease ($p<0.01$, $H_{(3,201)}= 32.01$) in the contribution of the mammalian prey component to the diet in autumn compared to the other seasons (Figure 3.9). Fruit consumption, in contrast, played a much greater part in the diet in the autumn season compared to the other seasons ($p<0.001$, $H_{(3,201)}= 104.71$) (Figure 3.9). Plant matter was significantly more important in winter than in autumn ($p<0.005$, $H_{(3,201)}= 15.66$) (Figure 3.9). There were no seasonal variations ($p>0.05$) for the remaining food items in the scats.

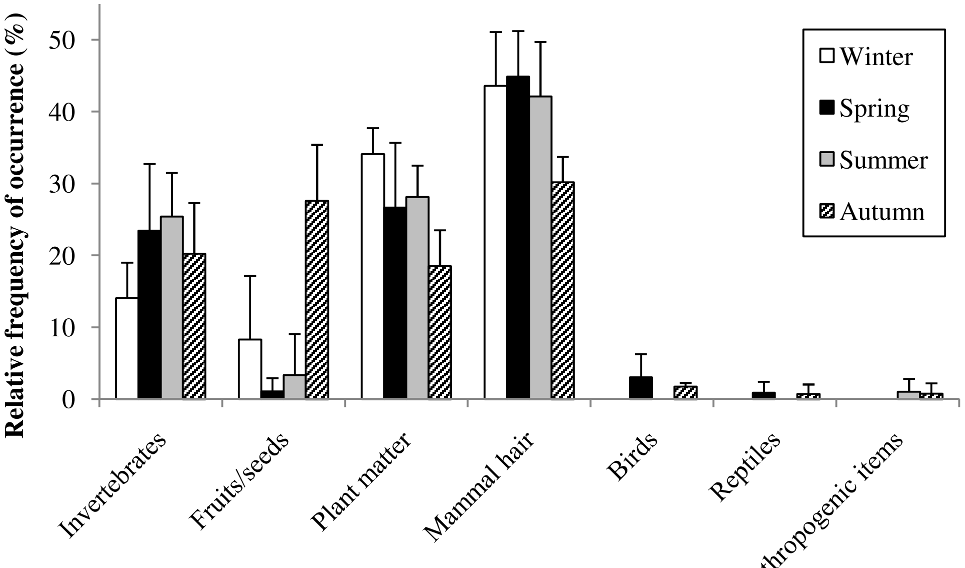

Figure 3.9 A comparison of the mean relative frequency of occurrence (± SD) of the seven food categories found in black-backed jackal scats at Kwandwe in winter, spring, summer and autumn, for the full year of study (June 2009 - May 2010).

3.3.4 Mammalian hair

A total of 14 and 19 mammalian prey species were identified in the scats of black-backed jackal at GFRR and Kwandwe, respectively. This represented a total of 23 mammalian species across both sites (Table 3.2). Unidentified mammalian prey species represented 6% of all mammalian hairs at both GFRR and Kwandwe (Table 3.2). Although predation on young and feeding on dead black-backed jackals is a possibility, it was assumed that most of the black-backed jackal hair found in the scats was due to allogrooming (Kaunda 1998). Black-backed jackal hair made up 22% of all mammalian hair identified from scats collected from GFRR and 28% from Kwandwe (Table 3.2). It can thus be inferred that 21% of all scats collected at GFRR and 26% of all scats collected at Kwandwe contained black-backed jackal hair (since 93% of all scats contained mammalian hair at both sites; Table 3.1). Of the remaining mammalian prey hair, even-toed ungulate hair (74%) and rodents (13%) were identified the most frequently (Table 3.2). Lagomorphs, hyracoids, carnivores and shrews were much less frequently observed in the scats at GFRR (Table 3.2). Similar trends were observed at Kwandwe, the only major differences being that rodents comprised a greater proportion (24%) of the mammalian prey hair component and ungulates made up a lower proportion (60%) than at GFRR (Table 3.2). There was no difference ($p>0.05$) in the consumption of ungulates or any of the other mammalian orders across seasons at both sites (Table 3.1).

Table 3.2 The mammalian species identified from black-backed jackal scats at GFRR and Kwandwe between June 2009 and May 2010. (N = number of positive hair identifications for each species, % = percentage out of total number of occurrences of all prey species). (25 hairs/season/site).

	GFRR										**Kwandwe**									
	Winter		**Spring**		**Summer**		**Autumn**		**All seasons**		**Winter**		**Spring**		**Summer**		**Autumn**		**All seasons**	
Mammals	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Artiodactyla	**15**	**75.0**	**14**	**70.0**	**14**	**82.4**	**15**	**71.4**	**58**	**74.4**	**14**	**66.7**	**5**	**45.5**	**10**	**50.0**	**14**	**70.0**	**43**	**59.7**
Alcelaphus buselaphus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	9.1	0	0.0	0	0.0	1	1.4
Antidorcas marsupialis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	9.1	0	0.0	1	5.0	2	2.8
Oryx gazella	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	9.1	1	5.0	0	0.0	2	2.8
Phacochoerus africanus	0	0.0	1	5.0	1	5.9	2	9.5	4	5.1	0	0.0	0	0.0	2	10.0	2	10.0	4	5.6
Raphicerus campestris	2	10.0	2	10.0	2	11.8	0	0.0	6	7.7	1	4.8	0	0.0	1	5.0	0	0.0	2	2.8
Sylvicapra grimmia	2	10.0	0	0.0	1	5.9	0	0.0	3	3.8	0	0.0	0	0.0	4	20.0	2	10.0	6	8.3
Syncerus caffer	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	9.1	0	0.0	0	0.0	1	1.4
Tragelaphus oryx	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	4.8	0	0.0	0	0.0	0	0.0	1	1.4
T. scriptus	3	15.0	3	15.0	8	47.1	12	57.1	26	33.3	10	47.6	0	0.0	1	5.0	5	25.0	16	22.2
T. strepsiceros	8	40.0	8	40.0	2	11.8	1	4.8	19	24.4	2	9.5	1	9.1	1	5.0	4	20.0	8	11.1
Carnivora																				
Proteles cristatus	0	0.0	1	5.0	0	0.0	0	0.0	1	1.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Hyracoidea																				
Procavia capensis	0	0.0	0	0.0	1	5.9	0	0.0	1	1.3	1	4.8	0	0.0	1	5.0	0	0.0	2	2.8
Lagomorpha	**0**	**0.0**	**1**	**5.0**	**0**	**0.0**	**0**	**0.0**	**1**	**1.3**	**0**	**0.0**	**0**	**0.0**	**2**	**10.0**	**1**	**5.0**	**3**	**4.2**
Lepus saxatilis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	5.0	1	1.4
Pronolagus rupestris	0	0.0	1	5.0	0	0.0	0	0.0	1	1.3	0	0.0	0	0.0	2	10.0	0	0.0	2	2.8
Rodentia	**3**	**15.0**	**1**	**5.0**	**2**	**11.8**	**4**	**19.0**	**10**	**12.8**	**4**	**19.0**	**3**	**27.3**	**6**	**30.0**	**4**	**20.0**	**17**	**23.6**
Graphiurus murinus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	9.1	0	0.0	0	0.0	1	1.4
Hystrix africaeaustralis	1	5.0	0	0.0	0	0.0	1	4.8	2	2.6	0	0.0	0	0.0	4	20.0	1	5.0	5	6.9
Mastomys coucha	0	0.0	0	0.0	1	5.9	1	4.8	2	2.6	0	0.0	0	0.0	1	5.0	1	5.0	2	2.8
Otomys irroratus	2	10.0	0	0.0	1	5.9	0	0.0	3	3.8	3	14.3	2	18.2	1	5.0	2	10.0	8	11.1
Pedetes capensis	0	0.0	1	5.0	0	0.0	1	4.8	2	2.6	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rattus rattus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	4.8	0	0.0	0	0.0	0	0.0	1	1.4
Rhabdomys pumilio	0	0.0	0	0.0	0	0.0	1	4.8	1	1.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Eulipotyphla	**1**	**5.0**	**0**	**0.0**	**0**	**0.0**	**0**	**0.0**	**1**	**1.3**	**0**	**0.0**	**0**	**0.0**	**1**	**5.0**	**0**	**0.0**	**1**	**1.4**
Crocidura flavescens	1	5.0	0	0.0	0	0.0	0	0.0	1	1.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Myosorex varius	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	5.0	0	0.0	1	1.4
Unidentified	**1**	**5.0**	**3**	**15.0**	**0**	**0.0**	**2**	**9.5**	**6**	**7.7**	**2**	**9.5**	**3**	**27.3**	**0**	**0.0**	**1**	**5.0**	**6**	**8.3**
Total N of prey spp.	20		20		17		21		78		21		11		20		20		72	
Canis mesomelas	5		5		8		4		22		4		14		5		5		28	

Ungulate hair was thus present in more than half of the scats at GFRR (54%) and a large proportion of the scats collected at Kwandwe (40%). At both sites, bushbuck comprised the majority (GFRR: 45%; Kwandwe: 37%) of the ungulate hairs identified, followed by kudu (GFRR: 33%; Kwandwe: 19%) (Table 3.2). Steenbok, warthog and common duiker were also consumed at both sites (Table 3.2). Other species rarely observed in the scats included red hartebeest, buffalo and eland (Table 3.2). Hider species (all the ungulates except Cape buffalo and warthog) comprised >85% of all ungulates consumed by black-backed jackal at both sites.

Vlei rat comprised the majority of the rodent species at both sites, closely followed by porcupine and the Natal multimammate mouse (*Mastomys coucha*) at both sites (Table 3.2). Other rodents included springhare at GFRR, and woodland dormouse (*Graphiurus murinus*) and black rat (*Rattus rattus*) at Kwandwe. Other mammalian species consumed included rock hyrax (*Procavia capensis*), Smith's red rock rabbit (*Pronolagus rupestris*), aardwolf and greater red musk shrew (*Crocidura flavescens*) at GFRR and forest shrew (*Myosorex varius*) and scrub hare (*Lepus saxatilis*) at Kwandwe (Table 3.2).

