SPATIAL AND TEMPORAL PATTERNS IN RESOURCE DISPERSION AND THE STRUCTURE OF RANGE USE AND CO-EXISTENCE IN A SOCIAL OMNIVORE *CHLOROCEBUS AETHIOPS*

by

ALAN SEAN BARRETT

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SUPERVISOR: PROF L R BROWN

CO-SUPERVISORS: PROF S P HENZI / PROF L BARRETT

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Declaration

I declare that **SPATIAL AND TEMPORAL PATTERNS IN RESOURCE DISPERSION AND THE STRUCTURE OF RANGE USE AND CO-EXISTENCE IN A SOCIAL OMNIVORE *CHLOROCEBUS AETHIOPS*** is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

....	....
A.S. Barrett	Date
alan.s.barrett@gmail.com	

Summary

The movements of two vervet monkey troops were studied to determine whether they optimize their rate of food intake in relation to seasonal energy availability. The effect of variation in habitat structure on the troops' foraging strategies while utilizing temporally and spatially distributed resources was determined. Troop home range boundaries were delineated, the various plant communities and species utilised by the troops identified and classified, and variations in home range and vegetation structure were reported. The diets of the troops were determined and compared. Effects of coexistence on competition were assessed. Vervet food trees were randomly selected, marked and seasonal phenological data collected. Samples of food items constituting the two troops diets were collected for energy analysis. Using geostatistical interpolation techniques, monthly energy values were extrapolated onto home range grids for the two vervet monkey troops. Grids were stored as database files that were interrogated through GIS simulation models. Using the stochastic processes inherent in Markov chain theory, a series of non-returning random walks were simulated for comparison to original routes taken by the two troops. Results from comparisons of home range energy, day range lengths and areas, shortest route energy to actual route energy, time spent in high energy areas, and energy utilisation from actual and randomly generated routes indicated that the two troops optimize resource energy available to them by adopting flexible foraging strategies. In environments where temporal and spatial variations in habitat structure affect the distribution of resources, it is essential that animals develop optimal foraging strategies to survive. For the two troops investigated, foraging strategies fluctuate between being time minimizers in more heterogeneous environments where resources are abundant, and energy maximisers in homogeneous environments where resources are constrained by low diversity and seasonality.

Key Terms

Animal movement; Range use; Plant communities; Phytosociology; Phenology; Diet; Caloric content; Energy; Bootstrapping; Vervet monkey; Interpolation; Foraging strategies.

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CHAPTER 1

INTRODUCTION

Animal movement patterns have long intrigued biologists, leading to much speculation about the reasons that particular daily paths are followed. The ability to travel through a home range in ways that optimise the rate of food intake in relation to time and energy costs should be under strong selection pressure (Krebs, 1978; Krebs & McCleery, 1984; Krebs & Davies, 1993). Ranging patterns generally, and route choice specifically, are important components of decision making that have notable consequences for behaviour, especially in environments where resources fluctuate strongly (Clutton-Brock, 1977; Post, 1978; Harrison, 1983; Chapman, 1988; Olupot *et al*., 1994, 1997; Hemingway & Bynum, 2005; Buzzard, 2006).

By analyzing the relationship between movement patterns and underlying resource energy gradients for two vervet monkey troops living in the Loskop Dam Nature Reserves (LDNR), it should be possible to determine whether they are optimizing resources available to them or not. To establish whether the troops are following routes with the highest energy yields, it is necessary to compare energy from actual routes travelled to a series of randomly generated routes, complete with time spent in underlying energy grid cells. An understanding of vervet spatial and temporal resource utilization will lead to an improved understanding of their general ecology, which will result in the better management and control of these animals, particularly in areas where they raid crops, orchards and even human dwellings, being labelled as problem animals (Lee *et al.*, 1986; Estes, 1992; Saj *et al.*, 1999). Knowing their habitat and resource requirements empowers managers to cater for their needs.

The LDNR is situated in the savanna biome and has a temperate sub-tropical climate with noticeable seasonality. Seasonality affects the phenology of plant communities and therefore the abundance, nature, and distribution of available resources, with the colder, drier months yielding fewer resources in terms of quantity and variety, compared with the warmer, wet season when more is available (Gautier-Hion, 1980, 1988; Tutin & White, 1998; Chapman *et al.*, 1999, 2002). Generally, as preferred resources diminish during the dry season, primates either track such foods across the landscape or turn to fallback foods that are available year-round (Arthur & Pianka, 1966; Pyke *et al*., 1977; Harrison, 1984; Lee, 1984; Foley, 1985; Whitten, 1988; Lee & Hauser, 1995, 1998; Hancock & Milner-Gulland, 2006). In this context, seasonal day ranges provide an indication of how animals move through their habitats to utilize available resources.

Prior to doing any route energy analysis, it is essential to evaluate resource availability within the study subjects' home ranges so that a context for the research can be established. Home range boundaries have to be delineated and central core areas need to be determined. Once home range boundaries have been determined, it is necessary to create an inventory of the various plant species and communities available within these areas and to determine structural and floristic variability between the home ranges. Such vegetation assessments are a prerequisite for any ecological or habitat related research (van Rooyen *et al*. 1981). To achieve this, the areas have to be sampled and classified according to acceptable and appropriate phytosociological methods. Habitat structure needs to be determined, and overall floristic analyses need to be undertaken. Variability between the two home ranges also needs to be assessed. Results from such analyses will provide the basic framework for further dietary analyses.

To understand how the two troops use their home ranges and the resources available to them, it is important next to identify the foods they eat and understand the extent to which patterns of usage tracks resource item availability across the seasons. Assessing whether diets reflect variability in home range structure and plant communities will help determine the extent to which such variability and seasonality influence the use of temporally and spatially distributed resources. As vervets are both omnivorous and social, this leads naturally to the question of how close coexistence affects the ability of individual troop members to optimise their diets. It may be that being an omnivore in a heterogeneous environment reduces immediate competition. If so, we would expect an increase in the variety of species and plant parts being utilised as the number of individually foraging animals' increases. This is clearly important because it has implications for the extent to which troop members can maintain spatial cohesion, and this, in turn, holds consequences for patterns of movement.

To understand how seasonality and habitat structure drive vervet ranging patterns, it is necessary to obtain quantitative data on the actual habitats in which the study troops live, this is achieved by mapping resource gradients – expressed as energy – in time and space. To do this it is necessary to determine the phenology of available plant resource trees and the energetic content of food items selected by the two troops in their respective home ranges. All vervet resource tree species have to be identified. Resource items on these trees, monthly availability of resource items and caloric content of resource items need to be ascertained. By determining which resources are available when, and what the caloric content of these resources are, data can be provided for extrapolation across the two troops home ranges for monthly route analyses.

Patterns of range use across the seasons are needed to determine whether the two troops structure their day journeys optimally in terms of utilizing available resource energy effectively. This can be achieved by extrapolating energy values from individual resource items based on the habitat's spatial structure across the two home ranges and using interpolation to construct seasonal energy grids for each habitat. Once this has been done, individual day routes can be laid on the grid to obtain an estimate of encountered energy. From the ultimate perspective of habitat use and spatial decision making, however, the obtained values are only interesting in relation to routes that might have been taken but weren't. Here it becomes necessary to describe feasible, alternative routes and compare their encountered energy to that of the actual routes.

The central themes of this study are therefore to determine and describe:

i. The extent to which variations in habitat structure affect the way in which two troops of vervet monkeys use their territories to optimize access to the temporally and spatially distributed resources available to them, in terms both of the time spent doing so and the resource energy available to them (Foley, 1985).
ii. The foraging patterns and strategies employed by the two troops to cope with such variations.

To achieve these objectives, this thesis is structured as follows: Chapter 2 examines available literature on LDNR, on vegetation in Southern Africa, and on phytosociology and the specific technique employed for classifying the plant communities occurring in the two study troops' home ranges. Chapter 2 also looks at available literature on phenological analyses, on the available techniques for monitoring and collecting vervet resource data, and on resource energy determination. Furthermore, Chapter 2 examines literature on vervets in general, on their diets and feeding ecology, on the way that they interact with their environments, and on how seasonality affects such environments and movement patterns. Finally, Chapter 2 looks at available literature on resource energy, on optimising the use of available resources, and on available methods for extrapolating and analysing movement and energy data. Chapter 3 describes the study site, the two vervet monkey home ranges, the study troops and the general methods used. Chapter 4 is a phytosociological evaluation and comparison of the two vervet troops' home ranges. Chapter 5 presents the two troops' diets and looks at the contribution of different food types to these. The importance of specific plant food species and troop preferences are also examined. Following on from this, Chapter 6 provides a phenological analysis of all the vervet tree resources utilised by the two troops, presenting information on resource items and overall tree energy content for extrapolation. Chapter 7 then deals with generating monthly energy grids from phenological data, creating random routes for comparison to actual routes and looking at time spent in energy grids in relation to available energy.

CHAPTER 2

LITERATURE REVIEW

2.1 Loskop Dam Nature Reserve

LDNR is situated in the Mpumalanga province of South Africa and is managed by the Mpumalanga Parks board (Emery *et al*., 2004; Ferrar & Lotter, 2007). The topography, geology and pedology of the reserve is diverse leading to a variety of habitat types, soil variations, land types and vegetation types (South Africa, 1975; Land Type Survey Staff, 1987; Visser, 1989; Buckle, 1992; Viljoen & Reimold, 1999; Eales, 2001).

The reserve contains several large mammal species excluding elephant and lion. A large variety of resident and migrant birds occur on the reserve and the dam contains numerous species of fish. Both reptiles and amphibians are well represented. The reserve has over 1 000 plant taxa. According to (Ferrar & Lötter, 2007), noteworthy plant and animal species occurring on or visiting the reserve include the very rare and endemic plant (*Haworthia koelmaniorum* var. *mcmurtryi*), Blue Cranes (*Anthropoides paradiseus*), Southern Ground Hornbill (*Bucorvus leadbeateri*), Cape Vulture (*Gyps coprotheres*), and the Giant Bullfrog (*Pycicephalus adspersus*).

The reserve falls within the summer rainfall region of South Africa and has a seasonally influenced climate. Summers are moderate to very hot and winters are mild to cold with the occurrence of frost on mountain tops and in low-lying valley bottoms (Theron, 1973; Low & Rebello, 1998). Rainfall is variable and occurs mainly in the form of short-lived high intensity thunderstorms that are associated with strong south-westerly winds. Rainfall and temperature data for the reserve is collected daily by reserve staff, and if necessary can be supplemented with extensive datasets from neighbouring farms.

2.2 Vegetation

For a broad overview of the vegetation occurring on the reserve and for Southern Africa in general, refer to Acocks (1988), Rutherford & Westfall (1994), Low & Rebelo (1996), Bredenkamp & van Rooyen (1998), Tainton (1999) and Mucina & Rutherford (2006). Two specific detailed analyses of the vegetation occurring on the reserve has previously been undertaken; Theron (1973) did a comprehensive investigation into the ecology of the plant growth on the reserve, and Götze *et al*. (1998) looked at the classification of plant communities and range condition assessment of two new areas incorporated into the reserve.

2.3 Phytosociology

Numerous methods for classifying plant communities exist, each with its pros and cons (Pears, 1968; van der Maarel, 1975; Belbin & McDonald, 1993; Ewald, 2003). For the purposes of this study, the phytosociological approach as proposed by Braun-Blanquet (Westhoff & van der Maarel, 1978) is most relevant and applicable as it was previously employed to successfully describe home range vegetation in a similar vervet study (Barrett *et al*., 2006); also having proved successful in describing vegetation in similar environments (Brown & Bredenkamp, 1994; Brown *et al*., 1996; Brown, 1997), to name but a few.

The techniques for stratifying vervet home range plant communities and for determining sample plot sizes and placement are extracted from Barbour *et al.* (1987) and Kent & Coker (1997). Plant taxon names are sourced from Arnold & de Wet (1993) and Germishuizen & Meyer (2003). The later references naming conventions is adhered to for all plant references throughout the dissertation, to ensure names used are current. The Braun-Blanquet cover abundance scale for assessing vegetation is sourced from Mueller-Dombois & Ellenberg (1974) and Barbour *et al.* (1987). The scale is slightly modified to be more inclusive. Erosion and terrain slope is assessed using the erosion classes provided by Matthee & Van Schalkwyk (1984), and the slope categories suggested by Barrett *et al*. (2006).

Several software packages are available for ecological and floristic data analysis (Hill, 1979; Hennekens, 1996, 1998; Wildi & Orlóci, 1996; Bruelheide, 1997, 2000; McCune & Mefford, 1999; Hennekens & Schaminée, 2001; Podani, 2001; Ter Braak & Smilauer, 2002; Tichý, 2002). All floristic data analysis and plant community derivation for the current study is undertaken using the TURBOVEG suite (Hennekens, 1998), which includes the Two-way indicator species analysis multivariate classification technique (TWINSPAN) (Hill, 1979). The visual editor MEGATAB (Hennekens, 1996) is used to generate home range phytosociological tables. For plant community identification, an adaptation by Grobler *et al*. (2006) of the '*diagnostic species*' methodology as defined by Westhoff and van der Maarel (1978) is used.

2.4 Phenology and energetic content of food

For a comprehensive understanding of vervet behaviour, it is imperative to understand the spatial and temporal dispersion of resources available to them in their home ranges (Chapman *et al*., 2005). The variability of available resources is closely linked to seasonality, with fluctuations being common throughout the year and between years (Chapman *et al*., 1999). By observing phenological patterning of primate resources, researchers are better able to support their behavioural hypotheses and results.

The value of long term phenological datasets has only recently been recognised, especially with global warming becoming an issue (Chapman *et* *al*., 1999; Chapman *et al*., 2005). Current trends are to establish long term research sites where such data can be collected for predictive modelling, the results of which are to be used to aid in the conservation of threatened areas (Chapman *et al*., 1999; Chapman *et al*., 2005).

The importance of spatial and temporal scales in ecological analyses was recognised in the 1980's when several researchers started looking at the impacts such had on the various plant and animal communities they were researching (Delcourt *et al.,* 1983; Addicott *et al.,* 1987; Meentemeyer & Box, 1987; Morris, 1987; Urban *et al.,* 1987).

Much of the current literature available on quantifying resources for primates concentrates on frugivore resources in tropical forests (Clutton-Brock, 1977; Raemakers, 1980; Leighton & Leighton, 1982; Terborgh, 1983; Chapman, 1990; Chapman *et al.,* 1992). As there is currently no known method for phenologically sampling vervet food resources in savanna environments, an adaptation of the methods utilized by Chapman in forest environments (Chapman *et al*., 1992; Chapman *et al.,* 1999; Chapman *et al*., 2002a; Chapman *et al*., 2005) and Smit in savanna environments (Smit, 1989a & 1989b) has been devised and is used for the current study.

To calculate the spatial volumes of resource bearing portions of vervet food trees in order to determine the numbers of resource items on such trees, it was necessary to investigate the various volume calculation methodologies available. Several methods for determining volume are available and range from the basic textbook calculations (Abramowitz & Stegun, 1972; Bostock & Chandler, 1975; Lennart & Westergren, 1990; Neill & Payne, 2002) to elaborate methods that include digital imagery and the construction of 3D tree models (Shlyakhter *et al*., 2001; Phattaralerphong & Sinoquet, 2004). Based on the general tree shapes found in the study area, volume calculations are restricted to the volume formulae for ellipsoids, right circular cones, frustums of right circular cones and right circular cylinders (Smit, 1996). For collecting linear tree dimension data, a modified version of the method described by Smit (1996) is used.

To find methods for determining the energy content of vervet plant resources, the work done by Golley (1969) and Verduin (1972) was looked at. Collected samples of plant resources consumed by the vervets are analysed for energy or caloric content using an adiabatic bomb calorimeter (Paine, 1971), and for crude protein and nitrogen percentages according to the (A.O.A.C., 1970).

2.5 Vervet monkeys

Vervets are guenons belonging to the subfamily Cercopithecinae. They are predominantly a savanna dwelling species that are amongst the most numerous and widespread of all the guenons (Cheney & Seyfarth, 1992). Vervets are adapted to hotter, drier environments with unstable food supplies, being distributed throughout Africa, south of the Sahara, from Somalia to Southern Africa (Skinner & Smithers, 1990; Estes, 1992; Kingdon, 1997). They have been introduced to the Caribbean islands of St. Kitts, Nevis and Barbados, probably brought there as pets by African slave traders in the 1600's (Denham, 1987).

Vervet habitats predominantly include savanna and woodlands bordering water. They are also found in riparian and related forests and even semi-desert environments, but not in deep rain forests (Cheney & Seyfarth, 1992). They are at ease both in trees and on the ground, using trees for sleeping, resting, protection and foraging. Vervets prefer fruit, but will eat a variety of vegetation including leaves, gum, flowers, seeds/pods, roots and bark. All parts of Acacia tree species are important to vervet monkeys. Diets are supplemented with insects, bird eggs, small birds, reptiles and even rodents (Skinner & Smithers, 1990). Unfortunately, vervets also raid crops and are labelled as problem animals in areas where they do this (Estes, 1992).

The effects that ecological factors have on vervet monkey ecology and behavior is considered by Hall & Gartlan (1965), Lee (1981), Brennan *et al.* (1985), Isbell & Young (1993), Adeyemo (1997), Baldello & Adan (1997 & 1998), Saj *et al*. (1999) and Barrett (2005).

According to Skinner & Smithers (1990), the size of vervets ranges from 46-66cm (head and body), and tail length from 50-72cm. Males are larger than females weighing between 4-5kg, with females being between 3.5-4.5kg. They have facial scent glands that they mark branches with. Their colouration varies, even within a troop, but most have a black face with white eyelids, and red and blue genitals. Vervets can reach ages up to 24 years old. Gestation periods are between 161-165 days, and they are known to have a variable breeding season (Cheney *et al*., 1988; Dunbar & Barrett, 2000). Usually only one young is born with eyes open and a dark/black coat. Babies start eating solids at around two months old when their colour changes to adult grey; mothers wean their babies at six months. Vervets reach sexual maturity at around five years old in the wild.

2.6 Habitat and dietary selectivity

According to (Eisenberg *et al.*, 1972; Kavanaugh, 1978; Skinner & Smithers, 1990; Estes, 1992, Dunbar & Barrett, 2000), vervet monkeys are generally considered to be opportunistic omnivores. Diet and resource utilisation information for non-specialist feeders, which include vervet monkeys, has been looked at by various researchers, the most relevant to the current study being Wrangham & Waterman (1981), Whitten (1983), Harrison (1984), Lee (1984), Skinner and Smithers (1990) and Lee & Hauser (1995), who suggest that vervet diets are usually restricted to a small number of staple foods with a wider supplementation on a seasonal basis. Lee (1984) and Whitten (1988) supply information more specific to savanna dwelling vervets, respectively suggesting that seasonality affects food quality and distribution, which in turn affects troop behaviour; and that group foraging influences the history and evolution of groups.

Not many detailed ecologically based dietary related research exists for vervets, with South Africa and Kenya being the only countries where such research has been undertaken and for which data is available. The different components constituting the diets of vervets from African study sites are presented by Whitten (1988), who did research on two troops from Samburu-Isiolo, Kenya; Isbell *et al*. (1998), who looked at two troops from Segera Ranch, Kenya; Pruetz & Isbell (2000), who looked at one troop from Segera Ranch, Kenya; and Barrett *et al*. (2005) who looked at one troop from Blydeberg, South Africa.

The importance of food and energy to primates is considered by Pyke *et al*. (1977), Krebs & McCleery (1984), Foley (1985) and Krebs & Davies (1993).

2.7 Energy and ranging patterns

De Moor & Steffens (1972), Wiens (1976) and Henzi *et al*. (1992) hypothesize that spatial and temporal resource availability is an important determining factor in the movement and social organisation patterns of various primate species. Holt *et al*. (1995) looked at what the current trends in ecosystem management are with regards to spatial and temporal scales; with Tappen (1960) and de Moor & Steffens (1972) highlighting that not much work has been done on vervet monkey ecology and behaviour in their natural environments.

The effects of temporal resource pulses on local animal populations has been elaborated on by Turner (1989), Caughley & Sinclair (1994), Kelly (1994) and Rose & Polis (1998); while Wrangham (1977), van Schaik (1989), Henzi *et al*. (1992), Boesch (1996), Sterck *et al*. (1997), Boesch & Boesch-Achermann (2000) look at the role that resource distribution plays in primate society.

The way that organisms interact with their environments, and the effects this has on their movement patterns has been looked at by several authors including Garber (2000), Johnson *et al.* (2001 & 2002), Mårell *et al.* (2002), Jonsen *et al.* (2003), Roshier & Reid (2003), Fernández *et al.* (2004), Nams (2005 & 2006), Hancock & Milner-Gulland (2006), Holden (2006), Di Fiore & Suarez (2007), Janson (2007), and Mueller & Fagan (2008). The influence that seasonal resources and energy has on primate diets and movement patterns is discussed by Robinson (1986), who suggests that memory plays an important role in feeding strategies, allowing primates to retain information on the location and availability of seasonal food resources. According to Hemingway & Bynum (2005), seasonality affects primate diets and ranging patterns, resulting in dietary changes which may or may not be accompanied by the tracking of preferred foods across the landscape, especially during periods of low resource availability or quality

Energy as a predictor of primate behaviour and abundance has been looked at by Lawes *et al.* (1990), Oates *et al.* (1990), Dasilva (1992), Henzi (1992), Gaynor (1994), Chapman *et al.* (2002a), and Wasserman & Chapman (2003), but not for vervet monkeys *per se*. Of particular relevance to the current study is the work done by Gaynor (1994), who did a quantitative analysis of baboon ranging and foraging effort in relation to food availability, looking specifically at day ranges in an attempt to determine whether food resources were being optimised using optimal foraging strategies as defined by Schoener (1971).

Optimal foraging theory is a topic of considerable interest to ecologists, anthropologists and primatologists (Arthur & Pianka, 1966; Schoener, 1971; Pyke *et al.*, 1977; Pianka, 1978; Foley, 1985; Stephens & Krebs, 1986; Garber, 1987; Melton, 1987; Krebs & Davies 1993). According to Foley (1985) and Alcock (1993), due to limited resources, natural selection favours life forms that increase their utilization of available resources relative to other life forms (energy maximizers), in the process increasing their reproductive success. Optimal foraging theory predicts that life forms *'tend'* towards optimality within the context of variation present and within the constraints of their environment (Foley, 1985), often being the starting point for research into feeding strategies, habitat utilization and animal route analysis (Schoener, 1971).

Generating monthly energy grids for vervet route analysis requires the extrapolation of energy figures across vervet home ranges. The role that geostatistics plays in ecological contexts is explored by Robertson (1987), who looks at interpolation with known variance as a method of successfully testing spatial and temporal ecological hypotheses where autocorrelation is evident. Interpolation is an accepted and well documented method of extrapolating ecological parameters (Robertson, 1987; Gotway & Hartford, 1996).

Using geostatistics, it is assumed that measurements taken at locations close together tend to be more alike than values observed at locations farther apart; Kriging with an assumed linear variogram is the preferred interpolation method for ecological studies (Cressie & Hawkins, 1980; Ripley, 1981; Zimmerman & Zimmerman, 1991; Mitasova & Jaroslav, 1993; Moore *et al.*, 1993). Kriging attempts to express trends suggested in data and has been used successfully with a high degree of predictive accuracy in various industries including the hydrological, agricultural and mining sectors (Journel & Huijbregts, 1978; Myers, 1981; Mulla, 1991; Gotway & Hartford, 1996). It produces geometrically accurate maps from irregularly spaced data, predicting data values at locations where actual measurements have not been made (Cressie, 1990, 1991). The origins, principles, utilisation and statistical acceptability of Kriging as a preferred interpolation technique are discussed by Cressie (1989a, 1989b, 1990, 1991). Comparisons of the applicability and strengths of various interpolation techniques were done by the authors with specific emphasis on the value of Kriging as a statistically acceptable interpolation technique for intermediate sized datasets. Journel & Huijbregts (1978), Webster & Burgess (1980), Myers (1981), Cressie (1986, 1989a, 1989b, 1990 & 1991), Mulla (1991) and Gotway & Hartford (1996) give an account of the history and origins of Kriging with detailed utilization discussions.

Schippers *et al*. (1996) examined the effectiveness of GIS-based random walks as a method of evaluating animal dispersal in heterogeneous landscapes. Various aspects of fractal geometry, random walk methodology and modelling for conservation and wildlife management are investigated by Cain (1985), Schippers *et al*. (1996), Turchin (1996), Barrett & Lowen, (1998), Ritchie (1998) and Hutchinson (2000).

For energy extrapolation, grid creation, the extraction of actual and random route energy profiles and for the comparison of routes, GIS based software offers attractive analyses options. Alternatives are to manually process data using hardcopies of maps and grids, using spreadsheet software for calculations; or to create software to do the required processing. The appeal to using standardized freeware packages is that the methodology becomes distributed, with the methods employed being repeatable and available for use elsewhere with minimal effort and cost. Several GIS software packages are available, ranging from free and cheap versions to costly corporate products. Clark Labs in the USA (http:\\www.clarklabs.org) offer a free downloadable version of IDRISI for student use, PLANETGIS is locally available in South Africa free of charge, MAPSOURCE® can be purchased at a reasonable cost, and ESRI products can be purchased with costs dependant on requirements. ARCVIEW® is an ESRI® product that offers users an array of extensions that are available on the internet at no cost; these extensions provide users with a wide variety of add- or plug-in options that greatly enhance the processing power of ARCVIEW®. If an extension has not yet been created for a specific requirement, the user can get such programmed at a cost, or they can do the programming themselves. Useful extensions for energy and route analysis include the random route generator created by Jenness (2005), the shape to point converter created by Huber (2000) and several ARVIEW® scripts including 3D analyst, area tools, network analyst, spatial analyst, surface tools and the Surfer extension. Extensions are available from several websites on the internet, with the main source of tested and working extensions being the ESRI scripts web page (http://arcscripts.esri.com/), additional resources and useful links are available on the ESRI website. Many government agencies and universities also have scripts and extensions available for free downloading.

Additional useful software packages for geospatial analysis include Surfer 8® and CARTALINX®. SURFER 8® is a powerful contouring, gridding, and surface mapping package for scientists and engineers, it converts x, y, z data into contour, surface, wireframe, vector, image, shaded relief, and post maps for use in most GIS systems. CARTALINX® is a digitizing and vector editing package meant as companion software to popular desktop GIS systems, using full topological data structures for robust data editing.

CHAPTER 3

STUDY SITE, SUBJECTS AND METHODS

3.1 Study Site

Loskop Irrigation Dam was completed in 1938 to provide water for the irrigation needs of agricultural practices taking place downstream. To ensure that downstream water users received good quality water, it was critical that the area surrounding the dam be managed properly. This led to the establishment of the LDNR in 1942 and the reserve was proclaimed in 1954 (Administrators Notice 223 of 1954), with additional land added on several occasions.

The reserve is currently under the management of the Mpumalanga Tourism and Parks Agency (MTPA) who are tasked under the current constitution of the Republic of South Africa (Act 108 of 1996, section 24) to protect the environment for present and future generations through reasonable legislation. The MTPA also implements measures to prevent pollution and environmental degradation, while promoting conservation and ensuring ecologically sustainable development and use of natural resources while striving for justifiable economic and social development.

Within the reserve, two vervet troops’ home ranges (referred to as the Donga troop and the Picnic troop), were used as study sites for this research. The two home ranges were geographically separated from one another and were approximately 4.5km apart. Locations of the home ranges are depicted in Figs 3.2 and 3.5 below.

3.1.1 *Location and size*

The LDNR is located 52km north of Middelburg on the N11 national road to Groblersdal in the Mpumalanga province (Fig 3.1). According to Emery *et al*. (2004) and Ferrar & Lotter (2007), the reserve currently covers 23 175ha, of which 2 350ha is water surface. It is located between longitude 29° 15’ 00” to 29° 40’ 00” E and latitude 25° 34’ 00” to 25° 56’ 00” S. At the heart of the reserve is the Loskop Irrigation Dam (approximately 24km long) situated in the Olifants River Valley. The dam is fed mainly by the perennial Olifants River and Krantz spruit and their respective tributaries (Theron, 1973). A network of small mountain streams and drainage channels originating from both inside and outside the reserves boundaries also drains into the dam.

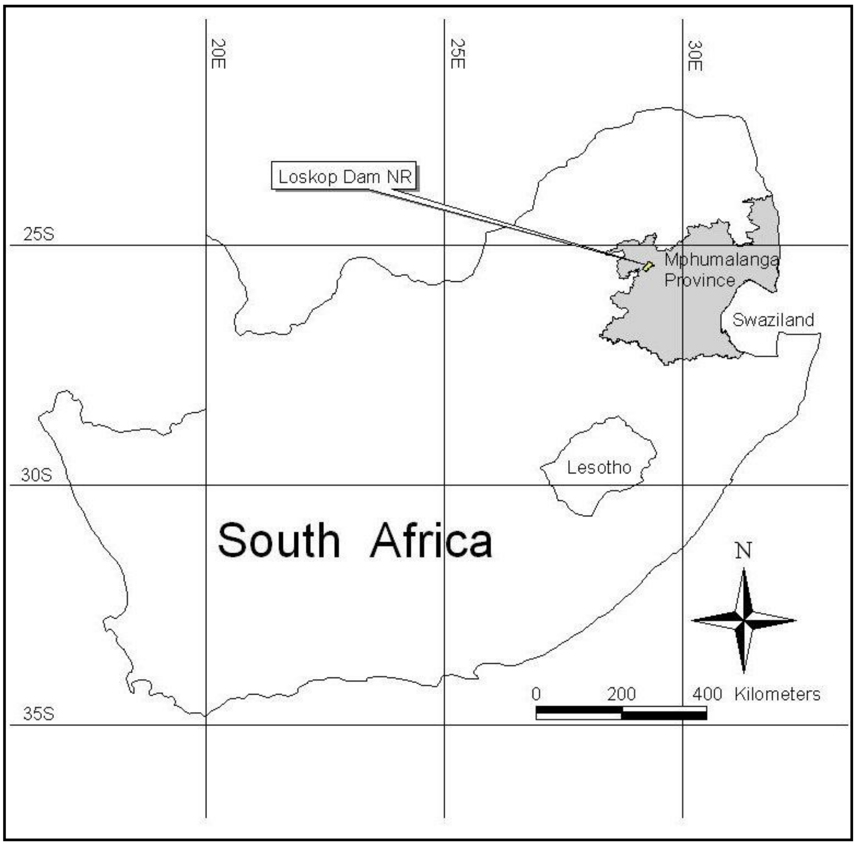


Figure 3.1. Location of the LDNR within the Mpumalanga Province of South Africa.

Landowners on the southern and western boundaries of the reserve farm with livestock and game. On the north-western boundary there is an urban development of the Kwarrielaagte community where livestock is kept on a communal grazing basis. Activities on the north-eastern and eastern boundaries include a mixture of resort or lodge developments together with game farming practices.

3.1.2 *Topography*

According to Emery *et al*. (2004) and Ferrar & Lotter (2007), the reserves topography ranges from dry undulating flat highlands through dry mountainous hilly highlands to dry mountainous hilly lowlands surrounding the dam (Fig 3.2). Altitude ranges from 991m to 1 420m above sea level, extending from the valley of the Olifants River incorporating the dam, up onto the surrounding plateau colloquially known as the highveld (Theron, 1973). The terrain varies from an incised plateau on the higher lying areas, through steep cliffs and a variety of slope types, to a few deep valleys and some relatively flat valley bottoms. Slopes on the southern section of the dam are mostly steep high cliffs, while those on the northern and north-western shores of the dam are less steep, more flat and culminate in undulating plains that lead onto the dam’s flood plains. The terrain is generally rugged and broken, attributing towards the overall heterogeneous nature of the reserves vegetation (Theron, 1973).

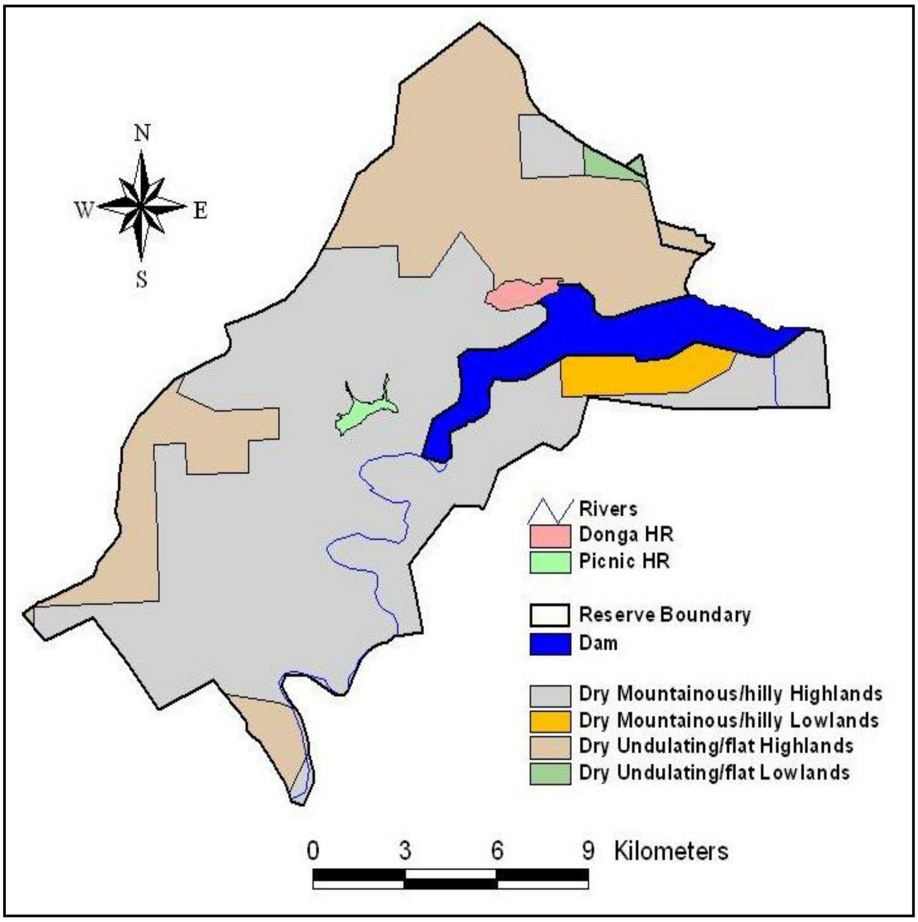


Figure 3.2. Landscape types occurring on LDNR with locations of vervet home ranges depicted.

The Donga troop's home range is generally steeper and more mountainous than the Picnic troop's home range, appearing to be more stable in terms of structure and human disturbance due to less historic human intervention in the form of agricultural practices compared to the Picnic.

3.1.3 *Geology*

According to Viljoen & Reimold (1999), the geology of LDNR includes part of the Bushveld Complex, the world's largest layered intrusion of its kind. The Complex is renowned for its size (approximately 66 000km^2), the persistence and regularity of the layering in its mafic and ultramafic rocks, and for the importance of its mineral deposits, particularly its layered rocks containing the worlds largest known resources of platinum-group metals, chromium and vanadium (Viljoen & Reimold, 1999).

Associated with the Complex are a number of smaller adjacent bodies and sills that have intruded into rocks of the Transvaal. Associated bodies occurring on the reserve include the Rooiberg Group, the Loskop Formation and the Waterberg Group.

The Bushveld Complex, the Rooiberg Group and the Loskop Formation all date back to the Vaalian Quaternary. The Waterberg Group dates back to the Mongolian Quaternary (South Africa, 1975; Visser, 1989; Buckle, 1992; Viljoen & Reimold, 1999; Eales, 2001).

The ***Bushveld Complex*** consists of the Rustenburg Layered Suite and the Rashoop Granophyre Suite amongst others. The Rashoop Granophyre Suite consists of granophyre and granite porphyry, the latter being intrusive into Rooiberg lava and possibly also into the granophyre. Granophyre occurs as material resembling sill intrusions, with sharp contacts into lava above and leptite or ferrodiorite below. Varieties include microgranophyre above and melanogranophyre basally. It is speculated that granophyre is partially a remobilization product of lava and quartzite that formed as a result of the emplacement of basic magma.

Metamorphic rocks associated with the Bushveld Complex include different types of hornfels of the Pretoria Group, occurring below the complex. Where Rooiberg lava forms the roof of the basic suite, lava has been transformed into leptite. A xenolithic strip between the main and upper zones consists of pyroxene hornfels and hornblende microgranite, which are respectively metamorphosed into Dullstroom basalt and red granophyric lava. Pyroxene hornfels also occur in the floor along the contact between Dullstroom basalt and the main zone (South Africa, 1975; Visser, 1989; Buckle, 1992; Viljoen & Reimold, 1999; Eales, 2001).

The ***Rooiberg Group*** consists mainly of lavas of rhyolitic to andesitic composition and includes a lower Damwal Formation and an upper Selonsrivier Formation. The Damwal Formation is well developed towards the south-east where it consists of basal lava followed by granophyric lava and subsequently black lava and black amygdaloidal lava (South Africa, 1975; Visser, 1989; Buckle, 1992; Viljoen & Reimold, 1999; Eales, 2001).

In the north-eastern parts lava has been altered to leptite. Layers of sedimentary and pyroclastic rocks are interbedded in the volcanic rocks, increasing towards the surface (South Africa, 1975; Visser, 1989; Buckle, 1992; Viljoen & Reimold, 1999; Eales, 2001).

The contact between the Damwal Formation with the Selonsrivier Formation constitutes the base of a prominent and continuous quartzite layer. The Selonsrivier Formation is relatively homogeneous consisting of red porphyritic lava (South Africa, 1975; Visser, 1989; Buckle, 1992; Viljoen & Reimold, 1999; Eales, 2001).

The ***Loskop Formation*** follows approximately concordantly on the Rooiberg Group with evidence of major regional unconformity. The Formation is separated from the overlying Waterberg sediments by a prominent regional unconformity and consists of a thick succession of finely layered siltstone, mudstone, feldspathic sandstone and shale (South Africa, 1975; Visser, 1989; Buckle, 1992; Viljoen & Reimold, 1999; Eales, 2001).

All Loskop Dam porphyritic granite is intrusive into the Loskop strata. Conglomerate layers and interlayered lava also occur higher up in the Loskop Formation. Lavas show great conformity with the lavas of the underlying Rooiberg Group and the deposition of the Loskop Formation is viewed as the final sedimentary phase of the development of the Transvaal basin, following directly from the volcanic phase of the Rooiberg Group (South Africa, 1975; Visser, 1989; Buckle, 1992; Viljoen & Reimold, 1999; Eales, 2001).

The ***Waterberg Group*** is represented by the Wilgerivier Formation, consisting of a thick continuous sequence of red to red-brown sediments including quartzite, grit and sandstone. Crossbedding is a common occurrence. The Formation is separated from underlying rocks by a prominent unconformity and rests with a sedimentary contact on the Nebo Granite (South Africa, 1975; Visser, 1989; Buckle, 1992; Viljoen & Reimold, 1999; Eales, 2001).

According to South Africa (1975), Visser (1989), Buckle (1992), Viljoen & Reimold (1999), and Eales (2001), the geology of the LDNR is as follows (Fig 3.3):

- The northern most section of the reserve consists of the lower zone of the ***Rustenburg Layered Suite*** forming part of the Magaliesberg Formation, which is part of the Bushveld Complex. The igneous column of the ***Rustenburg Layered Suite*** in the north of the reserve is made up of hybrid gabbro, gabbro and norite (lithologically classified as Vl). The sedimentary column contains quartzite and minor hornfels (lithologically classified as Vm).
- The ***Rashoop Granophyre Suite*** is to the south and west of the Rustenburg Layered Suite, also being part of the Bushveld Complex. The igneous column of the ***Rashoop Granophyre Suite*** consists of granophyre and pseudogranophyre (lithologically classified as Mr). The sedimentary column contains quartzite and minor hornfels (lithologically classified as Vm).
- The ***Damwal Formation*** forms part of the Rooiberg Group and is to the south of the Rustenburg Layered Suite and the Rashoop

Granophyre Suite. This Formation contains volcanic rocks (lithologically classified as Vdr).

- The ***Selonsrivier Formation*** is also part of the Rooiberg Group and forms a band through the centre of the reserve to the south of the Damwal Formation. The ***Selonsrivier Formation*** contains volcanic rocks - upper part hatched and lower part unhatched (lithologically classified as Vs).
- The ***Loskop Formation*** is to the south of the Selonsrivier Formation and encompasses most of the western and far eastern shores of the dam. The ***Loskop Formation*** contains shale, sandstone and volcanic rocks (lithologically classified as Vls).
- The ***Wilgerivier Formation*** forms part of the Waterberg Group in the southern most section of the reserve and encompasses the south-eastern shore of the dam. The ***Wilgerivier Formation*** contains sandstone, quartzite in places and conglomerate (lithologically classified as Mw).

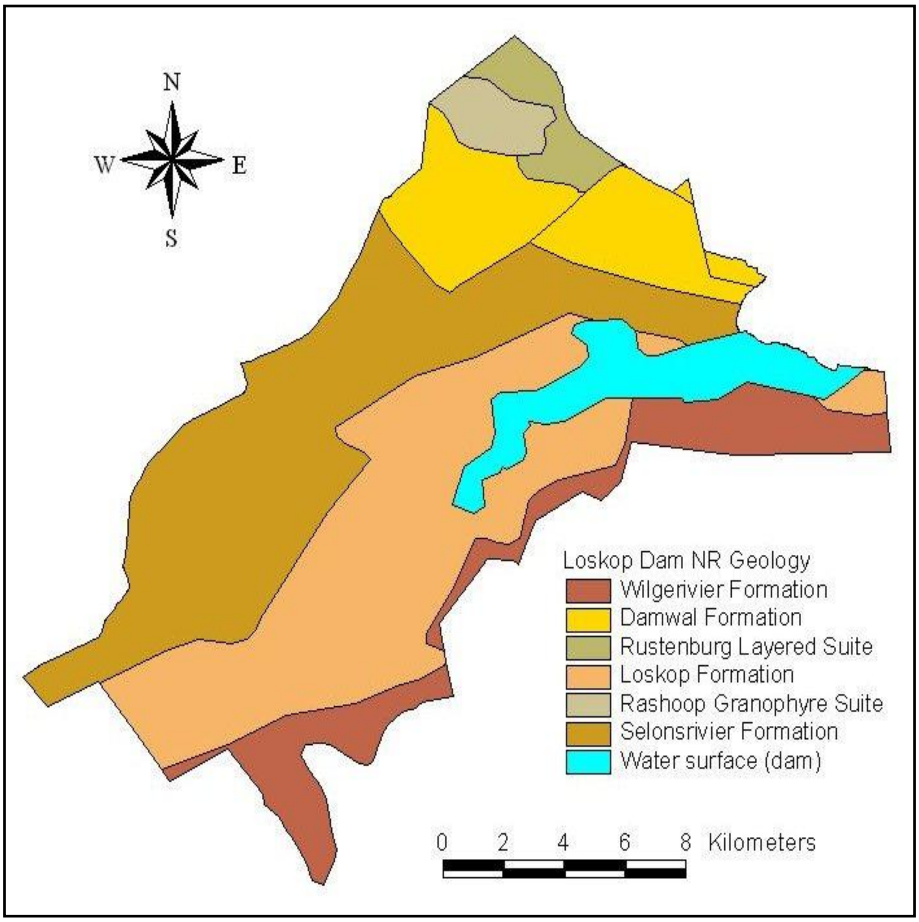


Figure 3.3. Geology of the LDNR adapted from the 1:250 000 Geological Series 2528 for Pretoria (South Africa, 1975).