3.3.5 Invertebrates

Invertebrate remains were represented by the exoskeletons of termites (Class Insecta: Order Blattaria), beetles (Class Insecta: Order Coleoptera), locusts (Class Insecta: Order Orthoptera) as well as scorpions (Class Arachnida: Order Scorpionida), millipedes (Class Diplopoda: Order Spirostreptida) and some unidentified invertebrates (Table 3.3). The most common invertebrate remains at both sites were beetles (mostly from the Tenebrionidae and

Scarabidae families; 37% of all invertebrates at GFRR and 42% at Kwandwe) and termites (mostly represented by the northern harvester termite *Hodotermes mossambicus*; 33% of all invertebrates at GFRR and 35% at Kwandwe) (Table 3.3). At GFRR, beetles occurred in 24% of all the scats and made up 9% of all remains found in the scats (Table 3.1). Termites were present in 21% of the scats, and made up 8% of all food remains in the scats collected at GFRR. At Kwandwe, beetles occurred in 21% of all scats and also made up 9% of all food remains (Table 3.1). Termites occurred in 18% of all scats and accounted for 7% of all remains at Kwandwe (Table 3.1). There was no seasonal difference ($p>0.05$) in the consumption of termites, locusts (family Acrididae), scorpions, millipedes or unidentified invertebrates at GFRR. There was, however, a significant increase ($p<0.05$, $F_{(3,8)}= 7.89$) in the consumption of beetles in autumn compared to the other seasons at GFRR. At Kwandwe, season did not have any effect ($p>0.05$) on the consumption of any of the other invertebrate categories. Dipteran larvae were found in scats collected at both sites, indicating that black-backed jackals feed on carrion and live prey at both study sites. Interestingly, only 1.98% (N = 4) of the scats at Kwandwe contained Diptera eggs or larvae, whilst 4.73% (N = 14) of the scats collected at GFRR contained signs of having eaten carrion.

Table 3.3 Invertebrate orders identified from back-backed jackal scats collected at Great Fish River Reserve and Kwandwe Private Game Reserve between June 2009 and May 2010. Values indicate total number of scats containing each order of invertebrates (*n* = total number of scats, N = number of scats containing traces of each species, % = percentage out of total number of occurrences of all invertebrate orders).

	GFRR										**Kwandwe**									
	Winter (*n* = 83)		**Spring (*n* = 69)**		**Summer (*n* = 71)**		**Autumn (*n* = 72)**		**All seasons (*n* = 295)**		**Winter (*n* = 55)**		**Spring (*n* = 42)**		**Summer (*n* = 38)**		**Autumn (*n* = 66)**		**All seasons (*n* = 201)**	
Invertebrates	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Insecta																				
Blattaria	20	40.8	25	39.7	13	22.8	16	27.6	74	32.6	6	33.3	11	45.8	10	32.3	12	30.0	39	34.5
Coleoptera	3	6.1	23	36.5	34	59.6	23	39.7	83	36.6	2	11.1	10	41.7	17	54.8	18	45.0	47	41.6
Orthoptera	4	8.2	4	6.3	6	10.5	12	20.7	26	11.5	0	0.0	0	0.0	2	6.5	8	20.0	10	8.8
Diptera	3	6.1	5	7.9	3	5.3	5	8.6	16	7.0	0	0.0	2	8.3	1	3.2	1	2.5	4	3.5
Arachnida																				
Scorpionida	0	0.0	2	3.2	0	0.0	0	0.0	2	0.9	0	0.0	0	0.0	1	3.2	0	0.0	1	0.9
Diplopoda																				
Spirostreptida	0	0.0	3	4.8	1	1.8	2	3.4	6	2.6	0	0.0	1	4.2	0	0.0	0	0.0	1	0.9
unidentified	19	38.8	1	1.6	0	0.0	0	0.0	20	8.8	10	55.6	0	0.0	0	0.0	1	2.5	11	9.7
Total N	49		63		57		58		227		18		24		31		40		113	

3.3.6 Fruits and seeds

In the autumn season, at both sites, the main fruit species were Karoo Cross-berry bush (*Grewia robusta*) and Karoo Num-num (*Carissa haematocarpa*) (Table 3.4). *Grewia robusta* represented 61% of the fruits consumed at GFRR, occurring in 28% of all the scats and representing 10% of all food remains, while *C. haematocarpa* represented 20% of all fruits consumed at GFRR, occurring in 9% of all scats, and representing 3% of all remains (Table 3.4). At Kwandwe, *C. haematocarpa* made up almost half (49%) of all fruit items consumed, was present in 37% of all scats and represented 14% of all food remains. *Grewia robusta*, on the other hand, was less important and only comprised 26% of all fruits consumed, was present in 20% of all scats and represented 7% of all food items (Table 3.4). Karoo Bluebush (*Diospyros lycioides*) constituted the remainder (25%) of the fruits consumed by black-backed jackal at Kwandwe, was present in 19% of all scats and represented 7% of all food items (Table 3.4). Other fruit species found less frequently in the autumn diet of the black-backed jackal at GFRR included, Kooboo Berry (*Cassine aethiopica*), Jacket Plum (*Pappea capensis*) and the False Spike-thorn (*Putterlickia pyracantha*) (Table 3.4).

Table 3.4 The PO and RPO of the fruit species in the diet of black-backed jackal for the autumn season, at Great Fish River Reserve and Kwandwe Private Game Reserve, in the Eastern Cape Province, South Africa (*n* = total number of scats, N = number of occurrences of each fruit species).

	GFRR (*n* = 72)			**Kwandwe (*n* = 66)**		
Fruit species	**N**	**PO%**	**RPO%**	**N**	**PO%**	**RPO%**
Carissa haematocarpa	9	9.0	3.2	26	37.4	13.5
Cassine aethiopica	1	1.0	0.4	0	0.0	0.0
Diospyros lycioides	0	0.0	0.0	13	18.7	6.8
Grewia robusta	28	28.0	10.0	14	20.1	7.3
Pappea capensis	1	1.0	0.4	0	0.0	0.0
Putterlickia pyracantha	1	1.0	0.4	0	0.0	0.0
unidentified 2	1	1.0	0.4	0	0.0	0.0
unidentified 3	2	2.0	0.7	0	0.0	0.0
unidentified 4	3	3.0	1.1	0	0.0	0.0
N total	46			53		

3.3.7 Study site comparison

Similar overall trends were observed at the two sites, with equivalent orders of importance of the different food categories, both in terms of PO and RPO (Figure 3.10). However, fruits were observed significantly more frequently ($p<0.05$, $U = 25948.50$) in the scats of black-backed jackal at Kwandwe (27%) than at GFRR (21 %) (Figure 3.10). By contrast, black-backed jackal scats at GFRR contained a significantly greater proportion ($p<0.05$, $U = 25769.50$) of invertebrates than those at Kwandwe (Figure 3.10). There was no significant difference ($p>0.05$) between the sites for any of the other food categories (Figure 3.10). In terms of invertebrate orders, there were no significant differences ($p>0.05$) in consumption of termites and beetles between the two sites (Table 3.3). In terms of fruit species, Karoo Num-num fruits were more important ($p<0.0001$, $U = 1510.0$) at Kwandwe, whilst berries of the

Karoo Cross-berry bush were more important ($p<0.05$, U = 1904.5) at GFRR (Table 3.4). The occurrence of mammalian hair in the scats was similar at the two sites (93% of all scats) (Table 3.1). Ungulates and rodent consumption was not significantly different ($p>0.05$) between the two sites. There was no statistical difference ($p>0.05$) in the occurrence of invertebrate orders in black-backed jackal scats between the two sites (Figure 3.10).

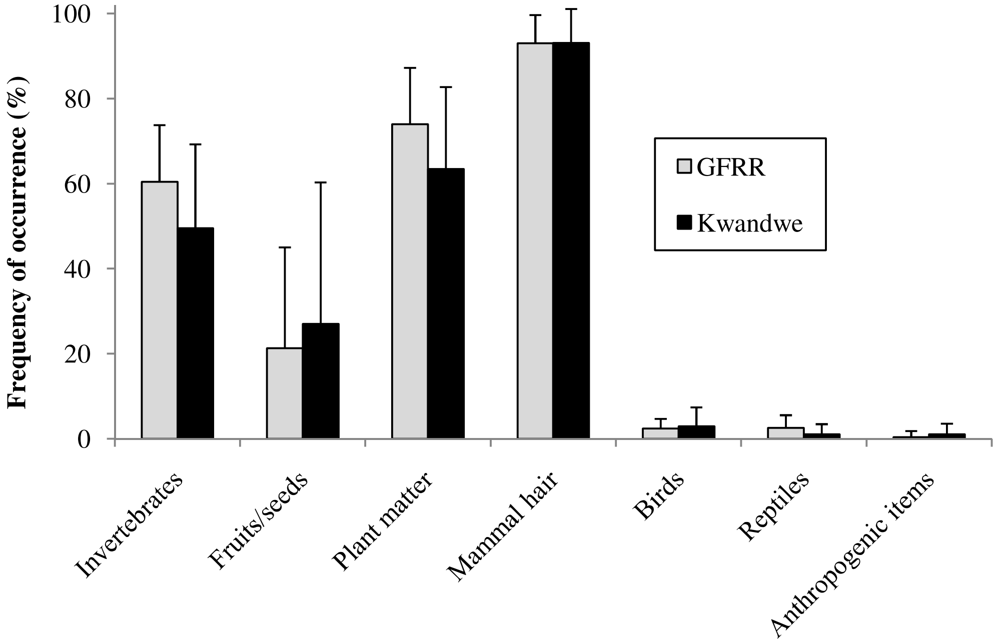

Figure 3.10 A comparison of the mean frequency of occurrence (± SD) of the seven food categories found in black-backed jackal scats at GFRR and Kwandwe for the year of study (June 2009 - May 2010).

3.4 Discussion

The diet of the black-backed jackal as established in this study probably reflects prey availability, which can vary significantly, both spatially and temporally (Pyke *et al.* 1977). Mammalian prey made up most of the diet of black-backed jackal at both study sites and was dominated by ungulates (bushbuck and kudu mostly) and rodents (predominantly vlei rat and porcupine). Higher levels of mammalian predation, in particular of ungulates, was expected at Kwandwe compared to GFRR, due to the difference in ungulate densities at the two sites (GFRR: 0.10 ungulates/ha; Kwandwe: 0.22 ungulates/ha) (Pyke *et al.* 1977). However, my results did not support this, suggesting that ungulate abundance did not significantly influence the diet of black-backed jackals. Indeed, predation is not always positively correlated with ungulate prey density (Wegge *et al.* 2009). Several authors have suggested that if remains from large (>15 kg) ungulate species are found in black-backed jackal scats, they are from scavenging (Rowe-Rowe 1976; Loveridge and Macdonald 2003; Skinner & Chimimba 2005; Klare *et al.* 2010). In this study, the most frequently consumed ungulates at both sites in this study were bushbuck and kudu, both of which are larger than 15 kg (kudu: ± 175 kg; bushbuck: ± 50 kg) (Skinner & Chimimba 2005). Some of the ungulates consumed may have been killed by caracal or brown hyaena at GFRR, however, both predators occur in very low numbers (Peinke & Peinke 2009), making it unlikely that either species produced significant numbers of carcasses for scavenging to occur (Klare *et al.* 2010). At Kwandwe, the other large predators could have produced such a large number of carcasses, however this should have produced a difference in the number of ungulates consumed between the two sites, but this was not the case. Because of the differences in ungulate density between the sites, ungulate consumption at Kwandwe may be mostly scavenging, while it may be mostly predation at GFRR, resulting in the non significant differences found in the current study. Given the black-backed jackal's small size (Bekoff *et al.* 1981; Walton & Joly 2003; Loveridge & Nel 2004; Ray *et al.* 2005), it is more likely that the predation of bushbuck and kudu at both sites was of neonatals rather than adult animals (Klare *et al.* 2010). Both bushbuck and kudu are considered hider species (Skinner & Chimimba 2005). Hider species leave their offspring hidden in tall vegetation during the first few weeks after birth (Lent 1974), where they remain very still until the mother returns to feed them (Estes 1991). This hiding behaviour has evolved to decrease the probability of calves being found by predators at an age when they are unable to outrun them (Fitzgibbon 1990). This hiding behaviour leaves neonatal animals susceptible to the active searching employed by black-backed jackal (Lamprecht 1978). Neonatals hidden in vegetation may therefore comprise an important part of black-backed jackal diet on both reserves (Bussiahn 1997; Do Linh San *et al.* 2009; Klare *et al.* 2010).