Generally the rocks occurring on the Loskop Dam valley floor are covered with alluvium and surface drift (Theron, 1973).

The underlying geology of the Donga home range consists of the sedimentary Loskop formation characterized by shale, sandstone and volcanic rocks in the south, and the Selonsrivier formation characterized mainly by the presence of volcanic rocks in the north-east. The underlying geology of the Picnic home range consists only of the Loskop formation.

3.1.4 *Pedology*

The pedology of the reserve is complex due to its harsh topography and the weathering of different geological substrate types. Acidic soils are quite common, especially in areas with underlying sandstone and rhyolite rock types. Soil types vary significantly over short distances, making soil mapping difficult if not impossible. Soil depth has a major influence on vegetation types occurring on the reserve.

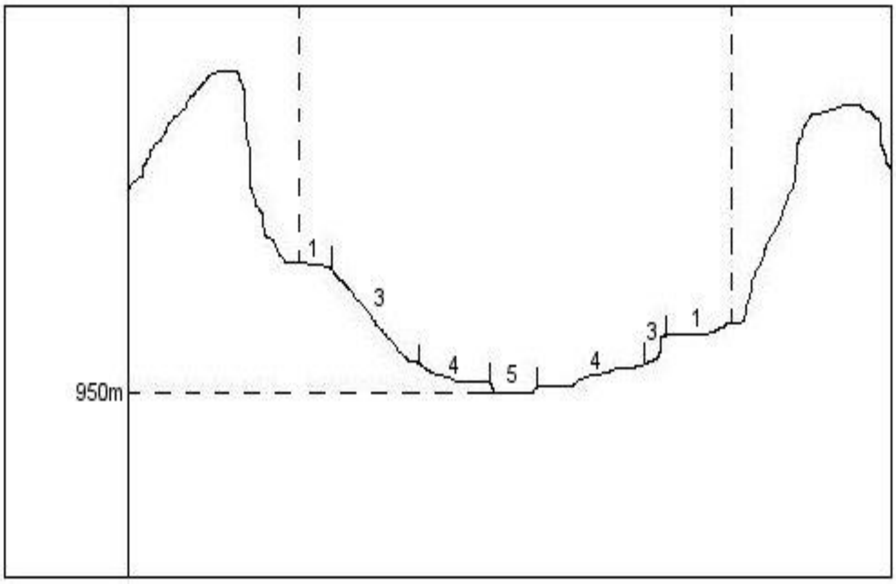
Plateaus or high lying areas are characterized by relatively shallow sandy to sandy-loam soils that are acidic (pH 3.5 to 4.5). Foothills and valley floors have deeper soils classified as sandy-loam to sandy-clay-loam, with soil pH varying from 4.5 to 5.5 (Land Type Survey Staff, 1987).

A variety of slope types occur as a result of the broken topography, resulting in a myriad of soil types that vary from talus like soils just below ridges, to very shallow soils on steeper slopes and ridges, to deeper soils close to and in valley bottoms. Most of the soils found in the reserve are acidic with pH values less than five.

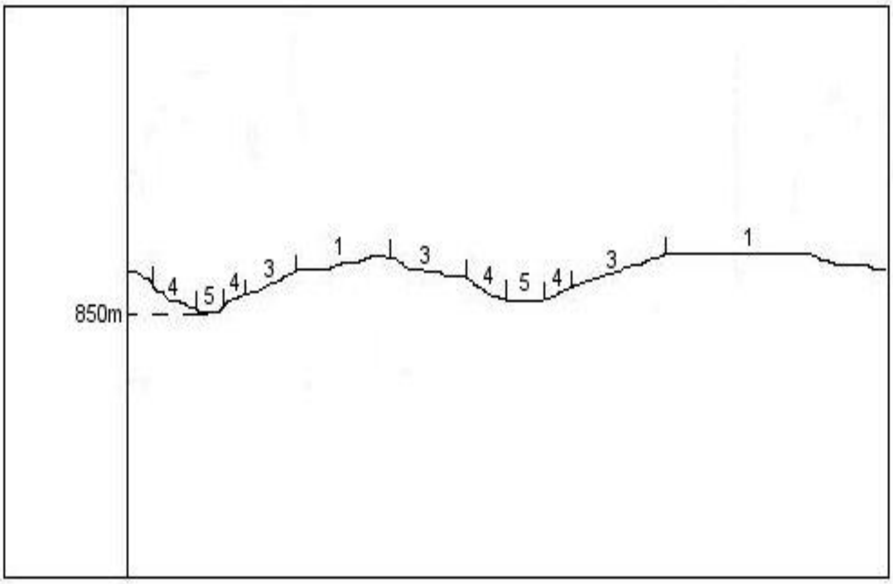
3.1.5 *Land types*

According to Land Type Survey Staff (1987), a land-type is defined as an area mapped at a scale of 1:250 000 that displays a marked degree of uniformity with respect to terrain form, soil pattern and climate. There is a close association between major plant communities and the different land types occurring in an area (Kooij *et al*., 1990; Bezuidenhout, 1993; Eckhardt, 1993; Brown, 1997; Barrett, 2005).

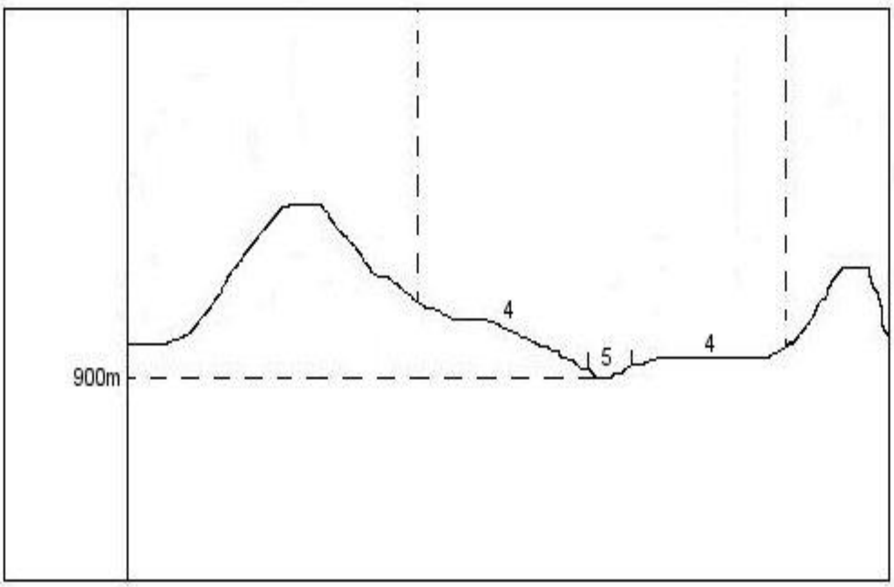
Five land types, namely Bc, Bd, Ea, Fa and Ib occur in the reserve as indicated in the terrain form sketch (Fig 3.4).



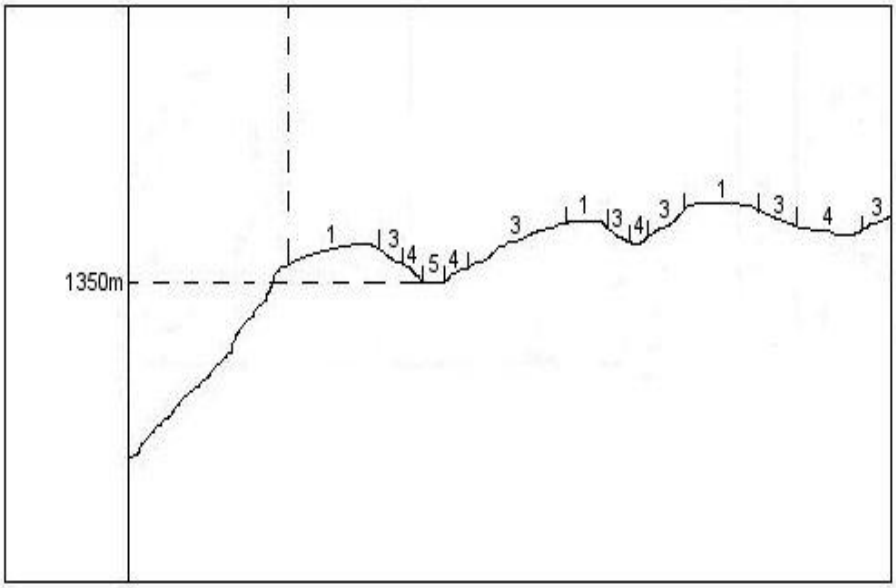
(a)



(b)



(c)



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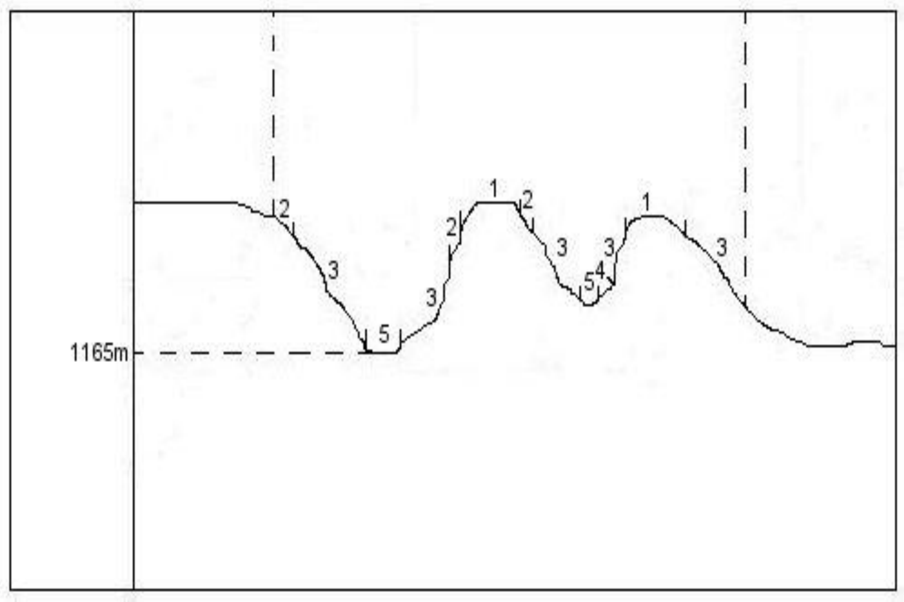


(e)

Figure 3.4. Terrain form sketches indicating the various land types of the study area. (a) is land type Bc, (b) is land type Bd, (c) is land type Ea, (d) is land type Fa, and (e) is land type Ib. Within the land type sketches, 1=Crest, 2=Scarp, 3=Mid slope, 4=Foot slope, 5=Valley bottom.

The ***B land type*** (plinthic catena) refers to a catena that occupies a large portion of the South African interior (Land Type Survey Staff, 1987). Upland duplex and margalitic soils are rare. In its perfect form this catena is represented by Hutton, Bainsvlei, Avalon and Longlands soil forms (from highest to lowest in the upland landscape). The valley bottom is comprised of one or other gley soil form e.g. Rensburg, Willowbrook, Katspruit, Champaigne. Additionally, Glencoe, Wasbank, Westleigh, Kroonstad, Pinedene and Tambankulu (rarely) forms are present. Klipfontein and occasionally Hillside soil series are also found. According to Land Type Survey Staff (1987), soils with hard plinthite are common over sandstones in moist climatic zones in the eastern parts of Southern Africa. Depending on water table activity over landscapes, Longlands and Avalon and related grey and yellow soils may predominate - sometimes to the exclusion of red soils. Where water tables have not extended beyond valley bottoms, red soils may predominate with plinthic soils being restricted to narrow strips of land around valley bottoms or pans. Plinthic soils must cover more than 10% of an area for it to be included into the B land type.

In the ***Bc and Bd land type's*** upland duplex and margalitic soils are either absent or occupy less than 10% of the area. Upland margalitic soils include one or more of the Arcadia, Bonheim, Tambankulu, Mayo and Milkwood soil forms. Upland duplex soils include one or more of the Estcourt, Sterkspruit, Swartland, Valsrivier and Kroonstad soil forms. Red and/or yellow apedal soils (Hutton, Bainsvlei, Avalon, Glencoe and Pinedene forms) that are dystrophic and or mesotrophic predominate over red and/or yellow apedal soils that are eutrophic, and in which red soils (mainly Hutton and Bainsvlei) occupy more than a third of the area.

In the ***Bc land type*** eutrophic, red soils are widespread. In this land type four terrain units are present i.e. crests comprising 10% of the land type, midslopes comprising 10%, footslopes comprising 65% and valley bottoms comprising 15%. Terrain type is A2 with more than 80% of the area having slopes less than 8%. Local relief ranges from 30 to 90m.

Crests slope range varies between 3 to 15% with range of slope length ranging between 10 to 200m. Soils found on crests include Mispah form (Zwartfontien and Shorrocks series - 25%), Shorrocks and Msinga series (5%), Zwartfontein and Clansthal series (5%), and Mispah form (Klipfontein and Trevanian series - 10%). Rockiness is estimated at 55%.

The slope range of midslopes varies between 6 to 20% with range of slope length ranging between 30 to 300m. Soils found on midslopes include Mispah form (Zwartfontien and Shorrocks series - 25%), Shorrocks and Msinga series (5%), and Zwartfontein and Clansthal series (5%). Rockiness is estimated at 65%.

The footslopes slope range varies between 2 to 8% while the range of slope length ranges between 300 to 1 000m. Soils found on footslopes include Shorrocks and Msinga series (30%), Zwartfontein and Clansthal series (10%), Mispah form (Klipfontein and Trevanian series - 15%), Soetmelk form (Heidelberg and Leksand series – 15%), Bainsvlei form (Lonetree series – 10%), Longlands form (Mkambati series – 5%), Swartland form (Sterkspruit series – 5%), Wasbank form (5%), and Glencoe form (Leslie series – 5%).

Valley bottoms slope range varies between 0 to 1% with range of slope length ranging between 30 to 200m. Soils found on valley bottoms include Longlands form (Mkambati series – 20%), Rockford, Leeufontein and Jozini series (40%), Swartland form (Sterkspruit series – 10%), and stream beds (30%).

Soils are mostly medium sandy loam to sandy clay loam (Soil classification Working Group, 1991). Soil depth varies from 100 to greater than 1 200mm. The geology of this land type is mainly shale, sandstone and conglomerate of the Loskop Formation; some ferrogabbro and ferrodiorite of the Upper zone, and gabbro and norite of the Main zone of the Rustenburg Layered Suite of the Bushveld Complex; rhyolite of the Damwal formation of the Rooiberg Group; and diabase (Land Type Survey Staff, 1987).

In the ***Bd land type*** eutrophic, red soils are not widespread. In this land type four terrain units are present i.e. crests comprising 30% of the land type, midslopes comprising 40% of the land type, footslopes comprising 28% of the land type and valley bottoms comprising 2% of the land type. Terrain type is A3 with more than 80% of the area having slopes less than 8%. Local relief ranges from 90 to 150m.

Crests slope range varies between 0 to 5% with range of slope length ranging between 1 000 to 2 000m. Soils found on crests include Grovedale, Kusasa, Hamman and Sandvlei series (40%), Glenrosa form (25%), Wesselnek, Denhere, Blinkklip, Windmeul, Newcastle and Soetmelk series (5%), Mispah form (Klipfontein series - 20%), and Portsmouth and, Bontberg and Shorrocks series (5%). Rockiness is estimated at 5%.

The slope range of midslopes varies between 3 to 6% with range of slope length ranging between 1 000 to 2 000m. Soils found on midslopes include Grovedale, Kusasa, Hamman and Sandvlei series (25%), Glenrosa form (25%), Wesselnek, Denhere, Blinkklip, Windmeul, Newcastle and Soetmelk series (20%), Mispah form (Klipfontein series - 15%), and Portsmouth and, Bontberg and Shorrocks series (10%). Rockiness is estimated at 5%.

The footslopes slope range varies between 2 to 4% while the range of slope length ranges between 300 to 1 000m. Soils found on footslopes include Grovedale, Kusasa, Hamman and Sandvlei series (25%), Glenrosa form (10%), Wesselnek, Denhere, Blinkklip, Windmeul, Newcastle and Soetmelk series (25%), Mispah form (Klipfontein series - 5%), Portsmouth and, Bontberg and Shorrocks series (10%), Grootfontein, Nyoka and Swartland series (10%), Balfour series (5%), Venda and Jozini series (5%), and Vaalsand series (5%).

Valley bottoms slope range varies between 0 to 1% with range of slope length ranging between 50 to 200m. Soils found on valley bottoms include Grovedale, Kusasa, Hamman and Sandvlei series (20%), Grootfontein, Nyoka and Swartland series (20%), Balfour series (40%), Venda and Jozini series (10%), and Vaalsand series (10%).

Soils are mostly coarse sandy loam to loamy sand or sandy loam (Soil classification Working Group, 1991). Soils depth varies from 200 to greater than 1 200mm. The geology of this land type is predominantly grey to pink coarse-grained granite (Nebro granite); some Ecca sandstone and shale, granophyric gneiss, schist, granulite and rhyolite of the Dennilton Formation of the Groblersdal Group (Land Type Survey Staff, 1987).

The ***Ea land type*** refers to an area more than half of which is covered by soil forms with vertic, melanic, red structured diagnostic horizons. Where duplex soils occur in non-rock land and the aforementioned soils cover a larger area than the duplex soils, or where exposed rock covers more than half of the land type, also qualifies an area for inclusion in the Ea land type. Land with a high base status containing dark coloured and/or red soils that are more often than not clayey, and that are associated with basic parent materials are indicative of this land type.

The Ea land type consists of two terrain units i.e. footslopes comprising 90% of the land type and valley bottoms comprising 10% of the land type. Terrain type is A3 with more than 80% of the area having slopes less than 8%. Local relief ranges from 90 to 150m.

Footslopes slope range varies between 2 to 6% while the range of slope length ranges between 300 to 1500m. Soils found on footslopes include Glendale and Shortlands series (35%), Makatini, Doveton and Shorrocks series (30%), Arcadia and Rydalvale series (20%), Nyoka and Swartland series (10%), and Glengazi and Bonheim series (5%).

Valley bottoms slope range varies between 0 to 1% with range of slope length ranging between 50 to 300m. Soils found on valley bottoms include Arcadia and Rydalvale series (60%), Nyoka and Swartland series (10%), and Glengazi and Bonheim series (30%).

Soils are mostly clay, clay loam and sandy clay (Soil classification Working Group, 1991). Soils depth varies from 450 to greater than 1 200mm. The geology of this land type is mainly gabbro and norite of the Lower zone of the Bushveld Complex (Land Type Survey Staff, 1987).

The ***F land type*** refers to pedologically young landscapes that are not predominantly rock and alluvial or aeolian, in which the main soil forming processes have been rock weathering (Land Type Survey Staff, 1987). The formation of orthic topsoil horizons and clay illuviation have typically given rise to lithocutanic horizons (Land Type Survey Staff, 1987). Dominant soil forms are Glenrosa and Mispah, with Oakleaf present in upland areas (Soil Classification Working Group, 1991).

In the ***Fa land type*** lime in the soil is not commonly encountered and is rare or absent throughout the landscape. In this land type four terrain units are present i.e. crests comprising 45% of the land type, midslopes comprising 40% of the land type, footslopes comprising 14% of the land type and valley bottoms comprising 1% of the land type. Terrain type is A4 with more than 80% of the area having slopes less than 8%. Local relief ranges from 150 to 300m.

Crests slope range varies between 0 to 5% with range of slope length ranging between 300 to 1500m. Soils found on crests include Mispah form (Williamson and Klipfontein series - 20%), Southwold, Oatsdale, Msinga and Hutton series (10%), Oatsdale, Hutton, Farningham and Appam series (25%), and Mispah form (Klipfontein and Williamson series - 20%). Rockiness is estimated at 25%.

The slope range of midslopes varies between 3 to 12% with range of slope length ranging between 300 to 1 500m. Soils found on midslopes include Mispah form (Williamson and Klipfontein series - 10%), Southwold, Oatsdale, Msinga and Hutton series (15%), Arrochar and Burford series (5%), Oatsdale, Hutton, Farningham and Appam series (30%), and Mispah form (Klipfontein and Williamson series - 20%). Rockiness is estimated at 20%.

The footslopes slope range varies between 3 to 6% with the range of slope length ranges between 100 to 400m. Soils found on footslopes include

Oatsdale, Hutton, Farningham and Appam series (50%), Mispah form (Klipfontein and Williamson series - 10%), and Msinga, Hutton and Farningham series (40%).

Valley bottoms slope range varies between 0 to 2% with range of slope length ranging between 50 to 200m. Soils found on valley bottoms include Waldene, Arrochar and Dundee series (100%).

Soils are mostly fine sandy clay loam to sandy clay (Soil classification Working Group, 1991). Soils depth varies from 100 to greater than 1 200mm. The geology of this land type consists of rhyolite from the Selonsrivier Formation of the Rooiberg Group; some Rashoop granophyre and Ecca sandstone (Land Type Survey Staff, 1987).

The ***I land type*** refers to miscellaneous land classes (Land Type Survey Staff, 1987).

The ***land type Ib*** indicates land types with exposed rock (country rock, stones or boulders), which covers 60-80% of the area. Four Ib land types occur on the reserve i.e. Ib10, Ib13, Ib16 and Ib17.

In the ***Ib10 land type*** five terrain units are present i.e. crests comprising 15% of the land type, scarps comprising 10% of the land type, midslopes comprising 65% of the land type, footslopes comprising 5% of the land type and valley bottoms comprising 5% of the land type. Terrain type is D4 with less than 20% of the area having slopes less than 8%. Local relief ranges from 150 to 300m.

Crests slope range varies between 0 to 15% with range of slope length ranging between 50 to 300m. Soils found on crests include Mispah form (25%), Southwold and Blinkklip series (10%), and Msinga and Shorrocks series (10%). Rockiness is estimated at 55%.

Scarps slope range is greater than 100% with range of slope length ranging between 10 to 200m. Soils found on scarps are Mispah form (10%). Rockiness is estimated at 90%.

The slope range of midslopes varies between 15 to greater than 100% with range of slope length ranging between 300 to 800m. Soils found on midslopes include Mispah form (15%), Southwold and Blinkklip series (5%); Msinga and Shorrocks series (5%), Williamson series (5%), and Swartland form (5%). Rockiness is estimated at 65%.

The footslopes slope range varies between 6 to 15% while the range of slope length ranges between 50 to 300m. Soils found on footslopes include Mispah form (10%), Southwold and Blinkklip series (5%), Msinga and Shorrocks series (15%), Burford series (5%), Swartland form (20%), and Msinga, Shorrocks and Bainsvlei series (25%). Rockiness is estimated at 20%.

Valley bottoms slope range varies between 0 to 5% with range of slope length ranging between 10 to 50m. Soils found on valley bottoms include Jozini and Leeufontein series (40%), Dundee form (30%), and stream beds (30%).

Rocks predominate in the landscape, with soils being mostly fine sandy clay loam (Soil classification Working Group, 1991). Soils depth varies from 100 to greater than 1 200mm. The geology of this land type is predominantly rhyolite from the Selonsrivier and Damwal Formations of the Rooiberg Group, and some quartzite of the Selonsrivier Formation (Land Type Survey Staff, 1987).

In the ***Ib13 land type*** four terrain units are present i.e. crests comprising 25% of the land type, midslopes comprising 65% of the land type, footslopes comprising 9% of the land type and valley bottoms comprising 1% of the land type. Terrain type is C4 with 20 to 50% of the area having slopes less than 8%. Local relief ranges from 150 to 300m.

Crests slope range varies between 0 to 15% with range of slope length ranging between 100 to 200m. Soils found on crests include Mispah form (Williamson, Klipfontein, Southwold and Msinga series - 30%), Lundini and Burford series (5%), and Msinga, Southwold and Glencoe series (10%). Rockiness is estimated at 55%.

The slope range of midslopes varies between 12 to 100% with range of slope length ranging between 400 to 800m. Soils found on midslopes include Mispah form (Williamson, Klipfontein, Southwold and Msinga series - 25%), and Lundini and Burford series (10%). Rockiness is estimated at 65%.

The footslopes slope range varies between 6 to 15% while the range of slope length ranges between 30 to 300m. Soils found on footslopes include Mispah form (Williamson, Klipfontein, Southwold and Msinga series - 30%), Lundini and Burford series (5%), Msinga, Southwold and Glencoe series (40%), and Waldene, Arrochar, Dundee and Jozini series (5%). Rockiness is estimated at 20%.

Valley bottoms slope range varies between 1 to 12% with range of slope length ranging between 10 to 100m. Soils found on valley bottoms include Msinga, Southwold and Glencoe series (30%), and Waldene, Arrochar, Dundee and Jozini series (70%).

Rocks predominate in the landscape, with soils being mostly fine sandy clay loam to sandy clay loam (Soil classification Working Group, 1991). Soils depth varies from 100 to 900mm. The geology of this land type is predominantly rhyolite from the Selonsrivier and Damwal Formations of the

Rooiberg Group, and some Rashoop granophyre (Land Type Survey Staff, 1987).

In the ***Ib16 land type*** five terrain units are present i.e. crests comprising 15% of the land type, scarps comprising 5% of the land type, midslopes comprising 55% of the land type, footslopes comprising 15% of the land type and valley bottoms comprising 10% of the land type. Terrain type is D5 with less than 20% of the area having slopes less than 8%. Local relief ranges from 150 to greater than 1 200m.

Crests slope range varies between 0 to 15% with range of slope length ranging between 200 to 600m. Soils found on crests include Mispah form (15%), Glenrosa form (Platt series - 5%), Mossdale and Soweto series (15%), and Middelburg and Kyalami series (10%). Rockiness is estimated at 55%.

Scarps slope range is greater than 100% with range of slope length ranging between 100 to 300m. Soils found on scarps include Mispah form (10%). Rockiness is estimated at 90%.

The slope range of midslopes varies between 12 to greater than 100% with range of slope length ranging between 400 to 1 000m. Soils found on midslopes include Mispah form (5%), Glenrosa form (Platt series - 5%), Mossdale and Soweto series (10%), and Middelburg and Kyalami series (5%). Rockiness is estimated at 75%.

The footslopes slope range varies between 2 to 12% while the range of slope length ranges between 50 to 500m. Soils found on footslopes include Mispah form (10%), Glenrosa form (Platt series - 10%), Mossdale and Soweto series (10%), Middelburg and Kyalami series (10%), Waterridge, Grovedale and Cartref series (10%), and Rondevlei and Hamman series (10%). Rockiness is estimated at 40%.

Valley bottoms slope range varies between 0 to 2% with range of slope length ranging between 50 to 300m. Soils found on valley bottoms include Dundee form (40%), Vaalriver and Levubu series (30%), and stream beds (30%).

Rocks predominate in the landscape, with soils being mostly medium coarse sand to loamy sand (Soil classification Working Group, 1991). Soils depth varies from 150 to greater than 1 200mm. The geology of this land type is mostly sandstone from the Wilgerivier Formation of the Waterberg Group (Land Type Survey Staff, 1987).

In the ***Ib17 land type*** two terrain units are present i.e. midslopes comprising 95% of the land type and valley bottoms comprising 5% of the land type. Terrain type is C4 with 20 to 50% of the area having slopes less than 8%. Local relief ranges from 150 to 300m.

The slope range of midslopes varies between 12 to 100% with range of slope length ranging between 200 to 500m. Soils found on midslopes include Mispah form (Williamson, Southwold, Msinga and Klipfontein series - 40%). Rockiness is estimated at 60%.

Valley bottoms slope range varies between 3 to 15% with range of slope length ranging between 10 to 50m. Soils found on valley bottoms include Mispah form (Williamson, Southwold, Msinga and Klipfontein series - 30%), Waldene series (30%), and Msinga, Glencoe and Doveton series (20%). Rockiness is estimated at 20%.

Rocks predominate in the landscape, with soils being mostly fine sandy clay loam (Soil classification Working Group, 1991). Soils depth varies from 100 to 900mm. The geology of this land type is mostly Rhyolite from the

Schrikkloof Formation of the Rooiberg Group (Land Type Survey Staff, 1987).

3.1.6 *Vegetation*

The LDNR is located in the savanna biome (Rutherford & Westfall, 1994; Low & Rebelo, 1996; Scholes, 1997; Bredenkamp & van Rooyen, 1998; Mucina & Rutherford, 2006). Savanna is described as vegetation with a herbaceous, usually graminoid lower layer, consisting of an upper layer of woody plants which can vary from sparse cover to 75% canopy cover (Edwards, 1983).

According to Rutherford & Westfall (1994), savanna plants are well adapted to withstand fire. Savanna fires are usually surface fires, the intensity of which are determined by their timing, amount of dry material available, and the associated fire regimes. While accidental fires are encountered on the reserve, fire mostly occurs as controlled block burns for management purposes i.e. for fire breaks, to remove moribund plant material, to destroy or suppress unacceptable or invasive plant species, to stimulate game movements and to control parasites such as ticks.

According to Acocks (1988), the reserves vegetation is classified as a mixture of Mixed Bushveld (Acocks veld type 18) and Sourish Mixed Bushveld (Acocks veld type 19), the Mixed Bushveld being extremely heterogeneous (Fig 3.5a).

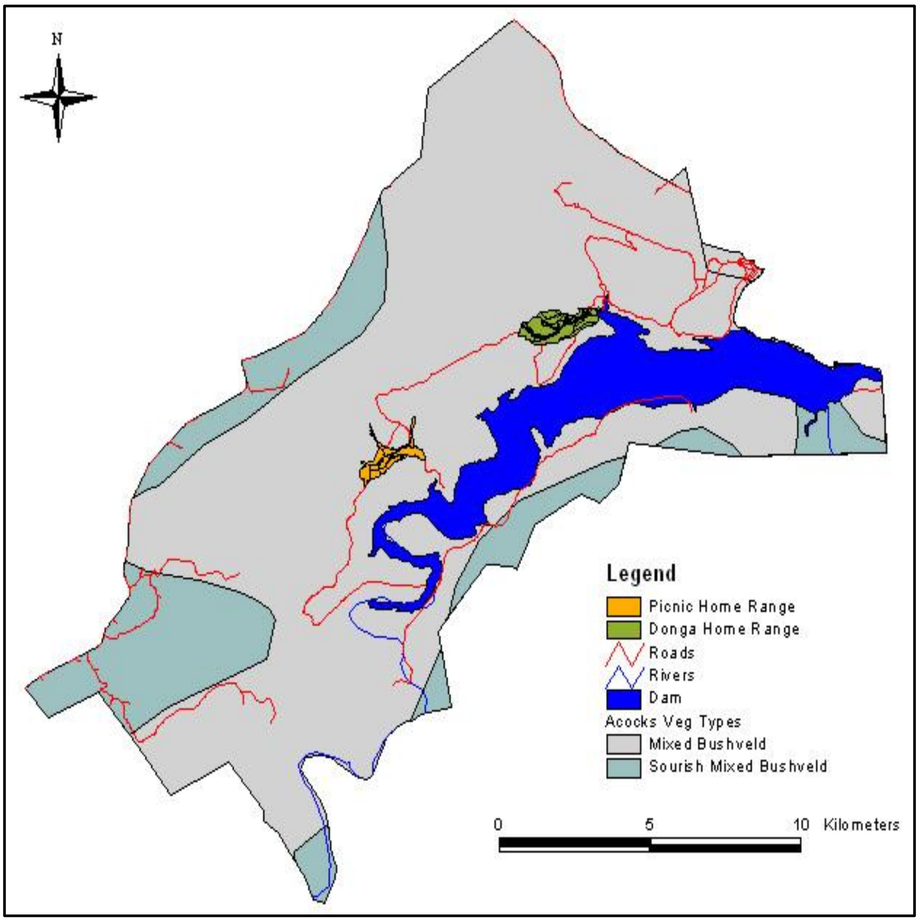
Bredenkamp & van Rooyen (1998), classify LDNR’s vegetation as Mixed Bushveld (veld type 18), characterized by vegetation that varies from dense, short bushveld to open tree savanna.

According to Mucina & Rutherford (2006), vegetation occurring on the mountains of the LDNR and surrounding areas belongs to the Central Sandy

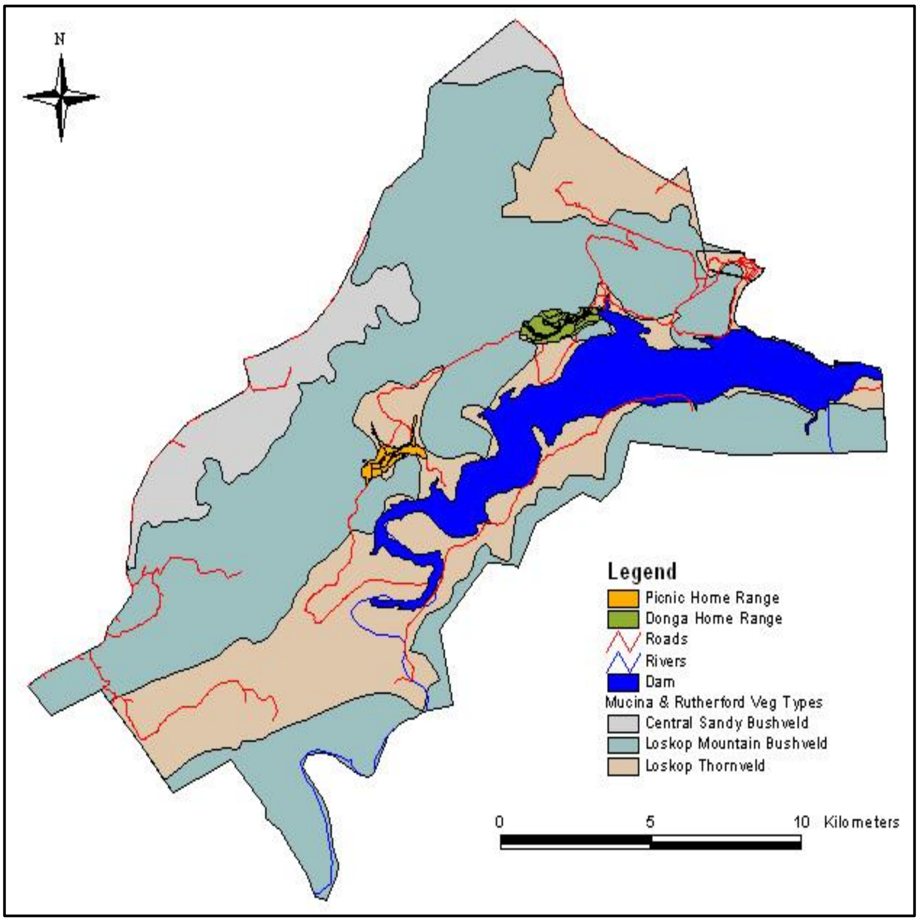
Bushveld (SVcb 12) and the Loskop Mountain Bushveld (SVcb 13) Vegetation Units, whereas vegetation occurring in the valley of the Olifants River which includes the Loskop Dam and surrounding areas belongs to the Loskop Thornveld Vegetation Unit (SVcb 14) (Fig 3.5b). These areas previously referred to as sourish mixed bushveld by Tainton (1999), occur as a maze of variation and transitions providing moderately good to poor grazing.

Loskop Mountain Bushveld is characterized by low mountains and ridges containing open tree savanna on lower-lying areas and a denser mostly broad-leafed tree savanna on lower slopes and midslopes (Mucina & Rutherford, 2006). The herbaceous layer is dominated by grasses. Endemic taxa include the geophytic herb *Gladiolus pole-evansii* and the succulent herb *Haworthia koelmaniorum* - both have been recorded for the reserve. There is a wide diversity of plant communities in the area that can be attributed to the great variation in geology, pedology and topography.

The Loskop Thornveld is characterized by valleys and plains of the upper Olifants River catchment (Mucina & Rutherford, 2006). Vegetation is mostly open, deciduous to semi-deciduous, tall, thorny woodland often dominated by various *Acacia* sp. The small tree *Acacia theronii* occurs in the Loskop thornveld and is considered a biogeographically important taxon for the region; however, it has not yet been recorded for the reserve to date.


N
Legend
Picnic Home Range
Donga Home Range
Roads
Rivers
Dam
Acocks Veg Types
Mixed Bushveld
Sourish Mixed Bushveld
0
5
10
Kilometers

(a)



(b)

Figure 3.5. Veld Types of the LDNR according to (a) Acocks (1988) and (b) Mucina & Rutherford (2006).

Vegetation for the Donga troop's home range is broadly classified as *Acacia caffra-Rhus leptodictya* woodland and the Picnic troop's home range is broadly classified as an *Acacia karroo-Dichrostachys cinerea* shrubland; however, for the purposes of this study it was deemed necessary to do a more detailed vegetative analysis of the areas (Chapter 4).

Plant species occurring on the LDNR are represented by 1071 plant taxa as listed in Appendix 1.

3.1.7 *Fauna*

The various mammalian, reptilian and amphibian species occurring on the LDNR are listed in Appendix 2.

3.1.8 *Climate*

LDNR is located in a summer rainfall area with moderate to very hot summers and mild to cold winters with the occurrence of frost on mountain tops and in low-lying valley bottoms (Theron, 1973). Rainfall occurs mainly in the form of short-lived high intensity thunderstorms associated with strong south-westerly winds.

According to Low & Rebello (1998), the rainfall for Mixed Bushveld varies from 350 to 650mm per annum. The majority of rainfall occurs in the summer season (November to April). Temperatures range from a minimum of -8°C to a maximum of 40°C, with an average of 21°C (Low & Rebello, 1998).

Temperatures experienced on high and low lying areas of the reserve differ noticeably. December's mean daily maximum temperatures for the low and high lying areas are 29.8°C (absolute maximum 39.7°C), and 26.5°C (absolute maximum 36.1°C) respectively. The mean daily minimum temperature in the low and high lying areas for the month of July are 8.1°C (absolute minimum 1.3°C), and 2.0°C (absolute minimum -11.7°C) respectively.

Low-lying areas are generally frost free, but temperatures can sporadically drop below 3°C. In high lying areas the frost period extends from May to September, with a few days of severe frost being recorded.

Due to the broken topography of the reserve, local variations in microclimate are common. Direct radiation from the sun varies with aspect and altitude, with north-facing slopes receiving more direct radiation than south-facing slopes, especially in winter. Mean maximum temperatures on north-facing slopes are 30.5°C, compared to the 28.7°C on south-facing slopes. Mean minimum temperatures on north-facing slopes are 11.7°C, compared to 10.4°C on south-facing slopes. In winter the mean maximum temperature on north-facing slopes is 24.5°C compared to 22.6°C for south-facing slopes.

The average annual rainfall for the study area, as measured by weather stations located at various pickets and at the reserve's entrance for the period 1 May 2002 to 30 April 2007 was 654mm, with a high of 931mm and a low of 365mm recorded for 1 May 2005 to 30 April 2006 and 1 May 2006 to 30 April 2007 respectively. The study period was a lot drier for both the dry and the wet seasons compared to the average for the last five years. Average monthly rainfall for the dry season (1 May 2006 to 31 October 2006) during the study period was 6mm compared to 11mm for the period 1 May 2002 to 31 October 2006 (Fig 3.6). Average monthly rainfall for the wet season (1 November 2006 to 30 April 2007) during the study period was 55mm compared to 87mm for the period 1 November 2002 to 30 April 2007 (Fig 3.6).

Average annual temperature for the period 1 May 2002 to 30 April 2007 was 21°C, with mean temperatures varying from 17°C during the dry winter season to 24°C in the wet summer season (Fig 3.6). During the study period the mean temperature for the dry winter season was 18.5°C which was warmer than for the period 1 May 2002 to 30 April 2007 and the mean temperature for the wet winter season was 24°C which was the same as for the period 1 May 2002 to 30 April 2007. A mean minimum temperature of 8.5°C (July 2006) and a mean maximum of 32°C (February 2007) was recorded for the study period.

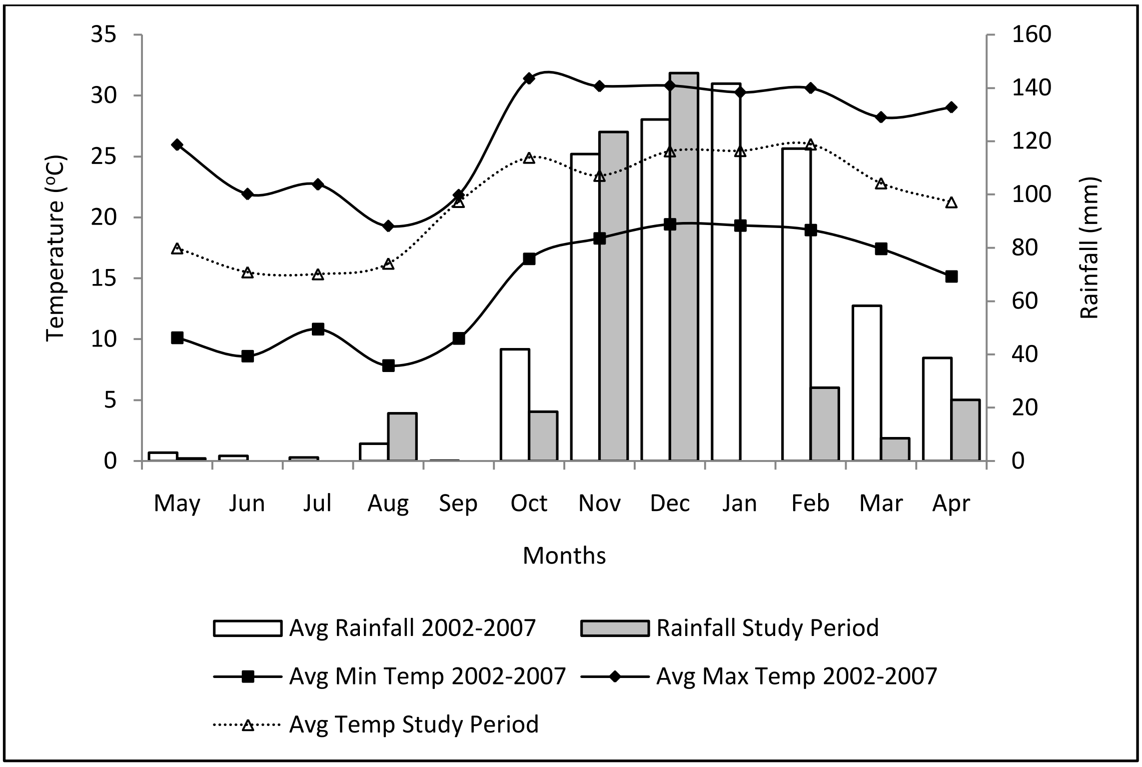


Figure 3.6. Average monthly rainfall and temperatures for LDNR from 1 May 2002 to 30 April 2007 compared to those for the study period 1 May 2006 to 30 April 2007.