Ungulates may have occurred more frequently in the scats than observed in this study, considering the tendency of scat analysis to underestimate the PO of large mammalian prey (Floyd *et al.* 1978; Putman 1984; Gamberg & Atkinson 1988; Bowland & Bowland 1991). However, other authors (Pimlott *et al.* 1969; Voigt *et al.* 1976) have demonstrated that scat contents can accurately represent the proportions of prey consumed, based on the availability and abundance of those prey items. Additionally, in the present study, scats with just a few hairs were common, probably due to the extended length of time hairs remain in the stomach, but being passed out regularly in the scats in small quantities (Bowland & Bowland 1991).

Nonetheless, ungulate hair was still observed frequently in the scats at both sites. In order to determine the importance to the diet of black-backed jackal, volume data of the different food items in each scat can be obtained and subjected to conversion factors to obtain ingested biomass values.

The importance of predation and scavenging to the diet of black-backed jackal varies temporally and spatially, depending on the presence/absence of apex predators (Van der Merwe *et al*. 2009) and the abundance of prey species (Estes 1991). Black-backed jackals may become active predators in areas where specialist predators are absent, such as on GFRR, due to reduced scavenging opportunities, although this only applies as long as the number of other predators is not too high to result in intraspecific conflict (Kaunda & Skinner 2003). Black-backed jackals are well adapted to a scavenging lifestyle (Domínguez-Rodrigo 2001) and it is probable that large ungulate prey remains were scavenged at both sites, whether from predator kills or from other fatalities such as disease or starvation (Klare *et al*. 2010). It is often believed that black-backed jackals can subsist mainly as scavengers in areas where specialist predators are numerous (Estes 1991; Kaunda & Skinner 2003; Hunter *et al*. 2006). However, the relatively low occurrence of fly larvae in black-backed jackal scats collected at both study sites suggests that scavenging may not be a major part of the black-backed jackal's diet in the Eastern Cape. This is consistent with several studies which found that carrion contributes very little to the diet of black-backed jackal (Wyman 1967; Houston 1979; Rowe-Rowe 1983a; Hunter *et al*. 2006). This may be due, in part, to high competition with vultures and the increased risk associated with proximity to large predators (lions and spotted hyaenas) which can result in death, as observed by Hunter *et al*. (2006) in the

Serengeti. This said, the high density of other large predators at Kwandwe means that scavenging from fresh carcasses void of fly larvae may have been highly likely there (J. Midgley 2011, pers. comm.), and this would thus not have been recognised as scavenging due to the lack of presence of fly larvae in the scats. Only very large carcasses (e.g. buffalo), which would take longer to be consumed, were likely to contain fly larvae (C. Bissett 2010, pers. comm.). Furthermore, the results of my study suggest that the presence of large predators had no significant effect on the diet of black-backed jackals as there was no significant difference in the consumption of mammalian prey between the two sites. The much larger brown hyaena (which is present at both sites) may exclude black-backed jackal from carcass sites, forcing them to hunt more frequently and rely less on scavenging (Van der Merwe *et al*. 2009). Scavenging plays an important role in structuring communities, through not only the nutrient cycle, but also by providing additional food resources to predators (facultative scavengers) without having any demographic effects on the species consumed (Wilson & Wolkovich 2011). Additionally, carrion plays an important role in saving energy for the consumer as the prey does not need to be chased and subdued (Wilson & Wolkovich 2011). However, interpretation of results is limited as it was recognised that, effectively, sample size was equal to one for each treatment.

The high occurrence of crepuscular or nocturnal rodent prey agrees with the black-backed jackal's overall crepuscular and nocturnal lifestyle (Fox 1971; Loveridge & Nel 2004; Skinner & Chimimba 2005). Invertebrates, dominated by beetles (mostly tenebrionids and scarabids) and termites, also made up a relatively large part of the black-backed jackal's diet. These invertebrates are also active at similar times as black-backed jackal: tenebrionid species which are active in summer exhibit crepuscular and nocturnal activity patterns (Ayal & Merkl 1994), different dung beetle species may be nocturnal or diurnal (Picker *et al*. 2004) and eyed reproductive termites fly out at dusk, usually after rain (Picker *et al*. 2004). The high consumption of invertebrates in spring and summer, when they would have been most abundant and readily available (Picker *et al*. 2004), confirms the black-backed jackal's highly opportunistic diet (Pyke *et al*. 1977). This characteristic is of significance to reserve owners as predation pressure on ungulates may be lower when alternative non-ungulate prey is available. Additionally, black-backed jackal may benefit reserve managers by feeding on harvester termites and other invertebrates which feed on grazing otherwise available to ungulates (Kaunda 2001; Kaunda & Skinner 2003). The greater proportion of invertebrate consumption at GFRR may be linked to the higher rainfall at GFRR compared to Kwandwe (Chapter 2), which supports a wider variety of invertebrate life (Wolda 1988). Additionally, the lower ungulate density at GFRR may allow more of the vegetation to be available for consumption by insect and other invertebrates, due to exploitative competition and incidental predation associated with the presence of ungulates (Gómez & González-Megías 2002).

The seasonal increase in fruit items in the diet in autumn should not necessarily be interpreted as a decrease in mammalian prey consumption during that season (Kaunda & Skinner 2003). An increase in fruit intake but equal consumption of mammalian prey would lower the RPO value of all the other food items, including the mammalian prey (Kaunda & Skinner 2003). However, the presence of any prey species within a scat is independent of the presence of any other species (Trites & Joy 2005). The high and stable frequency of occurrence of mammal hair across all seasons at GFRR is an indication of the importance of mammalian prey to the diet of black-backed jackal. The diet broadening results in this study are consistent with those from other studies which indicate that the consumption of fruits increases in autumn (Kaunda & Skinner 2003; Klare *et al*. 2010). Diet changes are linked in part to prey availability and abundance which increase the profitability of the prey, with the most profitable prey being favoured (Murdoch 1969; Begon *et al*. 2006). Diet broadening may be explained by a need to respond to increased demands for proteins, energy and other nutrients as a result of reproductive activities (Kaunda & Skinner 2003). The high consumption of mammalian prey (dominated by ungulates) in winter compared to autumn may be due to increased energetic demands linked to black-backed jackal winter and spring births (Bernard & Stuart 1992). Fruits, when they are available, provide an additional source of carbohydrates which is easily accessible, abundant, predictable (both spatially and temporally) and necessary for basic energy requirements. Furthermore, fleshy fruits may also provide a source of water in areas where water is scarce (Kaunda & Skinner 2003). Kaunda & Skinner (2003) found that the fruits of *Grewia* spp. were the most commonly ingested fruit by black-backed jackal in Mokolodi Nature Reserve in Botswana, and that black-backed jackal may play a role in seed dispersal for this species. The high consumption of fruits and invertebrates when they are most abundant is explained by the foraging theory which states that foraging decisions are based on maximum profitability, defined as the net energy gained/unit time (Schoener 1971). This involves the optimization of energy, which is in turn linked to fitness (Schoener 1971). Diets are broader when prey is scarce, due to the increase in searching time, and narrower when food is more abundant (MacArthur & Pianka 1966). This affects prey choice based on the likelihood of finding more profitable prey in the same length of time (MacArthur & Pianka 1966).

Birds, which could not be identified, made up a very small part of the black-backed jackal's diet in the study areas. This may be because, for the black-back jackal, they are relatively hard to catch and few attempts are successful (Kaunda & Skinner 2003). However, scat analysis has a poor success rate in identifying and quantifying the importance of birds and soft-bodied invertebrates (Reynolds & Aebischer 1991). Thus, avian prey, as well as invertebrates, may play more important roles in the diet of black-backed jackal than was determined in this study. Kaunda & Skinner (2003) also noted that black-backed jackals were observed to ingest larger quantities of invertebrates than those observed in the scats. Caterpillars are especially soft-bodied invertebrates and are thus more likely to be underestimated in terms of importance in the diet of black-backed jackal. Reptiles were also not frequently consumed; which was also recorded in other black-backed jackal diet studies (Kaunda 1998; Klare *et al*. 2010). The high proportion of plant matter found in the scats across seasons and at both sites suggests that it may be ingested mainly for bulk and roughage purposes (Kaunda 1998). Grass is ingested both voluntarily, to aid digestion and help meet the animal's vitamin C requirements, and accidentally when other food items, particularly invertebrates, are ingested (Smithers 1983; Kaunda 1998). Additionally, plant structural parts are poorly digested in carnivores' stomachs and can result in their overestimation in the scats (Jones *et al*. 2003).

Interpretation of the black-backed jackal's diet has ecological, socio-economic and epidemiological implications (Kaunda & Skinner 2003). Predation by black-backed jackal may affect population numbers of valuable herbivores in nature reserves (Ginsberg &

Macdonald 1990). Although frequency of occurrence data provides useful information regarding relative intake of different food items of black-backed jackal, further work in the Albany Thicket Biome, making use of biomass values is necessary in order to determine the importance of the different food items to the diet of black-backed jackal, and more importantly the effect of black-backed jackals on their prey populations. Alternatively, volume or mass values may be obtained (Balestrieri *et al.* 2011; Klare *et al.* 2011). Kruuk & Parish's (1981) technique which involves estimating the assessment of relative volumes of the food items by eye may also be used in place of calculating actual volumes. However, these values may not provide an exact representation of the effect of black-backed jackal predation on ungulates as it is still very difficult to determine the importance of scavenging to predation using scat analysis (Kaunda 1998). Furthermore, consumption of prey which is more digestible than others is harder to quantify and thus may result in a bias. These problems may be resolved by using stomach instead of scat content analyses (Norbury & Sanson 1992; Mills 1996).

CHAPTER FOUR

A COMPARISON OF SCAT ANALYSIS AND STOMACH CONTENT ANALYSIS TO ESTABLISH THE DIET OF BLACK-BACKED JACKALS, *CANIS MESOMELAS*

4.1 Introduction

Several methods, both direct and indirect, exist to determine the diet of terrestrial carnivores (Mills & Mills 1978; Korschgen 1980), including direct observations (Schaller 1972; Sillero-Zubiri & Gotelli 1995; Bissett 2004), continuous observations (Schaller 1972; Bissett 2004), scat analysis (Corbett 1989; Reynolds & Aebischer 1991; Kaunda & Skinner 2003; Giannatos *et al*. 2010; Goldenberg *et al*. 2010; Klare *et al*. 2010), stomach and intestine analysis (Bothma 1966b; Gipson 1974; Cavallini & Volpi 1995; Pezzo *et al*. 2003; Azevedo *et al*. 2006), radiolabeling (Constantine *et al*. 1959) and stable isotope analysis (Adams *et al*. 2010). The choice of method, however, is dependent on several factors, including the study animal's habits and the nature of the study area (Kaunda 1998) and the welfare of the animals involved (Darimont *et al*. 2008; Balestrieri *et al*. 2011). For example, direct observations are restricted to areas where vegetation is sparse (Krüger *et al*. 1999), while stomach analysis is restricted to common and unprotected species (Norbury & Sanson 1992).

Every method has its own set of inherent advantages and disadvantages. Direct observations allow prey species to be attributed to the correct predator, however, uneven search efforts in time and the opportunistic nature of observations may produce biased results as larger, more conspicuous prey is more likely to be noticed (Mills 1992). Scats are relatively easy to locate in the field and this allows different habitats to be sampled more homogeneously (Balestrieri *et al*. 2011). In addition, scat analysis does not require the destruction of any study animals (Balestrieri *et al*. 2011). The most serious problem related to scat analysis is the differential digestion of food items, whereby the proportion of certain prey items in the diet is either under- or overestimated according to the particular item's relative digestibility (Bowland & Bowland 1991; Norbury & Sanson 1992; Krüger *et al*. 1999). Decomposition rates, manipulation and consumption of scats by invertebrates and other animals may also affect their persistence in the field (Sanchez *et al*. 2004). Stable isotope analysis allows long-term dietary information to be obtained and reduces any bias linked to differential prey size and digestibility as isotopic dietary estimates are based on assimilated and not just ingested foods (Gannes *et al*. 1998; Adams *et al*. 2010). This method also allows diets to be apportioned between food items with different sources (e.g. marine and terrestrial) due to their isotopic composition but fails to provide detailed (i.e. taxonomic) dietary information, particularly when several dietary options are available (Roth 2002; Adams *et al*. 2010). Stomach content analysis alleviates some of the problems related to scat analysis such as differential passage rate of ingesta (see Chapter 3) (Norbury & Sanson 1992). As this method analyses only partially digested food, it is possible to identify remains to species-level (Witt 1980; Cavallini & Volpi 1995) and provides a more accurate assessment of the relative volume consumed of each food item (Feldhamer *et al*. 2007; Balestrieri *et al*. 2011). The use of stomachs also eliminates the risk of predator misidentification, as could be the case when working with scats (Pezzo *et al*. 2003). Furthermore, the presence of dipteran larvae in a stomach can indicate whether prey has been scavenged (Grafton 1965; Bothma 1966a; Mills 1996). The main disadvantage of stomach content analysis, however, is that it requires culling animals, which limits its use to common species and raises ethical concerns (Norbury & Sanson 1992). Alternatively, road fatalities may be used for stomach-content analysis studies (Nel & Kok 1999; Pezzo *et al*. 2003; Balestrieri *et al*. 2011).

Dietary study methods need to be as accurate as possible in order to understand the food habits of mammals and to ensure their proper management (Wydeven & Dahlgren 1982). Most studies on the diet of mammalian predators have relied primarily on scat and stomach content analyses, as they provide a clear indication of food items ingested, yet few studies have applied and compared the efficiency of these methods when assessing the diet of carnivores (Balestrieri *et al*. 2011). Studies on the diet of the red fox (Reynolds & Aebischer 1991; Cavallini & Volpi 1995) found important differences in the dietary components observed when using different methods. Thus, it is important to determine whether different diet analysis methods produce different results when analysing the diet of the black-backed jackal, particularly in light of its broad diet (Kaunda & Skinner 2003; Walton & Joly 2003; Loveridge & Nel 2004; Ray *et al*. 2005; Skinner & Chimimba 2005) and status as a problem animal (Hall-Martin & Botha 1980; Bekoff *et al*. 1984; Beinart 2003; Loveridge & Nel 2004).

Although numerous methods have been used in isolation to analyse the diet of the black-backed jackal, including scat analysis (Rowe-Rowe 1983a; Bothma *et al*. 1984; Avery *et al*. 1987; Hiscocks & Perrin 1987; Kaunda 1998; Kaunda & Skinner 2003; Do Linh San *et al*. 2009; Goldenberg *et al*. 2010; Klare *et al*. 2010), stomach content analysis (Bothma 1966b; Rowe-Rowe 1976; Hall-Martin & Botha 1980; Bussiahn 1997; Kaunda 1998) and direct observations (Hiscocks & Perrin 1987; Kaunda 1998), only one study (Kaunda 1998), based in Botswana, made use of both scat and stomach-content analyses. This is surprising considering the relative ease with which black-backed jackal scats may be found across their range (Walker 1996; Stuart & Stuart 2000; Hayward & Hayward 2010), as well as the relatively high culling rate of black-backed jackals, particularly on farmlands (Hey 1964; Rowe-Rowe 1975; Brand & Nel 1997; van Sittert 1998; Beinart 2003; Davies-Mostert *et al*. 2007), providing stomachs for analysis.

The aim of this study was to compare black-backed jackal diets using the analysis of stomach contents and scat samples in the Eastern Cape Province. I compared the diet composition of black-backed jackal as determined by scats and stomach contents collected from one site (Kwandwe Private Game Reserve).

4.2 Methods

4.2.1 Stomach collection

The stomach samples were obtained during the same period as the scat samples (May 2009 to April 2010). The stomachs were acquired from black-backed jackals shot during irregular predator control operations at Kwandwe. Thus, samples were unevenly distributed throughout the study period. Stomachs were collected for all months except August and December 2009 and February 2010, and the majority were collected in autumn (March - May). A total of 25 stomachs were collected: 17 stomachs in the autumn season, three in winter (June - August), four in spring (September - November) and one in summer (December - February). The bias towards autumn culling may be linked to the relatively low tourist season at that time of the year, which allows patrolling to be more widespread as it does not interfere with game drives (Bissett, pers. comm). Culling was conducted by Kwandwe staff with a 222 or 223 rifle, making use of either a caller and a spotlight, bait (e.g. intestines) or opportunistic encounters during predator control patrols on moonless nights. For each culled animal, the age, sex and location was recorded. Stomachs were removed, placed in plastic bags, labelled and stored in a deep freeze (-20ºC) until they were analysed.

4.2.2 Stomach analysis

There are several methods available to quantify prey categories in predator stomachs, including the use of counts, such as the number of stomachs containing a specific prey item (i.e. frequency of occurrence (PO) and relative frequency of occurrence (RPO)), or the total number of a specific prey found in each stomach (N) (Wetherbee & Cortés 2004). Alternative methods involve determining the bulk of each prey item, such as measuring the total mass (M) or total volume of each prey item (V) (Wetherbee & Cortés 2004). Like scat analysis, small prey items that occur frequently in stomachs may give the impression of being important when using count methods, whereas the consumption of one rare, but large prey item, expressed in terms of mass or volume can inflate importance (Wetherbee & Cortés 2004). The stomach contents of black-backed jackals from Kwandwe were subjected to the same analytical procedures and under the same conditions as the scat analysis for comparative purposes. Stomachs were weighed (g) prior to and subsequent to the removal of their contents. Each stomach was then cut open along its length using a scalpel and the contents emptied into white sorting trays (50cm x 35 cm x 4 cm). The stomach contents were rinsed with 500 ml of tap water to separate the food items from each other and to permit easier identification (Korschgen 1980; Hiscocks & Perrin 1987; Bowland & Bowland 1991; Bussiahn 1997; Loveridge & Macdonald 2003).

4.2.3 Overall diet

The overall diet (i.e. the distributions of food items by proportions) was determined by macroscopically identifying the stomach contents and recording the presence/absence of the different prey components in six broad categories: mammals, birds, invertebrates, fruits and seeds, other plant matter and anthropogenic items (Grafton 1965; Kaunda & Skinner 2003; Ciucci *et al*. 2004; Van der Merwe *et al*. 2009; Herbst & Mills 2010). Mammals were identified by the presence of hair, bone, teeth, and jaw and skull fragments (Kaunda & Skinner 2003). Bird remains were identified by the presence of feathers (Kaunda & Skinner 2003). Invertebrates were identified down to order, using a field guide (Picker *et al*. 2004). Fruits and seeds were identified to species by comparison with known specimens held at the Selmar Schönland Herbarium in the Albany Museum, Grahamstown. Anthropogenic food items were identified by the presence of unusual objects (e.g. plastic, rubber and metal). The PO and RPO were calculated for each of these dietary components (Grafton 1965; Van Aarde 1980; Cavallini & Volpi 1995; Kaunda 1998; Nel & Kok 1999; Azevedo *et al*. 2006; Balestrieri *et al*. 2011). As with scat analysis, fly larvae (Ellis & Shemnitz 1957) and ticks (Kok & Petney 1993) were omitted from the PO and RPO calculations. Some remains from the digestive tracts of prey (e.g. finely ground plant material and dung pellets) were not recorded as a separate prey category (Kaunda 1998). For the seasonal analysis and method comparisons of the PO and RPO values, months were pooled in the same way as the scat analysis: June - August = winter, September - November = spring, December - February = summer, March - May = autumn (Bissett 2004; Parker & Bernard 2005; Klare *et al*. 2010).

4.2.4 Mass

A further three categories were added to the six dietary categories used for PO and RPO: meat, bones and other items (Hall-Martin & Botha 1998; Kaunda 1998). The other items category consisted of unidentifiable matter left after sorting all other components (Korschgen 1980; Kaunda 1998). Food items were placed into separate labelled plastic dishes which were then placed into labelled paper bags and left to air dry in a well-ventilated area for a period of four days before being weighed (Bothma 1966b; Hall-Martin & Botha 1980; Cavallini & Volpi 1995). For each food component, the mass (g) was recorded and the percentage of the total mass of all food components calculated (Korschgen 1980; Nel & Kok 1999). Mean mass values were obtained for each month and percentage values calculated. For seasonal comparisons, months were pooled as previously described and seasonal aggregates and percentages calculated (Korschgen 1980).