3.2 Study subjects

The study subjects were two vervet monkey troops referred to as the Donga and Picnic troops. Troop names were derived from the general location of their home ranges, with the Donga troop living in an area comprising several Dongas, and the Picnic troop living in the vicinity of a Picnic spot. The study troops were initially identified by walking through riverine thickets and areas containing resource tree species until either an auditory cue was heard or a visual sighting of vervets was made. Four potential troops were identified and an attempt was made to locate and follow the various troops on foot over a three month period prior to selecting the two troops for the study and beginning habituation. The troops selected were the ones that accepted the presence of researchers fastest and that were located most often. Due to the nature of the research site and because multiple groups of researchers were going to be working with the troops, it was important to select troops with territories that were close to roads so that equipment could be transported. It was also important to select troops that were not occupying adjacent home ranges, but which used habitats that varied sufficiently to facilitate the examination of variation itself.

Troop compositions at the start and end of the study period are shown in Table 3.1. Changes to the Donga troop over the study period were as follows: one adult male died, one left/disappeared and one arrived; one adult female left/disappeared/died; one sub-adult male left/disappeared; two juveniles left/disappeared; six births. Changes to the Picnic troop over the study period were as follows: one adult male left/disappeared and one arrived; one adult female died; one sub-adult male left; one baby died and two were born.

Table 3.1. Troop composition at the start and end of the study period.

	Donga		**Picnic**	
Age-sex class	**Start of study**	**End of study**	**Start of study**	**End of study**
Adult male	3	3	3	3
Adult female	5	5	4	3
Sub-adult male	2	0	1	1
Sub-adult female	1	1	0	0
Juvenile	3	1	3	5
Baby	1	6	4	2
Total	**15**	**16**	**15**	**14**

3.3 Methods

A broad overview of the methods used in this study is provided here. Detailed descriptions of the methods used for specific components of the study will be provided in the relevant chapters.

I habituated two vervet monkey troops over a six month period from June 2005 to December 2005. During habituation I identified the study subjects and noted troop structure and composition. After habituation I undertook monthly field trips to LDNR for vervet monkey monitoring and plant data collection over an 18-month period from January 2006 to June 2007. For the duration of the study I tracked any changes to troop structure and composition.

I followed the two troops on foot from a distance of between five and 15 metres for as long as possible on data collection days. I collected data on an average of 9.6 days a month, and this provided 174 days of monkey data, of which 64 constituted all-day follows. I recorded data using a PALM HANDSPRING^{TM} data-logger, pre-loaded with PENDRAGON FORMS^{TM} software.

I took time-interval scan samples approximately every 30 minutes from all visible animals (Altmann, 1974). Duration of scan samples varied, based on how many individuals were available to be scanned, but did not exceed fifteen minutes per scan. I avoided repeatedly sampling conspicuous individuals by moving throughout the troops, and by sampling animals that were in clear view as well as those that were hidden.

Phytosociology related fieldwork was undertaken during November and December 2005, January 2006 and in December 2006.

3.3.1 *Study site*

For orientation purposes I created a scale map depicting the location of the LDNR in South Africa.

I determined and described the topography, geology, pedology, land types, general vegetation and fauna for the reserve using available literature.

I manually captured climate data for the reserve and surrounds from 1992 to 2007 using data collection sheets provided by reserve staff. Only data for the period 1 May 2002 to 30 April 2007 was described, graphically depicted and used for comparative purposes. Data from earlier years were discarded as they were sparse and inaccurate.

The boundaries and extents of the two troops' territories were determined and delineated. Home range boundaries were created using GPS co-ordinates collected while they were being followed for habituation purposes, during daily observational follows over the study period, and generally whenever they were encountered.

All vervet troop location waypoints and route co-ordinates were transferred into ArcView GIS software v. 3.3 (ESRI, Redlands, CA, USA). I did home range analysis in Arcview using the Animal Movement Extension Package v. 2.04 Beta (Hooge & Eichenlaub, 1997) in conjunction with Arcviews Spatial Analyst Extension v. 2.0a. Within the Animal Movements Extension, I used the minimum convex polygon method for determining the locations and sizes of each troops overall home range. Central core areas, '*the areas where the animals habitually sleep, feed and spend the majority of their time*', as defined by Hayne *et al.* (1949) and Samuel *et al. (*1985), was operationally determined using minimum convex polygons encompassing only the full day ranges for each respective troop. The full day ranges used for my analyses are therefore only a subset of the data used to determine the overall home ranges.

Whenever the vervets were encountered, any foods they were consuming were collected for dietary analysis.

3.3.2 *Phytosociology*

Due to the nature of the encompassing vervet study and the associated requirement for increased accuracy, a series of 1:10 000 digitized ortho photos of the LDNR was used in this study. Although there were broad scale similarities between this study and those of Theron (1973) and Götze *et al*. (1998), overall area selection and plot placement was different as this study concentrated on two vervet monkey home ranges and not the overall area. The current study consequently presents a more explicit representation of the vegetation for the two home ranges.

Environmental data collected included altitude, latitude and longitude, aspect, slope, percentage rockiness, percentage erosion, basic soil type, evidence of animal activity and fire damage.

The phytosociology of the two vervet monkey home ranges was determined using Braun-Blanquet procedures and the various plant communities occurring within each home range was demarcated.

3.3.3 *Habitat and dietary selectivity*

I extracted dietary information and food type preferences from my scan data for the two troops. A total of 2 641 individual foraging scans were collected for analysis.

I looked at the two troops' diets and identified which food items they consumed, determining cumulative species percentage contributions to their diets. I also examined seasonal species utilisation of their main food resources, and calculated their plant community and main resource species electivity using Ivlev's Electivity Index (Krebs, 1989).

3.3.4 *Phenology and energetic content of food*

I undertook monthly observations of leafing, budding, flowering, and fruiting on 113 tagged trees from July 2006 to June 2007. Over the 12 month period, I randomly selected, identified and tagged specimens of trees the vervets fed on to determine seasonal resource availability and abundance.

Using previously determined vervet home ranges and the plant communities present within these home ranges, I selected potential vervet resource species for phenological monitoring and data collection. I selected trees for tagging by taking resource plant species occurring in all communities of both the Donga and Picnic home ranges and listed them in three height classes (<1m, 1-3m, and >3m). For determining the numbers of trees to tag for monthly monitoring, and for samples to be sufficiently representative, I extracted 10% of each species in each height class. In the field I identified samples of selected trees, recorded their GPS locations and tagged them with numbered aluminium disks for identification and data collection.

Initially I collected benchmark information on all tagged trees; thereafter, over the duration of the study period, I visited tagged trees on a monthly basis to collect phenological data.

I collected tree dimension data using the '*one-man*' method (Smit, 1996) and quantified available resources using a combination of visual estimates, actual fruit counts and canopy volume extrapolation techniques.

3.3.5 *Energy and ranging patterns*

I used phenological data collected over a 12 month wet and dry cycle during the 18 month study period to generate representative monthly spatial energy grids, using interpolative techniques. Such sampling provided representative '*snapshots*' of spatial and temporal shifts in resources (Barbour *et al.*, 1987; Kent & Coker, 1997; de Bie *et al*., 1998).

Energy grids were created for both the Donga and Picnic areas by extrapolating calculated monthly energy figures (for trees and plots across the respective home ranges) using Kriging with an assumed linear variogram as the interpolation method. For plant communities occurring within the home ranges, where common resource plant species occurred in all phytosociology plant plots for the community, baseline energy values of those specific species were incorporated into all grid cells occurring within the plant community boundaries prior to interpolation.

To determine whether actual routes taken by the vervets had more energy than any alternative routes available to them, but not taken, I generated a series of random routes to which they could be compared. The randomness of the routes was constrained by the requirements that they be the same length as the original route and that they had to start and end at the same points as the original route.

3.3.6 *Statistics*

Wherever possible parametric tests were used; however, when data transformations were unable to induce normality, non-parametric tests were used (Siegel & Castellan, 1988; Zar, 1999; Field, 2005). Statistical tests were two-tailed except when specified otherwise. For all tests *P* was set at 0.05. All statistical analyses were performed with the SPSS^{TM} (version 11.5.0) statistical package. For Chapter 7, binomial tests were 1-tailed as the predictions were directional.

CHAPTER 4

PHYTOSOCIOLOGY

4.1 Introduction

Phytosociology is concerned with the methods for recognizing and defining plant communities, collectively termed '*classification'* (Barbour *et al.,* 1987; Kent & Coker, 1997). The main function of classification is to generate a set of plant communities for a particular area being investigated. Individual quadrats or vegetation samples are grouped together on the basis of similarities in their floristic composition into such plant communities. There are two main approaches to doing plant classifications, the '*subjective*' and the '*objective*' approaches (Barbour *et al.,* 1987; Kent & Coker, 1997). Due to the popularity and widespread use of the subjective Braun-Blanquet technique, and because of the applicability of its application in the Southern African sub-region (van Rooyen *et al*. 1981; Tueller, 1988; Fuls *et al*. 1992; Fuls, 1993; Bezuidenhout, 1996; Brown, 1997; Barrett *et al.,* 2006), the technique has been selected for use in this study. Vegetation assessments are a prerequisite for any ecological or habitat related research (van Rooyen *et al*., 1981).

To date no ecologically based vervet studies have been undertaken at LDNR. In general, very few detailed ecological studies of vervets have been undertaken in temperate sub-tropical areas (Struhsaker, 1967; Harrison, 1983, 1984; Whitten, 1988; Lee & Hauser, 1998; Isbell *et al*., 1998; Pruetz & Isbell, 2000; Barrett, 2005). At these low latitudes, overall habitat productivity is high and seasonal variability is relatively constrained (Caughley & Sinclair, 1994). Concerning vegetation studies undertaken at LDNR, Theron (1973) conducted the first detailed vegetation study of the reserve, and did a broad scale analysis of the overall vegetation using what appears to be a scale of

1:50 000 for his delineation of the area. Subsequently, Götze *et al*. (1998), using 1:30 000 aerial photographs, classified and assessed additional areas that have been added onto the north-eastern section of the reserve (two new farms called Rietfontein and Parys).

This study provides the basic framework for an encompassing research project on how two troops of vervet monkeys use their home ranges to obtain temporally and spatially distributed resources through their ranging patterns. Of interest is how the two home ranges vary in terms of vegetative structure and available resources. Here, the various plant communities that make up the two home ranges of the study subjects is identified, described and mapped, and the general structure of the areas is determined. A floristic analysis of both home ranges is undertaken and the results are compared. The results from this study are used for further dietary, phenological, energy and ranging pattern analyses in subsequent chapters.

4.2 Methods

I stratified the study area into physiognomic-physiographic units (Barbour *et al.,* 1987; Kent & Coker, 1997). A total of 69 sample plots (43 in the Donga home range and 26 in the Picnic home range) were located in a randomly stratified manner within these units to ensure that all variations in the vegetation are considered and sampled. Plot sizes were fixed at 400m^2 (Barbour *et al.,* 1987; Brown & Bredenkamp, 1994; Brown, 1997).

In light of taxon names constantly changing, this publication conforms to those of Arnold & de Wet (1993). Germishuizen & Meyer (2003) is also referenced in an effort to maintain the correctness of taxa names.

In each sample plot I recorded all plant species and assessed cover abundance using a modified Braun-Blanquet cover abundance scale (Mueller-Dombois & Ellenberg, 1974; Barbour *et al.,* 1987):

Scale	**Description**
r	One or few individuals with less than 1% cover of the total sample plot area.
+	Occasional and less than 1% cover of the total sample plot area.
1	Abundant with low cover or less abundant but with higher cover, 1-5% cover of the total sample plot area.
2	Abundant with 6-25% cover of the total sample plot area, irrespective of the number of individuals.
2a	6-12.5% cover.
2b	12.6-25% cover.
3	26-50% cover of the total sample plot area, irrespective of the number of individuals.
4	51-75% cover of the total sample plot area, irrespective of the number of individuals.
5	76-100% cover of the total sample plot area, irrespective of the number of individuals.

I estimated erosion within the following classes (Matthee & van Schalkwyk, 1984):

Class 1	0-25% - Slight.
Class 2	26-50% - Moderate loss of topsoil with slight soil cutting by run-off channels or gullies.
Class 3	51-75% - Severe loss of topsoil with marked soil cutting by run-off channels or gullies.
Class 4	76-100% - Total loss of topsoil and exposure of subsoil or deep intricate soil cutting by gullies.

Slope was estimated within the following categories (Barrett *et al*., 2006):

Level	0-3^0
Gentle	4-8^0
Moderate	9-16^0
Steep	17-26^0
Very steep	27-45^0

Tree densities were determined by counting the number of individual species within a quadrat and dividing this total by the number of quadrats in the community being sampled. Results were multiplied by the number of quadrats in a hectare to get density per hectare.

I analysed floristic data according to Braun-Blanquet procedures using the TURBOVEG suite (Hennekens, 1998), which includes the Two-way indicator species analysis multivariate classification technique (TWINSPAN) for deriving an initial approximation of the main plant communities (Hill, 1979). This numerical classification technique is regarded as a successful approach to vegetation classification by various phytosociologists (Brown & Bredenkamp, 1994; Bredenkamp & Bezuidenhout, 1995; Brown *et al*., 1996; Cilliers, 1998; Bredenkamp & Brown, 2006). The visual editor MEGATAB (Hennekens, 1996) was used to generate phytosociological tables. Further refinement of the classification was undertaken through the application of Braun-Blanquet procedures (Barbour *et al.,* 1987; Bredenkamp *et al.,* 1989; Kooij *et al.,* 1990; Bezuidenhout, 1993; Eckhardt, 1993; Brown & Bredenkamp, 1994; Kent & Coker, 1997). Using the final phytosociological tables and habitat information collected during sampling in the field, I identified, described and ecologically interpreted the different plant communities.

Using '*diagnostic species*' as defined by Westhoff & van der Maarel (1978), I identified the various plant communities occurring in the two vervet troops home ranges. Species were defined as diagnostic if they were present in at least 20% of the relevés of a particular plant community, whilst simultaneously being absent or less frequent in other communities. An adaptation of this definition was used in this study, with a species considered diagnostic for a particular community if it was present within the following constancy parameters (Grobler *et al*., 2006):

≥ 70% and with a constancy of ≤ 35% in all other communities
≥ 50% and with a constancy of ≤ 25% in all other communities
≥ 20% and with a constancy of ≤ 13% in all other communities.

'*Dominant species*' were defined as all species that had cover values exceeding a predetermined cover threshold value in any relevé of a selected vegetation unit (Westhoff & van der Maarel, 1978). For this study the vegetation was mostly heterogeneous and dominant species were not restricted to specific threshold values, but rather to explicit species with the highest overall cover abundance in the community.

Plant family representation within the two home ranges was compared to determine whether the two areas differed noticeably or not.

4.3 Results

4.3.1 *Donga home range classification*

The Donga home range could typically be classified as *Acacia caffra-Rhus leptodictya* woodland; however for the purposes of the encompassing vervet study it was necessary to do a more detailed vegetative analysis of the area. Noteworthy species occurring within the home range included the small erect deciduous tree *Dombeya rotundifolia*, the tree *Faurea saligna,* the deciduous shrub *Dichrostachys cinerea*, the erect shrub *Lippia javanica*, the spiny multi-stemmed shrub *Rhus pyroides,* the multi-stemmed *Grewia* spp. shrubs, the shrub *Euclea crispa,* and the tufted perennial grasses *Setaria sphacelata var. sphacelata* and *Panicum maximum.*

The Donga home range was 224ha in size. The analysis resulted in the identification of the following seven plant communities (Fig 4.1), which could be grouped into three major community types (Table 4.1):

1. *Lippia javanica-Loudetia simplex* Shrubland.
    1.1 *Lippia javanica-Loudetia simplex-Sclerocarya birrea* Woodland.
    1.2 *Lippia javanica-Loudetia simplex-Acacia caffra* Woodland.
2. *Acacia nilotica-Acacia caffra* Woodland.
    2.1 *Acacia nilotica-Acacia caffra-Cymbopogon plurinodis* Shrubland.
    2.2 *Acacia nilotica-Acacia caffra-Tragus berteronianus* Woodland.
    2.3 *Acacia nilotica-Acacia caffra-Elionurus muticus* Woodland*.*
3. *Olea europea subsp. africana-Rhus leptodictya* Woodland.
    3.1 *Olea europea subsp. africana-Rhus leptodictya-Carissa bispinosa* Woodland.
    3.2 *Olea europea subsp. africana-Celtis africana-Mimusops zeyheri* Woodland.

Table 4.1. Phytosociological table of the vegetation for the Donga troops home range.

Community Number	1													2														3																% Constancy	
	1.1				1.2									2.1					2.2				2.3					3.1							3.2										
Relevé numbers	18	19	20	29	13	15	12	14	21	25	22	23	24	11	26	27	28	30	1	2	3	4	8	9	10	16	17	5	6	7	34	32	35	33	39	44	36	38	40	42	37	41	43	Main Community	Other Communities
Species Group A																																													
Loudetia simplex	4	4	3	b	.	1	.	1	.	b	1	1	+	1	.	.	.	.	.	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	77	10
Ximenia caffra	1	.	1	1	1	1	1	.	1	1	1	1	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	85	7
Mundulea sericea	1	1	.	1	.	.	.	1	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	38	0
Xerophyta retinervis	+	.	+	+	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	46	3
Species Group B																																													
Sclerocarya birrea	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	+	.	.	.	.	.	.	.	b	.	.	.	.	.	.	.	.	.	.	.	.	75	8
Asparagus densiflorus	1	1	.	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	75	5
Eragrostis racemosa	1	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	75	0
Obetia tenax	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	25	0
Strychnos madagascariensis	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	25	0
Acacia dealbata	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	25	0
Dioscorea sylvatica	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	25	3
Species Group C																																													
Ozoroa paniculosa	.	.	.	b	.	1	.	.	.	.	1	1	1	.	.	.	.	.	.	.	.	.	b	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	44	9
Trachypogon spicatus	.	.	.	.	1	.	.	1	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	33	0
Eragrostis pseudosclerantha	.	.	.	1	.	.	.	1	.	b	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	33	6
Tapiphyllum parvifolium	1	.	.	.	.	.	.	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	22	3
Becium obovatum	.	.	.	.	.	+	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	22	0
Melinis nerviglumis	.	.	+	.	.	.	.	.	+	.	.	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	33	6
Species Group D																																													
Heteropogon contortus	1	1	+	1	.	.	.	.	1	1	1	1	1	.	1	1	1	1	.	.	.	.	.	b	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	72	12
Themeda triandra	.	.	.	.	.	.	.	+	1	.	1	.	.	1	.	.	.	1	.	.	.	+	.	.	.	.	.	.	.	.	.	+	1	.	.	.	.	.	.	.	.	.	.	28	12
Species Group E																																													
Hyparrhenia hirta	+	1	4	.	1	.	4	b	+	1	1	+	.	1	1	b	1	.	1	1	.	b	3	+	1	.	b	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	78	6
Combretum apiculatum	.	.	.	b	+	1	.	.	1	.	.	.	.	.	.	+	.	+	b	1	1	.	1	b	1	b	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	52	0
Lannea discolor	1	.	.	.	+	1	.	.	1	b	.	.	.	.	.	.	.	.	b	1	.	.	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	37	0
Bridelia mollis	.	.	.	b	.	1	.	.	1	.	.	.	.	.	.	1	.	1	.	1	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	30	0
Species Group F																																													
Acacia nilotica	.	.	.	1	.	.	.	.	.	1	.	.	.	+	b	b	b	b	1	+	1	b	.	1	+	1	b	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	93	10
Eragrostis lehmanniana	.	.	.	.	.	.	.	.	.	.	.	.	.	1	b	1	+	1	.	+	1	1	b	.	1	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	71	3
Elionurus muticus	.	.	.	.	.	.	1	1	.	.	.	.	.	b	.	.	.	.	4	.	.	1	.	3	1	3	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	50	10
Species Group G																																													
Cymbopogon plurinodis	.	.	.	.	.	.	.	.	.	.	.	1	1	.	1	1	b	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	80	5
Helichrysum rugulosum	.	.	.	.	.	.	1	.	.	.	.	.	.	+	.	b	b	1	.	.	.	.	.	.	1	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	80	8
Acacia tortilis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	b	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	b	.	.	.	.	.	.	.	.	.	.	.	40	3

Species Group H

Tragus berteronianus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	50	0
Asparagus transvaalensis	.	.	.	1	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	.	.	.	.	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	50	10

Species Group I

Gymnosporia buxifolia	.	.	.	.	.	.	.	+	.	.	.	.	.	1	1	b	.	.	+	+	b	.	.	1	1	.	1	1	.	1	1	1	1	.	1	.	.	.	.		.	.	.	67	9
Carissa bispinosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	+	1	+	.	.	.	.	.	+	1	1	1	1	.	b	.	.	.		.	.	.	.	+	52	5
Grewia flavescens	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	1	.	.	1	1	+	1	.	.	1	.	.	1	+	1	.	.	1	.	.	1	.	.	.	1	.	.	48	14
Asparagus africanus	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	+	.	.	.	1	1	.	.	.	.	.	.	1	1	.	+	.	.	.	.	+	.	.	.	.	.	.	33	9

Species Group J

Dichrostachys cinerea	1	1	1	b	1	1	.	1	.	1	1	1	1	1	b	1	1	1	1	1	1	b	b	b	1	b	.	1	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	82	0
Lippia javanica	+	+	1	1	+	+	+	+	+	1	1	+	1	.	1	1	1	1	+	1	1	1	1	1	1	.	+	+	.	.	1	1	1	.	.	.	.	.	.	.	.	.	.	85	0
Solanum panduriforme	1	+	1	1	.	+	.	1	1	1	.	.	+	.	b	+	1	1	.	1	.	+	.	.	1	.	1	1	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	59	0
Setaria sphacelata var. sphacelata	1	b	3	.	4	4	4	3	4	3	4	4	4	3	1	.	.	+	1	+	.	.	.	+	.	.	.	.	.	.	3	1	4	.	.	.	.	.	.	.	.	.	.	62	0
Pellaea calomelanos	1	.	1	1	.	1	+	+	1	.	1	+	1	.	.	.	.	.	.	.	.	.	1	.	.	b	.	.	.	+	.	.	1	.	.	.	.	.	.	.	.	.	.	41	0
Combretum molle	1	1	1	.	1	.	1	1	1	1	.	.	b	1	.	.	.	+	.	.	1	.	.	.	.	.	.	.	1	.	.	1	.	.	.	.	.	.	.	.	.	1	.	41	11
Cyperus obtusiflorus	1	1	+	.	1	+	1	.	+	1	1	1	1	+	.	.	.	.	r	.	.	.	1	+	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	47	0
Ruellia cordata	.	.	1	1	1	+	+	1	+	1	1	+	.	+	.	.	.	+	.	.	.	.	+	+	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	47	0
Grewia flava	1	.	1	.	.	.	.	1	.	+	.	.	.	.	+	.	.	1	.	.	1	1	+	1	.	1	1	.	1	1	.	1	.	.	.	1	.	.	.	.	.	.	.	44	11
Dombeya rotundifolia	.	.	.	1	1	1	1	1	1	b	.	1	1	b	b	1	.	b	1	1	1	1	b	1	1	.	1	1	.	.	1	1	1	.	.	.	.	.	.	.	.	.	.	74	0
Faurea saligna	.	.	.	.	1	3	3	b	.	.	b	3	1	b	.	.	.	.	b	b	.	.	.	.	b	.	.	.	b	.	b	.	1	.	.	.	.	.	.	.	.	.	.	41	0
Eragrostis chloromelas	1	.	.	.	b	.	.	+	1	1	1	.	.	.	1	1	b	1	.	1	.	+	.	.	.	+	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	44	0
Grewia monticola	1	.	.	1	1	1	.	.	.	.	.	.	.	.	.	+	.	1	.	.	.	.	1	.	.	.	.	.	.	.	1	1	.	1	.	.	.	.	.	.	.	.	.	29	0

Species Group K

Olea europa subsp. africana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	1	b	.	.	.	.	.	1	.	b	b	.	1	1	3	3	3	b	3	4	3	b	b	4	88	15
Celtis africana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	b	.	1	1	1	3	1	1	3	1	3	3	b	1	.	81	4
Mimusops zeyheri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	b	.	.	.	b	.	b	b	.	b	4	b	4	56	0
Euclea undulata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	1	.	.	1	.	.	.	1	1	.	1	1	b	1	.	b	56	7
Heteropyxis natalensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	.	.	.	.	1	.	1	1	b	.	.	1	.	50	0
Combretum erythrophyllum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	b	1	.	.	.	3	.	.	3	.	3	.	.	.	.	31	0
Spirostachys africana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	.	.	.	.	b	1	.	.	.	.	.	.	.	.	.	3	b	3	31	7
Maytenus undata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	b	b	.	.	.	1	.	.	.	19	0
Chaetachme aristata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	1	.	.	.	.	1	.	.	.	.	.	1	1	.	1	31	4

Species Group L

Panicum maximum	.	.	.	.	.	.	+	.	1	.	1	+	.	+	1	b	1	1	.	1	3	1	.	.	1	1	1	b	.	1	1	1	1	1	.	.	1	1	.	1	+	.	1	67	0
Rhus pyroides	.	.	.	.	+	1	.	.	.	.	.	.	.	1	.	1	.	1	+	1	1	.	1	.	b	.	1	b	1	.	.	1	.	1	.	.	1	+	.	b	.	1	+	51	0
Gerbera jamesonii	.	.	.	.	.	.	1	+	1	1	.	.	.	1	.	.	.	.	.	.	.	.	+	.	.	.	.	+	.	1	1	1	.	1	+	1	1	.	+	1	.	.	.	41	0

Species Group M

Rhus leptodictya	1	.	.	1	1	1	.	.	+	1	1	1	1	b	1	1	1	1	+	b	b	+	1	1	b	.	1	1	.	b	1	1	1	1	1	1	b	b	1	b	b	1	b	86	n/a
Acacia caffra	.	.	1	1	b	b	1	1	b	b	b	b	b	b	b	+	1	b	b	b	b	1	3	3	3	.	1	4	b	b	1	1	1	b	b	3	3	1	b	3	.	.	.	86	n/a
Euclea crispa	.	.	.	1	1	1	.	1	1	1	1	1	1	b	b	b	1	b	b	b	3	b	3	b	4	1	1	1	1	b	b	1	b	.	1	1	.	1	.	.	.	.	.	74	n/a
Berchemia zeyheri	.	.	1	1	+	.	.	.	.	.	.	.	.	.	1	1	.	1	1	b	1	b	1	1	1	.	1	3	3	b	1	.	1	.	1	.	3	1	.	b	b	3	b	60	n/a
Pappea capensis	.	.	.	1	.	1	.	.	.	.	.	.	.	1	1	1	.	+	.	1	b	+	1	.	1	.	.	b	1	b	.	1	.	.	1	b	b	.	.	.	.	.	3	44	n/a
Combretum zeyheri	1	.	.	1	b	.	1	.	.	.	.	.	.	.	b	.	.	b	.	.	.	.	.	.	.	.	.	.	b	.	.	.	.	.	1	.	.	b	.	.	.	.	.	21	n/a
Ziziphus mucronata	.	.	.	.	+	+	.	.	.	.	.	.	.	+	+	.	+	.	+	+	1	.	1	.	+	.	1	+	.	.	1	+	.	.	.	.	.	b	b	.	.	.	.	37	n/a

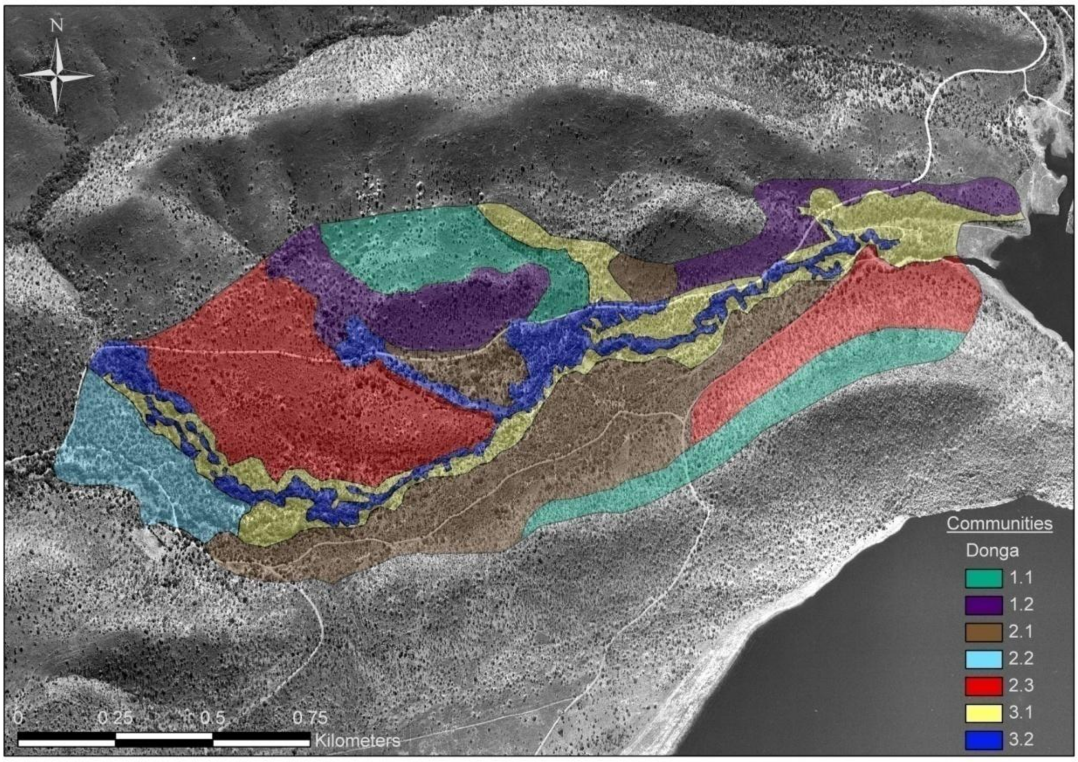


Figure 4.1. Vegetation map of the Donga home range depicting the various plant communities and sub-communities.

4.3.2 *Description of the Donga home range plant communities*

The Donga home range was characterized by a large Donga cutting through its centre. The large Donga had several smaller subsidiary dongas that merged into it at various locations along its course as it winded down towards the Loskop dam. Vegetation in and adjacent to the Donga was characterized by large riverine trees and shrubs with a sparse to non-existent forb and grass layer. Areas between the Dongas reflected the general vegetation of the area which was mostly open woodland.

1. *Lippia javanica-Loudetia simplex* Shrubland.

   This shrubland community covered approximately 25% (55ha) of the Donga home range and consisted of relatively rocky terrain that varied from gentle low lying valley bottoms to steeper midslopes. There were signs of trampling and several animal tracks occurred throughout this community. Evidence of fire damage could be seen in places, but was not recent and was likely due to the burning program that is in place on the reserve. Soils were sandy and well drained. Rock cover ranged from 10-90% with an average of 59% and erosion was estimated at 22% (slight to moderate). Altitude ranged from 1 018 to 1 105m, with the average slope being 16^{o}.

Species belonging to species group A were diagnostic for this community (Table 4.1). Diagnostic species included the large woody shrub *Mundulea sericea,* the large shrub *Ximenia caffra,* the small shrub *Xerophyta retinervis* and the tufted perennial grass *Loudetia simplex.*

The woody vegetation was dominated by the large shrub *Ximenia caffra* (species group A). The tree *Faurea saligna* and the erect shrub *Lippia javanica* (species group J) were prominent. The grass layer was dominated by the tufted perennial grasses *Setaria sphacelata var. spacelata* (species group J), *Loudetia simplex* (species group A) and *Hyparrhenia hirta* (species group E).

Two sub-communities were distinguished:

1.1 *Lippia javanica-Loudetia simplex-Sclerocarya birrea* Woodland.

The *Lippia javanica-Loudetia simplex-Sclerocarya birrea* sub-community was located in two large areas in the north-western and south-eastern sections of the home range (Fig 4.1). This sub-community comprised 13% of the home range (29ha) and 53% of community 1. It occurred throughout a valley bottom, on the foot- and mid-slopes of an elevated valley on the north-western boundary of the home range, and on the foot- and mid-slopes of the hills on the south-eastern boundary of the home range. The area was very rocky with average rock cover estimated at 70%. Erosion was estimated at 30% (slight to moderate). Altitude ranged from 1 052 to 1 105m with the average slope being 14^o.

Diagnostic species for this sub-community were represented by species from species group B (Table 4.1). Diagnostic species included the medium to large deciduous tree *Sclerocarya birrea,* the small to medium sized introduced tree *Acacia dealbata,* the small shrubby tree *Strychnos madagascariensis,* the small deciduous tree *Obetia tenax,* the erect to scrambling shrublet *Asparagus densiflorus,* the slender climber *Dioscorea sylvatica* and the tufted perennial grass *Eragrostis racemosa*.

The woody vegetation was dominated by the medium to large deciduous tree *Sclerocarya birrea* (species group B) and the deciduous shrub *Dichrostachys cinerea* (species group J). The tree *Combretum molle* and the erect shrub *Lippia javanica* (species group J) were prominent. The forb and grass layer was dominated by the tufted perennial grasses *Loudetia simplex* (species group A), *Setaria sphacelata var. spacelata* (species group J) and *Hyparrhenia hirta* (species group E). The singular fern *Pellaea calomelanos,* the forb *Solanum panduriforme* (species group J) and the tufted perennial grass *Heteropogon contortus* (species group D) were locally prominent.

The average number of plant species in this sub-community was $24/400m^2$. The tree layer had a 2-70% cover with an average of 21%; the shrub layer had a 2-10% cover with an average of 5%; the grass layer had a 1-60% cover with an average of 40%; and the forb layer had 1% cover. The shrub *Dichrostachys cinerea* had the highest density of 319 individuals/ha followed by the tree *Strychnos* *madagascariensis* with 138 individuals/ha and the tree *Combretum apiculatum* with 125 individuals/ha.

1.2 *Lippia javanica-Loudetia simplex-Acacia caffra* Woodland.

The *Lippia javanica-Loudetia simplex-Acacia caffra* sub-community was located in two areas to the north-east and north-west on the northern boundary of the home range (Fig 4.1). This sub-community comprised 12% of the home range (26ha) and 47% of community 1. The area was relatively rocky with average rock cover estimated at 54%. Erosion was estimated at 15% (slight). Altitude ranged from 1 018 to 1 098m with the average slope being 17^{o}.

Diagnostic species for this sub-community were represented by species from species group C (Table 4.1). Diagnostic species included the small round-crowned tree *Ozoroa paniculosa,* the much-branched deciduous shrub *Tapiphyllum parvifolium,* the weak perennial grass *Eragrostis pseudosclerantha,* the tufted perennial grasses *Trachypogon spicatus* and *Melinis nerviglumis,* and the forb *Becium obovatum*.

The woody vegetation was dominated by the small to medium-sized deciduous tree *Acacia caffra* (species group M), the tree *Faurea saligna,* the small erect deciduous tree *Dombeya rotundifolia* (species group J) and the large shrub *Ximenia caffra* (species group A). The tree *Combretum molle* and the erect shrub *Lippia javanica* (species group J) were prominent. The grass layer was dominated by the tufted perennial grass *Setaria sphacelata var. spacelata* (species group J), while the tufted perennial grass *Hyparrhenia hirta* (species group E) was prominent.

The average number of plant species in this sub-community was 24/400m^2. The tree layer had a 2-30% cover with an average of 12%; the shrub layer had a 5-20% cover with an average of 12%; the grass layer had a 40-80% cover with an average of 70%; and the forb layer had a 1-2% cover with an average of 1%. The tree *Faurea saligna* had the highest density of 472 individuals/ha followed by the tree *Acacia caffra* with 203 individuals/ha and the tree *Combretum molle* with 125 individuals/ha.

2. *Acacia nilotica-Acacia caffra* Woodland.

This woodland community covered approximately 52% (117ha) of the Donga home range and had relatively little rock cover, although there were sections that had a high cover. There was not much erosion. Rock cover ranged from 1-90% with an average of 17%. Erosion was estimated at 15% (slight). Altitude ranged from 1 015 to 1 090m, with the average slope being 8^o.

Species belonging to species group F were diagnostic for this community (Table 4.1). These included the shrub *Acacia nilotica* and the tufted perennial grasses *Eragrostis lehmanniana* and *Elionurus muticus.*

The woody vegetation was dominated by the small to medium-sized deciduous tree *Acacia caffra* and the shrub *Euclea crispa* (species group M). The medium sized tree *Rhus leptodictya* (species group M), the small erect deciduous tree *Dombeya rotundifolia* (species group J), the shrub *Acacia nilotica* (species group F), and the deciduous shrub *Dichrostachys cinerea* (species group J) were all prominent. In the grass layer the tufted perennial grass *Panicum maximum* (species group L) was locally prominent.

Three sub-communities were distinguished:

2.1 *Acacia nilotica-Acacia caffra-Cymbopogon plurinodis* Shrubland.

The *Acacia nilotica-Acacia caffra-Cymbopogon plurinodis* sub-community was located in three areas of the home range, one to the north-east, one in the centre and the other in the south-west extending north-east into the home range (Fig 4.1). This sub-community comprised 21% of the home range (48ha) and 41% of community 2. Rock cover was estimated at 6%. Erosion was estimated at 15% (slight). Altitude ranged from 1 031 to 1059m with the average slope being 9^o.

Diagnostic species for this sub-community were represented by species from species group G (Table 4.1). Diagnostic species included the medium to large tree *Acacia tortilis*, the perennial forb *Helichrysum rugulosum* and the tufted perennial grass *Cymbopogon plurinodis*.

There were no noticeably dominant species for this sub-community, however in the woody vegetation, the medium sized tree *Rhus leptodictya*, the small to medium-sized deciduous tree *Acacia caffra* (species group M), the small erect deciduous tree *Dombeya rotundifolia,* and the shrubs *Acacia nilotica* (species group F) and *Euclea crispa* (species group M) were all co-dominant. The deciduous shrub *Dichrostachys cinerea* (species group J) was prominent. In the grass layer the tufted perennial grasses *Eragrostis lehmanniana* (species group F) and *Panicum maximum* (species group L) were locally prominent.

The average number of plant species in this sub-community was $28/400m^2$. The tree layer had a 5-40% cover with an average of 26%; the shrub layer had a 10-80% cover with an average of 40%; the grass layer had a 30-80% cover with an average of 58%; and the forb layer had a 1-5% cover with an average of 2%. The shrub *Acacia nilotica* had the highest density of 870 individuals/ha followed by the shrub *Euclea crispa* with 570 individuals/ha and the tree *Dombeya rotundifolia* with 315 individuals/ha.

2.2 *Acacia nilotica-Acacia caffra-Tragus berteronianus* Woodland.

The *Acacia nilotica-Acacia caffra-Tragus berteronianus* sub-community was located on the western boundary of the home range (Fig 4.1). This sub-community comprised 6% of the home range (14ha) and 12% of community 2. Rock cover was estimated at 12%. Erosion was estimated at 15% (slight). Altitude ranged from 1 071 to 1 090m with the average slope being 5^o.

There were two diagnostic species for this sub-community namely the tufted annual grass *Tragus berteronianus* and the robust climber-scrambler *Asparagus transvaalensis* (species group H) (Table 4.1).

The woody vegetation was dominated by the large to medium-sized tree *Berchemia zeyheri*, the small to medium-sized deciduous tree *Acacia caffra* and the shrub *Euclea crispa* (species group M). The medium sized tree *Rhus leptodictya* (species group M), the small erect deciduous tree *Dombeya rotundifolia* (species group J), the shrub *Acacia nilotica* (species group F), the deciduous shrub *Dichrostachys cinerea* and the erect shrub *Lippia javanica* (species group J) were prominent. The grass layer was dominated by the tufted perennial grass *Panicum maximum* (species group L).

The average number of plant species in this sub-community was $28/400m^2$. The tree layer had a 25-80% cover with an average of 59%; the shrub layer had a 30-50% cover with an average of 40%; the grass layer had a 40-75% cover with an average of 60%; and the forb layer had a 1-5% cover with an average of 4%. The tree *Acacia caffra* had the highest density of 638 individuals/ha followed by the shrub *Euclea crispa* with 481 individuals/ha and the tree *Berchemia zeyheri* with 375 individuals/ha.

2.3 *Acacia nilotica-Acacia caffra-Elionurus muticus* Woodland.

The *Acacia nilotica-Acacia caffra-Elionurus muticus* sub-community was located in two sections of the vervet monkey's home range. One section was on the north-western boundary and the other was on the eastern boundary extending into the home range towards the south-east (Fig 4.1). This sub-community comprised 25% of the home range (55ha) and 47% of community 2. The area was relatively rocky with average rock cover estimated at 31%. Erosion was estimated at 15% (slight). Altitude ranged from 1 015 to 1 089m with the average slope being 9^{o}.

This sub-community was characterised by the absence of diagnostic species and species groups G and H (Table 4.1).

The woody vegetation was dominated by the tree *Combretum appiculatum* (species group E) and the shrub *Euclea crispa* (species group M). The tree *Acacia caffra,* the medium sized tree *Rhus leptodictya* (species group M) and the deciduous shrub *Dichrostachys cinerea* (species group J) were very prominent. The grass layer was dominated by the tufted perennial grass *Hyparrhenia hirta* (species group E) with the tufted perennial grasses *Elionurus muticus* and *Eragrostis lehmanniana* (species group F) being locally prominent.

The average number of plant species in this sub-community was $24/400m^2$. The tree layer had a 20-60% cover with an average of

32%; the shrub layer had a 10-40% cover with an average of 26%; the grass layer had a 5-75% cover with an average of 56%; and the forb layer had a 1-5% cover with an average of 2%. The tree *Acacia caffra* had the highest density of 470 individuals/ha followed by the shrub *Acacia nilotica* with 210 individuals/ha and the shrub *Euclea crispa* with 200 individuals/ha.

3. *Olea europea subsp. africana-Rhus leptodictya* Woodland.

This woodland community covered approximately 23% (52ha) of the Donga home range, having little rock cover and erosion. There were large trees throughout the area with not much forb cover. Rock cover ranged from 1-70% with an average of 9% and erosion was estimated at 22% (slight to moderate). Altitude ranged from 1005 to 1093m, with the average slope being 20^o.

Species belonging to species group K were diagnostic for this community (Table 4.1). Diagnostic species included the small to medium-sized evergreen tree *Olea europea subsp. africana,* the deciduous round crowned small to large tree *Celtis africana,* the small to medium-sized tree *Mimusops zeyheri,* the medium-sized to tall densely leaved deciduous tree *Combretum erythrophyllum,* the small to medium-sized deciduous tree *Heteropyxis natalensis,* the erect round crowned tree *Spirostachys africana,* the densely leaved shrub *Euclea undulata,* the large scrambling shrub *Chaetachme aristata* and the multi-stemmed shrub *Maytenus undata.*

The woody vegetation was dominated by the small to medium-sized evergreen tree *Olea europea subsp. africana,* the deciduous round crowned small to large tree *Celtis africana* (species group K), the tree *Acacia caffra,* the medium sized tree *Rhus leptodictya* and the large to medium-sized tree *Berchemia zeyheri* (species group M). The small to medium-sized trees *Pappea capensis* and *Ziziphus mucronata* (species group M), and the spiny multi-stemmed shrub *Rhus pyroides* (species group L) were prominent. The grass layer was dominated by the tufted perennial grass *Panicum maximum* with the perennial herb *Gerbera jamesonii* (species group L) being locally prominent.