4.2.5 Volume

Stomach contents were analysed volumetrically using the water displacement method (Grafton 1965; Korschgen 1980; Bothma 1966b; Hall-Martin & Botha 1980; Rowe-Rowe 1976). This method involved measuring the volume of water displaced by the food components before air-drying, using a measuring cylinder (Grafton 1965; Korschgen 1980; Bothma 1966b; Rowe-Rowe 1976). When stomachs contained negligible volumes (< 0.1ml) of certain food items, such as a few mammalian hairs, these were recorded as "trace" (Grafton 1965; Rowe-Rowe 1976; Korschgen 1980; Loveridge & Macdonald 2003). The total volume for each food category was expressed as a percentage of the volume of all items in all stomachs (percent volume) (Grafton 1965; Rowe-Rowe 1976; Korschgen 1980). Monthly aggregate volume values were calculated as this method is the most accurate when sample contents vary significantly in size, when samples are limited in number or when samples are unevenly distributed across seasons (Korschgen 1980). Months were pooled for seasonal comparisons as previously described and seasonal volume aggregates and percentages were calculated according to standard procedure (Korschgen 1980).

4.2.6 Data analysis

All proportional data were arcsine transformed prior to analyses (Zar 1996). Seasonal data for both the PO and RPO of invertebrates, fruits, mammal hair, plant matter, beetles, termites and locusts met the assumptions of normality and equal variance, thus one-way ANOVAs were conducted to determine seasonal changes among those food components (Zar 1996). For the remaining food items, Kruskal-Wallis tests were used to determine seasonal differences (Zar 1996). For the method comparison, one-way ANOVAs were conducted on the PO and RPO values of invertebrates, fruits, mammal hair and plant matter, and Mann–Whitney *U*-tests were used for the remaining food items (Zar 1996). In terms of mass and volume, seasonal data were normally distributed for mammalian remains, plant matter and other remains, thus one-way ANOVAs were conducted. A Kruskal-Wallis test was used for the remaining food items. All statistical tests were carried out using Statistica 9 (StatSoft, Inc. 2009).

4.3 Results

Stomachs from 17 male and eight female black-backed jackals were examined. In terms of age classes, 17 of the samples were adults (12 males and five females) and eight were subadults (five males and three females). Four stomachs were empty (two in winter and two in spring), representing 16% of the total sample, and belonged to an adult and a subadult female and two adult males.

4.3.1 Overall diet composition of black-backed jackal at Kwandwe

Across all seasons, plant matter was the most common item in the stomachs (PO ~67%), followed by mammal hair (58%) and invertebrates (53%) (Figure 4.1). Anthropogenic items (6%) and bird remains (2%) were much less prevalent (Figure 4.1). Although they were not observed in all seasons, fruits and seeds were present in more than half (54%) of the stomachs in autumn (Figure 4.1). There were no reptile remains in the stomachs.

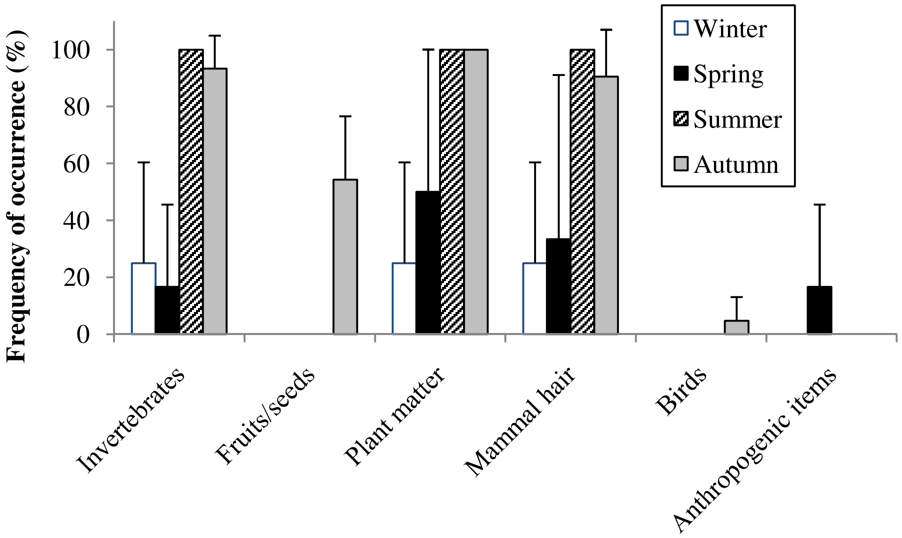

Figure 4.1 A comparison of the mean frequency of occurrence (± SD) of the six food categories found in black-backed jackal stomachs at Kwandwe for the full year of study (May 2009 - April 2010).

In terms of RPO, plant matter again accounted for most of the remains found in the stomachs (26%) across all seasons, followed by mammalian hair (22%) and invertebrates (20%) (Figure 4.2). Fruits and seeds (two species) also made up a substantial portion (16%) of food remains in the stomachs but in autumn only (Figure 4.2). Bird remains and anthropogenic items only made up a very small proportion of all food items and were only recorded in autumn and spring respectively (Figure 4.2).

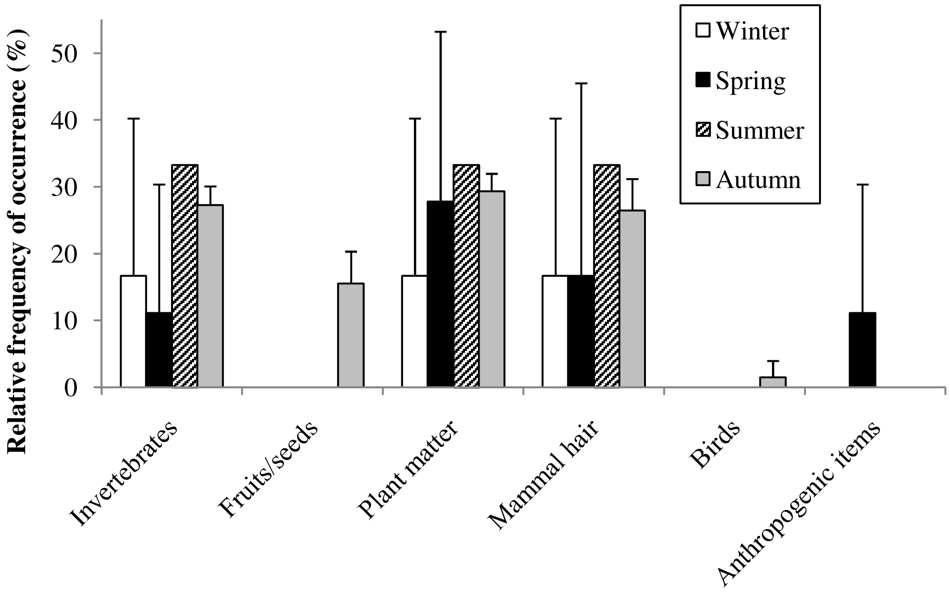

Figure 4.2 A comparison of the mean relative frequency of occurrence (± SD) of the six food categories found in black-backed jackal stomachs at Kwandwe for the full year of study (May 2009 - April 2010).

4.3.2 Seasonality of black-backed jackal diet

In terms of PO, invertebrates ($p<0.05$, $F_{(3,5)}= 9.08$) and fruits ($p<0.05$, $F_{(3,5)}= 7.03$) were more frequently consumed in autumn than in spring (Figure 4.1). Although not significant, plant matter and mammalian prey were also more frequently ingested in summer and autumn than in any other season (Figure 4.1). There were no seasonal differences ($p>0.05$) for bird remains or anthropogenic items. In terms of RPO, fruits made up a significantly ($p<0.05$, $F_{(3,5)}= 17.19$) greater proportion of all food items ingested in autumn than in any other season (Figure 4.2). The proportion of mammalian remains, plant matter, birds and anthropogenic items showed no significant change (p>0.05) across the seasons (Figure 4.2).

4.3.3 Invertebrates

Invertebrate remains were represented by the exoskeletons of termites (Class Insecta: Order Blattaria (Lo *et al*. 2007)), beetles (Class Insecta: Order Coleoptera), locusts (Class Insecta: Order Orthoptera), caterpillars (Class Insecta: Order Lepidoptera), millipedes (Class Diplopoda: Order Spirostreptida) and some unidentified invertebrates (Table 3.3). The most common invertebrate remains were beetles (mostly from the Tenebrionidae and Scarabidae families) (34% of all invertebrate remains), termites (mostly represented by *H. mossambicus*) (26%) and locusts (26%) (Table 4.1). There were no scorpion remains observed in the stomachs. There were no seasonal differences (p>0.05) in the consumption of any of the invertebrate orders.

Table 4.1 Invertebrate orders identified from black-backed jackal stomachs collected at Kwandwe between May 2009 and April 2010. (*n* = total number of stomachs, N = number of occurrences of each invertebrate category, % = percentage out of total number)

	Winter (*n* = 3)		**Spring (*n* = 4)**		**Summer (*n* = 1)**		**Autumn (*n* = 17)**		**All seasons (*n* = 25)**	
Invertebrates	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Insecta										
Blattaria	1	33.3	0	0.0	0	0.0	9	28.1	10	26.3
Coleoptera	1	33.3	1	50.0	1	100.0	10	31.3	13	34.2
Lepidoptera	1	33.3	0	0.0	0	0.0	0	0.0	1	2.6
Orthoptera	0	0.0	1	50.0	0	0.0	9	28.1	10	26.3
Diptera	0	0.0	0	0.0	0	0.0	2	6.3	2	5.3
Diplopoda										
Spirostreptida	0	0.0	0	0.0	0	0.0	1	3.1	1	2.6
unidentified	0	0.0	0	0.0	0	0.0	1	3.1	1	2.6
Total N	**3**		**2**		**1**		**32**		**38**	

4.3.4 Fruits and seeds

The fruits and seeds of only two species were observed in the stomach contents: *Diospyros lycioides* and *Grewia robusta*. These were observed in similar frequencies: *G. robusta* fruits were observed in 30% (*n* = 6) of the stomachs collected in autumn, representing 9% of all food remains. *Diospyros lycioides* fruits were present in 25% (*n* = 5) of the autumn stomachs, representing 7% of all food remains.

4.3.5 Mass

Mass (g) of the stomach contents from the 25 black-backed jackals collected at Kwandwe from May 2009 to April 2010, ranged between 0 and 635.48 g, with a mean of 150.38 g. Mean mass of stomach contents in adult males was 137 g (range 0 - 635 g) and 178 g (range 0 - 535 g) for female black-backed jackals. Mammalian remains (mostly meat) made up the majority (70%) of all food items in the stomachs in terms of mass (Table 4.2). This was followed by other remains, consisting of sand and unidentifiable digested matter (17%), invertebrates (7%) and fruits and seeds (3%) (Table 4.2). Plant matter made up a very small proportion (< 1%) of the total mass of all food items (Table 4.2). There was a significantly ($p<0.05$, $H_{(3,25)}= 10.03$) greater average mass of invertebrates observed in the stomachs in autumn compared to the other seasons (Table 4.2). There were no other significant ($p>0.05$) seasonal variations for the remaining food items in the stomachs.

Table 4.2 The average mass (M) of each food category/ stomach (g) and the percentage of the different categories observed in the stomachs of black-backed jackals at Kwandwe between May 2009 and April 2010. (*n* = number of stomachs, % = percentage out of total mass of all dietary categories).

	Winter (*n* = 3)		**Spring (*n* = 4)**		**Summer (*n* = 1)**		**Autumn (*n* = 17)**		**All seasons (*n* = 25)**	
Prey Category	**M**	**%**	**M**	**%**	**M**	**%**	**M**	**%**	**M**	**%**
Mammals	26.0	34.6	19.8	67.0	343.6	92.7	125.0	69.3	105.0	69.8
Mammal hair	0.7	0.9	2.7	9.0	1.2	0.3	3.2	1.8	2.7	1.8
Meat	25.2	33.7	14.0	47.4	337.4	91.0	121.3	67.3	101.2	67.3
Bones	0.0	0.1	3.1	10.6	5.1	1.4	0.5	0.3	1.0	0.7
Invertebrates	0.2	0.2	0.1	0.4	9.6	2.6	14.9	8.2	10.5	7.0
Fruits/seeds	0.0	0.0	0.0	0.0	0.0	0.0	6.5	3.6	4.4	2.9
Plant matter	0.4	0.6	0.4	1.2	2.9	0.8	1.2	0.6	1.0	0.7
Birds	0.0	0.0	0.0	0.0	0.0	0.0	trace	trace	0.0	0.0
Anthropogenic items	0.0	0.0	0.3	0.9	0.0	0.0	0.0	0.0	0.0	0.0
Rocks	6.6	8.8	0.1	0.4	3.2	0.9	4.8	2.7	3.5	2.3
Other	41.8	55.8	8.9	30.0	11.4	3.1	28.0	15.5	25.9	17.2
Total	**74.9**		**29.6**		**370.7**		**180.2**		**150.4**	

4.3.6 Volume

A total of 6.74 litres of stomach contents was examined from the 25 stomachs (Table 4.3). Mean food volume (ml) was 270 (range 0 - 1919 ml). Mean food volumes in adult males was 259 ml (range 0 - 1919 ml) and mean food volume in adult female black-backed jackals was 292 ml (range 0 - 1022 ml). Mammalian remains (mostly meat) made up the majority (74%) of the volume of all food items in the stomachs (Table 4.3). This was followed by unidentified remains (14%), invertebrates (7%) and fruits and seeds (3%) (Table 4.3). Plant matter only made up 2% of the total volume of all food items. As was observed with mass, there was a significantly greater volume of invertebrates in the stomachs in autumn ($p<0.05$, $H_{(3,25)}= 9.87$) compared to the other seasons (Table 4.3). No seasonal variations ($p>0.05$) were observed for the remaining food items in the stomachs.

Table 4.3 The average volume (V) of each food category/ stomach (ml) and the percentage of the different categories observed in the stomachs of black-backed jackals at Kwandwe between May 2009 and April 2010. (*n* = number of stomachs, % = percentage out of total volume of all dietary categories).

	Winter (*n* = 3)		**Spring (*n* = 4)**		**Summer (*n* = 1)**		**Autumn (*n* = 17)**		**All seasons (*n* = 25)**	
Prey Category	**V**	**%**	**V**	**%**	**V**	**%**	**V**	**%**	**V**	**%**
Mammals	40.2	44.1	43.3	70.4	383.0	80.6	252.4	74.7	198.7	73.7
Mammal hair	3.3	3.7	7.5	12.2	5.0	1.1	25.6	7.6	19.2	7.1
Meat	36.7	40.3	31.3	50.9	370.0	77.8	225.8	66.8	177.8	65.9
Bones	0.2	0.2	4.5	7.3	8.0	1.7	1.0	0.3	1.8	0.7
Invertebrates	1.3	1.5	0.8	1.2	29.0	6.1	26.4	7.8	19.4	7.2
Fruits/seeds	0.0	0.0	0.0	0.0	0.0	0.0	11.1	3.3	7.5	2.8
Plant matter	2.7	2.9	2.1	3.4	17.0	3.6	5.3	1.6	4.9	1.8
Birds	0.0	0.0	0.0	0.0	0.0	0.0	trace	trace	0.0	0.0
Anthropogenic items	0.0	0.0	0.2	0.3	0.0	0.0	0.1	0.0	0.1	0.0
Rocks	0.2	0.2	0.2	0.3	1.4	0.3	2.2	0.7	1.6	0.6
Other	46.7	51.3	15.0	24.3	45.0	9.5	40.4	12.0	37.3	13.8
Total	**91.0**		**61.4**		**475.4**		**338.0**		**269.6**	

4.3.7 Black-backed jackal diet in relation to sex and age

No significant differences ($p>0.05$) were found between the stomach contents of either males ($n = 17$) and females ($n = 8$), or adults ($n = 17$) and sub-adult black-backed jackals ($n = 8$) in terms of PO, RPO, mass or volume, for any of the food categories.

4.3.8 Comparison of two diet analysis methods

There were no significant differences ($p>0.05$) between the two methods for any of the food components in terms of PO (Figure 4.3). However, means suggest that invertebrates and plant matter were detected marginally more frequently in the stomachs compared to the scats (Figure 4.3). This said, both of these food categories made up a relatively small proportion of the total mass and volume of all food items. Mammalian hair and fruits, on the other hand, were more frequently detected in the scats than in the stomachs. In terms of RPO, mammalian hair made up a significantly greater proportion ($p<0.05$, $F_{(1,6)}= 6.69$) of the total food items in the scats than in the stomachs (Figure 4.4). There were no significant differences ($p>0.05$) between the two methods for any of the other food components in terms of RPO. Only 2% of the scats collected at Kwandwe contained dipteran eggs or larvae, whilst 8% of the stomachs contained signs of having eaten carrion. Interestingly, 67% of the stomachs contained stones (up to 2.5 cm in diameter), whilst only 28% of the black-backed jackal scats collected at Kwandwe contained stones.

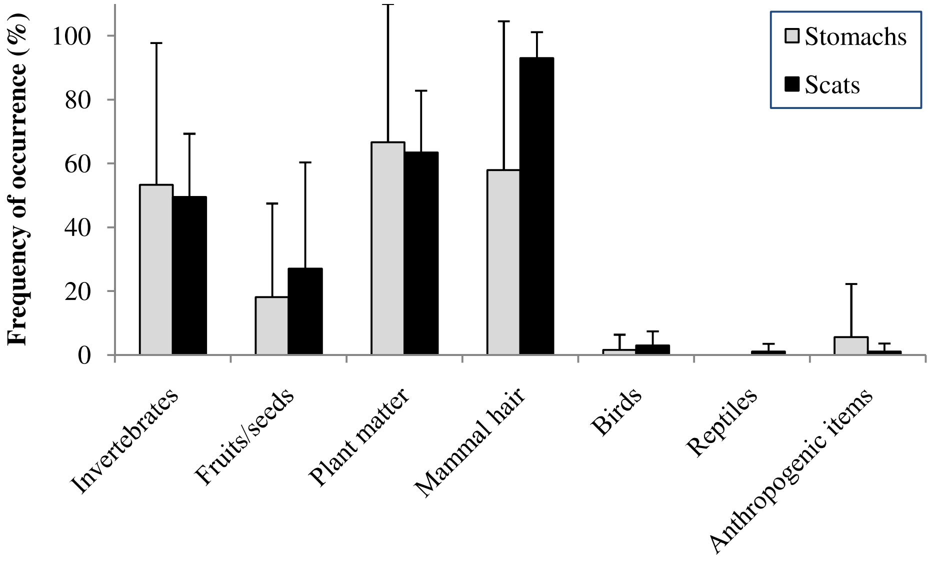

Figure 4.3 A comparison of the mean frequency of occurrence (± SD) of the seven food categories found in black-backed jackal stomachs and scats at Kwandwe.

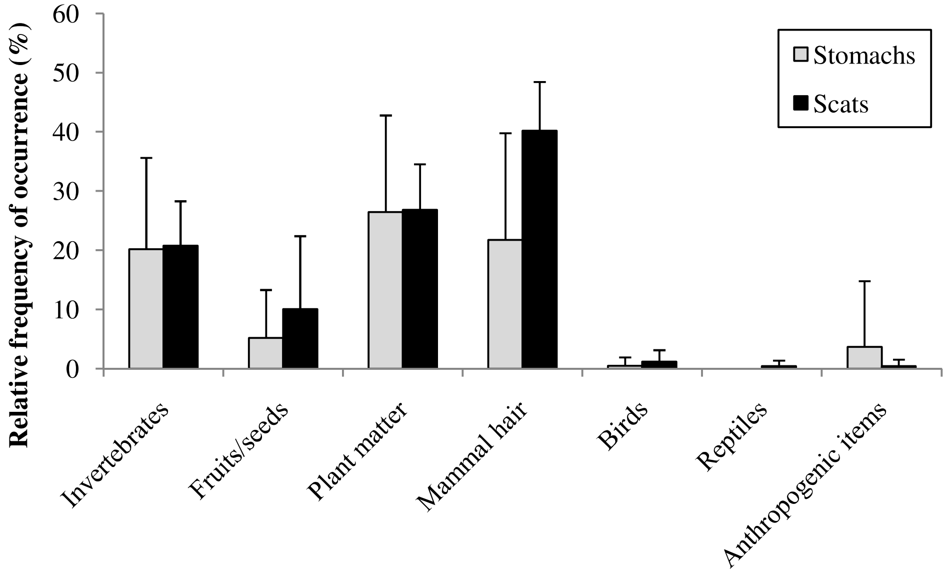

Figure 4.4 A comparison of the mean relative frequency of occurrence (± SD) of the seven food categories found in black-backed jackal stomachs and scats at Kwandwe.