Two sub-communities were distinguished:

3.1 *Olea europea subsp. africana-Rhus leptodictya-Carissa bispinosa* Woodland.

The *Olea europea subsp. africana-Rhus leptodictya-Carissa bispinosa* sub-community consisted of several areas interlaced with sub-community 3.2 and spanning through the centre of the home range from the eastern to the northern and western boundaries (Fig 4.1). This sub-community comprised 14% of the home range (31ha) and 60% of community 3. Rock cover was estimated at 13%. Erosion was estimated at 30% (slight to moderate). Altitude ranged from 1 005 to 1 089m with the average slope being 14^{o}.

This sub-community was characterised by the absence of diagnostic species and the presence of species groups I, J and K (Table 4.1).

Characteristic of this woodland sub-community was the local dominance of the tufted perennial grass *Setaria sphacelata var. sphacelata* (species group J).

The woody vegetation was dominated by the small to medium-sized deciduous tree *Acacia caffra* (species group M). The small to medium-sized evergreen tree *Olea europea subsp. africana,* the deciduous round crowned small to large tree *Celtis africana* (species group K), the medium sized tree *Rhus leptodictya,* the large to medium-sized tree *Berchemia zeyheri* (species group M) and the spiny evergreen shrub *Carissa bisponosa* (species group I) were locally prominent. The grass layer was dominated by the tufted perennial grass *Panicum maximum* (species group L) with the tufted perennial grass *Setaria sphacelata var. sphacelata* (species group J) being locally prominent.

The average number of plant species in this sub-community was 24/400m^2. The tree layer had a 5-100% cover with an average of 67%; the shrub layer had a 2-20% cover with an average of 10%; the grass layer had a 0-80% cover with an average of 21%; and the forb layer had a 1-10% cover with an average of 3%. The tree *Acacia caffra* had the highest density of 200 individuals/ha followed by the shrub *Euclea crispa* with 175 individuals/ha and the shrub *Dichrostachys cinerea* with 114 individuals/ha.

3.2 *Olea europea subsp. africana-Celtis africana-Mimusops zeyheri* Woodland.

The *Olea europea subsp. africana-Celtis africana-Mimusops zeyheri* sub-community, like sub-community 3.1 consisted of several areas interlaced with sub-community 3.1 and spanning through the centre of the home range from the eastern to the northern and western boundaries (Fig 4.1). This sub-community comprised 9% of the home range (21ha) and 40% of community 3. The area was not very rocky with average rock cover estimated at 5%. Erosion was estimated at 15% (slight). Altitude ranged from 1025 to 1093m with the average slope being 25^o.

As with sub-community 3.1, this sub-community was characterised by the absence of diagnostic species. This sub-community was distinguished from 3.1 by the absence of species groups I and J (Table 4.1).

The woody vegetation was dominated by the small to medium-sized evergreen tree *Olea europea subsp. africana,* the deciduous round crowned small to large tree *Celtis africana,* the small to medium-sized tree *Mimusops zeyheri* (species group K) and the medium sized tree *Rhus leptodictya* (species group L). The small to medium-sized deciduous tree *Acacia caffra* and the large to medium-sized tree *Berchemia zeyheri* (species group M) were locally prominent with the small to medium-sized deciduous tree *Heteropyxis natalensis* and the densely leaved shrub *Euclea undulata* (species group K) occurring almost exclusively in this community.

The average number of plant species in this sub-community was 12/400m^2. The tree layer had 90% cover; the shrub, grass and forb layers all had 3% cover. The tree *Olea europaea subsp. africana* had the highest density of 75 individuals/ha followed by the tree *Celtis africana* with 44 individuals/ha and the trees *Acacia caffra* and *Berchemia zeyheri* both having 36 individuals/ha.

Table 4.2 depicts additional plant species recorded for the Donga home range but not regarded as prominent enough to be reflected in Table 4.1 due to their overall constancy values being below 9.5%. The species names and the communities they occurred in are presented.

Table 4.2. Table of less prevalent plant species occurring in the Donga home range but not presented in Table 4.1.

Species name	Community	Species name	Community	Species name	Community
Acacia burkei	1.2, 2.1, 2.3, 3.2	*Digitaria sanguinalis*	2.2, 3.1	*Lantana rugosa*	1.2, 2.1, 3.1
Acacia mellifera	3.1	*Diospyros whyteana*	3.2	*Laportea grossa*	3.1
Acacia robusta	3.1	*Diplorhynchus condylocarpon*	1.1	*Ledebouria apertiflora*	2.1
Aristida congesta subsp. congesta	2.3	*Dovyalis zeyheri*	3.2	*Melhania prostrata*	2.3
Aristida stipitata	1.1, 1.2, 2.3, 3.1	*Eragrostis gummiflua*	1.2, 2.1	*Melinis repens*	1.2
Asparagus suaveolens	2.2	*Felicia mossamedensis*	1.2	*Peltophorum africanum*	2.2
Asparagus virgatus	2.1, 3.1	*Ficus craterostoma*	3.2	*Rhoicissus tridentata*	3.1
Barleria rotundifolia	2.2	*Ficus sur*	3.2	*Rhus dentata*	2.3
Brachiaria brizantha	1.2, 3.1	*Flacourtia indica*	2.3, 3.1	*Robinia pseudoacacia*	3.1
Cenchrus ciliaris	2.2	*Flueggea virosa*	3.1	*Scolopia zeyheri*	1.2, 2.1, 3.1, 3.2
Clerodendrum triphyllum	3.1	*Grewia bicolor*	2.2	*Sida cordifolia*	2.1
Combretum hereroense	3.2, 3.2	*Grewia occidentalis*	2.3	*Stoebe vulgaris*	1.2
Commiphora schimperi	3.1	*Hyperthelia dissoluta*	2.1	*Strophanthus speciosus*	3.1
Crossandra greenstockii	1.2, 2.2	*Indigofera daleoides*	1.2, 3.1	*Terminalia brachystemma*	2.1
Diaphananthe millarii	3.1	*Jasminum breviflorum*	3.1	*Thunbergia atriplicifolia*	3.1
Digitaria eriantha	1.2	*Kalanchoe brachyloba*	2.3	*Vitex rehmannii*	3.1

4.3.3 *Picnic home range classification*

The Picnic home range could typically be classified as an *Acacia karroo-Dichrostachys cinerea* shrubland. In the same way that a detailed vegetative analysis was undertaken for the Donga home range, similarly the Picnic home range was analyzed. Noteworthy species occurring within the Picnic home range included the small to medium-sized deciduous tree *Acacia caffra*, the medium sized tree *Rhus leptodictya,* the shrub *Solanum panduriforme,* the erect shrub *Lippia javanica* and the tufted perennial grasses *Panicum maximum* and *Heteropogon contortus.*

The Picnic home range was 138ha in size. The analysis resulted in the identification of the following eight plant communities (Fig 4.2), which could be grouped into four major community types (Table 4.3):

1. *Acacia caffra-Setaria sphacelata var. sphacelata* Woodland.
    1.1 *Acacia caffra-Setaria sphacelata var. sphacelata-Ziziphus mucronata* Woodland.
    1.2 *Acacia caffra-Setaria sphacelata var. sphacelata-Dombeya rotundifolia* Woodland.
2. *Acacia karroo-Dichrostachys cinerea* Shrubland.
3. *Heteropogon contortus-Sclerocarya birrea* Woodland.
    3.1 *Heteropogon contortus-Sclerocarya birrea-Urochloa oligotricha* Shrubland.
    3.2 *Heteropogon contortus-Sclerocarya birrea-Ledebouria apertiflora* Shrubland.
    3.3 *Heteropogon contortus-Sclerocarya birrea-Cenchrus ciliaris* Shrubland.
    3.4 *Heteropogon contortus-Sclerocarya birrea-Faurea saligna* Woodland.
4. *Hyperthelia dissoluta* Grassland.

Table 4.3. Phytosociological table of the vegetation for the picnic troops home range

Community Number	1								2						3										4			
	1.1				1.2										3.1			3.2			3.3		3.4				% Constancy	
Relevé numbers		1	2	2					1	1	2	2	2	1		1	1	1	1	1		1			2	2	Main	Other
	8	5	4	5	1	3	4	7	8	9	0	2	1	6	9	0	1	2	3	7	6	4	2	5	3	6	Community	Communities
Species Group A																												
Setaria sphacelata var. sphacelata	1	4	b	3	4	1	4	3	.	.	.	.	.	.	.	.	.	3	1	b	.	+	3	1	.	.	100	33
Bridelia mollis	b	1	b	b	1	b	3	.	.	1	.	.	.	1	.	.	.	.	1	.	.	1	1	.	.	.	88	28
Combretum zeyheri	.	b	1	3	b	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	63	0
Celtis africana	.	.	1	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	38	0
Asparagus virgatus	+	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	38	0
Species Group B																												
Ziziphus mucronata	1	1	1	+	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	100	9
Rhoicissus tridentata	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	50	5
Brachiaria brizantha	b	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	50	5
Digitaria eriantha	+	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	50	0
Lantana rugosa	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	50	0
Species Group C																												
Terminalia brachystemma	.	.	.	.	.	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	25	0
Trachypogon spicatus	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	25	0
Strychnos cocculoides	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	25	0
Sporobolus fimbriatus	.	.	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	50	0
Species Group D																												
Acacia nilotica	.	.	.	.	.	.	.	.	3	b	1	.	.	b	.	.	.	.	.	.	.	.	.	.	.	.	67	0
Tragus berteronianus	.	.	.	.	.	.	.	.	4	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	33	0
Tieghemia quinquenervia	.	.	.	.	.	.	.	.	.	.	b	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	33	0
Euclea undulata	.	.	.	.	.	.	.	.	.	b	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	33	0
Pappea capensis	.	.	.	.	.	.	.	1	1	1	.	+	.	.	.	.	.	.	.	.	.	1	.	.	.	.	50	10
Helichrysum rugulosum	.	.	.	.	.	.	.	.	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	33	0

Species Group E																												
Hyparrhenia hirta	.	.	.	.	1	1	.	.	1	.	1	.	1	+	.	.	.	.	.	.	.	.	.	.	.	.	60	0
Grewia flavescens	.	.	.	.	.	1	.	1	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	40	0
Asparagus africanus	.	.	.	+	.	.	.	1	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	6
Species Group F																												
Grewia flava	1	1	1	1	.	1	1	1	1	1	1	+	1	.	1	1	.	.	.	.	.	.	.	.	.	.	86	17
Pogonarthria squarrosa	.	1	.	+	.	1	+	b	1	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	50	0
Eragrostis superba	.	.	.	1	.	+	.	+	1	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	29	17
Species Group G																												
Acacia caffra	b	b	1	b	b	1	+	b	.	.	b	1	b	1	.	1	.	b	b	b	b	1	.	.	.	.	82	0
Solanum panduriforme	1	1	.	.	1	1	.	1	b	1	1	.	1	1	1	1	1	+	1	b	1	.	.	.	.	.	77	0
Rhus leptodictya	1	.	.	.	1	1	1	1	1	3	.	b	1	.	1	1	.	1	.	1	1	.	.	.	.	.	64	0
Eragrostis lehmanniana	.	.	.	.	.	3	3	.	1	1	b	1	+	1	b	1	1	.	.	1	+	.	.	.	.	.	59	0
Rhus pyroides	b	1	1	1	1	1	1	1	.	.	.	+	+	+	.	1	.	.	.	.	.	1	.	.	.	.	59	0
Euclea crispa	1	1	.	1	1	1	1	b	.	1	.	+	.	.	.	.	.	1	1	.	b	.	.	.	.	.	55	0
Dombeya rotundifolia	1	b	1	.	1	1	3	1	.	.	.	1	.	b	.	.	1	1	.	.	.	1	.	.	.	.	55	0
Grewia monticola	.	1	.	.	.	.	1	.	.	1	.	1	.	+	1	1	1	1	1	1	.	1	.	.	.	.	55	0
Aristida stipitata	.	.	.	1	.	.	+	.	b	1	b	1	1	b	+	1	+	.	.	1	.	.	.	.	.	.	55	0
Gymnosporia buxifolia	1	1	3	.	.	.	1	b	.	b	.	1	.	b	.	1	.	.	.	.	1	1	.	.	.	.	50	0
Eragrostis chloromelas	.	.	b	1	1	.	.	1	.	.	.	.	+	1	1	.	.	1	.	.	1	.	.	.	.	.	41	0
Berchemia zeyheri	.	1	.	.	1	.	1	.	.	1	.	+	.	.	.	.	+	1	.	.	1	1	.	.	.	.	41	0
Flueggea virosa	.	1	1	1	.	.	.	.	.	1	.	.	1	.	.	.	.	1	1	.	.	.	.	.	.	.	32	0
Species Group H																												
Sclerocarya birrea	.	.	.	.	.	1	.	.	.	.	.	.	.	.	3	3	3	b	1	1	.	b	b	3	.	.	75	7
Ozoroa sphaerocarpa	.	1	.	.	.	.	.	.	.	.	.	.	+	.	1	1	.	b	1	b	.	.	1	1	1	.	67	14
Combretum apiculatum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	b	1	.	b	b	b	1	1	.	.	.	.	58	0
Loudetia simplex	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	1	.	+	b	3	.	.	50	0
Ozoroa paniculosa	.	1	.	.	.	1	.	1	.	.	.	.	.	.	.	1	.	1	1	1	.	1	1	1	.	.	58	21
Cymbopogon plurinodis	.	.	.	.	.	.	1	.	.	.	.	.	.	.	1	.	.	.	.	1	.	.	1	1	.	.	33	7
Themeda triandra	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	b	b	.	.	.	1	.	.	.	25	14
Asparagus densiflorus	.	1	.	.	.	.	.	.	.	+	.	.	.	.	+	.	.	.	+	+	.	.	1	+	.	.	42	14
Pellaea calomelanos	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	+	1	.	.	+	42	7

Species Group I										
Urochloa oligotricha	. . . .	. . . .	. . . . . .	4 4 5	. . .	. .	. .	. .	100	0
Combretum erythrophyllum	. . . .	. . . .	. . . . . .	1 1 .	. . .	. .	. .	. .	67	0
Eragrostis micrantha	. . . b	. . . .	. . . . . .	1 1 .	. 1 .	. .	. .	. .	67	9
Boophane disticha	. . . .	. . . .	. . . . . .	. . 1	. . .	. .	. .	. .	33	0
Eragrostis pseudosclerantha	. . . .	. . . 1	 1	1 . .	1 . .	. .	. .	. .	33	13
Species Group J										
Ledebouria apertiflora	. + . +	. . . .	. . + . . +	. . +	+ 1 1	+ .	. .	. .	100	26
Commelina erecta	+ . . .	. . . .	. . . . . .	. + .	1 + .	. .	. .	. .	67	9
Vangueria infausta	. . . .	. . . .	. . . . . .	. . .	. 1 .	. .	. .	. .	33	0
Species Group K										
Cenchrus ciliaris	+ . . .	. . . .	. . . . . +	. . .	. . .	4 4	. .	. .	100	8
Carissa bispinosa	. . . .	. . . .	. . . . . .	. . .	. . .	1 1	. .	. .	100	0
Asparagus transvaalensis	1 . . .	. . . .	. 1 . 1 1 .	. . .	. . .	1 1	. .	. .	100	17
Spirostachys africana	. . . .	. . . .	. . . . . .	. . .	. . .	b .	. .	. .	50	0
Cyrtanthus brachysiphon	. . . .	. . . .	. . . . . .	. . .	. . .	1 .	. .	. .	50	0
Senna bicapsularis	. . . .	. . . .	. . . . . .	. . .	. . .	. 1	. .	. .	50	0
Species Group L										
Faurea saligna	. b . .	. . . 1	. . . . . .	. . .	. . .	. .	1 b	. .	100	8
Diplorhynchus condylocarpon	. . . .	. . . .	. . . . . .	. . .	. . .	. 1	1 1	. .	100	4
Strychnos madagascariensis	. . . .	. . . .	. . . . . .	. . .	. . .	. .	. b	. .	50	0
Thunbergia atriplicifolia	. . . .	. . . .	. . . . . .	. . .	. . .	. .	1 +	. .	100	0
Xerophyta retinervis	. . . .	. . . .	. . . . . .	. . .	. . +	. .	1 +	. .	100	4
Species Group M										
Hyperthelia dissoluta	1 1 . .	. . . .	. . . . . .	. . .	. . .	. .	4 1	5 5	100	9

Species Group N

Panicum maximum	3	1	3	1	1	1	1	1	.	1	1	1	1	1	+	1	+	1	1	1	1	1	.	1	+	+	92	n/a
Acacia karroo	1	b	1	1	b	b	b	b	b	b	b	3	b	b	1	b	b	b	1	.	b	b	.	.	1	.	85	n/a
Dichrostachys cinerea	1	b	b	b	1	1	1	1	b	b	3	b	b	b	1	1	b	b	1	b	b	1	1	.	.	.	88	n/a
Heteropogon contortus	1	b	1	+	b	1	1	1	3	1	b	.	3	1	1	1	1	3	3	b	.	1	1	1	.	.	85	n/a
Lippia javanica	1	1	1	1	1	1	1	1	1	.	.	.	1	1	1	1	1	1	1	1	.	1	1	1	.	.	77	n/a
Cyperus obtusiflorus	.	1	.	+	1	.	.	.	.	.	+	.	.	.	.	.	.	+	1	1	.	.	.	+	.	+	35	n/a
Ruellia cordata	+	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	1	1	.	.	31	n/a
Combretum molle	.	1	1	.	.	.	.	.	.	.	.	.	+	.	.	.	.	1	.	b	.	.	1	.	.	.	23	n/a
Ximenia caffra	.	.	1	1	.	.	.	.	.	.	1	1	.	.	.	1	.	.	.	.	.	.	1	.	.	.	23	n/a

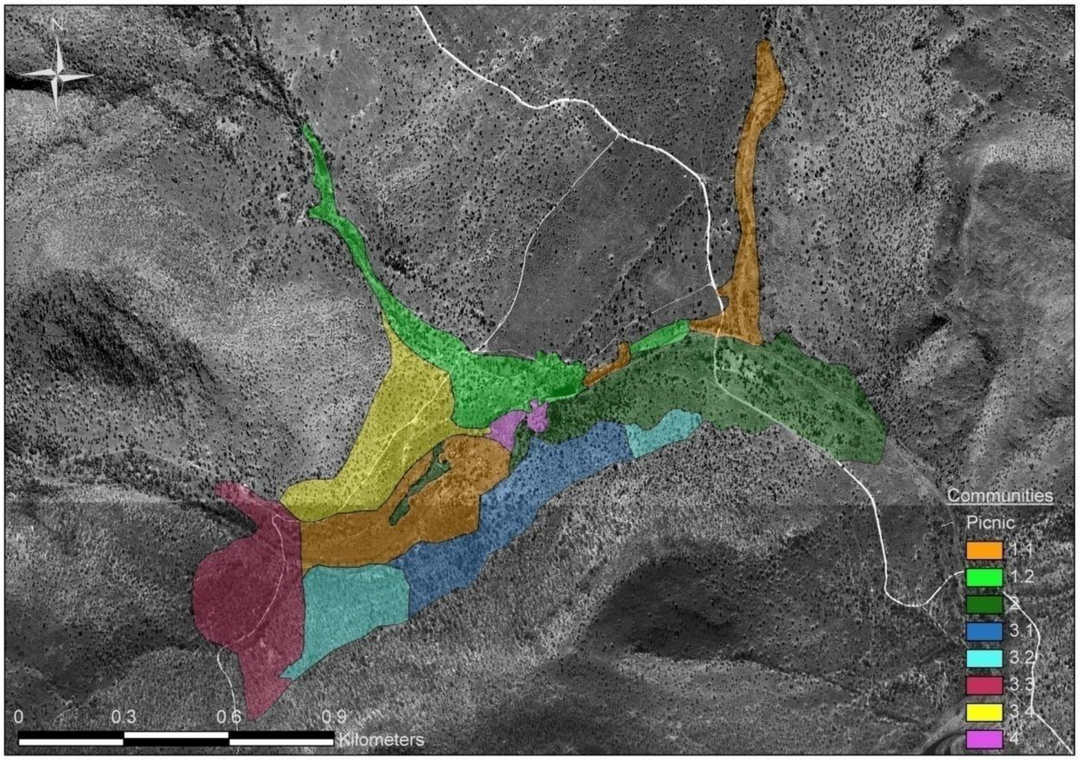


Figure 4.2. Vegetation map of the Picnic home range depicting the various plant communities and sub-communities.

4.3.4 *Description of the Picnic home range plant communities*

The Picnic home range was characterized by a series of dry stream beds cutting through it. There were two small man made dams in the area, previously used for livestock and agricultural purposes. The home range was mostly open shrubland and woodland with a depleted herbaceous layer due to a history of overgrazing and irregular agricultural practices prior to the establishment of the LDNR. The grass layer was well represented in areas, with *Panicum maximum* occurring throughout the home range and *Heteropogon contortus* being prominent. Forbs were locally abundant throughout the home range with several species appearing seasonally.

1. *Acacia caffra-Setaria sphacelata var. sphacelata* Woodland.

This woodland community covered approximately 31% (42ha) of the Picnic home range with rock cover and erosion being relatively low. Rock cover ranged from 1-20% with an average of 8% and erosion was estimated at 15% (slight). Altitude ranged from 1 032 to 1 064m, with the average slope being 12^{o}.

Species belonging to species group A were diagnostic for this community (Table 4.3). Diagnostic species included the small to medium-sized deciduous tree *Combretum zeyheri,* the deciduous round crowned small to large tree *Celtis africana,* the shrub *Bridelia mollis,* the erect shrublet *Asparagus virgatus* and the tufted perennial grass *Setaria sphacelata var. sphacelata.*

The woody vegetation was dominated by the small to medium-sized deciduous tree *Acacia caffra* (species group G), the evergreen shrub *Acacia karroo* and the deciduous shrub *Dichrostachys cinerea* (species group N). The small erect deciduous tree *Dombeya rotundifolia*, the spiny multi-stemmed shrub *Rhus pyroides,* the shrub *Euclea crispa* (species group G), the erect shrub *Lippia javanica* (species group N) and the multi-stemmed shrub *Grewia flava* (species group F) were prominent. The grass layer was dominated by the tufted perennial grasses *Panicum maximum* and *Heteropogon contortus* (species group N).

Two sub-communities were distinguished:

1.1 *Acacia caffra-Setaria sphacelata var. sphacelata-Ziziphus mucronata* Woodland.

The *Acacia caffra-Setaria sphacelata var. sphacelata-Ziziphus mucronata* sub-community consisted of three areas. Two areas occurred on the northern boundary of the home range, one towards the north-east as a finger like projection jutting out of the home range and the other on the central northern boundary. The third area was embedded within the home range in the south-west (Fig 4.2). This sub-community comprised 19% of the home range (26ha) and 61% of community 1. The area was not very rocky with average rock cover estimated at 10%. Erosion was estimated at 15% (slight). Altitude ranged from 1032 to 1065m with the average slope being 12^{o}.

Diagnostic species for this sub-community were represented by species from species group B (Table 4.3). Diagnostic species included the small to medium-sized tree *Ziziphus mucronata,* the erect shrub *Lantana rugosa,* the robust climber *Rhoicissus tridentata,* and the tufted perennial grasses *Digitaria eriantha* and *Brachiaria brizantha.*

The woody vegetation was dominated by the small to medium-sized deciduous tree *Acacia caffra* (species group G) and the deciduous shrub *Dichrostachys cinerea* (species group N). The the multi-stemmed shrub *Grewia flava* (species group F), the spiny multi-stemmed shrub *Rhus pyroides* (species group G), the evergreen shrub *Acacia karroo* and the erect shrub *Lippia javanica* (species group N) were prominent. The grass layer was dominated by the tufted perennial grass *Panicum maximum* (species group N) with the tufted perennial grass *Heteropogon contortus* (species group N) being locally prominent.

The average number of plant species in this sub-community was $28/400m^2$. The tree layer had a 20-60% cover with an average of 39%; the shrub layer had a 5-40% cover with an average of 26%; the grass layer had a 70-80% cover with an average of 75%; and the forb layer had a 0-5% cover with an average of 3%. The shrub *Gymnosporia buxifolia* had the highest density of 563 individuals/ha followed by the shrub *Dichrostachys cinerea* with 431 individuals/ha and the tree *Acacia caffra* having 413 individuals/ha.

1.2 *Acacia caffra-Setaria sphacelata var. sphacelata-Dombeya rotundifolia* Woodland.

The *Acacia caffra-Setaria sphacelata var. sphacelata-Dombeya rotundifolia* sub-community consisted of two sections, both occurring on the northern boundary of the home range, one was a finger like projection jutting out of the home range towards the north-west (Fig 4.2). This sub-community comprised 12% of the home range (16ha) and 39% of community 1. The area was not very rocky with average rock cover estimated at 5%. Erosion was estimated at 15% (slight). Altitude ranged from 1 033 to 1 059m with the average slope being 12^{o}.

Diagnostic species for this sub-community were represented by species from species group C (Table 4.3). Diagnostic species included the small tree *Strychnos cocculoides,* the semi-deciduous shrub *Terminalia brachystemma* and the tufted perennial grasses *Trachypogon spicatus* and *Sporobolus fimbriatus.*

The woody vegetation was dominated by the small erect deciduous tree *Dombeya rotundifolia,* the shrub *Euclea crispa* (species group G) and the evergreen shrub *Acacia karroo* (species group N). The small to medium-sized deciduous tree *Acacia caffra,* the medium sized tree *Rhus leptodictya,* the spiny multi-stemmed shrub *R. pyroides* (species group G), the deciduous shrub *Dichrostachys cinerea* and the erect shrub *Lippia javanica* (species group N) were prominent. The grass layer was dominated by the tufted perennial grass *Heteropogon* *contortus* (species group N) with the tufted perennial grass *Panicum maximum* (species group N) being locally prominent.

The average number of plant species in this sub-community was 24/400m^2. The tree layer had a 5-40% cover with an average of 20%; the shrub layer had a 5-80% cover with an average of 33%; the grass layer had a 30-70% cover with an average of 55%; and the forb layer had a 0-1% cover with an average of 1%. The shrub *Acacia karroo* had the highest density of 456 individuals/ha followed by the shrub *Bridelia mollis* with 431 individuals/ha and the tree *Dombeya rotundifolia* having 300 individuals/ha.

2. *Acacia karroo-Dichrostachys cinerea* Shrubland.

This shrubland community occurred as two sections, one formed the eastern boundary of the home range and the other smaller section occurred within the home range just west of its centre. The *Acacia karroo-Dichrostachys cinerea* Shrubland community covered approximately 22% (31ha) of the Picnic home range (Fig 4.2). Rock cover ranged from 1-5% with an average of 3% and erosion was estimated at 38% (slight to moderate). Altitude ranged from 1 031 to 1 052m, with the average slope being 8^o.

Species belonging to species group D were diagnostic for this community (Table 4.3). Diagnostic species included the small to medium-sized tree *Pappea capensis,* the shrub *Acacia nilotica,* the parasitic shrub *Tieghemia quinquenervia,* the densely leaved shrub *Euclea undulata,* the perennial forb *Helichrysum rugulosum* and the tufted annual grass *Tragus berteronianus.*

The woody vegetation was dominated by the evergreen shrub *Acacia karroo* and the deciduous shrub *Dichrostachys cinerea* (species group N). The medium sized tree *Rhus leptodictya* and the shrub *Solanum panduriforme* (species group G) were prominent. The grass layer was dominated by the tufted perennial grasses *Aristida stipitata* and *Eragrostis lehmanniana* (species group G) with the tufted perennial grasses *Heteropogon contortus* and *Panicum maximum* (species group N) being locally prominent.

No sub-communities were distinguished for this community.

The average number of plant species in this community was 20/400m^2. The tree layer had a 10-80% cover with an average of 40%; the shrub layer had a 10-80% cover with an average of 39%; the grass layer had a 5-40% cover with an average of 22%; and the forb layer had a 0-1% cover with an average of 1%. The shrub *Acacia karroo* had the highest density of 558 individuals/ha followed by the shrub *Dichrostachys cinerea* with 483 individuals/ha and the shrub *Gymnosporia buxifolia* having 408 individuals/ha.

3. *Heteropogon contortus-Sclerocarya birrea* Woodland.

This woodland community covered approximately 46% (63ha) of the Picnic home range and had relatively high rock cover and erosion. Rock cover ranged from 2-50% with an average of 22% and erosion was estimated at 21% (slight to moderate). Altitude ranged from 1 045 to 1 097m, with the average slope being 12^o.

Species belonging to species group H were diagnostic for this community (Table 4.3). Diagnostic species included the medium to large deciduous tree *Sclerocarya birrea,* the small round-crowned trees *Ozoroa sphaerocarpa* and *O. paniculosa,* the small to medium-sized deciduous tree *Combretum apiculatum* usually denoting shallow soils, the erect to scrambling shrublet *Asparagus densiflorus,* the singular fern *Pellaea* *calomelanos,* and the tufted perennial grasses *Loudetia simplex, Cymbopogon plurinodis* and *Themeda triandra.*

The woody vegetation was dominated by the evergreen shrub *Acacia karroo* and the deciduous shrub *Dichrostachys cinerea* (species group N). The erect shrub *Lippia javanica* (species group N) was locally prominent. The grass layer was dominated by the tufted perennial grass *Heteropogon contortus* (species group N) with the tufted perennial grass *Panicum maximum* (species group N) being prominent locally.

Four sub-communities were distinguished for this community:

3.1 *Heteropogon contortus-Sclerocarya birrea-Urochloa oligotricha* Shrubland.

The *Heteropogon contortus-Sclerocarya birrea-Urochloa oligotricha* sub-community occurred on the central southern boundary of the home range (Fig 4.2). This sub-community comprised 11% of the home range (15ha) and 24% of community 3. The area was not very rocky with average rock cover estimated at 15%. Erosion was estimated at 15% (slight). Altitude ranged from 1 054 to 1 057m with the average slope being 10^o.

Diagnostic species for this sub-community were represented by species from species group I (Table 4.3). Diagnostic species included the medium- to tall-sized and densely leaved deciduous tree *Combretum erythrophyllum,* the poisonous bulb *Boophane disticha,* the tufted perennial grasses *Urochloa oligotricha* and *Eragrostis micrantha,* and the weak perennial grass *E. pseudosclerantha.*

The woody vegetation was dominated by the medium to large deciduous tree *Sclerocarya birrea* (species group H), the evergreen shrub *Acacia karroo* and the deciduous shrub *Dichrostachys cinerea* (species group N). The shrub *Solanum panduriforme,* the multi-stemmed shrub *Grewia monticola* (species group G) and the erect shrub *Lippia javanica* (species group N) were prominent. The grass layer was dominated by the tufted perennial grass *Eragrostis lehmaniana* (species group G) with the tufted perennial grass *Heteropogon contortus* (species group N) being locally prominent.

The average number of plant species in this sub-community was 20/400m^2. The tree layer had a 40-50% cover with an average of 45%; the shrub layer had a 10-40% cover with an average of 23%; the grass layer had a 40-60% cover with an average of 53%; and the forb layer had a 1-2% cover with an average of 1%. The shrub *Dichrostachys cinerea* had the highest density of 425 individuals/ha followed by the tree *Combretum apiculatum* with 292 individuals/ha and the shrub *Acacia karroo* having 275 individuals/ha.

3.2 *Heteropogon contortus-Sclerocarya birrea-Ledebouria apertiflora* Shrubland.

The *Heteropogon contortus-Sclerocarya birrea-Ledebouria apertiflora* sub-community occurred as two areas adjacent to sub-community 3.1 and flanking it to the east and west on the southern boundary of the home range (Fig 4.2). This sub-community comprised 9% of the home range (12ha) and 19% of community 3. The area was relatively rocky with average rock cover estimated at 37%. Erosion was estimated at 15% (slight). Altitude ranged from 1 045 to 1 097m with the average slope being 12^o.

Diagnostic species for this sub-community were represented by species from species group J (Table 4.3). Diagnostic species included the small stout semi-deciduous to deciduous tree *Vangueria infausta,* the bulbous forb *Ledebouria apertiflora* and the perennial forb *Commelina erecta.*

The woody vegetation was dominated by the small to medium-sized deciduous tree *Acacia caffra* (species group G)*,* the tree *Combretum appiculatum,* the small round-crowned tree *Ozoroa sphaerocarpa* (species group H) and the deciduous shrub *Dichrostachys cinerea* (species group N). The multi-stemmed shrub *Grewia monticola* (species group G) and the erect shrub *Lippia javanica* (species group N) were prominent. The forb and grass layer was dominated by the tufted perennial grass *Heteropogon contortus* (species group N) with the forb *Solanum panduriforme* (species group G), the robust sedge *Cyperus obtusiflorus* and the tufted perennial grass *Panicum maximum* (species group N) being locally prominent.

The average number of plant species in this sub-community was 28/400m^2. The tree layer had a 25-30% cover with an average of 28%; the shrub layer had a 20-40% cover with an average of 28%; the grass layer had a 40-80% cover with an average of 57%; and the forb layer had a 1% cover. The tree *Combretum apiculatum* had the highest density of 658 individuals/ha followed by the shrub *Dichrostachys cinerea* with 483 individuals/ha and the tree *Acacia caffra* having 417 individuals/ha.

3.3 *Heteropogon contortus-Sclerocarya birrea-Cenchrus ciliaris* Shrubland*.*

The *Heteropogon contortus-Sclerocarya birrea-Cenchrus ciliaris* sub-community formed the western boundary of the home range (Fig 4.2). This sub-community comprised 14% of the home range (20ha) and 31%

of community 3. The area was not very rocky with average rock cover estimated at 9%. Erosion was estimated at 38% (moderate). Altitude ranged from 1 073 to 1 087m with the average slope being 16°.

Diagnostic species for this sub-community were represented by species from species group K (Table 4.3). Diagnostic species included the erect round crowned tree *Spirostachys africana,* the spiny evergreen shrub *Carissa bispinosa,* the introduced rounded shrub *Senna bicapsularis,* the deciduous bulb *Cyrtanthus brachysiphon,* the robust climber-scrambler *Asparagus transvaalensis* and the tufted perennial grass *Cenchrus ciliaris.*

The woody vegetation was dominated by the small to medium-sized deciduous tree *Acacia caffra* (species group G), the evergreen shrub *A. karroo* and the deciduous shrub *Dichrostachys cinerea* (species group N). The large to medium-sized tree *Berchemia zeyheri* and the erect shrub *Gymnosporia buxifolia* (species group G) were locally prominent. In the grass layer *Panicum maximum* (species group N) was prominent.

The average number of plant species in this sub-community was 24/400m^2. The tree layer had a 40% cover; the shrub layer had a 10-20% cover with an average of 15%; the grass layer had a 5-20% cover with an average of 13%; and the forb layer was not represented. The shrub *Acacia karroo* had the highest density of 375 individuals/ha followed by the shrub *Dichrostachys cinerea* and the tree *Spirostachys africana* both having 213 individuals/ha.

3.4 *Heteropogon contortus-Sclerocarya birrea-Faurea saligna* Woodland.

The *Heteropogon contortus-Sclerocarya birrea-Faurea saligna* sub-community formed the north-western boundary of the home range (Fig

4.2). This sub-community comprised 12% of the home range (16ha) and 26% of community 3. The area was rocky with average rock cover estimated at 43%. Erosion was estimated at 15% (slight). Altitude ranged from 1 086 to 1 088m with the average slope being 9^{o}.

Diagnostic species for this sub-community were represented by species from species group L (Table 4.3). Diagnostic species included the tree *Faurea saligna,* the small shrubby tree *Strychnos madagascariensis,* the perennial shrublet *Thunbergia atriplicifolia,* the small shrub *Xerophyta retinervis* and the sparse shrub *Diplorhynchus condylocarpon.*

The woody vegetation was dominated by the medium to large deciduous tree *Sclerocarya birrea* (species group H) and the tree *Faurea saligna* (species group L). The small round-crowned trees *Ozoroa sphaerocarpa* and *O. paniculosa* (species group H)*,* the erect shrub *Lippia javanica* and the shrublet *Ruellia cordata* (species group N) were prominent. The grass layer was dominated by the tufted perennial grasses *Loudetia simplex* (species group H) and *Hyperthelia dissoluta* (species group M), with the tufted perennial grasses *Cymbopogon plurinodis* (species group H) and *Heteropogon contortus* (species group N) being prominent.

The average number of plant species in this sub-community was $24/400m^2$. The tree layer had a 5-25% cover with an average of 15%; the shrub layer had a 2% cover; the grass layer had a 70% cover; and the forb layer had a 1% cover. The tree *Sclerocarya birrea* had the highest density of 175 individuals/ha followed by the trees *Combretum molle* and *Faurea saligna* both having densities of 88 individuals/ha.

4. *Hyperthelia dissoluta* Grassland.

This grassland community covered 1% (2ha) of the Picnic home range (Fig 4.2). The area had no rock. Erosion was estimated at 45% (moderate). Altitude was 1 052m with the average slope being 2^o.

This community was characterised by the absence of diagnostic species. It was distinguished from sub-community 3.4 by the absence of species group L (Table 4.3).

The small round-crowned tree *Ozoroa sphaerocarpa* (species group H), the evergreen shrub *Acacia karroo* (species group N) and the tufted perennial grass *Panicum maximum* (species group N) were prominent. The grass layer was dominated by the tufted perennial grass *Hyperthelia dissoluta* (species group M).

No sub-communities were distinguished for this community.

The average number of plant species in this community was 4/400m^2. The tree and forb layers were not represented; the shrub layer had a 5% cover; and the grass layer had a 90% cover. The shrub *Acacia karroo* had the highest density of 100 individuals/ha followed by the shrub *Ozoroa sphaerocarpa* with 50 individuals/ha.

Table 4.4 depicts additional plant species recoded for the Picnic home range but not regarded as prominent enough to be reflected in Table 4.3 due to their overall constancy values being below 8%. The species names and the communities they occur in are presented.

Table 4.4. Table of less prevalent plant species occurring in the Picnic home range but not presented in Table 4.3.

Species name	Community	Species name	Community	Species name	Community
Acacia burkei	2	*Erythroxylum pictum*	2	*Justicia betonica*	1.1
Acacia robusta	2	*Eustachys paspaloides*	1.1	*Lannea edulis*	4.1
Bothriochloa insculpta	2	*Felicia mossamedensis*	2	*Melinis nerviglumis*	4.1
Coccinia palmata	1.1, 3.2	*Felicia muricata*	2	*Opuntia ficus-indica*	2
Commelina africana	1.1	*Gerbera jamesonii*	1.1, 1.2		
Diospyros lycioides	1.1	*Hyperacanthus amoenus*	4.1		

4.3.5 *Community environmental ordination*

4.3.5.1 *Donga home range*

There was a positive association between rock cover and altitude in the Donga home range, with the higher lying areas being rockier than the lower lying areas. Community one which is at a higher altitude than communities two and three was rockier (Fig 4.3). Erosion was more evident in the lower lying areas.

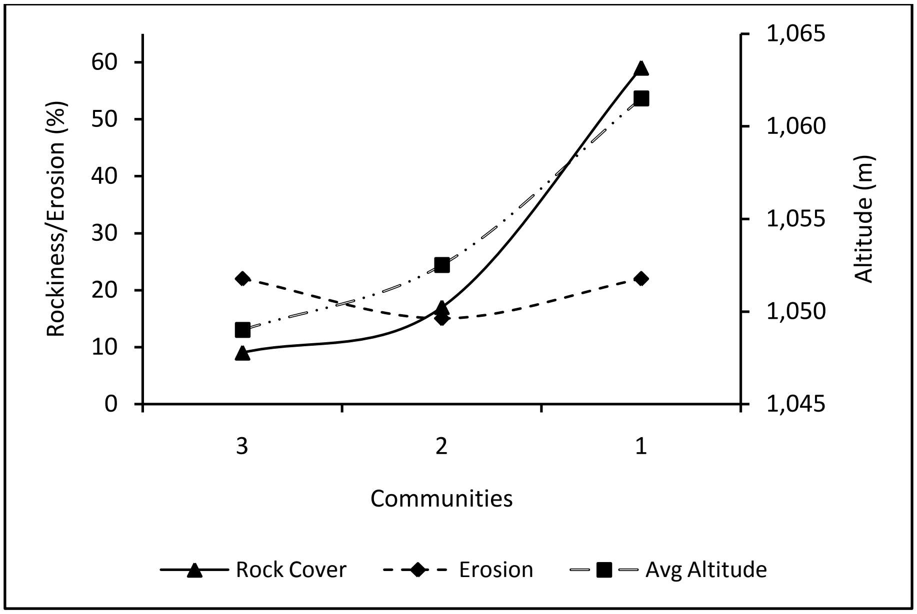


Figure 4.3. Rock cover and erosion in relation to altitude for the Donga home range communities. Communities are arranged according to a gradient of increasing altitude.

There was an inverse relationship between tree cover and altitude resulting in lower lying areas having higher tree cover than higher lying areas. Community one which was at a higher altitude than communities two and three had significantly less tree cover than communities two and three (Fig 4.4). Conversely, the grass layer was positively correlated with altitude, with higher lying areas (community 1) having higher grass cover than lower lying areas. This was related to higher tree cover in lower lying areas out-competing grasses for sun and nutrients through the area of their canopies and the nature of their root systems respectively. The shrub layer was predominantly represented in community two which was at an intermediate altitude between communities one and three (Fig 4.4). High tree cover and excessive exposure as experienced in lower and higher lying areas respectively did not limit shrub development in community two. The forb layer was generally not well represented throughout the home range, except after good rainfall when there were short lived flushes of various forb species.

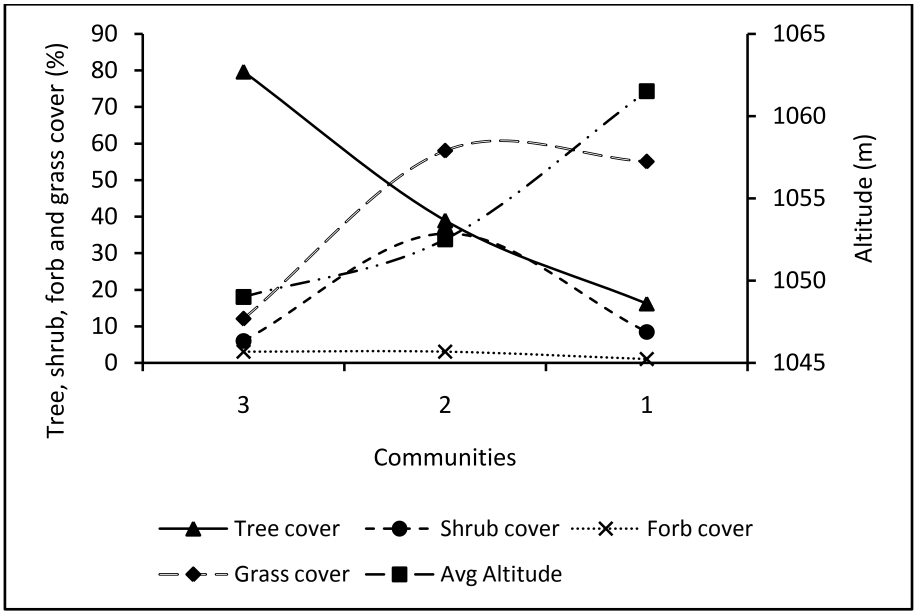


Figure 4.4. Tree, shrub, forb and grass cover in relation to altitude for the Donga home range communities. Communities are arranged according to a gradient of increasing altitude.