4.4 Discussion

Both stomach content and scat collection methods depicted the black-backed jackal as a generalist and opportunistic predator, mainly relying on mammals and invertebrates. Nonetheless, differences emerged when analysing the importance of the main food items, suggesting that each method may underestimate the relative importance of some food items (Norbury & Sanson 1992; Mills 1996). The results suggest invertebrates make up a more important part of the diet of the black-backed jackal than is usually assumed when using scat analysis (Pezzo *et al*. 2003). The importance of invertebrates to the diet of black-backed jackal depends heavily on the analytical method used (e.g. frequency, biomass, volume or mass) (Pezzo *et al*. 2003; Klare *et al*. 2011). In fact, the importance of invertebrates in the diet may appear even lower when using quantitative scat analysis methods (i.e. biomass, volume and mass) than they do based on qualitative ones (i.e. frequency data) (Klare *et al*. 2011), due to their relatively small size and high digestibility (Hall 1972; Dickman & Huang 1988; Jones *et al*. 2003). Thus, the importance of invertebrates may be further underestimated in other scat analysis studies than it was in this study. The results of this study show that invertebrates were consumed as frequently as mammalian prey throughout the year. However, mammalian prey was recorded in greater quantity (i.e. volume and mass).

According to the stomach content analysis, the diet of the black-backed jackal was dominated by mammalian prey and invertebrates (mostly beetles, locusts and termites), both volumetrically and in frequency. Although plant matter was observed frequently in the stomachs, it made up very little of the total mass or volume, suggesting it is ingested coincidentally or for its fiber content (Grafton 1965; Kaunda 1998; Pezzo *et al*. 2003). Fruits were only consumed in autumn, which is probably linked to the increased availability and abundance of the fruit species during that season (van Wyk & van Wyk 1997), supporting the black-backed jackal's opportunistic and generalist feeding habits (Kaunda & Skinner 2003; Walton & Joly 2003; Loveridge & Nel 2004; Ray *et al*. 2005; Skinner & Chimimba 2005). The fruit species consumed were also observed in other black-backed jackal diet studies conducted in South Africa (Grafton 1965; Klare *et al*. 2010) and seem to be favoured by black-backed jackal.

The method-comparison results were similar to those of another study on the diet of the red fox, *Vulpes vulpes* (Cavallini & Volpi 1995). The authors demonstrated that mammal remains were more abundant in scats than in stomachs, while invertebrates and plant matter (excluding fruits) were more abundant in stomach contents (Cavallini & Volpi 1995). They attributed this difference to the sampling bias linked to the different methods of collection. Stomachs were more likely to have been obtained from younger, inexperienced and non-territorial animals which would have fed on easier prey (invertebrates and plant matter), while scats of dominant, resident foxes were more likely to be discovered and collected (Cavallini & Volpi 1995). However, the greater PO of invertebrates in the stomachs is more likely to be linked to digestibility (Hall 1972; Dickman & Huang 1988; Jones *et al*. 2003). Invertebrates with relatively soft body parts, such as termites, caterpillars and larvae, usually undergo complete digestion in black-backed jackal digestive systems (Kaunda & Skinner 2003). The greater proportion of dipteran larvae observed in the stomachs compared to the scats supports this. Similarly, Dickman & Huang (1988) found that although scat analysis provided a reliable method to determine the diet of generalist insectivores that eat hard-bodied invertebrates, soft-bodied invertebrates were underestimated due to their high digestibility. Invertebrate consumption may be further underestimated by scat analysis if the invertebrate prey is small or if the predator is satiated when it feeds, as certain diagnostic parts of the prey may not be swallowed and prey is more finely chewed (Dickman & Huang 1988). In addition, invertebrate consumption may be underestimated when prey consists of only a few invertebrate species consumed in large quantities (Dickman & Huang 1988). Kaunda and Skinner (2003) also observed black-backed jackal ingesting arthropods more frequently and in larger proportions than what was detected in their scats. The invertebrate orders identified in the scats were similar to those found in the stomachs, except for one stomach which contained caterpillar remains. The daily and seasonal activity patterns of the invertebrate orders consumed (Ayal & Merkl 1994; Picker *et al.* 2004) confirm the black-backed jackal's nocturnal habits (Fox 1971; Loveridge & Nel 2004; Skinner & Chimimba 2005). These invertebrates are active at similar times as black-backed jackals (Ayal & Merkl 1994; Picker *et al.* 2004). In addition, the high consumption of invertebrates in spring and summer, when they were most abundant and readily available (Picker *et al.* 2004), confirms the black-backed jackal's highly opportunistic diet (Pyke *et al.* 1977). However, the presence of several invertebrate orders per stomach suggests black-backed jackal may also actively search for these species during those periods when they are more readily available and abundant (Grafton 1965).

The high occurrence of stones, sand and grit detected in the stomachs in this study has also been observed in other studies (Grafton 1965; Bothma 1966a) which noted that rock material is commonly found in the stomachs of small canids and is thought to be swallowed unintentionally (Grafton 1965; Bothma 1966a).

An individual's age and sex can have a significant effect on its feeding patterns (Engen & Stenseth 1989). Parental or reproductive roles produce sex differences in diets due to differences in body size which determine the size of the prey which can be caught (Werner & Gilliam 1984; Birks & Dunstone 1985). Dietary constraints and experience may result in age-related dietary differences (Engen & Stenseth 1989), such as affecting functional response, entire food types, foraging station and foraging time (Polis 1984). Additionally, younger individuals are less likely to search for prey which involves risky exposure due to the effect this risk may have on the reproductive contribution of the individual to future generations (Engen & Stenseth 1989). However, age and sex did not have any effect on the dietary components of black-backed jackals in this study. A larger sample size may be required to observe food preferences of the different ages and sexes (Bothma 1966a; Pezzo *et al.* 2003). Alternatively, the social habits of the black-backed jackal may also have played a role in the similarity of diets among age and sex classes (Pezzo *et al.* 2003). The younger animals were all sub-adults and may have been helpers, which assist the dominant pair with the raising of the subsequent litter, thus having access to similar food as the adult dominant pair, sharing the same territory (Moehlman 1983).

In conclusion, although scat analysis appears to overestimate mammalian prey and fruits, the results were not significantly different from those of stomach content analysis for seasonal trends in terms of the PO and RPO of food items in the diet of black-backed jackal. Thus, scat analysis can provide an efficient and relatively accurate source of information on the diet of the black-backed jackal in reserves in the Eastern Cape. Nonetheless, over- and underestimations need to be kept in mind when making conclusions about dietary habits of the black-backed jackal based on scat analysis. The main limitations of stomach content analysis relate to the limited sample size obtainable. Frequency analysis methods provide an indication of food types more likely to be consumed by black-backed jackals (Grafton 1965; Korschgen 1980). By contrast, volumetric analysis methods provide a more accurate reflection of the quantity of food items ingested. However, both of these methods fail to provide an indication of the numbers of food items ingested, which can be particularly important when determining the impact of black-backed jackal on prey populations (Grafton 1965; Korschgen 1980). The best method to determine dietary importance involves recording both the frequency and amount (mass or volume) of a food category (Grafton 1965; Hyslop 1980). Both gravimetric and volumetric data provided similar results, thus only one method is necessary to determine the importance of the food items in terms of quantity.

CHAPTER FIVE

SUMMARY

Consumer-prey interactions are the fundamental linkage among species in food webs, which in turn are an essential feature of ecosystems (Estes 1996; Campbell *et al*. 2009). An ecosystemic approach to the management and conservation of wildlife is increasingly being favoured as an alternative to the traditional approach of species-level management (Jones & Lawton 1995; Estes 1996). This is due to an increased awareness that the number of extant species is too large to enable conservation of all biodiversity and that species' survival depends on the species' habitat (Estes 1996). However, the species is the unit of extinction and the relationship between species and ecosystems is still poorly understood, making the practical application of ecosystem management complex (Estes 1996). Two major current ecological themes within ecosystem management are i) which resources are necessary to maintain viable predator populations (bottom-up effects), and ii) what influences predators have on their ecosystems (top-down effects) (Estes 1995, 1996). Numerous mammalian predators play important roles as keystone species within their ecosystems (Estes 1996). A keystone species is defined as one which has an impact on its community or ecosystem that is disproportionately large relative to its abundance (Power *et al*. 1996). This role highlights the importance of understanding the requirements of predators (e.g. food resources) when defining guidelines for ecosystem management (Estes 1996).

The extinction of apex predators in numerous ecosystems has led to mesopredator release, where small to mid-sized predators, such as the black-backed jackal, have increased in abundance (Estes 1996; Prugh *et al*. 2009; Ritchie & Johnson 2009) and have, in turn, been elevated to the role of apex predators (Prugh *et al*. 2009). The success of black-backed jackal across their range has resulted in the species playing a significant role as a top predator across their range in southern Africa, not only on livestock farms (Beinart 2003; Loveridge & Nel 2004; Hayward *et al*. 2007) but also on nature reserves (Kaunda & Skinner 2003).

In two reserves of the Eastern Cape Province (Kwandwe Private Game Reserve and Great Fish River Reserve), a total of 23 mammalian species were consumed by black-backed jackals. The majority of the mammalian prey consisted of ungulates followed by rodents. The results suggest that the black-backed jackal may be an important predator of ungulates, particularly during the lambing season. During that time, predation appears to focus on hider species, bushbuck and kudu, which are easier to capture than follower species. Fruits were particularly important in autumn, when mammalian prey decreased in importance. The main fruit species consumed during that time were *C. haematocarpa*, *D. lycioides* and *G. robusta*. Scavenging seemed to play a minor part of the black-backed jackal's diet, although scat analysis is not an accurate method to determine scavenging (Kaunda 1998). Furthermore, it is not possible to determine the importance of scavenging if fresh meat is consumed.

In order to conserve and manage a predator species, baseline information on the predator (e.g. its status, range, habitat requirements and prey items) is necessary (Kaunda 1998). This needs to be followed by an understanding of the broader context of that species within its environment, with information on economic, cultural and political factors, followed by designing and implementing more comprehensive approaches to conservation and finally, ongoing research, including monitoring and feedback (Kaunda 1998). This information then needs to be passed on to decision-makers to make the suitable decisions regarding management and conservation (Kaunda 1998). Although the results of my study suggest that black-backed jackals may be important predators of certain ungulate species, further studies on prey preference, biomass ingested and the effects on population viability of the prey species is required before predator management measures are implemented.

The possibility that the results of my study were a product of the small, enclosed systems, rather than the habitat, should be considered. However, results on diet switching, mammalian prey and scavenging are similar to several other black-backed jackal diet studies conducted in different areas (Kaunda & Skinner 2003; Do Linh San *et al*. 2010; Klare *et al*. 2010). Thus, this study is probably a true reflection of the diet of the black-backed jackal in the Albany Thicket Biome.

Appendix A List of mammals recorded at Great Fish River Reserve, Eastern Cape, South Africa.