4.3.5.2 *Picnic home range*

There appeared to be a positive association between rock cover and altitude for the Picnic home range, with the exception of community four (Fig 4.5). Erosion was higher at low altitudes and varied at intermediate altitudes, with the exception of community four which occurred in the dry river bed forming the confluence of two non-perennial streams. Erosion in the Picnic home range was largely attributed to previous mismanagement and overgrazing.

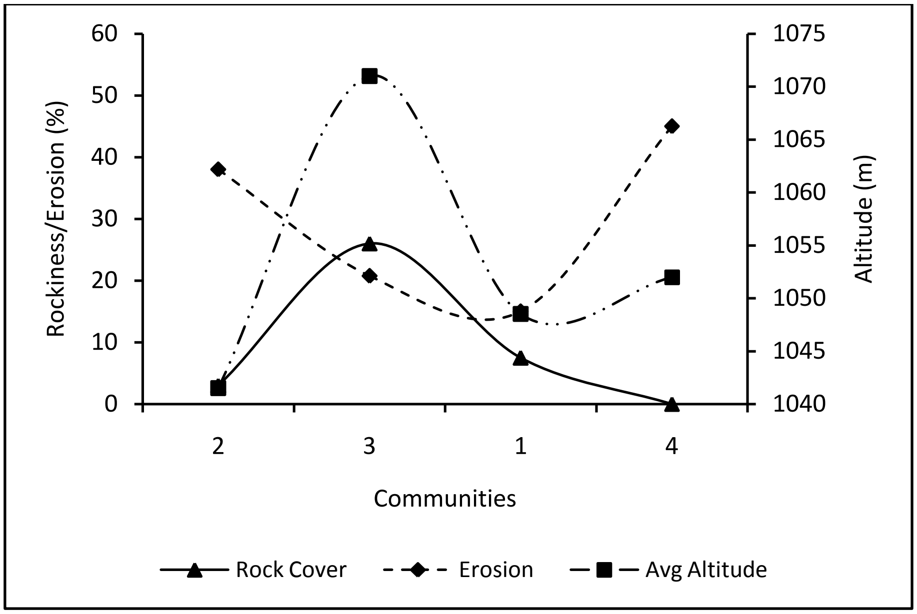


Figure 4.5. Rock cover and erosion in relation to altitude for the Picnic home range communities. Communities are arranged according to a gradient of increasing overall cover.

Tree cover was highest at intermediate altitudes with high and low lying areas having lower tree cover (Fig 4.6). Tree and grass cover were negatively associated to one another with increasing tree cover leading to decreases in grass cover. Shrub cover was highest at lower altitudes. Forb cover was constant regardless of altitude or grass and tree cover. As in the Donga home range, the forb layer was generally not well represented, except after good rainfall when there were short lived flushes of various forb species.

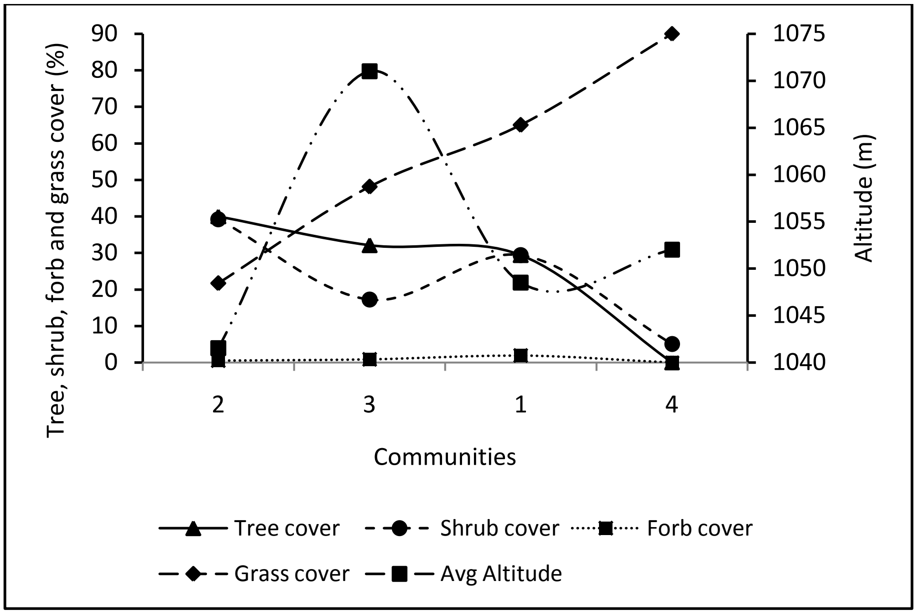


Figure 4.6. Tree, shrub, forb and grass cover in relation to altitude for the Picnic home range communities. Communities are arranged according to a gradient of increasing overall cover.

4.3.5.3 *Donga vs. Picnic*

In the Picnic home range community three occurred on the foot- and mid-slopes of a hill and was represented by large *Sclerocarya birrea* specimens which contributed towards a higher tree and associated shrub cover than would be expected for this community. This was attributed to the habitat requirements of *Sclerocarya birrea* which includes sandy to sandy loam soils found predominantly between the tops of hills and valley bottoms.

The grass layers of both home ranges corresponded, with higher lying areas having higher grass cover than lower lying areas, with the exception of community three in the Picnic home range. As mentioned above, community three had large *Sclerocarya birrea* trees providing too much shade for the grass layer to predominate. In community 3, *Panicum maximum* was the exception as it prefers growing in shady areas, and the *Sclerocarya birrea* trees provided conditions conducive to its growth.

The forb layer was not well represented in either home range with most herbaceous plants being restricted to the shaded and sheltered areas under trees and shrubs where soil moisture conditions were more conducive to their persistence, compared to the more exposed surrounding areas. Forbs flourished after short periods (four to five days) of abundant rainfall, but their tenure was transient as soils dried out rapidly when sunny conditions returned.

There were conspicuous topographical contrasts between the two vervet monkey troop's home ranges with the Donga area being more rugged and hilly than the Picnic area which was more level and uniform in appearance. Average slope for the Donga was 3.6^{o} steeper than that of the Picnic area with average slope being 13.6^{o} and 10^{o} respectively. Donga plant communities occurred at higher and lower altitudes than those of the Picnic home range, with Donga altitudes ranging from 1 005m to 1 105m and Picnic altitudes ranging from 1 031m to 1 097m respectively. Donga plots had higher rock cover than those of the Picnic area, with average rock cover percentages being 27.6% and 15.7% respectively. Even though the Picnic area was less steep than the Donga, erosion in the Picnic plots was on average 6% more than for the Donga plots. The higher erosion in the Picnic area was attributed to the general topography of the area being more conducive to previous agricultural practices such as cattle and crop farming, of which there was evidence throughout the area. The Donga areas topography was not conducive to crop farming and had less associated erosion, however there was a natural lick in the Donga home range that attracted several animal species causing the area adjacent to the lick to be trampled and eroded.

The invasive weedy annual herbs *Bidens pilosa* and *Tagetes minuta* occurred in both home ranges, but densities in the Picnic area exceeded those in the

Donga. There were a higher number of large trees in the Donga, whereas in the Picnic area many large trees were removed by farmers for crop planting. The larger number of tall seed producing trees contributing towards a vast seed bank in the soil was the main reason that the Donga area had a larger number of small trees when compared to the Picnic area. However, in most instances these small trees will not survive to adulthood due to competition for light and resources, particularly in the densely shaded areas that comprised relatively extensive portions of the home range. The Picnic area had more medium sized trees than the Donga, this was attributed to previous human interference, resulting in large homogenous stands of similar size and age trees including *Acacia karroo* and *Terminalia brachystemma* encroaching in certain areas where overgrazing occurred.

There were still signs of previous human impacts throughout the two home ranges investigated, mostly due to long term indirect anthropogenic influences including agricultural practices and overgrazing with cattle and goats. Fire and grazing are strong determinants of the vegetation structure in the reserve and both are manipulated by reserve staff as part of the areas overall management plan. Regular block burns and game manipulation through live capture, hunting and culling are undertaken in an attempt to maintain and improve the reserves vegetation and carrying capacity. Since the proclamation of the LDNR human impacts have been minimized through sound conservation management principles being applied in the area and there is a general tendency towards a more stable successional stage throughout the reserves communities. Natural ecological processes are being encouraged, which theoretically should lead to more enduring and natural vegetative representation within the reserve.

4.3.6 *Floristic analysis*

Floristic analyses were done for both the Donga and Picnic home ranges and results were compared.

4.3.6.1 *Donga home range*

The flora for the Donga home range was represented by 43 families constituting 94 genera that contained 127 species (refer Table 4.5).

Table 4.5. Plant families identified in the Donga home range, indicating the number of genera and species occurring in each family.

Families	Genera	Species
PTERIDOPHYTES		
Pteridaceae	1	1
LILIOPSIDA (Monocotyledons)		
Asparagaceae	1	5
Commelinaceae	1	1
Cyperaceae	1	1
Hyacinthaceae	1	1
Iridaceae	1	1
Orchidaceae	1	1
Poaceae	19	29
Velloziaceae	1	1
MAGNOLIOPSIDA (Dicotyledons)		
Acanthaceae	4	4
Anacardiaceae	4	7
Apocynaceae	3	3
Asteraceae	4	4
Boraginaceae	1	1
Burseraceae	1	1
Cactaceae	1	1
Celastraceae	2	2
Combretaceae	2	6
Crassulaceae	2	2
Ebenaceae	3	4
Euphorbiaceae	3	3
Fabaceae	5	12
Flacourtiaceae	3	3
Heteropyxidaceae	1	1
Lamiaceae	1	1
Malvaceae	1	1
Moraceae	1	2
Olacaceae	1	1
Oleaceae	2	2
Papilionoideae	1	1
Proteaceae	1	1
Rhamnaceae	2	2
Rubiaceae	2	2
Sapindaceae	1	1
Sapotaceae	1	1
Solanaceae	1	1
Sterculiaceae	2	2
Strychnaceae	1	1
Tiliaceae	1	5
Ulmaceae	2	2
Urticaceae	2	2
Verbenaceae	4	4
Vitaceae	1	1

For the Donga home range the two largest plant families were *Poaceae* and *Fabaceae* constituting 22.8% and 9.4% of the total flora respectively. *Poaceae* was represented by 29 species with *Fabaceae* having 12 species. Other smaller, yet significant families included *Anacardiaceae* with seven species representing 5.5% of the total flora; *Combretaceae* had six species representing

4.7%; and *Asparagaceae* and *Tiliaceae* both had five species each representing 3.9%. Combined these families represented 50.4% of the flora for the Donga home range, while the remaining 36 families constituted 49.6% comprising 63 different plant species (Fig 4.7).

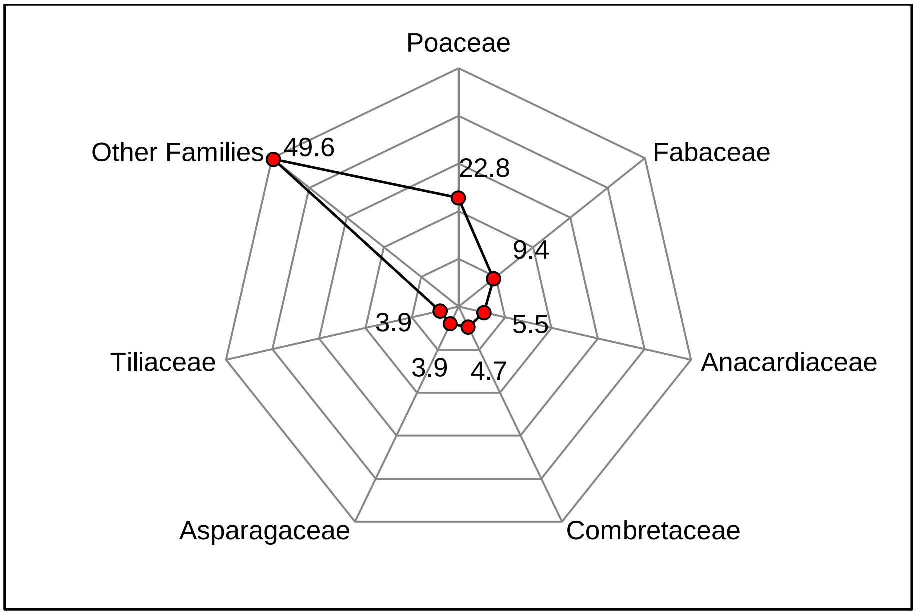


Figure 4.7. Dominant plant families for the Donga home range. Percentage contributions to total flora for the area are depicted.

Species identified in the Donga home range are listed in Appendix 1.

4.3.6.2 *Picnic home range*

The flora for the Picnic home range was represented by 34 families constituting 72 genera that contained 94 species, as reflected in Table 4.6.

Table 4.6. An alphabetical list of plant families identified in the Picnic home range, indicating the number of genera and species occurring in each family.

Families	Genera	Species
PTERIDOPHYTES		
Pteridaceae	1	1
LILIOPSIDA (Monocotyledons)		
Amaryllidaceae	2	2
Asparagaceae	1	4
Commelinaceae	1	2
Cyperaceae	1	1
Hyacinthaceae	1	1
Iridaceae	1	1
Poaceae	21	25
Velloziaceae	1	1
MAGNOLIOPSIDA (Dicotyledons)		
Acanthaceae	3	3
Anacardiaceae	4	6
Apocynaceae	2	2
Asteraceae	3	4
Cactaceae	1	1
Celastraceae	1	1
Combretaceae	2	5
Cucurbitaceae	1	1
Ebenaceae	2	3
Erythroxylaceae	1	1
Euphorbiaceae	3	3
Fabaceae	3	6
Loranthaceae	1	1
Olacaceae	1	1
Proteaceae	1	1
Rhamnaceae	2	2
Rubiaceae	2	2
Sapindaceae	1	1
Solanaceae	1	2
Sterculiaceae	1	1
Strychnaceae	1	2
Tiliaceae	1	3
Ulmaceae	1	1
Verbenaceae	2	2
Vitaceae	1	1

For the Picnic home range the largest plant families included *Poaceae* constituting 26.6% of the total flora, and *Anacardiaceae* and *Fabaceae* both constituting 6.4% respectively. *Poaceae* was represented by 25 species with *Anacardiaceae* and *Fabaceae* both having six species each. Other smaller, yet significant families included *Combretaceae* with five species representing 5.3% of the total flora; and *Asparagaceae* and *Asteraceae* both with four species each representing 4.3%. Combined these families represented 53.2% of the flora for the Picnic home range, while the remaining 28 families constituted 46.8% comprising 44 different plant species (Fig 4.8).

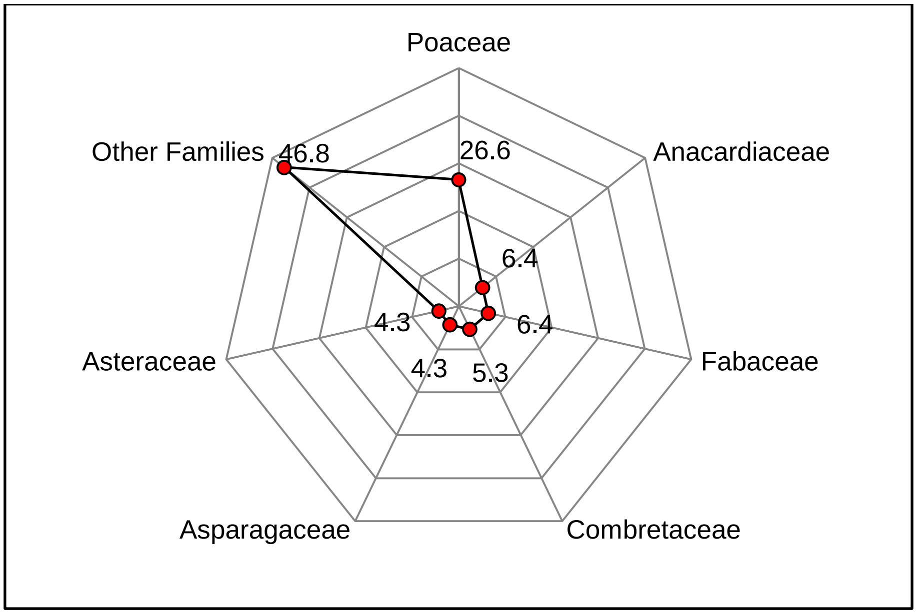


Figure 4.8. Dominant plant families for the Picnic home range. Percentage contributions to total flora for the area are depicted.

Species identified in the Picnic home range are listed in Appendix 1.

4.3.6.3 *Donga vs. Picnic*

The Donga home range was represented by 43 plant families consisting of 127 species, whereas the Picnic home range was represented by 34 families consisting of 94 species, resulting in increased heterogeneity in the Donga area (Table 4.7).

Table 4.7. Comparative study area characteristics for the two home ranges.

Attribute	Donga Home Range	Picnic Home Range
Number of plant families	43	34
Number of plant species	127	94
Density of trees larger than three metres high (No./ha)	42	57
Level of disturbance	Low/Medium (erosion)	High (erosion, previous agricultural practices)
% Tree cover	44	29
% Shrub cover	18	22
% Forb cover	2	1
% Grass cover	43	55
% Total cover	74	72

The two home ranges had 30 plant families in common, with the Donga home range having 13 families not represented in the Picnic home range and the Picnic home range having four families not represented in the Donga home range.

Donga plant families not found in the Picnic home range included *Boraginaceae, Burseraceae, Crassulaceae, Flacourtiaceae, Heteropyxidaceae, Lamiaceae, Malvaceae, Moraceae, Oleaceae, Orchidaceae, Papilionoideae, Sapotaceae* and *Urticaceae.* Picnic plant families not found in the Donga home range included *Amaryllidaceae, Cucurbitaceae, Erythroxylaceae* and *Loranthaceae.*

The plant families *Anacardiaceae* (the mango family) which is mostly trees and shrubs, and *Asteraceae* (the daisy family) which is the largest family of flowering plants occurring mostly as herbs and sometimes as shrubs had a stronger presence in the Picnic home range. The plant families *Fabaceae* (the legume or pod-bearing family) which is the second largest plant family represented mostly as herbs, shrubs or trees and sometimes even scramblers, and *Tiliaceae* (the jute and linden family) occurring as trees, shrubs or herbs had a stronger presence in the Donga home range.

From a structural perspective, the Donga home range had more trees (25.8%) that were greater than three metres in height compared to the Picnic home range (23.9%). The Picnic area had more trees between one and three metres high (50%) compared to the Donga area (46.7%). And the Donga had more trees that were less than one metre in height (27.4%) compared to the picnic area (26%). Overall tree, shrub, forb and grass cover for the donga was 46.7%, 16.4%, 3.5% and 41.2% respectively. The Picnic tree, shrub, forb and grass cover was 31%, 25.7%, 1% and 51% respectively. Overall vegetation cover for the Donga home range was 75.6% compared to 70.6% for the Picnic home range.

Both areas were protected by hills and ridges, but the Donga home range more so than the Picnic home range. The Donga and Picnic home ranges were located relatively close to one another and were therefore exposed to similar overall climatic conditions. Both areas had non-perennial streams and drainage channels originating within the reserve running through them. Such streams were dry for long periods of time throughout the year.

The water retention capacity of the two home ranges was different due to their contrasting topographies and human impacts. The Picnic home range had several dry non-perennial stream beds traversing the area and merging to form larger streams that flowed down into the Loskop dam. Along the larger stream beds were two manmade impoundments that had previously been erected to dam water for livestock watering. Such impoundments and the overall flat topography of the area contributed towards the Picnic home range having a higher water retention capacity than the Donga home range. The Donga home range was part of several drainage channels leading from higher lying areas and was generally less flat than the Picnic area, resulting in faster runoff of flood water and less water holding ability.

Differences between the Donga and Picnic home range plant family representation was not significant ($t_{46} = 0.037$, $P = 0.97$).

4.4 Discussion

The Braun-Blanquet approach to classifying and identifying plant communities in the field proved to be accurate and effective for the purposes of this study. Floristically defined plant communities were successfully classified and identified as a basis for further investigation.

According to Kruger (2004), vegetation and resources are closely related to the climate of a particular area and give rise to distinct vegetative zones. Results showed variations in the vegetation occurring in the two home ranges, with topographical differences and the effects of environmental factors influencing plant species availability.

In terms of plant species representation on a broader scale, the Donga home range showed affinity to the *Faurea saligna-Setaria perennis* (now *Setariasphacelata var. sphacelata*), *Acacia caffra-Setaria sphacelata* and *Combretum apiculatum-Heteropogon contortus* tree savannas as described by Theron (1973). There was also a similarity to the *Acacia caffra-Setaria sphacelata* community as described for two newly proclaimed areas (Rietfontein and Parys) by Götze *et al*. (1998). The Picnic home range had broad affinities to the *Acacia caffra-Combretum apiculatum-Themeda triandra* and *Combretum apiculatum-Heteropogon contortus* tree savannas as described by Theron (1973). Additionally, there were similarities to the *Combretum apiculatum-Themeda triandra* community as described by Götze *et al*. (1998).

The general vegetation for the two home ranges had several similarities and could be combined into a single large *Acacia caffra-Dichrostachys cinerea-*

Panicum maximum shrubland community. Other prominent species included *Rhus leptodictya, Dombeya rotundifolia, Berchemia zeyheri* and *Eragrostis chloromelas*. Overall, the two home ranges had no significant differences when comparing plant family representation.

The Donga and Picnic home ranges had sufficient plant resources to provide for the social and foraging needs of vervet monkeys. The areas met the critical habitat requirement needs for vervet monkeys by providing sufficient food species to sustain viable troops, even during the drier periods when resources were less abundant (hence their presence in the area). The larger tree species provided protection from predators while the vervets fed and slept. Both areas had access to drinking water. Such habitats contribute significantly towards the diversity of both plant and animal species occurring within and adjacent to them.

Studies on specific animals and their home ranges are important in determining which habitats animals utilise. This information can be used by Nature Reserves to focus and inform management in decision making processes regarding burning, carrying capacity determination, censusing and species management. The following is an example of how results from this study could assist reserve management: if the Picnic and Donga home ranges are identified as management units to be burnt as part of Loskop's burning program, untimely burning of these areas could have dire consequences to the territorial vervets as their food resources would be affected. The Picnic home range would be more susceptible to such a practice than the Donga due to the Picnic area being more homogenous, with most of the areas vegetation being connected. This as opposed to the Donga area where the various Dongas serve to separate the areas vegetation. The erosion in the Picnic area does however offer some respite by forming natural fire breaks. Also, existing management practices can be adapted should the potential consequences of such practices prove to be deleterious to the species involved.

The subsequent chapter will look at the seasonal diets of the two vervet troops as a precursor to exploring the phenology of resources they utilize.

CHAPTER 5

HABITAT AND DIETARY SELECTIVITY

5.1 Introduction

The acquisition of food is central to the structuring of primate behaviour and activity, since only when they meet their daily dietary requirements, can primates afford to invest their time in alternate activities (Krebs & Davies, 1993). It is generally assumed that foraging behavior is therefore geared to trade-offs between energy intake and expenditure (Pyke *et al*., 1977; Krebs & McCleery, 1984; Foley, 1985). Understanding patterns of home range use must, therefore, begin with the identification of the foods that are used and an understanding of the extent to which patterns of usage tracks item availability across the seasons.

Resource availability is affected generally by seasonally influenced ecological constraints, especially in higher-latitude environments (Barbour *et al.*, 1987; Cowling *et al.*, 1997; Kent & Coker, 1997). Locally, of course, small-scale variability in habitat structure (soils, aspect and gradient) consequently can mean that while different troops in a population face the same broad cycles, their responses may well differ, being structured by the particular circumstances within the foraging areas available to them. There is little available information on the extent of similarity in the diets of different groups within a population, both broadly and at the level of specific items. However, Codron *et al*. (2006) have used isotopic analyses of baboon faecal material to show that local vegetation profiles (the availability of grass) is reflected in dietary profile differences. Such differences are likely to be even more marked in species that are territorial. Baboons do not defend territorial boundaries (Whiten *et al*., 1987), whereas vervets, for example, do (Henzi & Lucas, 1980; Cheney, 1981). To the extent to which such defence constrains access to particular resources, we might expect increased differentiation in local diets and, consequently, habitat use across seasons.

The two vervet monkey study troops not only live in an environment characterised by seasonal rainfall that is often unpredictable (Mucina & Rutherford, 2006), but also, as indicated earlier, occupy territories that differ structurally. To determine the extent to which habitat structure and seasonality influence the use of temporally and spatially distributed resources, it is necessary to begin by assessing whether the diets themselves reflect this variability.

In this chapter, therefore, I begin at the level of identified plant communities available in each of the two territories, and use i) electivity indices to determine whether some communities are preferred over others. I then consider ii) the contribution of different food types to the diet by season before iii) considering the importance of specific food species to each of the two troops generally and at the level of age-sex class. I also briefly examine individual choice in the context of local competition. That is, if close coexistence increases the likelihood of competition, which is one of the negative corollaries of predator-driven sociality (van Schaik *et al.*, 1983), then one of the possible advantages of being an omnivore is that it can reduce conflict. This is relevant to our understanding of ranging patterns in relation to resource availability, and so I test the following prediction: as the number of simultaneously foraging individuals' increases, there will be a corresponding increase in the variety of food types and plant species being used.

5.2 Methods

Plant community electivity and the main seasonal forage species electivity was calculated using Ivlev's Electivity Index (Krebs, 1989):

$$SE = \frac{(r1 - n1)}{(r1 + n1)}$$

Where SE = community or species electivity

$r1$ = proportion of community utilized or proportion of species in diet

$n1$ = proportion of community available in home range or proportion of species available in home range.

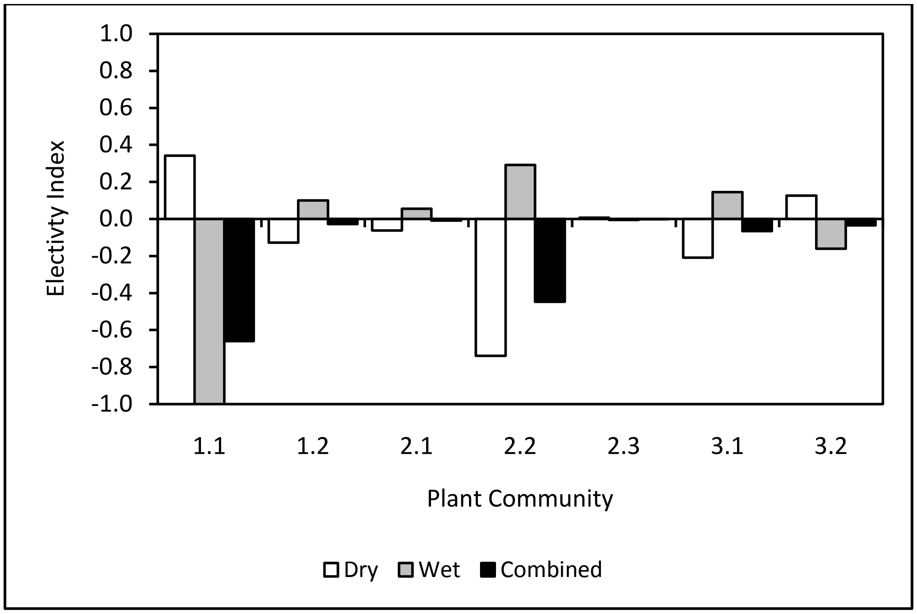
The proportion of a community utilized and of the different plant species in the vervets diets was calculated as a percentage of the overall communities size and as a percentage of all the species in their diets respectively, while the proportion of a community and of species available in their home ranges was calculated as a percentage of the size of all communities and as a percentage of all species occurring within their home ranges respectively.

Values for the electivity index ranged between -1 and 1, with 0 indicating random selection, >0 indicating a positive selection, and <0 indicating avoidance or selection against a particular community or species.

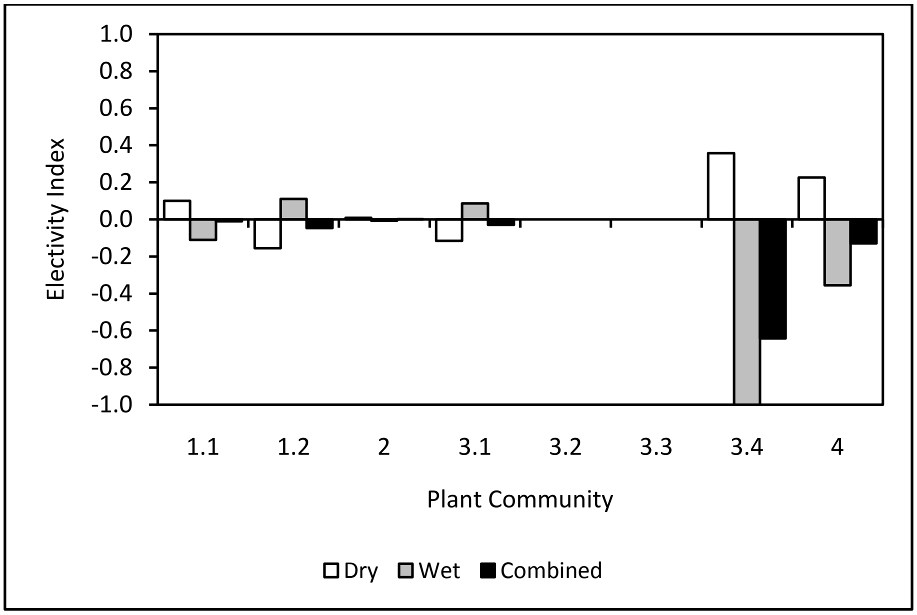
5.3 Results

5.3.1 *Plant community electivity*

Seasonal plant community electivity by the two troops is depicted in Fig 5.1. Results indicate that seasonality had a marked effect on community utilization for both troops.



(a)



(b)

Figure 5.1. Seasonal plant community electivity for the Donga troop (a) and the Picnic troop (b). Refer to 4.3.1 and 4.3.3 for community names.

The Donga troop showed a preference for the *Lippia javanica-Loudetia simplex-Sclerocarya birrea* (1.1) and the *Olea europea subsp. africana-Celtis africana-*

Mimusops zeyheri (3.2) woodland sub-communities during the dry season. During the wet season, they preferred the *Acacia nilotica-Acacia caffra-Tragus berteronianus* (2.2), the *Olea europea subsp. africana-Rhus leptodictya-Carissa bispinosa* (3.1) and the *Lippia javanica-Loudetia simplex-Acacia caffra* (1.2) woodland sub-communities. They showed a distinct aversion to the *Acacia nilotica-Acacia caffra-Tragus berteronianus* (2.2) woodland sub-community during the dry season and to the *Lippia javanica-Loudetia simplex-Sclerocarya birrea* (1.1) woodland sub-community during the wet season.

The Picnic troop indicated a preference for the *Heteropogon contortus-Sclerocarya birrea-Faurea saligna* (3.4) woodland sub-community, the *Hyperthelia dissoluta* (4) grassland community and the *Lippia javanica-Loudetia simplex-Sclerocarya birrea* (1.1) woodland sub-community during the dry season. During the wet season, they preferred the *Acacia caffra-Setaria sphacelata var. sphacelata-Dombeya rotundifolia* (1.2) woodland and the *Olea europea subsp. africana-Rhus leptodictya-Carissa bispinosa* (3.1) shrubland sub-communities. There was a marked aversion to the *Heteropogon contortus-Sclerocarya birrea-Faurea saligna* (3.4) woodland sub-community during the wet season. From a dietary perspective the *Heteropogon contortus-Sclerocarya birrea-Ledebouria apertiflora* (3.2) and the *Heteropogon contortus-Sclerocarya birrea-Cenchrus ciliaris* (3.3) shrubland sub-communities were not utilised.

5.3.2 *Diet*

Table 5.1 depicts a seasonal breakdown of the various plant part percentages contributing towards the Donga troop’s diet.

Table 5.1. Seasonal breakdown of the various plant part percentages contributing towards the Donga troop's diet.

Plant Species	% of Tot	Cumulative	Tot % Dry	Tot % Wet	Contribution Towards Tot % Dry					Contribution Towards Tot % Wet				
					Flower	Fruit	Gum	Leaf	Pod	Flower	Fruit	Gum	Leaf	Pod
Acacia caffra	17.6	17.6	8.7	8.9	27.1	0.8	0.0	32.3	39.8	5.8	0.7	6.6	74.5	12.4
Olea europaea s. africana	8.5	26.1	4.3	4.2	0.0	87.9	0.0	10.6	1.5	0.0	89.1	0.0	10.9	0.0
Berchemia zeyheri	8.2	34.3	0.4	7.8	0.0	66.7	0.0	33.3	0.0	0.0	100.0	0.0	0.0	0.0
Mimusops zeyheri	7.8	42.2	4.5	3.3	0.0	100.0	0.0	0.0	0.0	3.9	96.1	0.0	0.0	0.0
Combretum zeyheri	6.5	48.6	2.2	4.2	5.9	91.2	0.0	0.0	2.9	4.6	49.2	0.0	10.8	35.4
Euclea crispa	6.5	55.1	3.8	2.7	0.0	91.4	0.0	8.6	0.0	4.9	90.2	0.0	4.9	0.0
Rhus pyroides	6.1	61.2	0.3	5.7	0.0	60.0	0.0	40.0	0.0	0.0	97.7	0.0	2.3	0.0
Celtis africana	4.7	65.9	1.2	3.5	0.0	100.0	0.0	0.0	0.0	0.0	98.1	0.0	1.9	0.0
Ficus sur	4.6	70.5	2.9	1.7	0.0	91.1	0.0	8.9	0.0	0.0	80.8	0.0	19.2	0.0
Acacia robusta	4.1	74.6	3.3	0.8	70.0	0.0	0.0	12.0	18.0	8.3	8.3	0.0	8.3	75.0
Acacia karroo	3.8	78.4	0.9	2.9	0.0	0.0	28.6	14.3	57.1	0.0	0.0	29.5	47.7	22.7
Sclerocarya birrea	3.6	82.0	1.5	2.1	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
Euclea undulata	2.2	84.2	0.8	1.4	0.0	91.7	0.0	0.0	8.3	0.0	86.4	0.0	13.6	0.0
Rhus leptodictya	2.2	86.4	1.0	1.2	20.0	40.0	0.0	33.3	6.7	0.0	15.8	0.0	84.2	0.0
Ziziphus mucronata	2.1	88.5	1.0	1.2	6.7	93.3	0.0	0.0	0.0	5.3	94.7	0.0	0.0	0.0
Lannea schweinfurthii	1.6	90.1	0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
Ficus craterostoma	1.4	91.6	1.2	0.2	0.0	89.5	0.0	10.5	0.0	0.0	100.0	0.0	0.0	0.0
Acacia ataxacantha	1.2	92.7	1.0	0.2	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0
Acacia burkei	0.8	93.6	0.8	0.1	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	100.0	0.0
Carissa bispinosa	0.8	94.4	0.8	0.1	8.3	91.7	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
Combretum erythrophyllum	0.8	95.2	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	8.3	0.0	83.3	8.3
Pappea capensis	0.7	95.9	0.3	0.4	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
Chaetachme aristata	0.6	96.5	0.2	0.4	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
Mayteunis undata	0.5	97.0	0.4	0.1	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
Robinia pseudoacacia	0.5	97.5	0.0	0.5	0.0	0.0	0.0	0.0	0.0	28.6	71.4	0.0	0.0	0.0
Acacia nilotica	0.4	97.8	0.1	0.3	0.0	0.0	0.0	0.0	100.0	0.0	25.0	25.0	25.0	25.0
Combretum apiculatum	0.4	98.2	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	83.3	0.0	0.0	16.7
Mystroxylon aethiopicum	0.3	98.6	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
Eriosema psoraleoides	0.3	98.9	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	80.0
Grewia flavescens	0.3	99.2	0.3	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Combretum hereroense	0.2	99.3	0.1	0.1	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
Peltophorum africanum	0.2	99.5	0.1	0.1	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
Ximenia caffra	0.2	99.7	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
Barleria rotundifolia	0.1	99.9	0.1	0.0	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0	0.0
Grewia monticola	0.1	99.9	0.1	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tapinanthus sp.	0.1	100.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0

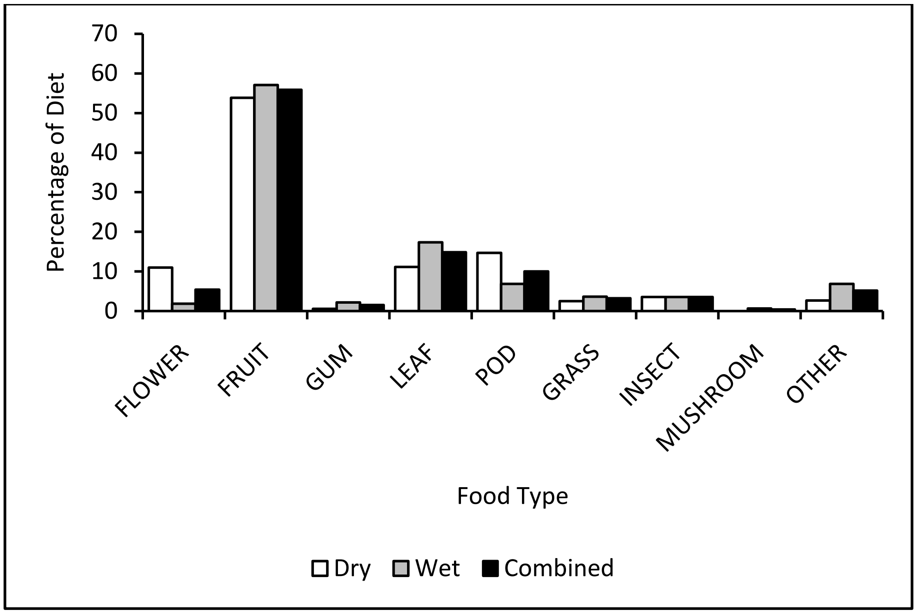
Similarly, Table 5.2 depicts a seasonal breakdown of the various plant part percentages contributing towards the Picnic troop's diet.

Table 5.2. Seasonal breakdown of the various plant part percentages contributing towards the Picnic troop's diet.

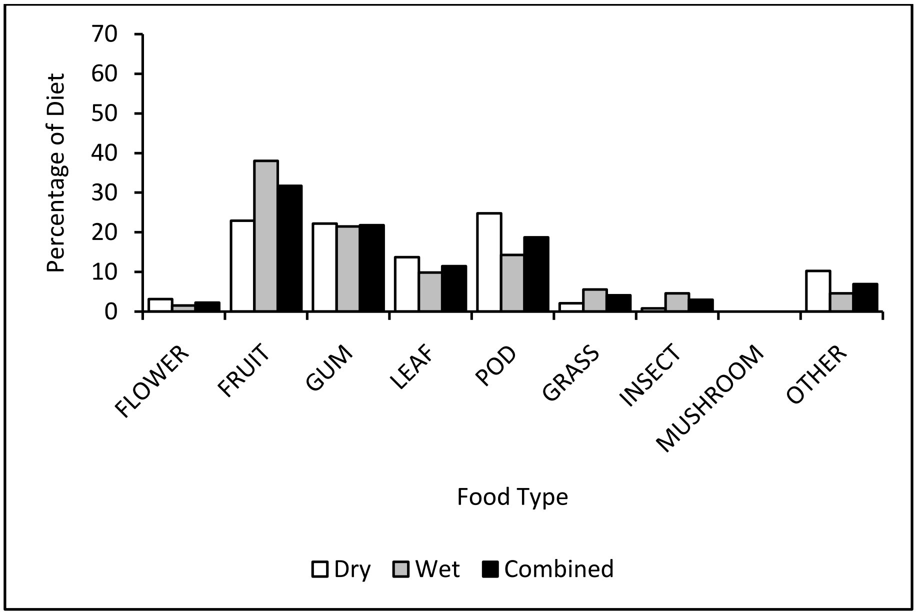
Plant Species	% of Tot	Cumulative	Tot % Dry	Tot % Wet	Contribution Towards Tot % Dry					Contribution Towards Tot % Wet				
					Flower	Fruit	Gum	Leaf	Pod	Flower	Fruit	Gum	Leaf	Pod
Acacia karroo	32.6	32.6	18.1	14.5	0.7	0.0	52.5	12.2	34.5	0.0	0.0	67.9	12.5	19.6
Rhus pyroides	17.8	50.4	4.2	13.6	0.0	59.4	0.0	40.6	0.0	0.0	96.2	0.0	3.8	0.0
Acacia caffra	10.0	60.4	3.8	6.2	6.9	0.0	13.8	24.1	55.2	2.1	0.0	58.3	14.6	25.0
Acacia burkei	6.1	66.5	1.8	4.3	21.4	0.0	35.7	0.0	42.9	12.1	0.0	15.2	24.2	48.5
Ziziphus mucronata	6.1	72.6	4.0	2.1	0.0	90.3	0.0	9.7	0.0	0.0	93.8	0.0	6.3	0.0
Combretum zeyheri	5.5	78.1	3.4	2.1	3.8	96.2	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
Celtis africana	4.3	82.3	0.9	3.4	0.0	85.7	0.0	14.3	0.0	0.0	96.2	0.0	3.8	0.0
Acacia nilotica	4.2	86.5	2.1	2.1	0.0	0.0	12.5	25.0	62.5	0.0	0.0	6.3	25.0	68.8
Acacia robusta	2.7	89.2	1.0	1.7	37.5	0.0	0.0	62.5	0.0	0.0	0.0	7.7	0.0	92.3
Peltophorum africanum	1.9	91.2	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	86.7	0.0	13.3	0.0
Euclea crispa	1.6	92.7	0.8	0.8	0.0	100.0	0.0	0.0	0.0	0.0	83.3	0.0	16.7	0.0
Dichrostachys cinerea	1.4	94.2	1.3	0.1	0.0	0.0	0.0	10.0	90.0	0.0	0.0	0.0	0.0	100.0
Sclerocarya birrea	1.4	95.6	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
Combretum erythrophyllum	1.2	96.8	0.4	0.8	0.0	66.7	0.0	33.3	0.0	0.0	0.0	0.0	100.0	0.0
Berchemia zeyheri	0.6	97.4	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
Eriosema psoraleoides	0.6	98.1	0.6	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0
Ximenia caffra	0.6	98.7	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
Protasparagus sp.	0.4	99.1	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0
Tapinanthus sp.	0.4	99.5	0.3	0.1	100.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Grewia flava	0.3	99.7	0.1	0.1	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
Pterocarpus rotundifolius	0.3	100.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0

5.3.3 *Troop seasonal food type selection*

Seasonal and combined food type selection by the two troops is indicated in Fig 5.2. Fruit makes up the largest portion of the Donga troop's diet across both seasons, followed by leaves and pods (Fig 5.2a). The Picnic troop food type selection is less dominated by a single source, with fruit, gum, leaves and pods all making strong contributions to their diet (Fig 5.2b).



(a)



(b)

Figure 5.2. Seasonal and combined proportions of food types selected by the Donga troop (a) and the Picnic troop (b).

Food source selection was significantly different across the two seasons for both the Donga ($X^2(8) = 129.45$, $P < 0.01$) and the Picnic troop ($X^2(8) = 61.29$, $P < 0.01$).

5.3.4 *A comparison of the utilization of food types by the two troops*

Food types selected by the two troops differed significantly $X^2(8) = 28.52$, $P < 0.01$. The Donga troop consumed more flowers, fruit and leaves than the Picnic troop, which consumed more gum, pods and grass (Fig 5.3).

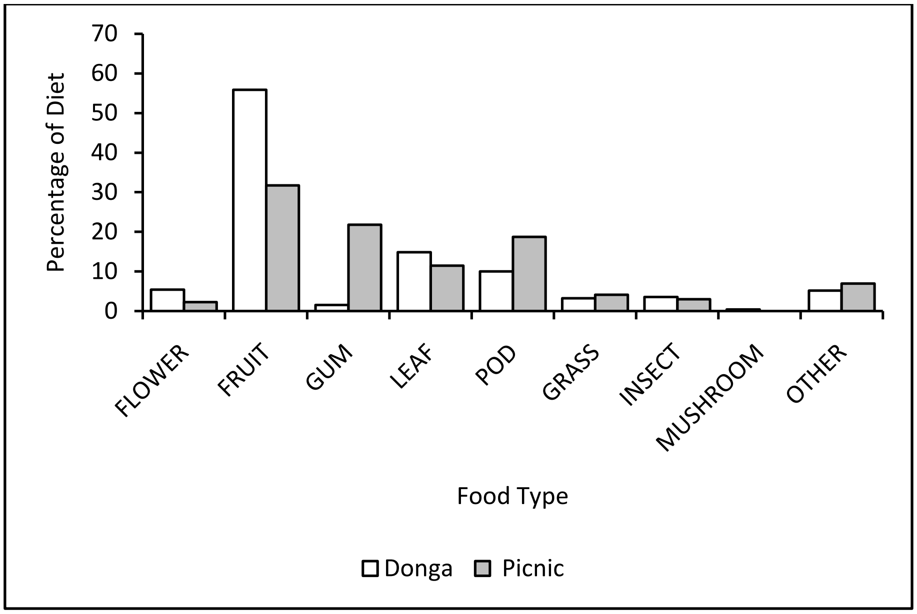
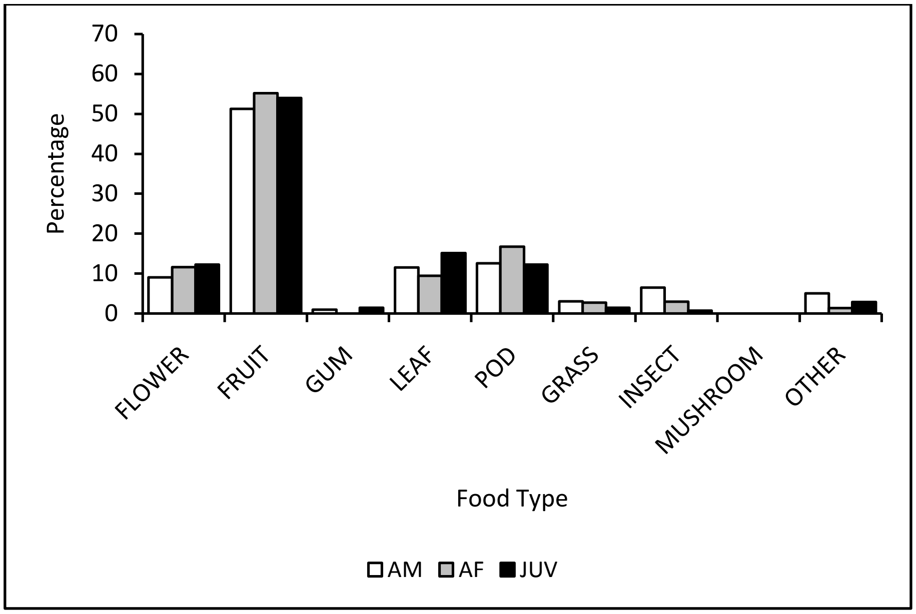


Figure 5.3. Overall proportions of food types selected by the two troops.

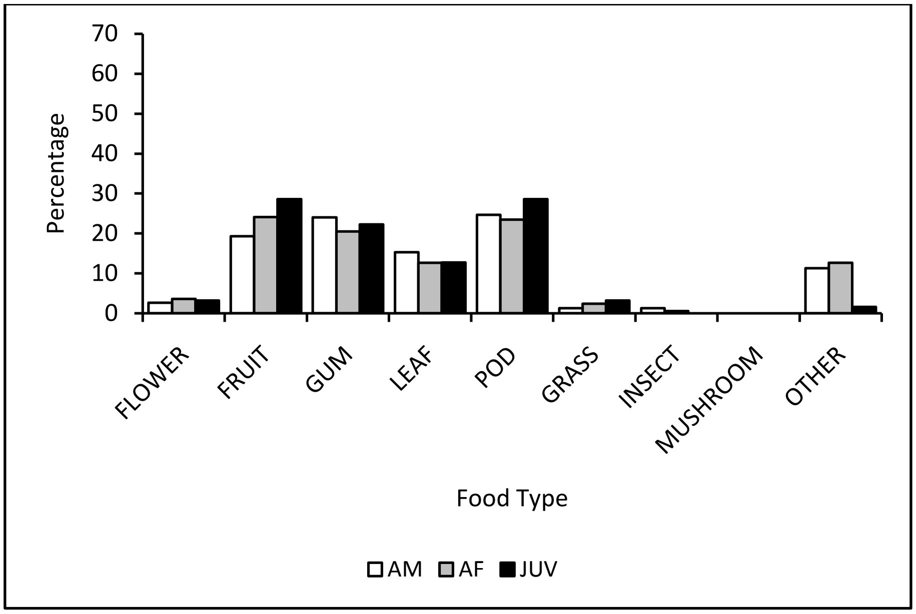
5.3.5 *Age-sex class seasonal food type selection*

A dry season comparison of the food types selected by the different age-sex classes for the Donga troop (Fig 5.4a) showed that fruit was the main food type selected by all age-sex classes, followed by pods (AM and AF), leaves (AM and JUV) and flowers (AF and JUV). For the Picnic troop in the dry season (Fig 5.4b), pods were the most selected food type (AM and JUV), followed by fruit

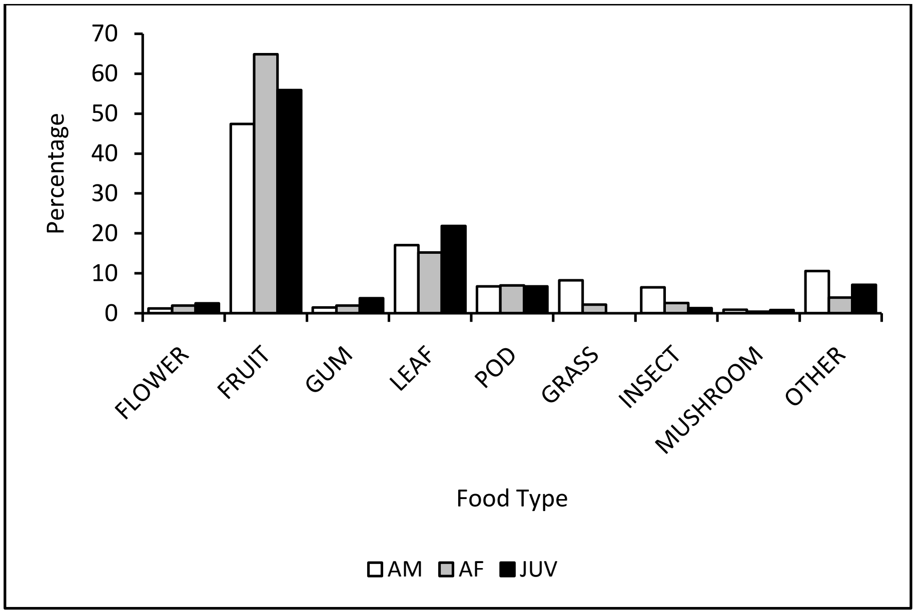
(AF & JUV), gum (AM and JUV) and leaves (AM). For the Donga troop, during the wet season (Fig 5.4c), fruit is the main food type selected by all age-sex classes, followed by leaves. For the Picnic troop wet season (Fig 5.4d), fruit is the most selected food type for all age-sex classes, followed by gum, pods (AF) and leaves (AM and JUV).



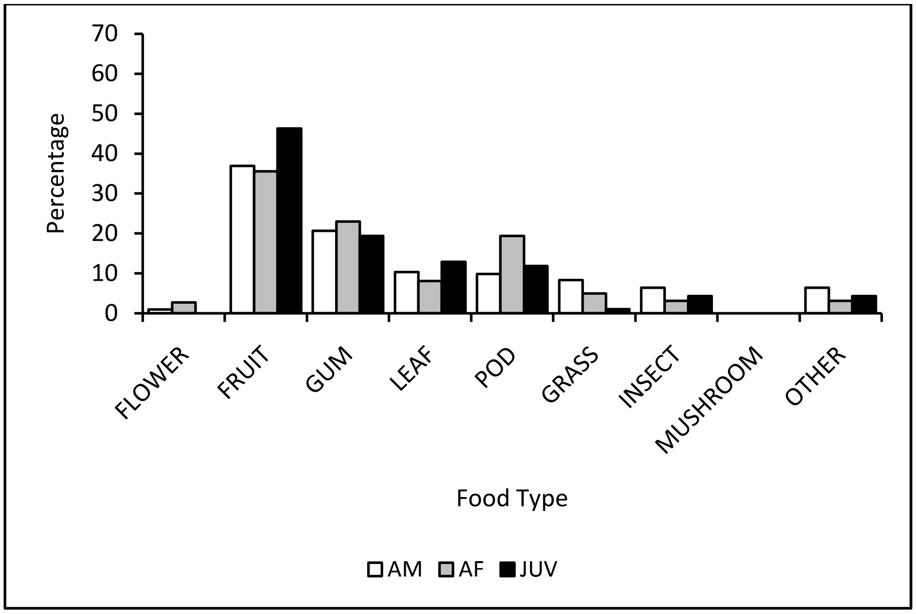
(a)


70
60
50
40
30
20
10
0
Percentage
FLOWER
FRUIT
GUM
LEAF
POD
GRASS
INSECT
MUSHROOM
OTHER
Food Type
AM
AF
JUV

(b)


70
60
50
40
30
20
10
0
Percentage
FLOWER
FRUIT
GUM
LEAF
POD
GRASS
INSECT
MUSHROOM
OTHER
Food Type
AM
AF
JUV

(c)



(d)

Figure 5.4. Proportions of food types selected by the various age-sex classes for the Donga troop in the dry season (a), the Picnic troop in the dry season (b), the Donga troop in the wet season (c), and the Picnic troop in the wet season (d).

During the dry season, for the Donga troop, the proportions of various food types selected varies noticeably across the age-sex classes ($X^2(14) = 27.14$, $P < 0.01$); for the Picnic troop there are no noticeable variations ($X^2(14) = 11.09$, $P = 0.67$).

During the wet season, for both the Donga troop ($X^2(16) = 77.06$, $P < 0.01$) and the Picnic troop ($X^2(14) = 26.38$, $P = 0.02$) the proportions of various food types selected varies significantly across the different age-sex classes.

5.3.6 *Across troop age-sex class seasonal food type selection*

There are significant between-troop differences in seasonal food type selection across all age-sex classes:

- For the dry season adult females $X^2(7) = 145.02$, $P < 0.01$ and wet season $X^2(8) = 130.99$, $P < 0.01$,
- for the dry season adult males $X^2(7) = 89.09$, $P < 0.01$ and wet season $X^2(8) = 67.18$, $P < 0.01$,
- for the dry season juveniles $X^2(7) = 41.75$, $P < 0.01$ and wet season $X^2(8) = 35.41$, $P < 0.01$.

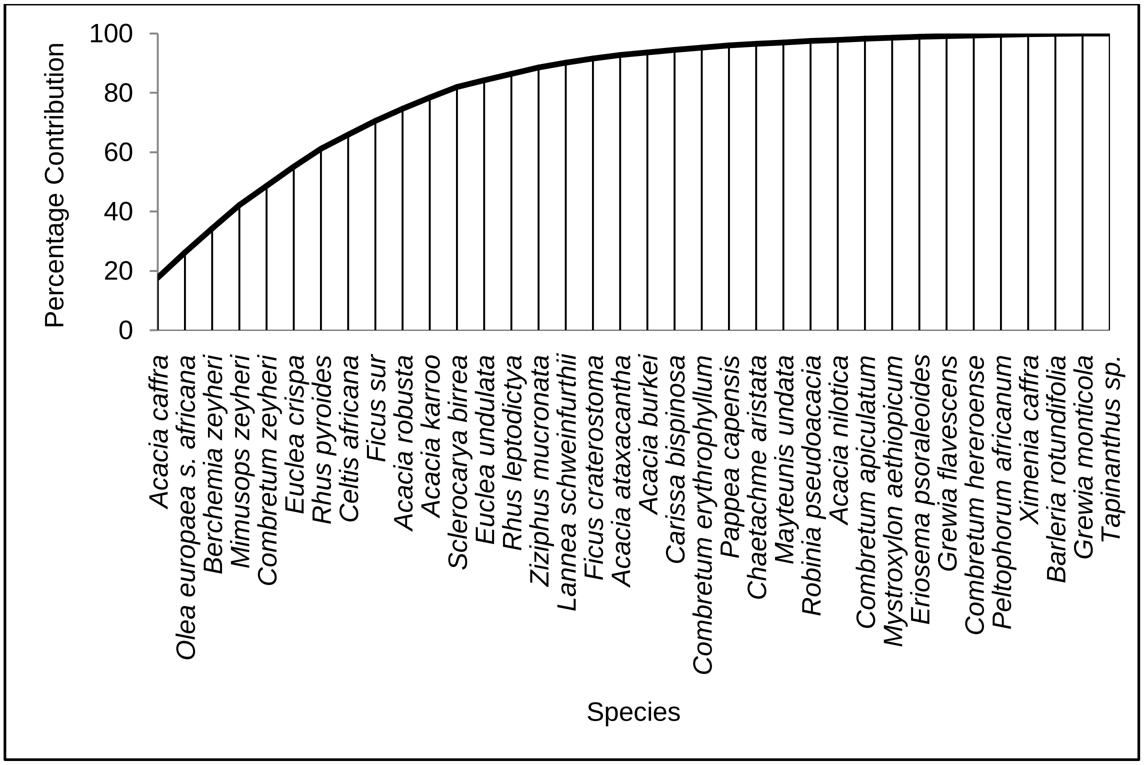
5.3.7 *Number of foraging individuals vs. variety of food types selected*

There was a positive correlation between the number of individuals foraging simultaneously and the variety of food types being eaten for both the Donga ($r_s = 0.387$, df = 612, $P < 0.01$) and the Picnic troop ($r_s = 0.481$, df = 338, $P < 0.01$).

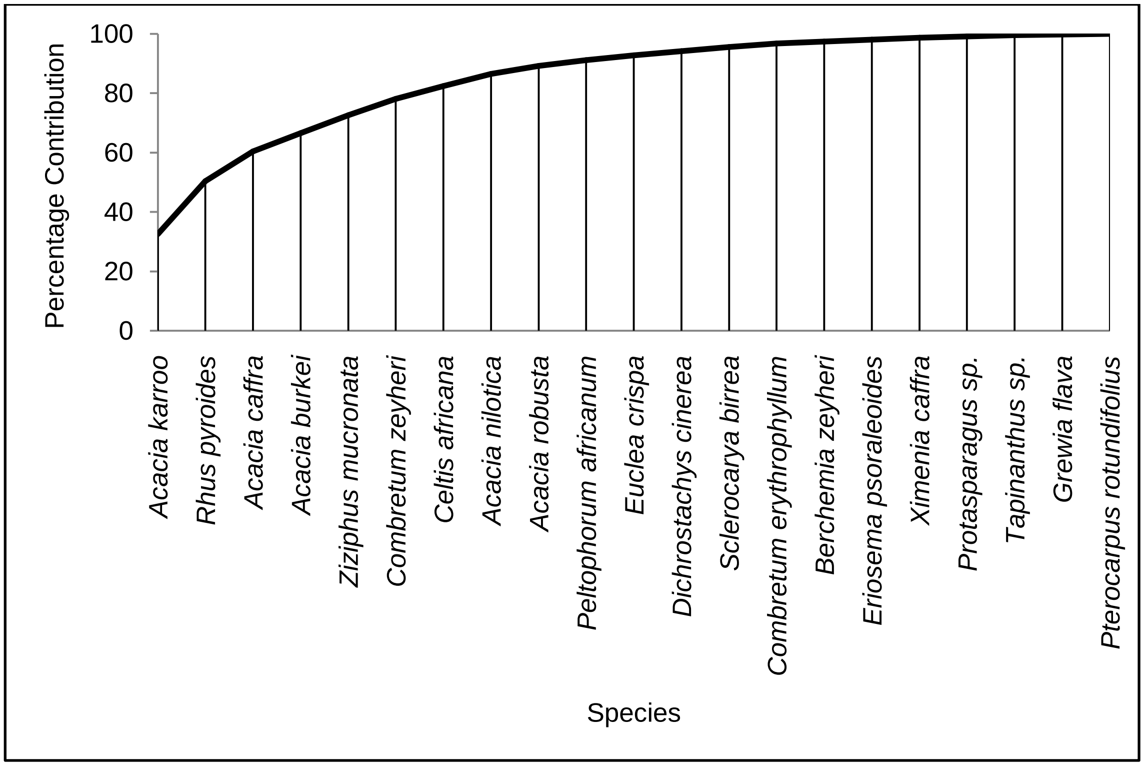
5.3.8 *Species–level contributions to diet*

In order to determine the relative importance of different tree resource species in the two territories, I ranked these in relation to their cumulative contribution to the diet (Fig 5.5).

The Donga Troop exploited a total of 36 different species, of which six - *Acacia caffra, Olea europaea subsp. africana, Berchemia zeyheri, Mimusops zeyheri, Combretum zeyheri, Euclea crispa* – constituted 50% of the total contribution, with 75% of the contribution coming from 11 species (Fig 5.5a). The Picnic troop used 21 different species, of which only two species - *Acacia karroo* and *Rhus pyroides* – were responsible for 50% of the total usage, with 75% of the contribution coming from six species (Fig 5.5b).


Percentage Contribution
100
80
60
40
20
0
Acacia caffra
Olea europaea s. africana
Berchemia zeyheri
Mimusops zeyheri
Combretum zeyheri
Euclea crispa
Rhus pyroides
Celtis africana
Ficus sur
Acacia robusta
Acacia karroo
Sclerocarya birrea
Euclea undulata
Rhus leptodictya
Ziziphus mucronata
Lannea schweinfurthii
Ficus craterostoma
Acacia ataxacantha
Acacia burkei
Carissa bispinosa
Combretum erythrophyllum
Pappea capensis
Chaetachme aristata
Mayteunis undata
Robinia pseudoacacia
Acacia nilotica
Combretum apiculatum
Mystroxylon aethiopicum
Eriosema psoraleoides
Grewia flavescens
Combretum hereroense
Peltophorum africanum
Ximenia caffra
Barleria rotundifolia
Grewia monticola
Tapinanthus sp.
Species

(a)

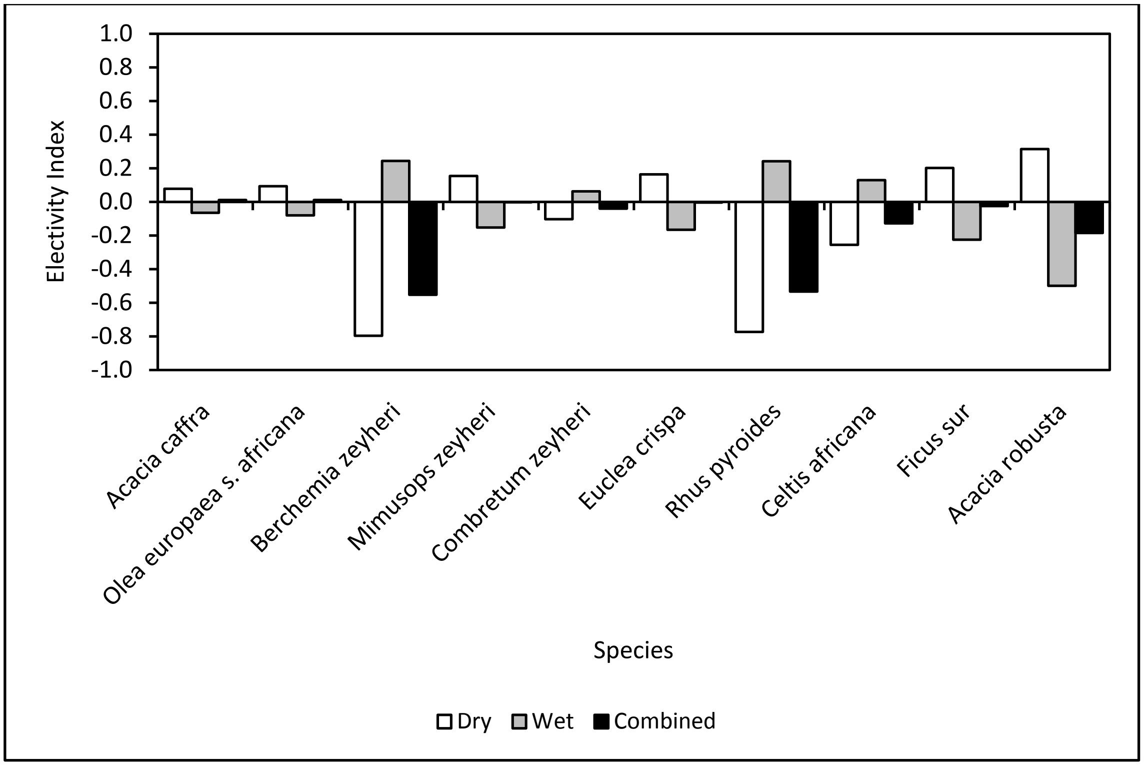

Percentage Contribution
100
80
60
40
20
0
Acacia karroo
Rhus pyroides
Acacia caffra
Acacia burkei
Ziziphus mucronata
Combretum zeyheri
Celtis africana
Acacia nilotica
Acacia robusta
Peltophorum africanum
Euclea crispa
Dichrostachys cinerea
Sclerocarya birrea
Combretum erythrophyllum
Berchemia zeyheri
Eriosema psoraleoides
Ximenia caffra
Protasparagus sp.
Tapinanthus sp.
Grewia flava
Pterocarpus rotundifolius
Species

(b)

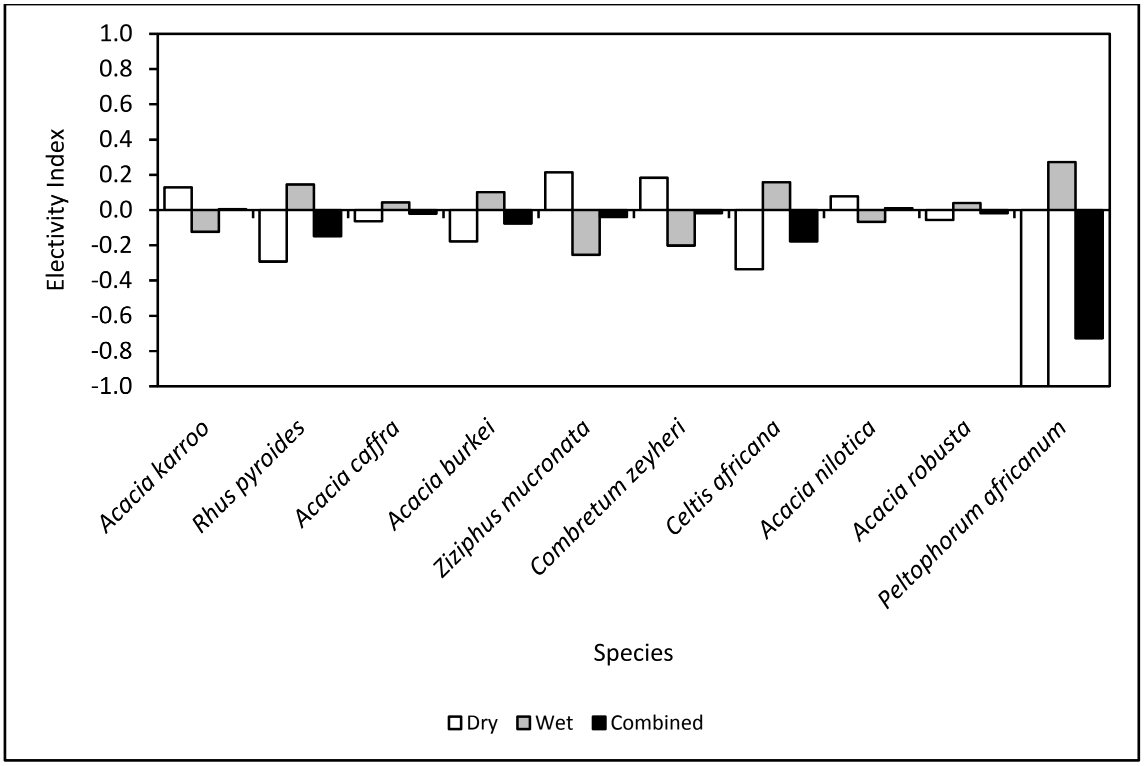
Figure 5.5. Cumulative percentage species contributions of plants selected for the Donga troop (a) and the Picnic troop (b). Species contributing most to the diets are closest to the y-axis.

5.3.9 *Plant species electivity*

Seasonal plant species electivity by the two troops is depicted in Fig 5.6. Plant species shown are the 10 most commonly utilized species by troop for both seasons (refer Fig 5.5).



(a)



(b)

Figure 5.6. Plant species electivity for the Donga troop (a) and the Picnic troop (b).

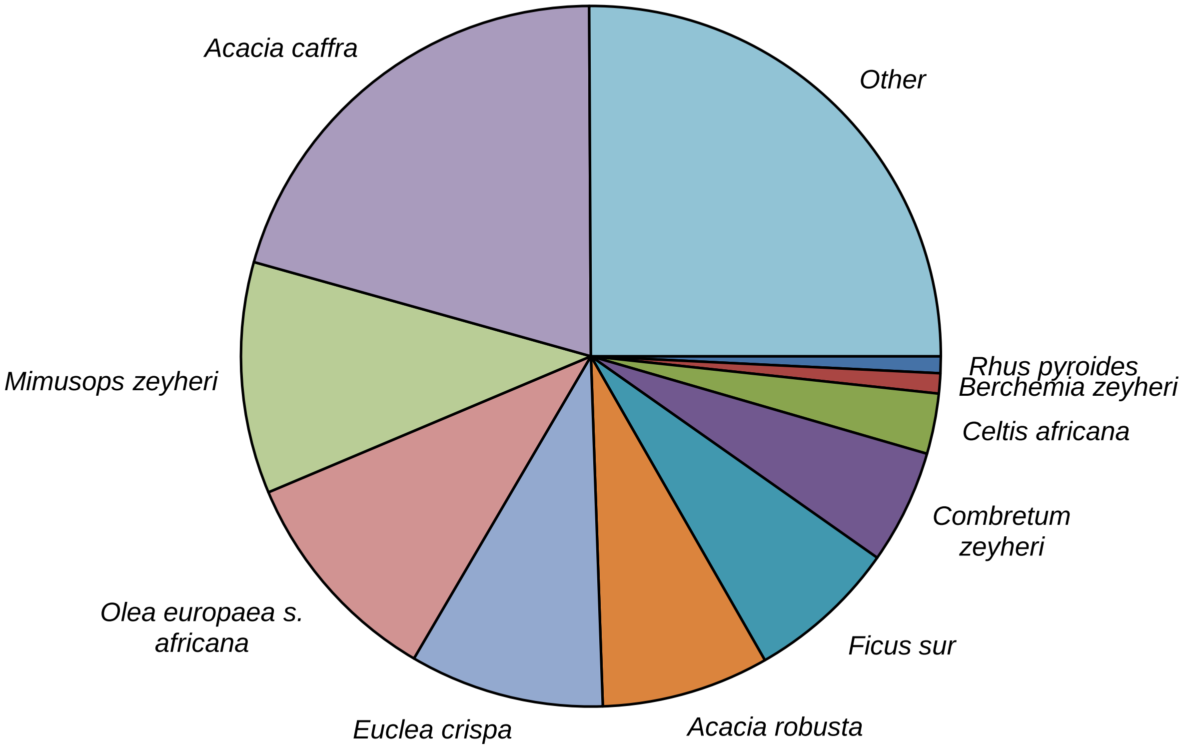
The data indicate strong seasonal effects on the choice of food plant species that tracked phenology (refer Fig 6.1). For the Donga troop, *Acacia robusta, Ficus sur* and *Euclea crispa* were the most preferred species during the dry season, with *Berchemia zeyheri*, *Rhus pyroides* and *Celtis africana* being preferred during the wet season. For the Picnic troop *Ziziphus mucronata, Combretum zeyheri* and *Acacia karroo* were preferred during the dry season, with *Peltophorum africanum*, *Celtis africana, Rhus pyroides* and *Acacia burkei* being preferred during the wet season. Overall, however, the 10 most commonly utilised species by the two troops had electivity values that indicated that they were being targeted rather than being used in relation only to their relative abundance in the territories. The Picnic troop showed a marked aversion to *Peltophorum africanum* during the dry season.

5.3.10 *Contributions of commonly utilised species to diet*

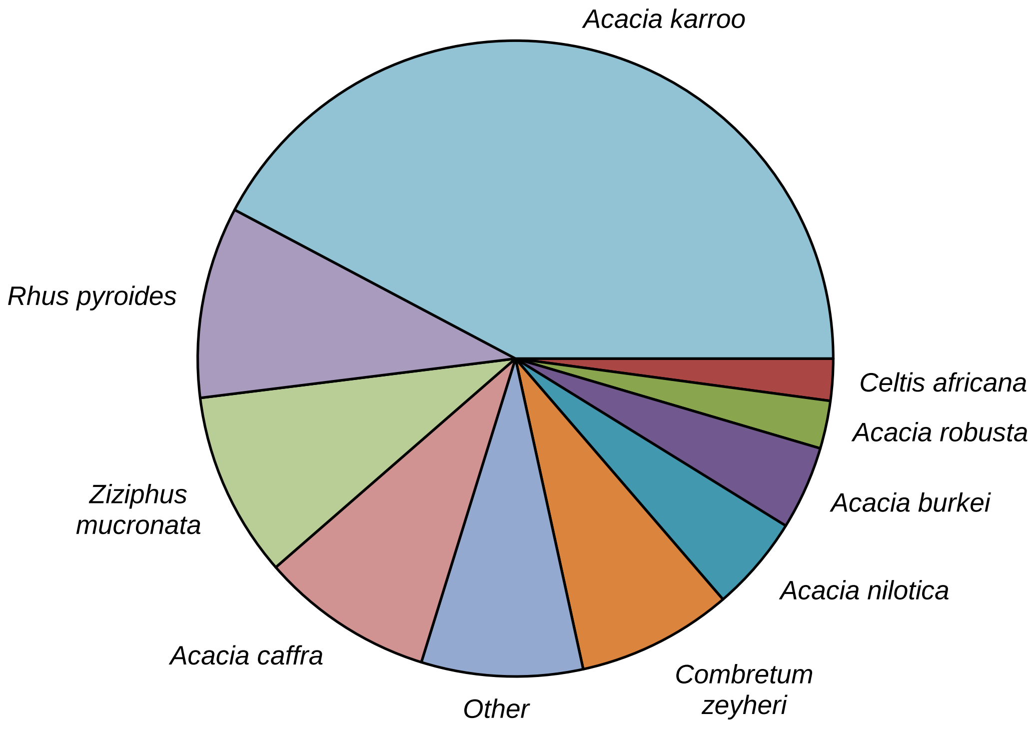
Seasonal plant species contributions for the 10 most commonly utilized species to the two troops diets are depicted in Fig 5.7.

During the dry season the most utilised resource species for the Donga troop were *Acacia caffra* and *Mimusops zeyheri* (Fig 5.7a), and for the Picnic troop was *Acacia karroo* (Fig 5.7b)

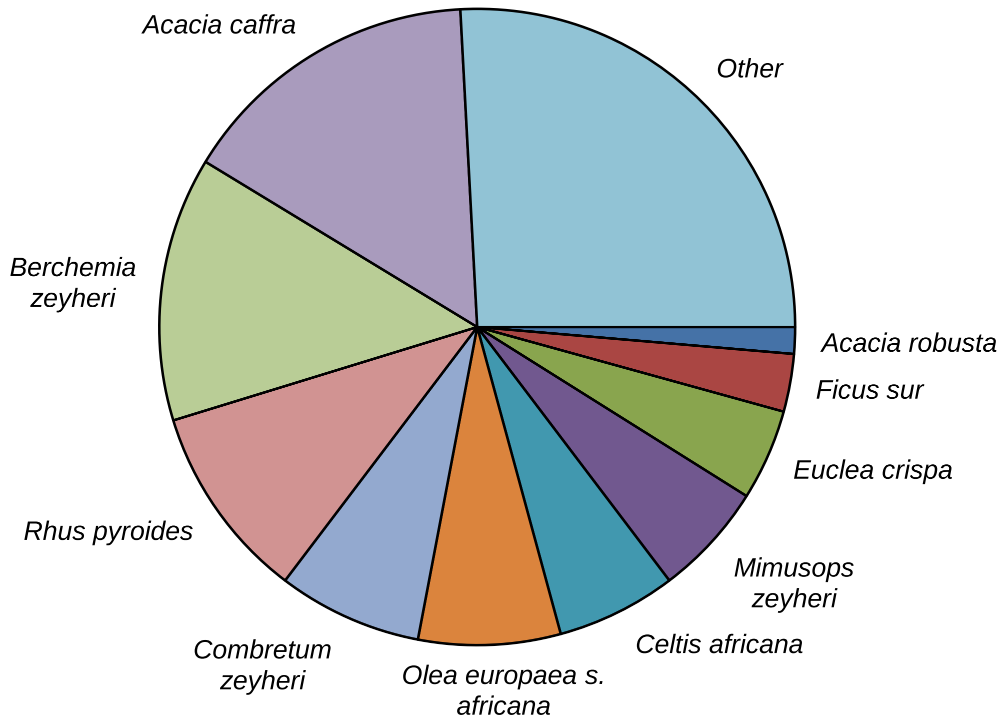
During the wet season the most utilised resource species for the Donga troop were *Acacia caffra* and *Berchemia zeyheri* (Fig 5.7c), and for the Picnic troop were *Acacia karroo* and *Rhus pyroides* (Fig 5.7d).



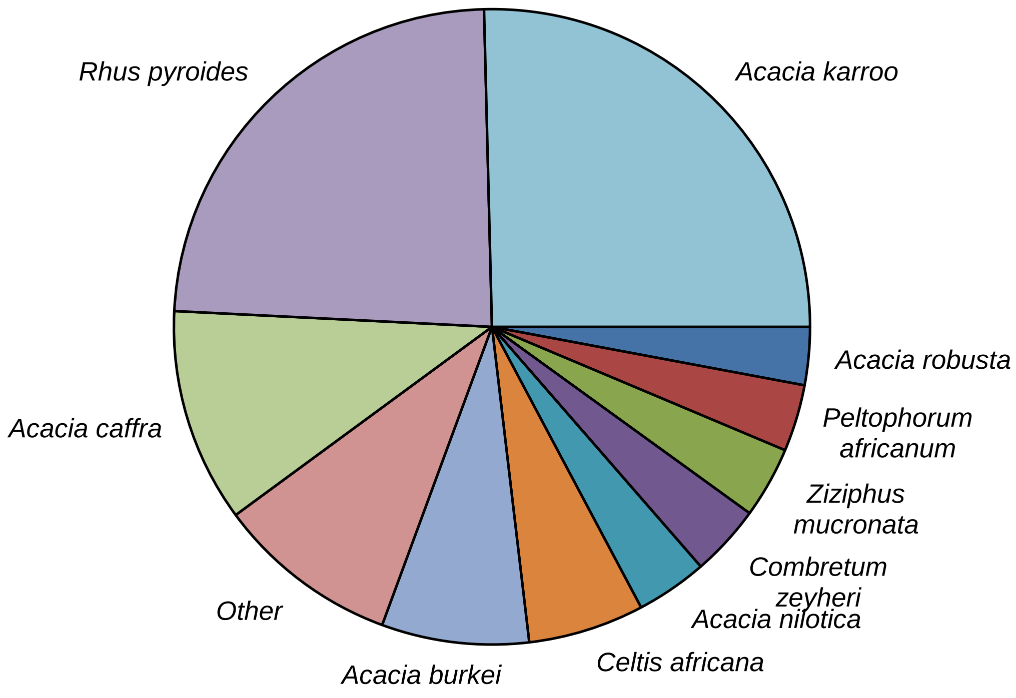
(a)


Acacia karroo
Rhus pyroides
Celtis africana
Acacia robusta
Acacia burkei
Ziziphus mucronata
Acacia nilotica
Acacia caffra
Combretum zeyheri
Other

(b)


Acacia caffra
Other
Berchemia zeyheri
Acacia robusta
Ficus sur
Euclea crispa
Rhus pyroides
Mimusops zeyheri
Celtis africana
Combretum zeyheri
Olea europaea s. africana

(c)



(d)

Figure 5.7. The 10 most commonly utilized plant species for the Donga troop during the dry season (a), for the Picnic troop during the dry season (b), for the Donga troop during the wet season (c), and for the Picnic troop during the wet season (d).

5.3.11 *Number of foraging individuals vs. number of resource species utilised*

There was a positive correlation between the number of individuals foraging simultaneously and the number of food species being used for both the Donga (r_s = 0.498, df = 612, P < 0.01) and the Picnic troop (r_s = 0.522, df = 338, P < 0.01).

5.4 Discussion

Taken as a whole, the data indicates that dietary choices, at the level of both species and food type, differed seasonally and across the two territories, with plant community and species electivity being determined by local habitat structure (Tables 4.1, 4.3). The Donga troop, for instance, generally selected more fruit and leaves, whereas the Picnic troop selected more pods, grass and insects. This broad difference suggests that the choice of food species and type at any one time may then be driven by phenological shifts in resource availability and abundance, underpinned, in turn, by the effects of climate on such resources. This will be considered in the next chapter.

Overall, food type selection indicated variations in home range structure manifested in plant community and available resource species differences as observed for the two troops. Donga troop used a total of 36 different plant species compared to Picnic troop's 21. By the same token, while six species accounted for 50% of the Donga troop's overall diet, only two species did the same for Picnic troop. Plant species that provided resources to the Donga troop throughout the year included *Celtis africana, Ficus sur, Mimusops zeyheri* and *Ziziphus* mucronata. Those doing the same for the Picnic troop included *Acacia nilotica, A. robusta* and *Ziziphus mucronata*. These may be considered fallback species, which together with various grass species and gum (for the Picnic troop) provided resources to the two troops when preferred species became scarce.

Age-sex class seasonal food type selection data revealed that for the Donga troop there were noticeable variations in the proportions of food types selected by the different age-sex classes for both seasons. Differences were however only apparent during the wet season for Picnic troop. It may well be that this is due to differences in plant community structure between the two territories (refer Table 4.7) interacting with phenological variability. If greater heterogeneity in

Donga troop's territory presents a greater array of foods at any time, then this will explain the local variability in diet. This will be assessed in the next chapter.

As with baboons, vervet monkeys are generally considered to be opportunistic omnivores (Eisenberg *et al.*, 1972; Skinner & Smithers, 1990; Estes, 1992, Dunbar & Barrett, 2000) and the two Loskop troops are clearly no exception to this classification. Comparison of the representation of different components in the diet of vervet monkeys across different African study sites (Table 5.3), reveals firstly that the Loskop troops show no distinctive differences to those from other areas and, secondly, that there is as much variability between the two Loskop troops (in the relative reliance on gum, for example) as there is between Loskop and any other site. This emphasizes once again the need to consider the extent of local habitat heterogeneity when assessing the consequences of regional (or broad habitat type) factors on diet and dietary strategies. It also highlights the importance of opportunism as a strategy to deal not only with seasonal variation in food availability, but also with the constraints that territoriality places on the range of foods that is locally available.

Table 5.3. Proportions of various food types selected by vervet monkeys from available research.

		Proportions of food types selected							
Study location	**Troop ID**	**Flowers**	**Fruit**	**Gum**	**Leaves**	**Seeds & Pods**	**Grass**	**Arthropods**	**Other**
LDNR - South Africa [1]	Donga	5.4	55.8	1.5	14.8	10.0	3.2	3.6	5.6
LDNR - South Africa [1]	Picnic	2.2	31.7	21.8	11.5	18.8	4.1	3.0	6.9
Blydeberg - South Africa [2]	Mitchell	1.5	48.5	0.2	1.8	18.0	2.7	4.0	23.3
Segera Ranch - Kenya [3]	Unk	3.4	0.0	21.4	3.9	8.3	4.2	1.5	57.5
Segera Ranch - Kenya [4]	Large	6.6	7.6	28.0	4.0	7.5	8.1	1.3	37.3
Segera Ranch - Kenya [4]	Small	3.3	1.1	59.4	0.0	9.4	0.0	4.5	22.5
Samburu-Isiolo - Kenya [5]	RR trp	51.5	8.7	0.0	16.5	21.7	0.0	1.6	0.0
Samburu-Isiolo - Kenya [5]	LM trp	44.6	7.4	0.0	17.5	28.5	0.0	2.0	0.0

1 Current study, 2007; 2 Barrett *et al*., 2005; 3 Pruetz & Isbell, 2000; 4 Isbell *et al*., 1998; 5 Whitten, 1988

In the next chapter I will extend this analysis of dietary choice by incorporating estimates of availability obtained from phenological data.

CHAPTER 6

PHENOLOGY AND ENERGETIC CONTENT OF FOOD

6.1 Introduction

The spatial and temporal availability of resources are paramount in predicting vervet monkey ranging patterns and habitat use. In the previous chapter I described the diets of the two study troops, specifically with regards to the effects of seasonality and habitat structure on the broad patterns of usage of different items. To understand the way in which these two factors drive observed ranging patterns, it is ultimately necessary to map resource gradients, expressed as energy, in time and space. To do this, however, it is necessary first to determine the temporal distribution of available resource energy in the two home ranges - the focus of this chapter.

Research in tropical and sub-tropical regions suggests that observed phenological patterns are driven by both abiotic and biotic factors including rainfall, irradiance, temperature, mode of seed dispersal, activity of pollinators and/or seed dispersers, variation in germination conditions, canopy position and the relative abundance of the trees themselves (Smythe, 1970; Frankie *et al*., 1974; Opler *et al*., 1976; Rathke & Lacey, 1985; Wheelwright, 1985; Tutin & Fernandez, 1993; van Schaik *et al*., 1993; Newbery *et al*., 1998; Chapman *et al.,* 1999).