Order Artiodactyla

Potamochoerus porcus	Bushpig
Phacochoerus africanus	Warthog
Hippopotamus amphibius	Hippopotamus
Alcelaphus buselaphus	Red hartebeest
Sylvicapra grimmia	Grey duiker
Raphicerus campestris	Steenbok
Raphicerus melanotis	Cape Grysbok
Syncerus caffer	Cape Buffalo
Tragelaphuss oryx	Eland
Tragelaphus strepsiceros	Kudu
Tragelaphus scriptus	Bushbuck

Order Carnivora

Aonyx capensis	African clawless otter
Atilax paludinosus	Water mongoose
Canis mesomelas	Black-backed jackal
Caracal caracal	Caracal
Cynictis penicillata	Yellow mongoose
Felis silvestris	African wild cat
Galerella pulverulenta	Cape grey mongoose
Genetta genetta	Small-spotted genet
Ictonyx striatus	Striped polecat / Zorilla
Mellivora capensis	Honey badger / Ratel
Otocyon megalotis	Bat-eared fox
Panthera pardus	Leopard
Parahyaena brunnea	Brown hyaena
Poecilogale albinucha	Striped weasel
Proteles cristatus	Aardwolf
Suricata suricatta	Suricate
Vulpes chama	Cape fox

Order Chiroptera

Miniopterus schreibersii	Schreibers' long-fingered bat
Myotis tricolor	Temminck's hairy bat
Nycteris thebaica	Egyptian slit-faced bat
Rhinolophus capensis	Cape horseshoe bat
Rhinolophus clivosus	Geoffroy's horseshoe bat
Tadarida aegyptiaca	Egyptian free-tailed bat

Order Hyracoidea

Procavia capensis	Rock dassie

Order Insectivora

Atelerix frontalis	South African hedgehog
Amblysomus hottentotus	Hottentot golden mole
Crocidura cyanea	Reddish-grey musk shrew
Crocidura flavescens	Greater musk shrew
Elephantulus rupestris	Smith’s rock elephant-shrew
Macroscelides proboscideus	Round-eared elephant-shrew
Myosorex varius	Forest shrew
Suncus infinitesimus	Least dwarf shrew

Order Lagomorpha

Lepus saxatilis	Scrub Hare
Pronolagus rupestris	Smith's red rock rabbit

Order Perissodactyla

Diceros bicornis	Black rhinoceros

Order Primates

Cercopithecus pygerythrus	Vervet monkey
Papio ursinus	Chacma baboon

Order Rodentia

Cryptomys hottentotus	Common molerat
Dendromus melanotis	Grey climbing mouse
Desmodillus auricularis	Short-tailed gerbil
Georychus capensis	Cape molerat
Grammomys dolichurus	Woodland thicket rat
Graphiurus murinus	Woodland dormouse
Hystrix africaeaustralis	Porcupine
Mus minutoides	Pygmy mouse
Mastomys coucha	Southern multimammate mouse
Micaelamys namaquensis	Namaqua rock mouse
Otomys irroratus	Vlei rat
Otomys unisulcatus	Bush vlei rat
Pedetes capensis	Springhare
Rhabdomys pumilio	Striped mouse
Saccostomus campestris	Pouched mouse
Thryonomys swinderianus	Greater cane-rat

Order Tubulidentata

Orycteropus afer	Aardvark

Appendix B Mammalian species recorded during the 2009 census at Great Fish River Reserve, Eastern Cape, South Africa (* Numbers not shown for security reasons).

Order Artiodactyla		
Burchell's Zebra	*Equus burchelli*	135
Blesbok	*Damaliscus dorcas phillipsi*	7
Blue Wildebeest	*Connochaetes taurinus*	6
Bushbuck	*Tragelaphus scriptus*	154
Bushpig	*Potamochoerus porcus*	7
Cape Buffalo	*Syncerus caffer*	215
Common duiker	*Sylvicapra grimmia*	53
Eland	*Tragelaphus oryx*	624
Giraffe	*Giraffa camelopardalis*	23
Greater Kudu	*Tragelaphus strepsiceros*	1758
Hippopotamus	*Hippopotamus amphibius*	9
Impala	*Aepyceros melampus*	41
Mountain Reedbuck	*Redunca fulvorufula*	9
Nyala	*Tragelaphus angasii*	18
Red hartebeest	*Alcelaphus buselaphus*	425
Springbok	*Antidorcas marsupialis*	1
Steenbok	*Raphicerus campestris*	54
Warthog	*Phacochoerus africanus*	860
Waterbuck	*Kobus ellipsiprymnus*	16
Order Carnivora		
Aardwolf	*Proteles cristatus*	1
Bat-eared fox	*Otocyon megalotis*	1
Black-backed jackal	*Canis mesomelas*	71
Honey badger / Ratel	*Mellivora capensis*	1
Order Perissodactyla		
Black rhinoceros	*Diceros bicornis*	*
White rhinoceros	*Ceratotherium simum*	*
Order Primates		
Chacma baboon	*Papio ursinus*	728
Order Tubulidentata		
Aardvark	*Orycteropus afer*	1
Order Proboscidae		
Southern African elephant	*Loxodonta africana*	3

Appendix C List of mammals recorded at Kwandwe Private Game Reserve, Eastern Cape, South Africa.

Order Artiodactyla

Aepyceros melampus	Impala
Alcelaphus buselaphus	Red hartebeest
Antidorcas marsupialis	Springbok
Connochaetes gnou	Black Wildebeest
Damaliscus dorcas phillipsi	Blesbok
Equus burchelli	Burchell's Zebra
Giraffa camelopardalis	Giraffe
Hippopotamus amphibius	Hippopotamus
Kobus ellipsiprymnus	Waterbuck
Oryx gazella	Gemsbok
Pelea capreolus	Grey Rhebuck
Phacochoerus africanus	Warthog
Potamochoerus porcus	Bushpig
Raphicerus melanotis	Cape Grysbok
Raphicerus campestris	Steenbok
Redunca fulvorufula	Mountain Reedbuck
Sylvicapra grimmia	Grey duiker
Syncerus caffer	Cape Buffalo
Tragelaphus oryx	Eland
Tragelaphus scriptus	Bushbuck
Tragelaphus strepsiceros	Greater Kudu

Order Carnivora

Acinonyx jubatus	Cheetah
Aonyx capensis	African clawless otter
Atilax paludinosus	Water mongoose
Canis mesomelas	Black-backed jackal
Caracal caracal	Caracal
Cynictis penicillata	Yellow mongoose
Felis silvestris	African wild cat
Galerella pulverulenta	Cape grey mongoose
Genetta genetta	Small-spotted genet
Ictonyx striatus	Striped polecat / Zorilla
Leptailurus serval	Serval
Mellivora capensis	Honey badger / Ratel
Otocyon megalotis	Bat-eared fox
Panthera leo	Lion
Panthera pardus	Leopard
Parahyaena brunnea	Brown hyaena
Poecilogale albinucha	Striped weasel
Proteles cristatus	Aardwolf
Suricata suricatta	Suricate

Vulpes chama	Cape fox

Order Chiroptera

Miniopterus schreibersii	Schreibers’ long-fingered bat
Myotis tricolor	Temminck's hairy bat
Nycteris thebaica	Egyptian slit-faced bat
Rhinolophus capensis	Cape horseshoe bat
Rhinolophus clivosus	Geoffroy’s horseshoe bat
Tadarida aegyptiaca	Egyptian free-tailed bat

Order Hyracoidea

Procavia capensis	Rock dassie

Order Insectivora

Atelerix frontalis	South African hedgehog
Amblysomus hottentotus	Hottentot golden mole
Crocidura cyanea	Reddish-grey musk shrew
Crocidura flavescens	Greater musk shrew
Elephantulus rupestris	Smith’s rock elephant-shrew
Macroscelides proboscideus	Round-eared elephant-shrew
Myosorex varius	Forest shrew
Suncus infinitesimus	Least dwarf shrew

Order Lagomorpha

Lepus saxatilis	Scrub Hare
Pronolagus rupestris	Smith's red rock rabbit

Order Perissodactyla

Ceratotherium simum	White Rhinoceros
Diceros bicornis	Black rhinoceros

Order Primates

Cercopithecus pygerythrus	Vervet monkey
Papio ursinus	Chacma baboon

Order Proboscidae

Loxodonta Africana	African elephant

Order Rodentia

Cryptomys hottentotus	Common molerat
Dendromus melanotis	Grey climbing mouse
Desmodillus auricularis	Short-tailed gerbil
Georychus capensis	Cape molerat
Grammomys dolichurus	Woodland thicket rat
Graphiurus murinus	Woodland dormouse
Hystrix africaeaustralis	Porcupine

Mus minutoides	Pygmy mouse
Mastomys coucha	Southern multimammate mouse
Micaelamys namaquensis	Namaqua rock mouse
Otomys irroratus	Vlei rat
Otomys unisulcatus	Bush vlei rat
Pedetes capensis	Springhare
Rhabdomys pumilio	Striped mouse
Saccostomus campestris	Pouched mouse
Thryonomys swinderianus	Greater cane-rat

Order Tubulidentata

Orycteropus afer	Aardvark

Appendix D Mammalian species recorded during the 2007 census at Kwandwe Private Game Reserve, Eastern Cape, South Africa (* Numbers not shown for security reasons, ** Actual numbers known).

Order Artiodactyla		
Burchell's Zebra	*Equus burchelli*	279
Black Wildebeest	*Connochaetes gnou*	70
Blesbok	*Damaliscus dorcas phillipsi*	6
Blue Wildebeest	*Connochaetes taurinus*	1
Bushbuck	*Tragelaphus scriptus*	209
Bushpig	*Potamochoerus porcus*	8
Cape Buffalo	*Syncerus caffer*	46
Cape Grysbok	*Raphicerus melanotis*	0
Common duiker	*Sylvicapra grimmia*	152
Eland	*Tragelaphus oryx*	81
Gemsbok	*Oryx gazella*	112
Giraffe	*Giraffa camelopardalis*	33
Greater Kudu	*Tragelaphus strepsiceros*	1388
Hippopotamus	*Hippopotamus amphibius*	8
Impala	*Aepyceros melampus*	221
Mountain Reedbuck	*Redunca fulvorufula*	19
Nyala	*Tragelaphus angasii*	14
Red hartebeest	*Alcelaphus buselaphus*	171
Springbok	*Antidorcas marsupialis*	138
Steenbok	*Raphicerus campestris*	47
Warthog	*Phacochoerus africanus*	1447
Waterbuck	*Kobus ellipsiprymnus*	105
Order Carnivora		
Aardwolf	*Proteles cristatus*	3
Black-backed jackal	*Canis mesomelas*	34
Brown hyaena	*Parahyaena brunnea*	0
Cheetah	*Acinonyx jubatus*	8**
Leopard	*Panthera pardus*	0
Lion	*Panthera leo*	20**
Order Perissodactyla		
Black rhinoceros	*Diceros bicornis*	*
White rhinoceros	*Ceratotherium simum*	*

Order Primates		
Chacma baboon	*Papio ursinus*	3 troops
Order Tubulidentata		
Aardvark	*Orycteropus afer*	1
Order Proboscidae		
Southern African elephant	*Loxodonta africana*	18

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