According to Singh & Kushwaha (2006), the seasonal duration of leafing or flushing, flowering and fruiting determine phenological behaviour in tropical and sub-tropical trees. Major phenological events may occur at various times during both the wet and the dry season (Fensham & Bowman, 1992). According to Sarmiento & Monasterio (1983), and van Schaik *et al.* (1993), there may be considerable variation between years, species and life-forms in the timing of such events. van Schaik *et al.* (1993) states that most savanna woody plants produce new leaves and flowers in bursts rather than continuously, displaying seasonal variations in the presence of new leaves, flowers, and fruits.

The major products of plant anabolism can be analysed by measuring the caloric content of dried and pulverized plant material. This provides an average value for the mixture of plant products represented by it. According to Verduin (1972), such average values have little nutritional significance when making inferences regarding the allocation of such energy towards specific physiological functions such as reproduction or growth. However, when these are combined with behavioural data they have enormous predictive potential and can prove invaluable in ranging pattern analyses.

Because resources exhibit seasonal and intraspecific differences in nutritional content, it is crucial to sample consumed resources across the annual cycle (Garber, 1987). In this chapter, therefore, I use data collected each month to describe the phenological patterns of vervet resource trees in the study area. I then identify keystone resources, determine energy availability (caloric content) of the main resource items consumed by the two troops in order to assess i) the effect that temperature and rainfall have on available resource energy and ii) how available energy affects resource selection.

6.2 Methods

Quantification of available resources has been undertaken in tropical forests, where the focus was on the ecology of fruiting trees and the behavior of frugivorous consumers (Clutton-Brock, 1977; Raemakers, 1980; Leighton & Leighton, 1982; Terborgh, 1983; Chapman, 1990; Chapman *et al.,* 1992). In this study I made use of a combination of the quantification methods used in Uganda (Chapman *et al.*, 1992) and in South African savanna (Smit 1989a; Smit 1989b).

As a consequence of vegetation density and the inaccessibility of many trees, it was not feasible to collect reliable tree dimension estimates quickly and accurately using direct measurement techniques. I therefore used the inexpensive, relatively quick '*one-man*' method described by Smit (1996). I modified the technique slightly and collected all linear tree dimension data using improvised equipment.

Instead of using a 35mm slide as suggested by Smit (1996), I used a clear fiberglass reader with calibrated markings matching the markings on a 3m measuring-stick. Within the 3m markings, I sub-divided the reader into 0.25m segments for refined measurements. At the bottom and at the 3m point on the measuring stick I marked the stick with luminous yellow tape. To get the measurements of a particular tree, I placed the measuring stick vertically adjacent to the trunk of the tree at ground level. I then paced away from the stick until the sticks luminous markings lined up to the 3m markings on the fiberglass reader. At this point I used the reader to measure all linear tree dimensions in intervals of 3m and/or 0.25m, whichever was required. If a tree was on a slope, I calculated its height on the uphill side. Initially I used a clinometer for calibration testing of the '*one-man*' method, particularly for tree heights. The methods corresponded well and the results obtained were constantly within 0.5cm of one another. For the original method and for accuracy and calibration testing, refer to Smit (1996). Subsequently, I further improvised the above method to shorten time spent in the field. Instead of taking all the measurements in the field, I placed the 3m marked stick against a tree to be measured and took a digital photograph of the entire tree and stick. I measured all tree dimensions with photo editing software, using the stick in the photo for scale. Results from this technique correlated well with results from measurements taken in the field.

Initial phenology data collected included:

- TAG_ID
- SPECIES_NAME
- HEIGHT_OF_FIRST_LEAVES (m)
- BASE_DIAMETER__OF_FOLIAGE_AT_HEIGHT_OF_FIRST_LEAVES (cm)
- HEIGHT_OF_MAX_CANOPY_DIAMETER (m)
- MAX_CANOPY_DIAMETER (m)
- OVERALL_TREE_HEIGHT (m)

Monthly phenology data collected included:

- TAG_ID
- SPECIES_NAME
- AVAILABLE_FOOD_ITEM (flower, leaf bud, young leaf, old leaf, unripe fruit/pod, ripe fruit/pod, other)
- RELATIVE_ABUNDANCE_OF_FOOD_ITEM_ON_GROUND (0, 1-5, 6-12, 13-25, 26-50, 51-75, 76-100%)
- RELATIVE_ABUNDANCE_OF_FOOD_ITEM_<1m (0, 1-5, 6-12, 13-25, 26-50, 51-75, 76-100%) x4
- RELATIVE_ABUNDANCE_OF_FOOD_ITEM_1-3m (0, 1-5, 6-12, 13-25, 26-50, 51-75, 76-100%)
- RELATIVE_ABUNDANCE_OF_FOOD_ITEM_>3m (0, 1-5, 6-12, 13-25, 26-50, 51-75, 76-100%)
- NO_OF_FOOD_ITEMS_IN_1m^3
- NO_OF_GRASSHOPPERS_IN_3x20m_STRIP

I modified a three-meter extendable garden tree-pruning shears to catch/collect resources cut off from the middle of tree canopies, preventing them from falling to the ground and into inaccessible areas.

According to Chapman *et al.* (1992), the various methods of estimating resource abundance (particularly fruit) for biological studies are all susceptible to potential errors and no particular method is more suitable than any other. Various authors have a predisposition towards specific methods based on personal preference, objectives of the research being undertaken and repeatability of the method(s) being employed. The DBH and visual estimates methods have been shown to produce accurate estimates of fruit and resource abundance in forest environments (Chapman *et al*., 1992). As LDNR falls within the savanna biome, and because the nature of savanna trees differs significantly from those occurring in forest environments (Hoffman & Franco, 2003; Hoffman *et al*., 2005), for the purposes of this study I employed a combination of visual estimates, actual fruit counts and canopy volume extrapolation. Seeing that a single observer collected all phenological data over the study period, I did not do any inter-observer variability calculations or adjustments.

Since the current study needed only overall temporal estimates of spatial energetic pathways for extrapolation across the two troops' home ranges, I analysed collected samples at the laboratory for crude protein (%), nitrogen (%) and energy content (KJ).

To determine wet weights of collected samples in the field, I used a 'US Balance US-1000XR' high capacity professional digital pocket scale. I counted samples (where applicable) and air-dried them in a storage room out of direct sunlight. I processed collected food items in a similar manner to the way the vervets did when observed foraging i.e. if the monkeys split a pod and only ate the seeds, I extracted the seeds from the pods prior to counting, wet weighing, drying and further processing. I stored field dried samples in sealed plastic containers with silica gel desiccant sachets to prevent mould or moisture from affecting them until after the study period. At the laboratory, dry matter was determined by drying a portion of each sample overnight in a thermal draft oven at 105^{o}C, as per standard laboratory procedure. Dried samples were ground using a Wiley

Mill (larger fruit samples were ground with a coffee grinder) so that they could pass through a one millimeter mesh screen to ensure that the consistency of the samples did not undermine results.

I estimated crude protein percentage using Kjeldahl nitrogen percentage (A.O.A.C., 1970) and multiplied the results by the standard conversion of 6.25 (Nelson & Sommers, 1973). Crude Protein represents the total amount of nitrogen (available and unavailable) and provides a '*ballpark estimate'* of the protein value in the resource or sample. The higher the crude protein value, the higher the digestibility (Konandreas & Anderson, 1982).

Gross energy (GE) was determined using bomb calorimetry (0.5g sample weighed to 0.0001g) following standard procedure (Paine, 1971). I corrected for the remaining fuse wire and for the number of calories produced by the formation of nitric acid. I used GE because other energy values, such as digestible energy (DE) or metabolizable energy (ME), are not constants but functions of food composition, the amount of food consumed per unit of time, and the ability of the consuming primate to digest or metabolize their food (National Research Council, 1978; Ad Hoc Committee on Nonhuman Primate Nutrition, 2003).

6.3 Results

6.3.1 *Resource availability*

Different plant species have different phenologies affected by changing variables which makes predicting what vervets will consume at different times of the year difficult. Some trees require specific environmental conditions to synchronise before they produce fruit or resources (Chapman *et al.*, 2005), resulting in the vervets not being able to achieve complete dietary stability and their diets varying based on current availability. The main forage species showed a certain amount of heterogeneity across months in their contribution to the vervets' diets; however, this was not strictly linked to patterns of rainfall and the dry season because, as described above, different species have different phenologies. The result was that while the vervets consumed different plant species resource items in different months, there was a constant supply of resource items throughout the year on resource tree species, especially leaves and fruits/pods (Fig 6.1). Fig 6.2 shows species level resource item availability for the top 10 combined vervet monkey resource trees as selected by the two troops (from Table 6.1).

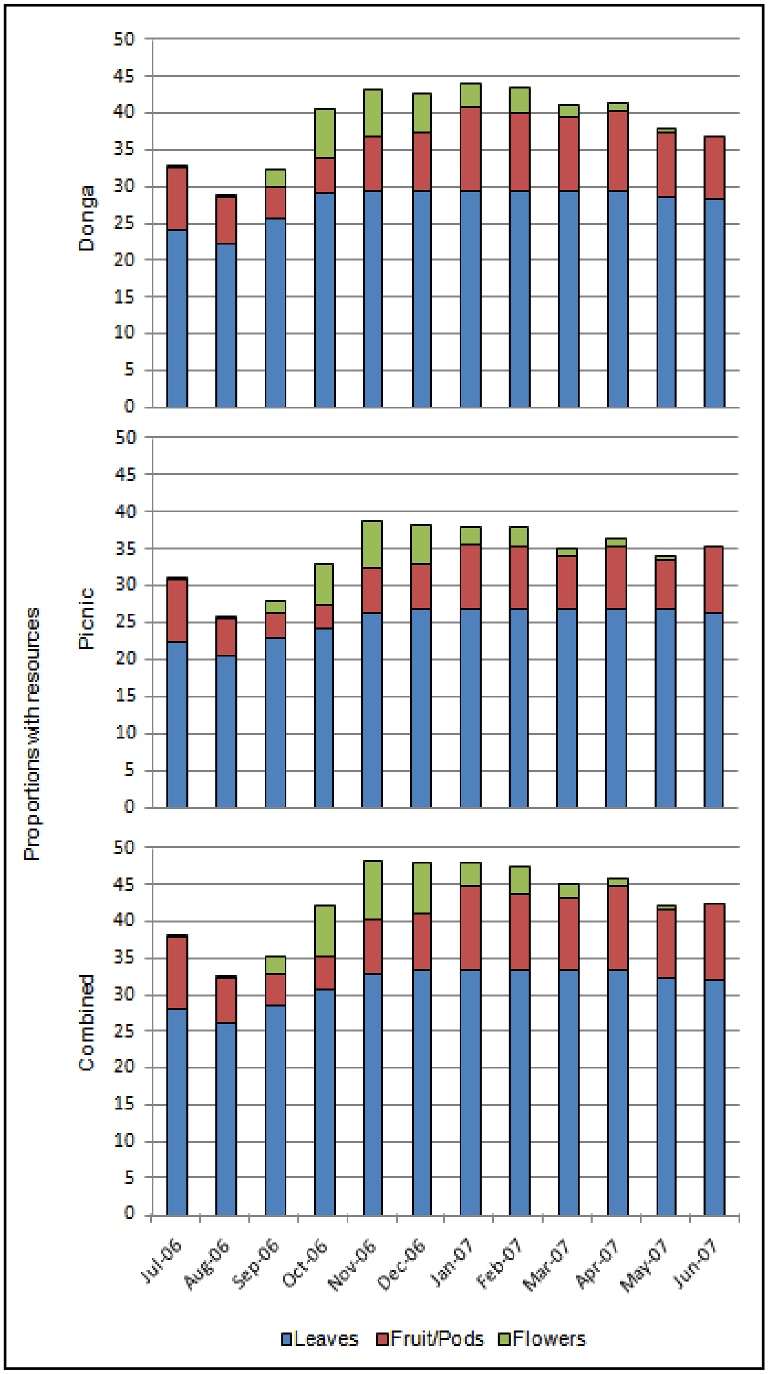


Figure 6.1. Monthly proportions of available resource items consumed (*n*=36) on all trees sampled (*n*=113), for the main vervet resource species (*n*=25) by home range and combined.

Table 6.1 shows the top 10 resource tree species selected by the two troops for the dry, wet and combined seasons.

Table 6.1. The top 10 resource tree species by season and combined as selected by the two troops in order of preference, where 1 indicates most selected or preferred.

Preference Rank	Picnic Troop		
	Dry Season	Wet Season	Combined
1	*Acacia karroo*	*Acacia karroo*	*Acacia karroo*
2	*Rhus pyroides*	*Rhus pyroides*	*Rhus pyroides*
3	*Ziziphus mucronata*	*Acacia caffra*	*Acacia caffra*
4	*Acacia caffra*	*Acacia burkei*	*Acacia burkei*
5	*Combretum zeyheri*	*Celtis africana*	*Ziziphus mucronata*
6	*Acacia nilotica*	*Acacia nilotica*	*Combretum zeyheri*
7	*Acacia burkei*	*Combretum zeyheri*	*Celtis africana*
8	*Dichrostachys cinerea*	*Ziziphus mucronata*	*Acacia nilotica*
9	*Acacia robusta*	*Peltophorum africanum*	*Acacia robusta*
10	*Celtis africana*	*Acacia robusta*	*Peltophorum africanum*
Preference Rank	Donga Troop		
	Dry Season	Wet Season	Combined
1	*Acacia caffra*	*Acacia caffra*	*Acacia caffra*
2	*Mimusops zeyheri*	*Berchemia zeyheri*	*Olea europaea s. africana*
3	*Olea europaea s. africana*	*Rhus pyroides*	*Berchemia zeyheri*
4	*Euclea crispa*	*Combretum zeyheri*	*Mimusops zeyheri*
5	*Acacia robusta*	*Olea europaea s. africana*	*Combretum zeyheri*
6	*Ficus sur*	*Celtis africana*	*Euclea crispa*
7	*Combretum zeyheri*	*Mimusops zeyheri*	*Rhus pyroides*
8	*Sclerocarya birrea*	*Acacia karroo*	*Celtis africana*
9	*Ficus craterostoma*	*Euclea crispa*	*Ficus sur*
10	*Celtis africana*	*Sclerocarya birrea*	*Acacia robusta*

The top 10 combined resource species selected by the two troops (Table 6.1) are depicted in Fig 6.2. The proportions of available resource items (leaves, fruits or pods and flowers) constituting the available monthly energy for each vervet plant resource species is reflected in the bottom graph for each species. The upper line graph indicates overall resource energy fluctuation over the study period. Species graphs give an indication of which resources were available on which tree species over the study period and what its energy contribution was.

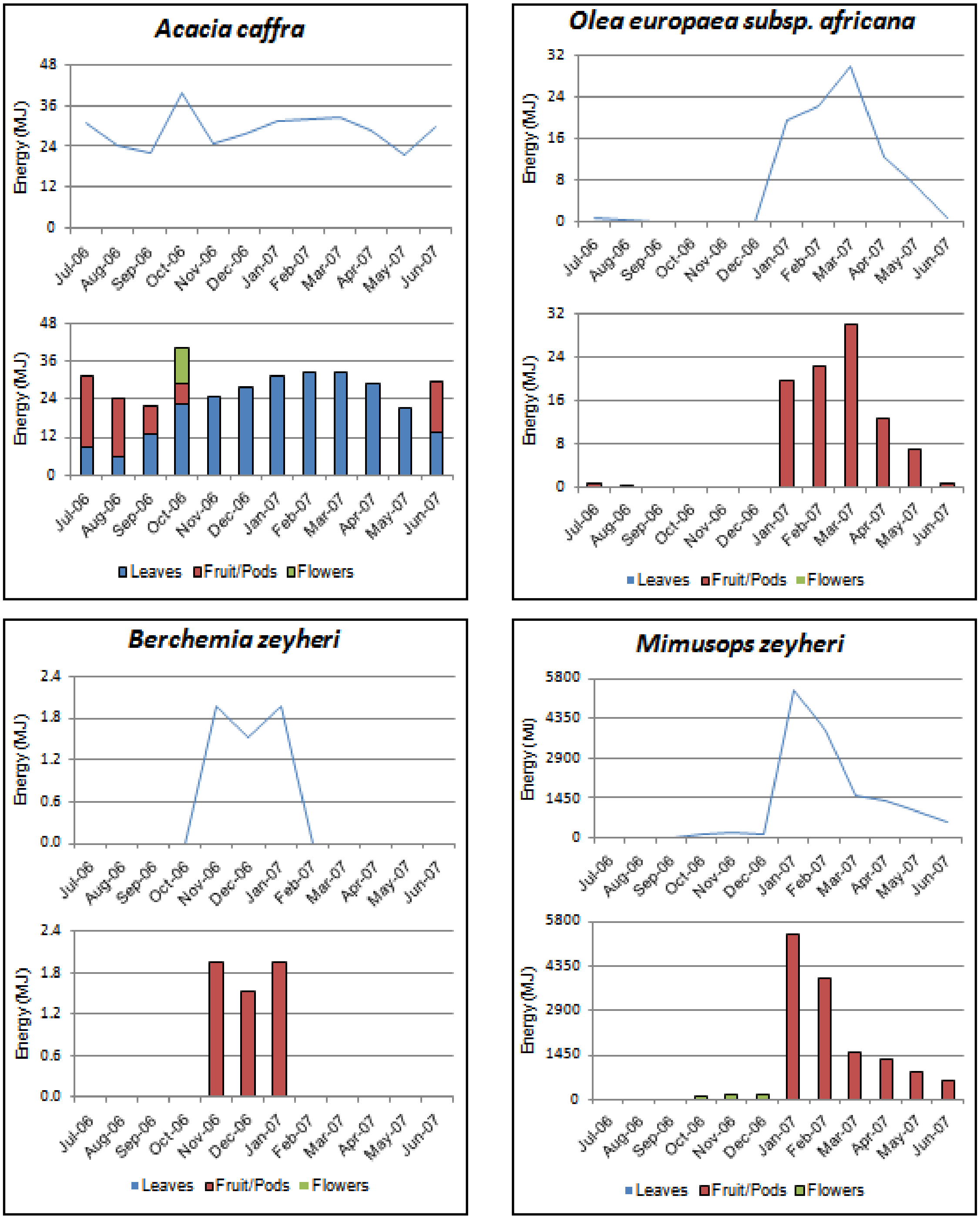


Figure 6.2. Monthly diversity of leafing, fruiting and flowering phenology for the top 10 vervet monkey resource trees as selected by the two troops for the study period.

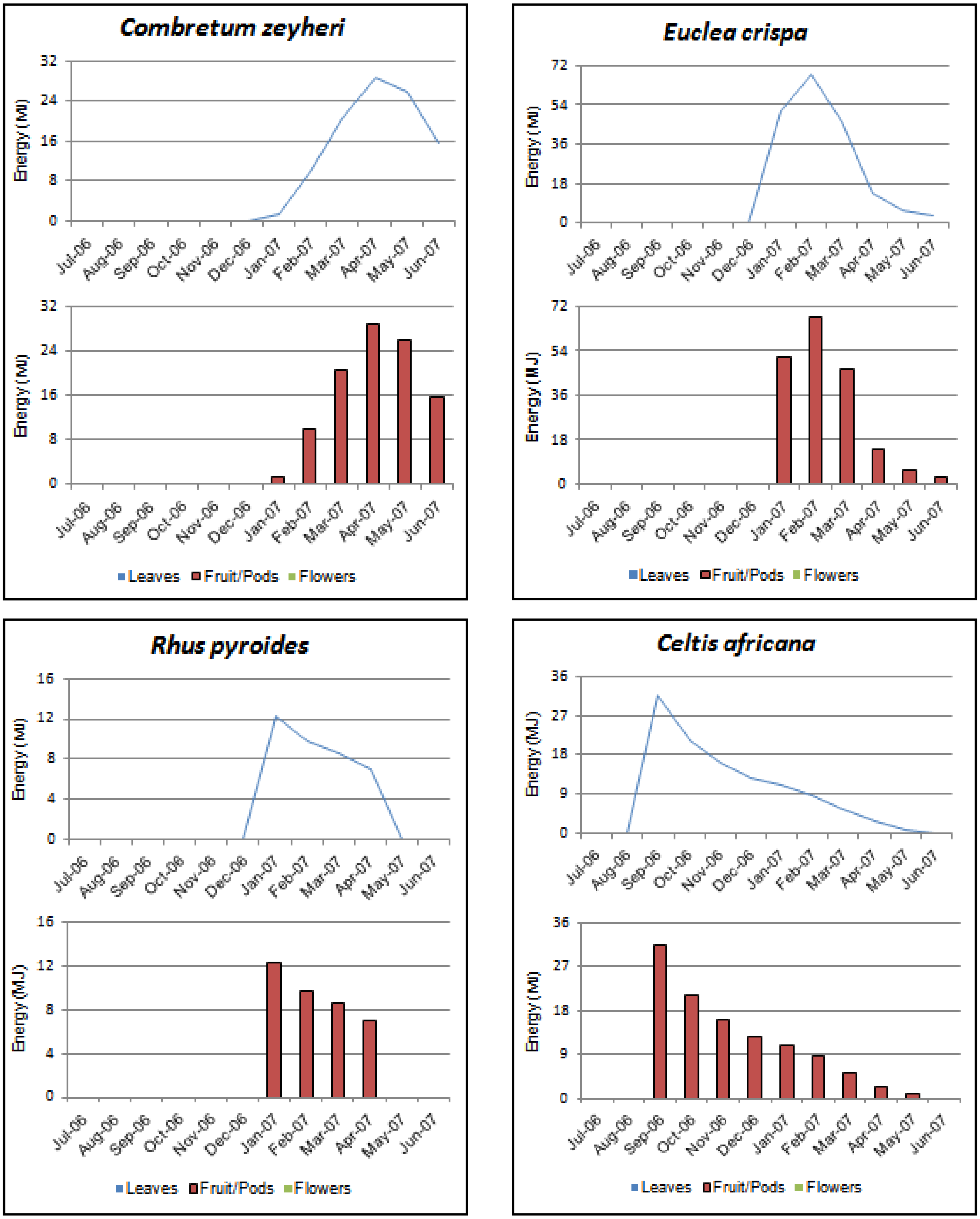


Figure 6.2 (cont.)

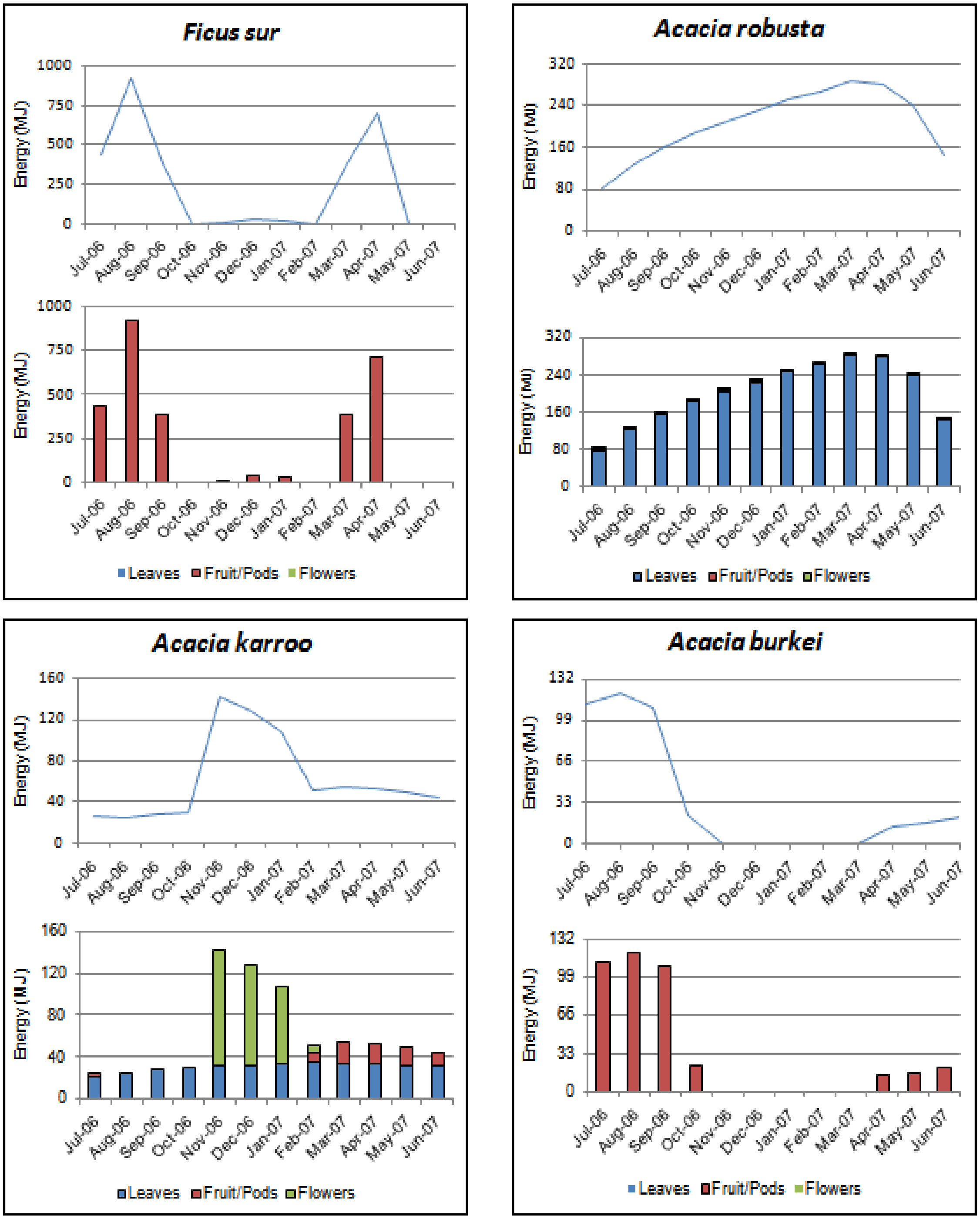


Figure 6.2 (cont.)

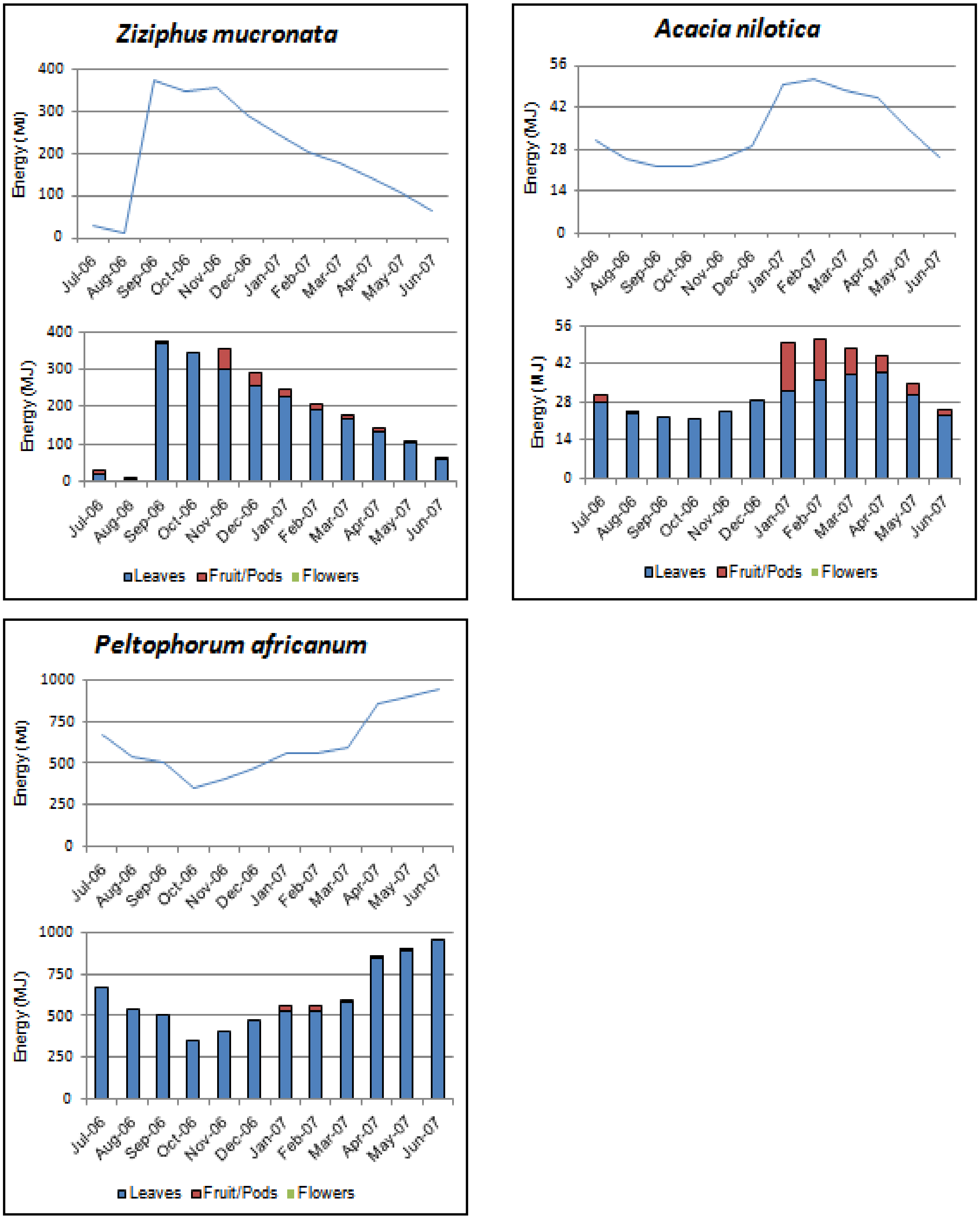


Figure 6.2 (cont.)

It is difficult to portray phenological data graphically, and while many statistical approaches (for example spectral analysis) offer useful means of detecting cycles, they do not illustrate the intensity of fruiting or flowering events throughout the cycle. Bearing this limitation in mind, the use of graphical representations of important aspects of the data was used to illustrate the intensity of cyclic patterns of phenological events, even if only for a 12 month period.

Comparisons of available tree resources utilized by the two troops over the study period showed that for leaves (U = 27, P < 0.01) there was a significant difference between the two home ranges, with Donga trees having more leaves than those from the Picnic. For fruits/pods (U = 46, P = 0.13) and flowers (U = 65, P = 0.69), there were no significant differences between the home ranges.

6.3.2 *Vervet resource phenology*

Phenology of the main vervet resource items for the study period is shown in Fig 6.3.

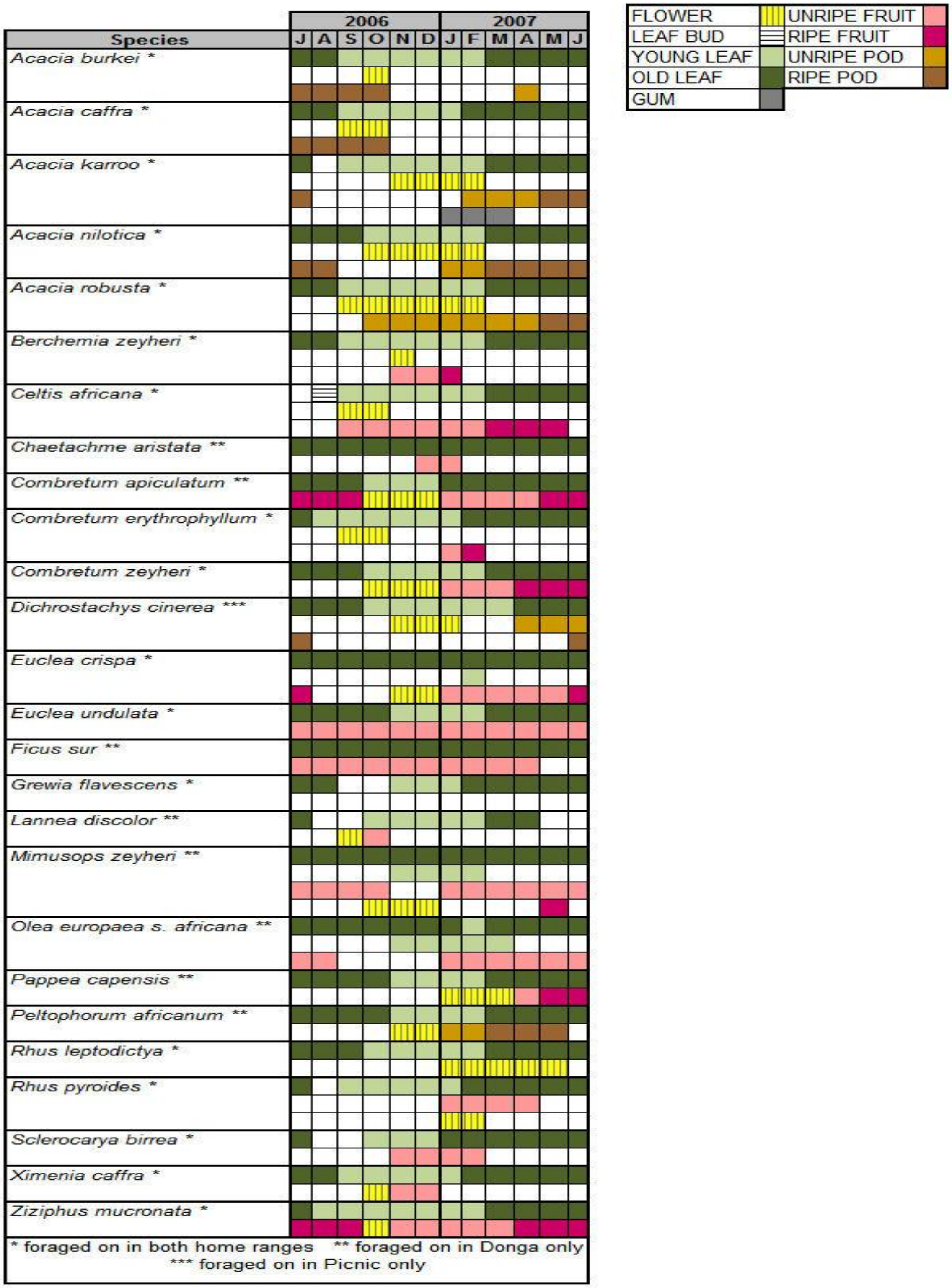


Figure 6.3. Leafing, fruiting and flowering phenology of vervet resource trees for the two vervet home ranges. Species selection by the two troops is also shown.

Vervet foods at LDNR fell into two main seasonality categories. Some showed year-round resource availability such as *Euclea undulata*, *Ficus sur*, *Mimusops zeyheri* and *Ziziphus mucronata* which were considered keystone or mainstay species, and others that were highly seasonal with resources only being available at certain times of the year such as the various *Acacia sp*. pods, *Berchemia zeyheri* fruits, *Celtis africana* fruits, *Olea europaea subsp. africana* fruits, *Lannea discolor* fruits and *Sclerocarya birrea* fruits.

6.3.3 *Keystone resources*

Of critical importance in seasonally driven environments are keystone resources that act as fallback foods during times of scarcity. According to Terborgh (1986), such keystone species provide resources when other species have stopped producing food, most noticeably during the annual period of minimum resource availability (the dry season). At LDNR keystone resources included *Ficus sur* and *Mimusops zeyheri* fruit which was available for most months of the year, and *Euclea undulata* fruit and *Ziziphus mucronata* leaves and fruits that were available throughout the year. Large, mature, fruit producing trees were frequently utilised by both the vervets and baboons.

For the Donga troop (refer Table 5.1), *Mimusops zeyheri* contributed towards 7.8% of their overall diet (across both seasons), 4.5% towards their dry season diet and 3.3% towards their wet season diet. *Ficus sur* contributed towards 4.6% of the troops overall diet, 2.9% towards their dry season diet and 1.7% towards their wet season diet. *Euclea undulata* contributed towards 2.2% of the troops overall diet, 0.8% towards their dry season diet and 1.4% towards their wet season diet. *Ziziphus mucronata* contributed towards 2.1% of the troops overall diet, 1.0% towards their dry season diet and 1.1% towards their wet season diet.

With regards to the Picnic troop (refer Table 5.2), only *Ziziphus mucronata* occurred within their home range and it contributed towards 6.1% of the troops overall diet, 4.0% towards their dry season diet and 2.1% towards their wet season diet.

6.3.4 ***Resource item energy***

Table 6.2 depicts resource item energy analyses results for all resource species (keystone and other species, including those that flushed erratically at various times of the year are shown). Erratic species flushes were observed when abnormal environmental conditions occurred, for example when winter temperatures suddenly increased and accompanying thunderstorm activity took place.

Table 6.2. Plant resource analysis for food items consumed by the vervet study troops. Breakdowns are per gram dry.

		Per gram dry			
Species	**Part**	**Items**	**N%**	**CP%**	**KJ**
****Acacia ataxacantha***	***seeds***	***14***	***4.4***	***27.5***	***19.41***
Acacia burkei	pods	1	2.4	15.3	17.623
Acacia caffra	leaves	28	2.1	12.9	18.736
Acacia caffra	pods	7	4.2	26.1	18.264
Acacia caffra	flowers	10	5.1	32.0	17.924
Acacia karoo	leaves	29	4.0	24.9	18.535
****Acacia karoo***	***gum***	***1***	***0.2***	***1.4***	***15.31***
Acacia karoo	flowers	26	2.0	12.3	16.492
Acacia karoo	seed	87	5.2	32.2	17.962
Acacia karoo	pods	7	1.9	11.8	17.715
Acacia nilotica	flowers	27	2.1	13.1	18.136
Acacia nilotica	pods	3	1.7	10.7	17.443
Acacia robusta	leaves	6	1.9	11.9	18.398
Acacia robusta	pods	9	2.9	18.1	17.266
Acacia robusta	flowers	60	3.9	24.2	17.99
****Garcinia livingstonei***	***fruit***	***20***	***N/A***	***N/A***	18.009
Berchemia zeyheri	fruit	14	1.6	10.2	17.905
****Bridelia mollis***	***fruit***	***8***	***1.0***	***6.3***	17.994
Celtis africana	fruit	17	2.6	16.5	14.065
Chaetachme aristata	fruit	24	2.8	17.3	14.711
Combretum erythrophyllum	leaves	34	N/A	N/A	18.536
Combretum zeyheri	fruit	2	4.5	28.1	19.553
****Dichapetalum cymosum***	***fruit***	***1***	***1.1***	***6.6***	***16.65***
Dichrostachys cinerea	pods	14	2.8	17.4	16.936
****Dovyalis zeyheri***	***fruit***	***2***	***0.8***	***5.0***	***14.64***
****Eriosema psoraleoides***	***seeds***	***51***	***3.1***	***19.4***	***17.82***
Euclea crispa	fruit	67	1.1	6.7	17.995
Euclea undulata	fruit	16	0.7	4.2	17.323
Ficus sur	fruit	2	1.6	10.2	17.762
****Flacourtia indica***	***fruit***	***1***	***0.5***	***3.2***	***17.37***
Grewia flavescens	fruit	4	1.4	8.5	18.186
Lannea discolour	fruit	9	1.5	9.5	19.854
Mimusops zeyheri	flowers	41	2.0	12.8	17.297
Mimusops zeyheri	fruit	0	0.7	4.3	19.051
****Mushroom***	***fruit***	***1***	***N/A***	***N/A***	***17.7***
****Mystroxylon aethiopicum***	***fruit***	***4***	***0.5***	***2.9***	***18.1***
Olea europea	fruit	26	0.6	4.0	17.612
Papea capensis	fruit	6	1.3	7.8	19.754
Peltophorum africanum	leaves	2	N/A	N/A	18.482
Peltophorum africanum	pods	6	1.4	9.1	19.054
****Protasparagus sp.***	***leaves/stems***	***15***	***3.1***	***19.6***	***17.88***
****Rhoicissus tridentata***	***fruit***	***4***	***1.3***	***8.3***	***19.61***
Rhus leptodycta	fruit	225	N/A	N/A	17.607
Rhus pyroides	fruit	176	1.9	11.7	16.593
Sclerocaryea birrea	fruit	1	0.6	3.5	15.007
****Taphinanthus natalitius***	***flower***	***21***	***2.2***	***13.8***	***18.21***
Ximenia caffra	fruit	1	1.8	11.3	21.062
Ziziphus mucronata	fruit	11	2.8	17.2	15.623
Ziziphus mucronata	leaves	10	2.7	17.1	16.631

**** = Species that produced resources in erratic bursts, or species that the vervets were observed foraging on but were not on the list for phenological data collection.***

All parts of the major plant species consumed by the vervets over the study period and that were sampled for analyses are shown in Table 6.2. The species name, number of items analysed, percentage of Nitrogen (N), percentage of Crude Protein (CP), and total energy (KJ/gram) of the plant parts sampled are shown in the Table.

6.3.5 *Temperature and rainfall*

From observations of resource trees occurring within the two troop's home ranges, seasonal fruiting and flowering patterns were discerned (Fig 6.4).

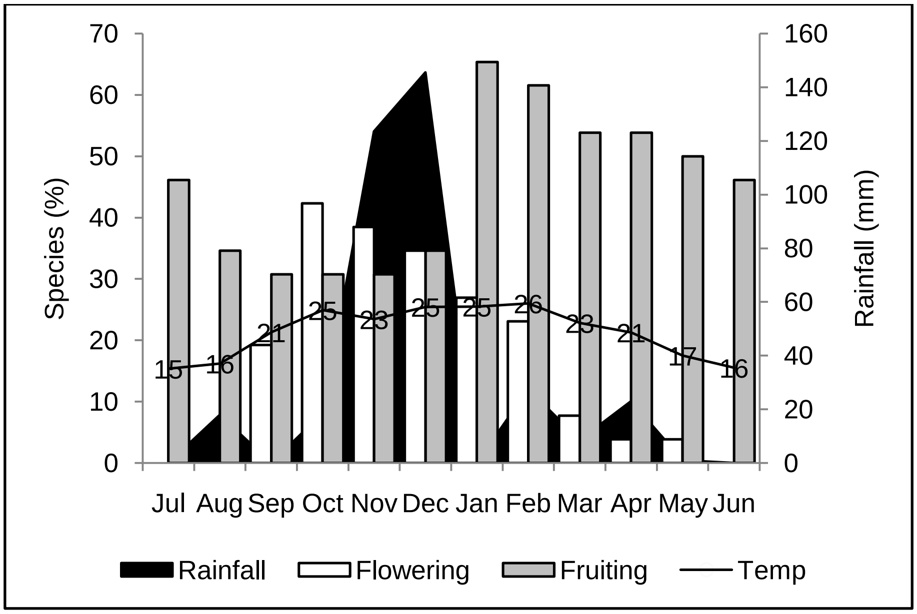


Figure 6.4. Monthly percentages of species in flowering and fruiting phenophases for the study period. Monthly temperature and rainfall are also shown.

A peak in flowering occurred towards the end of the dry season, with a maximum of 42% of available food resource trees flowering in October, steadily declining thereafter and no species flowering from June to August. Flowering was linked to temperature increases and as daily temperatures began to increase in September and October, flowering commenced.

Fruiting peaked towards the middle of the wet season, with a maximum of 65% of available food resource trees fruiting in January and 62% in February. Fruits were available throughout the year, with the September to November period having only 31% of available resources fruiting per month, being the period of lowest resource availability. Fruiting occurred after the maximum rainfall period (Fig 6.4), reaching its peak between one and two months after such (November – December).

The relationship between temperature and the proportion of available resources showed a significant positive correlation, with increased temperatures leading to a marked increase in resource availability ($r_s = 0.667$, df = 10, $P = 0.02$).

The relationship between rainfall and the proportion of available resources also showed a positive correlation that was not significant, with increased rainfall leading to more available resources ($r_s = 0.530$, df = 10, $P = 0.08$).

Temperature was the deciding factor causing plants to produce more resources and to become productive after the cooler winter months.

6.3.6 *Temperature and energy*

Fig 6.5 shows the relationship between temperature and available energy for all vervet resource items consumed. The delay or lag in resource tree energy production to temperature is shown in Fig 6.5 where it can be seen that trees took a while to respond to increases in temperature before their production increased. This made logical sense for woody plant species which were the main focus in this study. Trees have well developed root systems that penetrate deeply into the soil (often into the water table), where they obtain sufficient moisture from deeper soil layers. Having well developed root systems makes trees less dependent on rainfall, hence the non significant relationship between rainfall and the proportion of available resources (refer 6.3.5 Temperature and rainfall above). This was not the case for herbaceous plants and grasses that have shallow root systems, often with morphological adaptations to cope with water stress. The affect of temperature on trees was visibly noticeable, as soon as day length and daily temperatures increased after the colder winter months, leaf buds quickly appeared and within a few days barren landscapes turned green and lively.

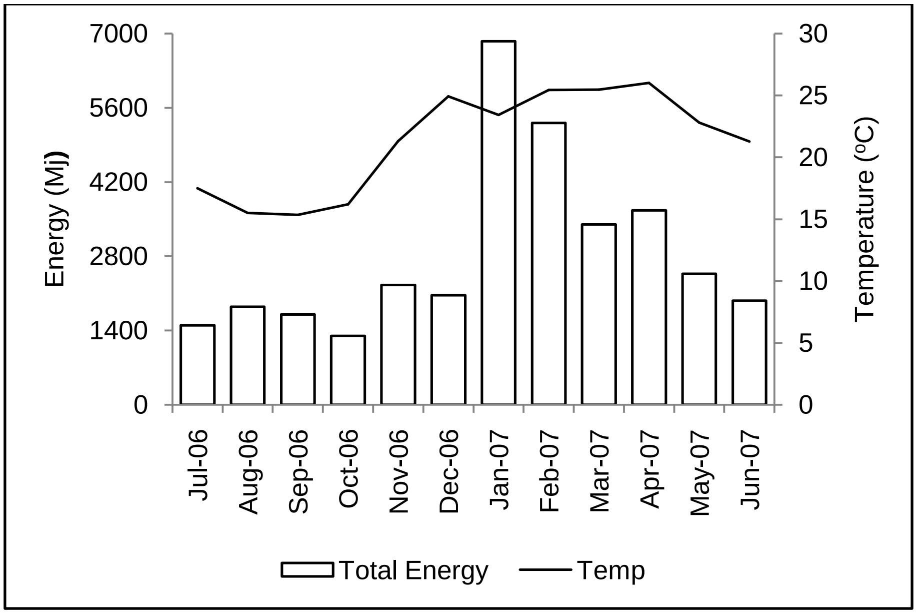


Figure 6.5. Relationship between temperature and available vervet resource energy. As temperature begins to increase, after a short lag, available energy increases.

The overall effect of rainfall on energy production must not be undermined in light of the above. There are several factors that influence energy production in plants and they all work synchronously to provide plants with the essential resources they require to be productive.

6.3.7 *Resource selection vs. available energy*

For the top 10 combined resource tree species selected by the two troops (Table 6.1), I assessed whether they were seasonally preferentially selecting foods with the highest energy or not. There was a very weak negative correlation between preference rank and energy for the Picnic troop during the dry season (r_s = -0.018, df = 8, P = 0.96), a weak positive correlation for the Picnic troop during the wet season (r_s = 0.358, df = 8, P = 0.31), a significant negative correlation for the Donga troop during the dry season (r_s = -0.661, df = 8, P = 0.04), and a weak negative correlation for the Donga troop during the wet season (r_s = -0.370, df = 8, P = 0.29). The overall trend was towards negative correlations, indicating that as food rank increased (less preferred), energy decreased. The Picnic wet season was the exception, with increased food rank being accompanied by increased energy. The reason for the increased energy during the wet season was that *Peltophorum africanum* resources (leave and pods) became available and their preference rank was higher (not preferred), compared to other top 10 species selected. These troop-level differences will be considered further in chapter 7.

6.4 Discussion

The phenology of plants is shaped by biotic and abiotic factors. Biotic factors have less of an impact, usually affecting only one particular species or community in an often localised area. Abiotic factors are more pervasive and widespread having an increased impact over an extended area. The characteristic climate associated with tropical and sub-tropical savanna environments is alternating cool dry seasons with hot wet seasons. Peaks in irradiance are more often than not accompanied by peaks in flowering, except where water stress makes this impossible (van Schaik *et al.,* 1993). Day length, or a combination of day length and rising temperatures, often triggers plant physiological activity after winter dormancy (Rathcke & Lacey, 1985). Seasonal climates have a direct impact on the phenology of a particular area and the production of consumer resources (leaves, fruit, pods, seeds and flowers) undergoes temporal variation in most seasonal environments (Koptur *et al*., 1988). The data in this chapter confirm this for LDNR, where a significant increase in resources and potential energy yields was found during the warm wet season when plant species were more productive.

According to Chapman *et al.* (1999), phenological patterns need to be studied over relatively long periods of time for meaningful results to be obtained from such studies. Several trends that appear after one or two years of sampling disappear when a larger sample of many years becomes available for analysis (see also Terborgh & van Schaik, 1987). In addition to this, many trends apparent at one site are often not observed at a second similar site, despite the fact that such sites might be in close proximity to one another, sharing many of the same species and experiencing similar climatic conditions. Such findings question the generality of conclusions derived from a single location and call for further effort to document phenological patterns (Chapman *et al.*, 1999). Observations of several common resource trees sampled in the two home ranges displayed differing phenological trends, but this was not investigated as part of this study. With this in mind, it would be valuable to continue to conduct phenological analyses of species occurring at LDNR both for comparison to these results, and for more general phenological patterns to become apparent.

Resource item energy analyses provides data for further spatial exploration and extrapolation across the home ranges in chapter 7, and has been used here to show the proportional energy contributions of the main resource items in the two troops resource tree species.

CHAPTER 7

ENERGY AND RANGING PATTERNS

7.1 Introduction

Interactions between organisms and their environments are often intricate, giving rise to elaborate movement patterns as animals track resources across space and time (Garber, 2000; Johnson *et al.,* 2001, 2002; Mårell *et al.,* 2002; Jonsen *et al.*, 2003; Roshier & Reid, 2003; Fernández *et al.,* 2004; Nams, 2005, 2006; Hancock & Milner-Gulland, 2006; Holden, 2006; Janson, 2007; Mueller & Fagan, 2008).

Although the use of a home range or habitat is likely to be influenced by the distribution of important resources such as sleeping sites (Barton *et al.,* 1992), or the relationship between habitat structure and the risk of predation (Cowlishaw, 1997), it is likely that movement will primarily be underpinned by the distribution of foods and/or water, especially so at the relatively high latitudes of the subtropics.

Various primate species have different strategies for dealing with resource seasonality at different latitudes. In baboons, for example, Kummer (1968), Dunbar & Dunbar (1974), Anderson (1981) and Henzi *et al.* (1992), report that troops range further during the dry season, while Altmann & Altmann (1970), Post (1978) and Gaynor (1994) found no noticeable seasonal ranging differences. Olupot *et al.* (1994 & 1997), found that mangabeys (*Cercocebus albigena*) move longer distances in the wet season than during the dry season. According to Gillespie & Chapman (2001), resource availability and group size have an effect on red colobus monkey (*Procolobus badius*) day ranges: larger groups have significantly longer day ranges than smaller groups, with resource availability significantly predicting day range for larger groups, but not for smaller ones. For blue monkeys (*Cercopithecus mitis*), there is no relationship between day range and group size (Butynski, 1990). Seasonal variation in day range lengths for Campbell's monkey (*Cercopithecus campbelli*), the lesser white-nosed guenon (*C. petaurista*), and the Diana monkey (*C. Diana*) are not significant (Buzzard, 2006). Patas (*Erythrocebus patas*) and Tantalus (*Cercopithecus aethiops tantalus*) monkeys travel further during the dry season (Nakagawa, 1999). According to de Moor & Steffens (1972), and Barrett (2005), vervets generally travel longer distances during the dry than the wet season.

Seasonality affects the phenology of plant communities and therefore the abundance, nature, and distribution of available resources, with the colder, drier months yielding fewer resources in terms of quantity and variety, compared to the warmer, wet season when more is available (Gautier-Hion, 1980, 1988; Tutin & White, 1998; Chapman *et al.*, 1999, 2002b). Generally, as preferred resources diminish during the dry season, primates either track such foods across the landscape in an effort to improve encounter rates, optimizing available resources (Arthur & Pianka, 1966; Pyke *et al*., 1977; Foley, 1985; Hancock & Milner-Gulland, 2006), or they turn to fallback foods (refer 5.4 Discussion) that are available year-round (Harrison, 1984; Lee, 1984; Whitten, 1988; Lee & Hauser, 1995, 1998). In this context, seasonal day ranges provide an indication of how a species moves through its habitat to utilize available resources.

While I have shown that the vervets in this study use plant communities differentially and that this is a consequence of their constituent plants, there is a need to identify a currency, such as protein/fibre ratios (Barton & Whiten, 1994) or energy (Altmann, 1991) that simplifies the analysis of movement patterns. Energy has been used to good effect as a simple index of food quality (Oates *et al.*, 1990; Dasilva, 1992; Henzi *et al.,* 1992; Chapman *et al.,* 2002a; Wasserman & Chapman, 2003) and has the advantage of being relatively easy to determine.

Most of the energy-related African primate work comes from the tropics, with the exception of research in Southern Africa on baboons (Henzi *et al*., 1992; Gaynor, 1994) and samangos (Lawes *et al.*, 1990; Lawes, 1991).

In this chapter I describe the patterns of range use across the seasons and use the derived distribution of energy as a means to test hypotheses. My approach is based on the quantitative approach taken by Gaynor (1994), who analysed baboon day range use in relation to the spatial distribution of available resource energy to determine whether route choice optimised access to energy.

To determine whether the two vervet troops structure their day journeys optimally (in terms of effectively utilizing available resource energy), I investigate their route selection. I begin by comparing overall and seasonal resource energy available to the two troops in their home ranges. Overall and seasonal day range lengths and areas are then compared across and within the two troops. The effect that plant species diversity has on energy availability is also examined. To see whether the two troops are actively deciding on the daily routes they follow, or whether such routes are purely random, I compare actual route lengths and energy values to those of the shortest straight-line routes between the start and end points of actual routes. How the troops react to high energy areas in terms of time spent in such areas is also looked at. I then compare the overall and seasonal energy encountered by the two troops on their actual daily routes to that from a set of alternative randomly generated routes. Finally, I look at overall and seasonal actual route energy variations across troops.

I expect that there will be more resource energy available to the two troops during the wet season when there is a larger variety and abundance of available plant resources. I would then predict that the monkeys would travel shorter distances during this period. I expect that the Picnic troop's day journey lengths will be longer than the Donga troop's in both seasons, as their territory encompasses a less heterogeneous and more degraded environment (refer Phytosociology and Phenology chapters). I expect that as plant species diversity increases, so will available resource energy. For the comparisons of actual route lengths and energy to those of the shortest straight-line routes, I expect actual routes to be longer and to have more energy; otherwise the troops would not be taking such routes. I also expect the troops to spend less time in high energy, resource rich areas as an increased abundance of resources can be harvested faster. Finally, I expect that the two troops will follow routes based on underlying energy pathways and that they will select routes with the highest energy yields.

7.2 Methods

7.2.1 *Energy availability*

I determined energy available to the vervets in their home ranges by sampling the trees they foraged on and by determining the energy yields of foods consumed. I describe home range dimensions and plant community structure in the Phytosociology chapter. I tagged and numbered representative samples of each tree species with aluminum disks (refer Figure 6.1), recording the GPS co-ordinates of all tagged trees for monthly phenological monitoring.

Tree volumes

The dimensions of all tagged resource trees were determined to calculate tree volumes. Tree dimension parameters collected included overall tree height (A), height of maximum canopy diameter (B), height of first leaves (C), maximum canopy diameter (D), and base diameter of foliage at height of first leaves (E). Additional information required for volume calculations included crown height (F) calculated as $A – B$ and height of tree base (G) calculated as $B – C$. I describe the measurement of these parameters in the Phenology chapter.

According to Smit (1996), the spatial volume of any tree, regardless of its shape or size can be calculated using the volume formulae for ellipsoids, right circular cones, frustums of right circular cones and right circular cylinders. These shapes show considerable resemblance to the various tree shapes and tree parts. Depending on the shape of a tree, any of the above formulae or a combination of formulae may be used to calculate spatial volume.

For the purposes of this study and due to the general symmetry of tree shapes occurring at the study site, a combination of the following two formulae were used in all volume calculations.

i. The dome shaped segment or the area above the maximum canopy diameter of trees (referred to as $V1$) was calculated using the volume formula for half an ellipsoid as follows:

$$V1 = \frac{\left(\frac{22}{7}\right)(D^2)(F)}{6}$$

Where $V1$ = volume of dome
D = maximum canopy diameter
F = crown height.

ii. As the base diameters of foliage at the heights of the first leaves were greater than zero and less than the maximum canopy diameter for all trees in the study, the volume formula for a frustum of a right circular cone was used to calculate the volume of tree area below the level of maximum canopy diameter ($V2$) as follows:

$$V2 = \left(\frac{1}{3}\right)\left(\frac{22}{7}\right)(G)\left(\left(\frac{D}{2}\right)^2 + \left(\frac{D}{2}\right)\left(\frac{E}{2}\right) + \left(\frac{E}{2}\right)^2\right)$$

Where $V2$ = volume of frustum
D = maximum canopy diameter
E = base diameter of foliage at height of first leaves
G = height of tree base.

Total volume for a tree was calculated as $V1+V2$. A visual basic program (Microsoft Visual Basic 6.0®) that performs the above calculations and applies resource energy values to the results was created to simplify data collection and to provide overall energy values for sampled trees for extrapolation across the home ranges.

Tree resources

As part of the monthly phenological monitoring of vervet resource trees, a randomly selected branch in each tagged tree was marked using a red ribbon. This branch was used to visually estimate the number of resource items on a tree by counting the number of items available each month in 1 m^3 of the branch and by then extrapolating this into the total number of counting units in the tree volume. This sampling method is described by Dinerstein (1986), Chapman *et al*. (1992) and Ganzhorn (2003), and is considered the preferred method for measuring variability over time due to its accuracy. The method is however, very demanding of time and energy, becoming inaccurate if more than one observer is used due to inter-observer variability. During this study, only one observer did all the phenological monitoring.

Food item energy

Throughout the study period, I collected all plant parts consumed by the two troops. Those that were out of reach were collected using a modified extendible pruning shears with a collection bucket attached to the end of the shears (refer 6.2 Methods).

I dried samples in the field for wet weight determination and later in ovens at the laboratory where the nutritional analysis took place for dry weight determination (refer 6.2 Mehtods).

Samples were analysed for energy (kilojoule) and crude protein content (refer 6.2 Methods). The energy content (kJ/g) of samples was determined using bomb calorimetry. I assessed the crude protein (nitrogen) content of the plant parts using Kjeldahl procedures. The energy and crude protein content of 61 vervet food items was determined (this includes the majority of food items consumed, but excludes any insects they randomly consumed and an unidentified Liana species that they completely consumed during one observation and that was not observed again).

Tree energy

I calculated overall monthly available resource energy for each tagged resource tree by multiplying the energy values for a single resource item into the number of those resource items in $1m^3$. I then multiplied these values by the total tree volume using the aforementioned visual basic program, resulting in an energy figure for the entire tree for a particular resource. I accumulated energy figures for all tree resource items available in a month, resulting in an overall energy value of all resource items for a given tree (Tree Energy Value, TEV).

I also calculated the TEV's for species from the vegetation plots used for plant community delineation (refer Phytosociology chapter); only species that matched the tagged species were used.

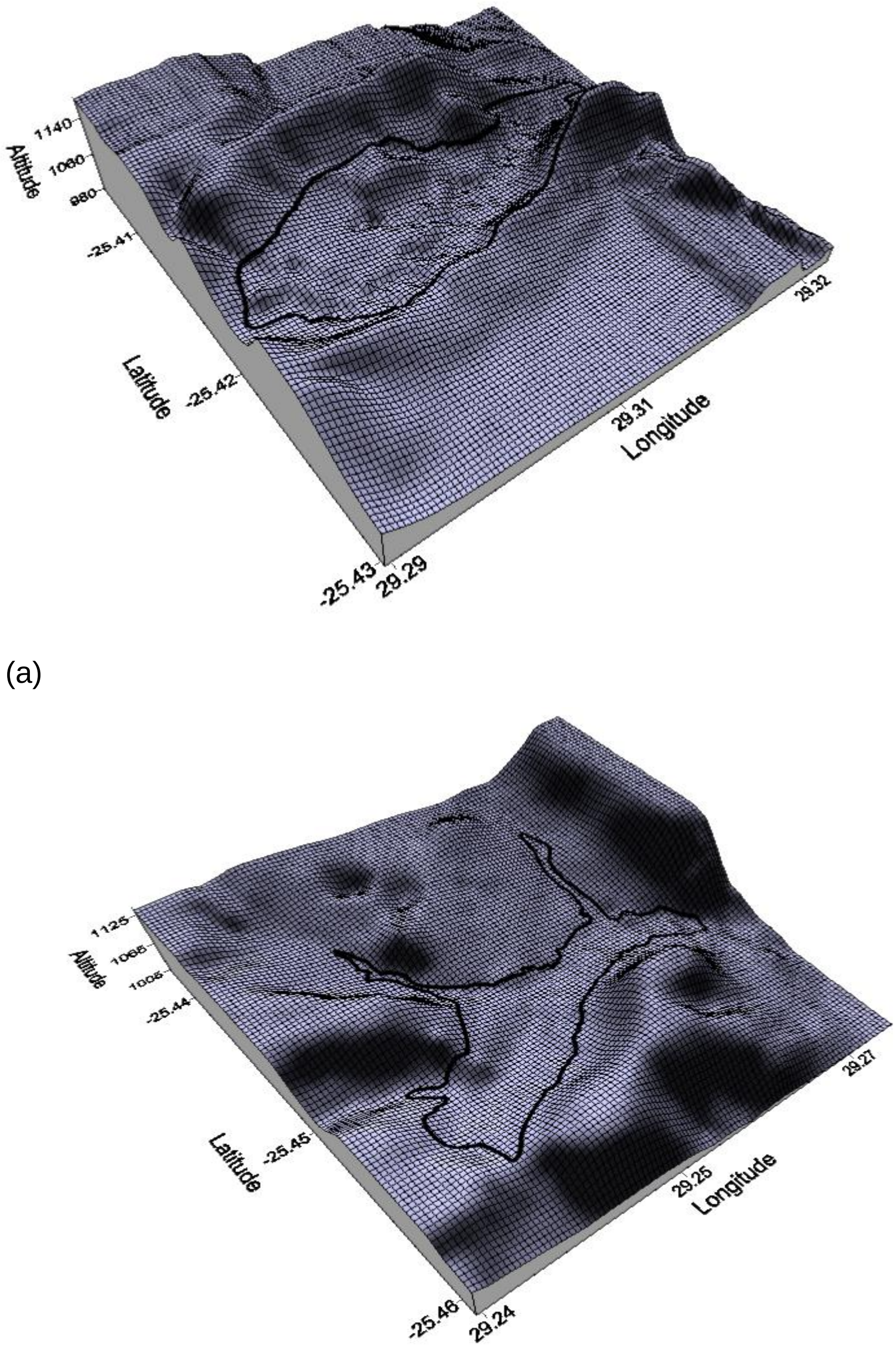
Home range energy interpolation

Monthly energy grids for both the Donga and Picnic areas were created by extrapolating calculated monthly energy figures for trees and plots across the respective home ranges. For plant communities where common resource plant species occurred in all phytosociology plant plots for the community, baseline energy values of those specific species were incorporated into all grid cells occurring within the community boundaries prior to interpolation.

To do this, I used Kriging with an assumed linear variogram as the interpolative method (Ripley, 1981; Zimmerman & Zimmerman, 1991; Mitasova & Jaroslav, 1993; Moore *et al*., 1993). Kriging was selected as it is known to have high predictive accuracy and can produce geometrically accurate maps from irregularly spaced data (Journel & Huijbregts, 1978; Myers, 1981; Mulla, 1991; Cressie, 1990, 1991; Gotway & Hartford, 1996).

Energy grids

To generate energy grids for interrogation in Arcview 3.3, it was necessary to create initial grids that contained the topology of the areas being sampled i.e. the two home ranges. Initial grids provided co-ordinates for further energy analyses. Such grids (Figure 7.1) were created by extrapolating GPS co-ordinates collected over the duration of the study period. Co-ordinates used for generating initial grids included daily vervet routes, tagged tree waypoints, community vegetation plot waypoints, digitized home range boundary and contour line waypoints, and feature waypoints. The software package SURFER 8.05® (2004, Golden Software, Inc., Colorado) was used to generate all grids.

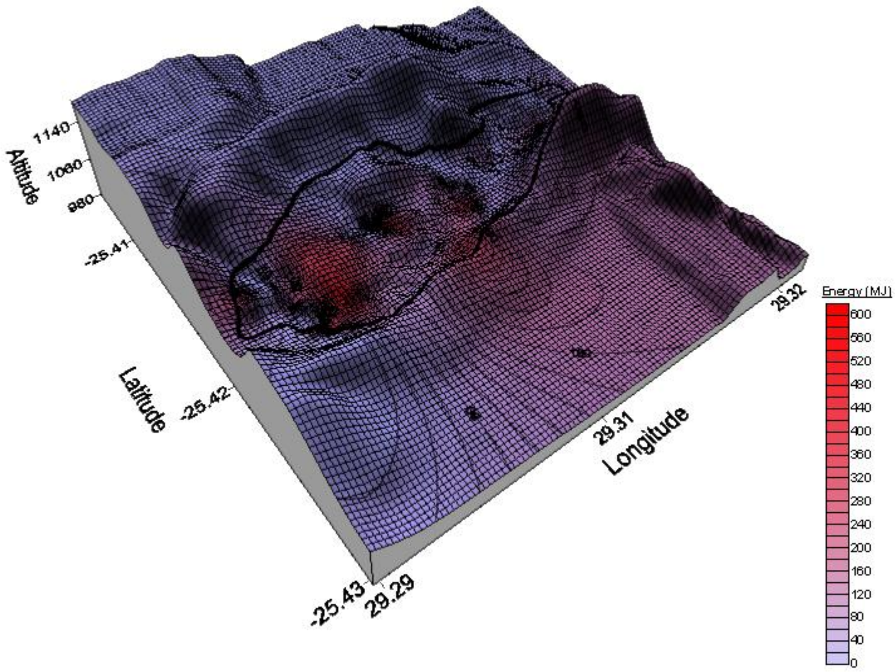


(a)

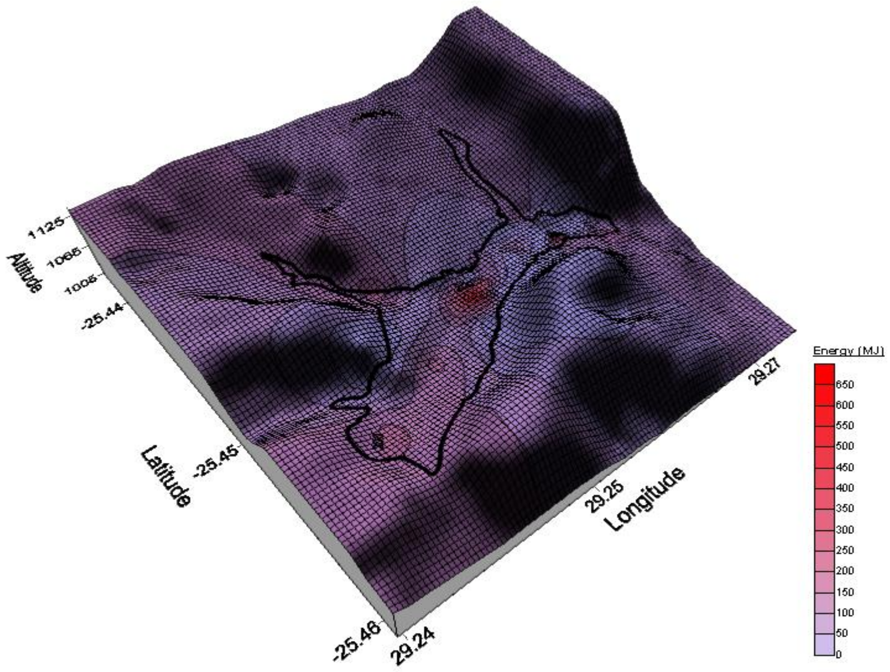
(b)

Figure 7.1. Initial grids for the Donga (a) and the Picnic (b) home ranges depicting the overall topography of the two areas and showing the home range boundaries, longitude, latitude and altitude.

Initial grids were clipped to home range boundaries and the minimum and maximum grid co-ordinates of these home range grids were used to generate a second series of 100 x 100 = 10 000 grids for each respective home range. Individual grid sizes were 0.11ha and were kept the same for both home ranges. Monthly energy values and their associated co-ordinates were overlaid onto the clipped home range grids and interpolated using Kriging, resulting in monthly home range energy surfaces used for route analysis (Figure 7.2).



(a)



(b)

Figure 7.2. Home range energy grids and surfaces (represented as contours) for a single month (July 2006) for the Donga (a) and Picnic (b). The home range boundaries, longitude, latitude, altitude and energy gradients are depicted.

I generated separate monthly energy grids and surfaces for each month of the study period for both home ranges.

7.2.2 *Home range utilisation*

Actual daily routes

On all occasions during the study period when the vervets were found and followed, their routes were recorded by collecting GPS waypoints of the troop's '*centre of mass*'. Refer to 3.3.1 for home range determination.

During each day journey the position of the troop being followed was recorded using a GPS logger programmed to save a waypoint every 10 seconds while the troops' geographic position (latitude, longitude and altitude) changed. While the troop was stationary, the GPS was set to record waypoints at 30 minute intervals.

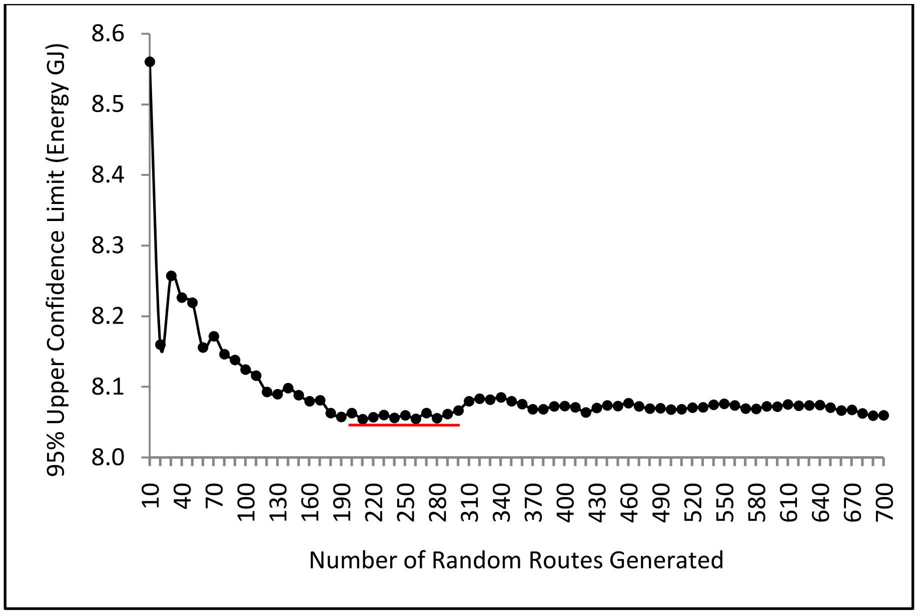
I transferred chronological waypoints to a geo-referenced orthographic aerial photograph where all waypoints were joined together into '*route*' segments and collectively combined into a day range for a particular day using the spatial data builder software package CARTALINX 1.2® (1999).

Number of random routes

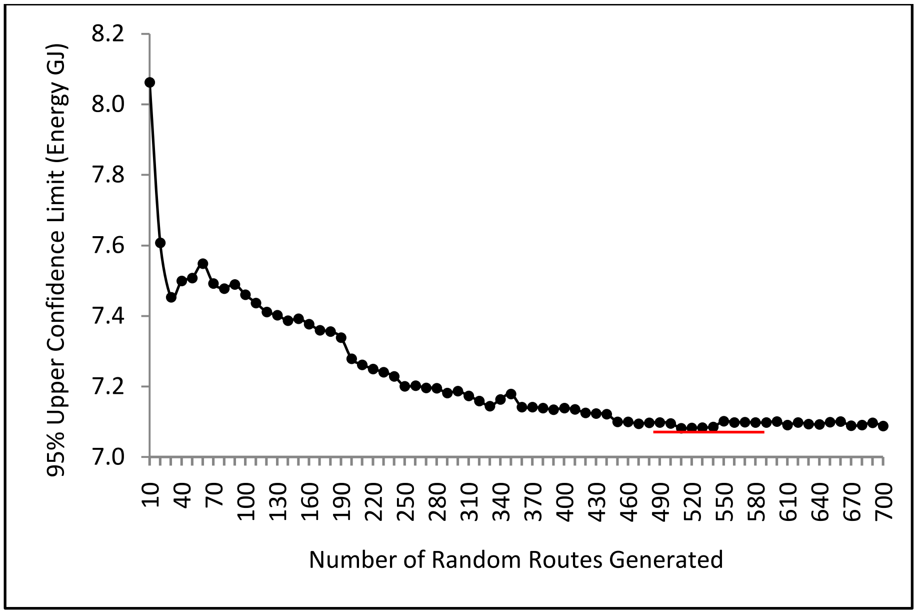
To determine how many random routes to generate for each original route, one actual route from each troop was randomly selected and a series of random routes were generated incrementally through a bootstrapping exercise. Bootstrapping involved repeatedly generating increasing numbers of random routes whilst computing the upper 95% confidence limit to identify critical values for the one-tailed binomial tests (Zar, 1999), and then observing whether there were noticeable changes to the computed values. Initially 10 random routes were generated and the upper 95% confidence limit of these 10 routes energy values was plotted. I then incremented the number of random routes being generated by 10, generating 20 random routes, and again plotted the upper 95% confidence limit of these 20 routes energy values. I continued incrementing the number of random routes being generated by 10 while plotting the upper 95% confidence limits until the graph being produced flattened out and no further noticeable changes occurred to the upper 95% confidence limits. When this point was reached, I continued to generate random routes until I reached 700 random routes for both troops; this was done to confirm that the graph had indeed flattened out. Where the graph flattened, a tangent was dropped to the X-axis and the next incremental number of random routes, rounded up to the next 100 was selected as the number of random routes to generate.

In some instances the number of random routes generated for an actual route was less than the minimum required for the two troops. This occurred when an actual day journey was very short and the animals only moved over a few grid cells due a disturbance such as rain, fire or the presence of competitors or predators such as baboons. On account of the reduced number of route segments available for randomisation on such days, there was a lack of overall variability, resulting in less than the minimum number of random routes required being generated.

Consequently, I compared each actual Donga troop day journey to 300 random routes, and each Picnic troop day range to 600 random routes (Figure 7.3).



(a)



(b)

Figure 7.3. Results of a bootstrapping exercise for determining the number of random routes required for each original route for both the Donga troop (a) and the Picnic troop (b). The red lines indicate asymptotes.

Random route generation

Daily routes travelled by the two vervet troops were randomized using the ARCVIEW® extension '*Alternate Animal Movement Routes v. 2.1*' (Jenness, 2005).

Random routes were generated by breaking the actual route into a set of vertex-to-vertex segments. Vertex segments are created when the GPS co-ordinates or points that a route consisted of are joined i.e. it is the arcs or lines that are formed when all the points making up a route are connected to create the route. The vertex-to-vertex segments are therefore the separate arcs or lines that have been disjoined for a route. Once the vertex segments had been separated, they were randomly rearranged into alternate routes (Figure 7.4). Alternative routes have the same route segments and segment lengths as the actual route they are based on, but their internal and deviation angles differ from those of the original route. The end result is a set of alternate routes of the same length, that start and end at the same place as the actual route, but which might well have gone through entirely different areas, being straighter or more meandering.

Several geometrically based indices (including distances, bearings and internal angles) defined by the route segments were derived for each random route generated. Indices describe the geometric aspects of the random routes i.e. how much they deviate from those of the original route and are used by the '*Alternate Animal Movement Routes v. 2.1*' software package to ensure that random routes are different from the actual route and from one another; also ensuring that the random routes occur within the area traversed by the troops (i.e. within their respective home ranges bounding polygons).

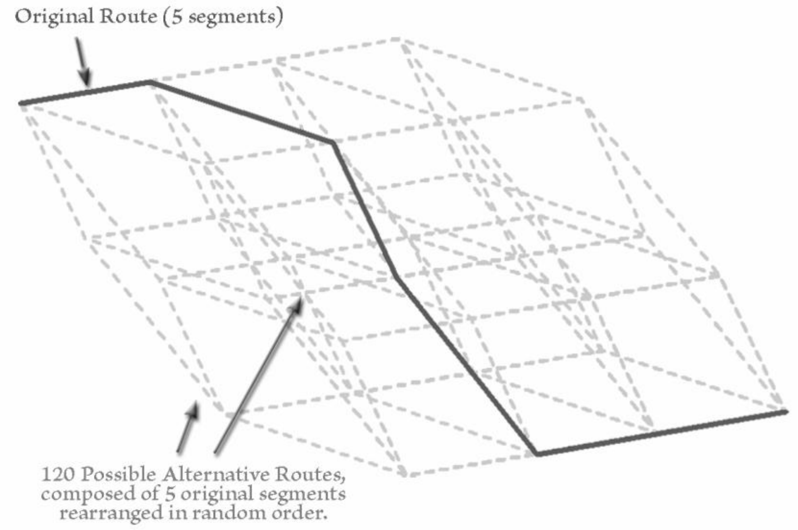
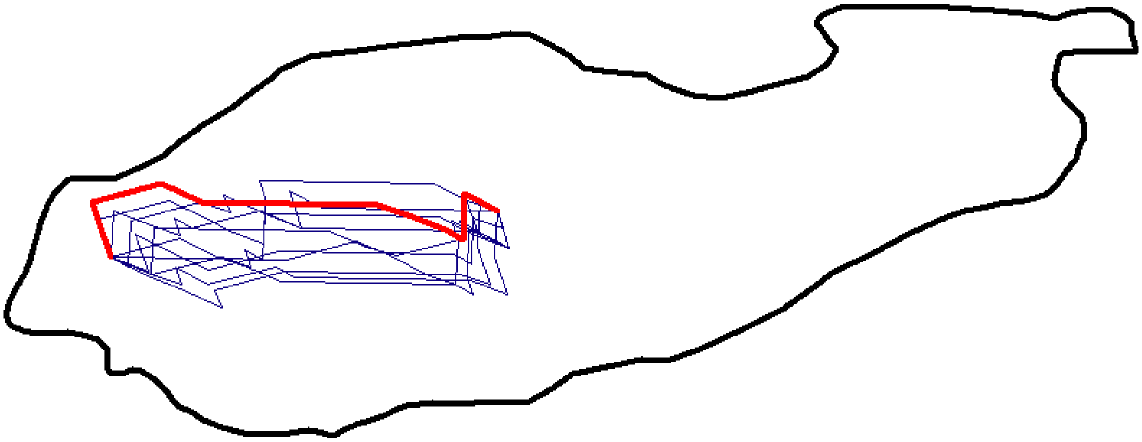


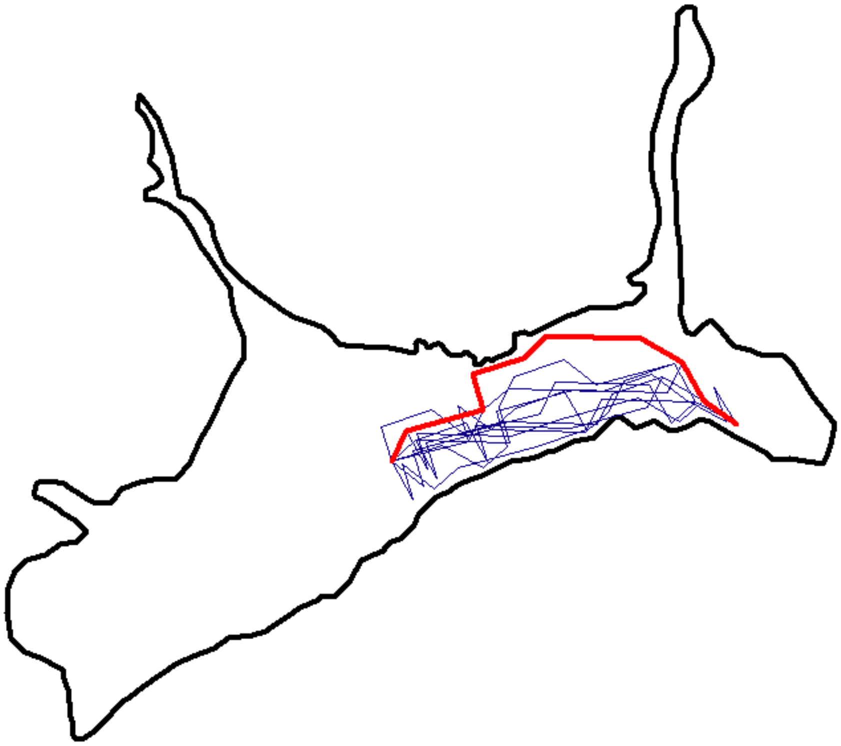
Figure 7.4. Visual representation of how random routes were generated from a single original route composed of five segments (Jenness, 2005). Dotted lines indicate all potential combinations of alternative routes that could be generated for a single original route.

To make each alternate route unique, the placement, bearings, internal angles and deviation angles defined between the various route segments was changed. Internal angles are formed by two route segments and are always less than or equal to 180°. They are equal to 180° if the segment continues on the exact same bearing as the segment before it, and 0° if the path doubles back and goes in exactly the opposite direction. Deviation angles reflect how much the bearing of a particular segment deviates from the bearing of the segment prior to it. Deviation and internal angles are supplementary.

The number of potential alternate routes that could be calculated is dependent on the number of possible permutations of segments available in the actual route (Jenness, 2005). The number of routes generated is also affected by the bounding polygon (i.e. the home range boundary). The actual route and its randomly generated alternatives were extracted to vector shape files for analysis. Figure 7.5 shows a representative portion of the random routes generated through bootstrapping for the Donga and Picnic home ranges.



(a)



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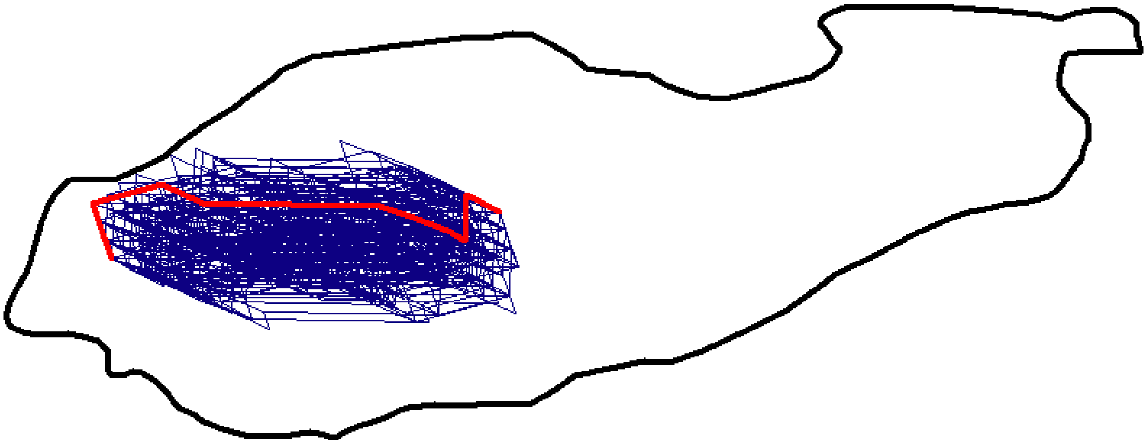
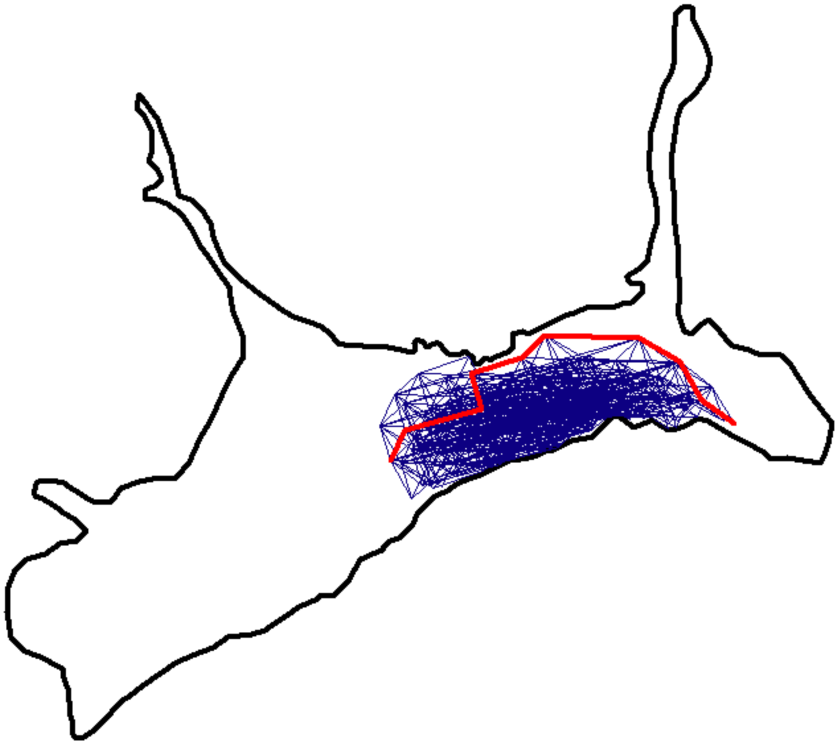


(c)



(d)

Figure 7.5. Randomly generated routes for the two home ranges showing 10 randomly generated routes for the Donga (a), 10 for the Picnic (b), 300 for the Donga (c) and 600 for the Picnic (d). The red route is the actual route; blue routes are randomly generated routes.

Route energy

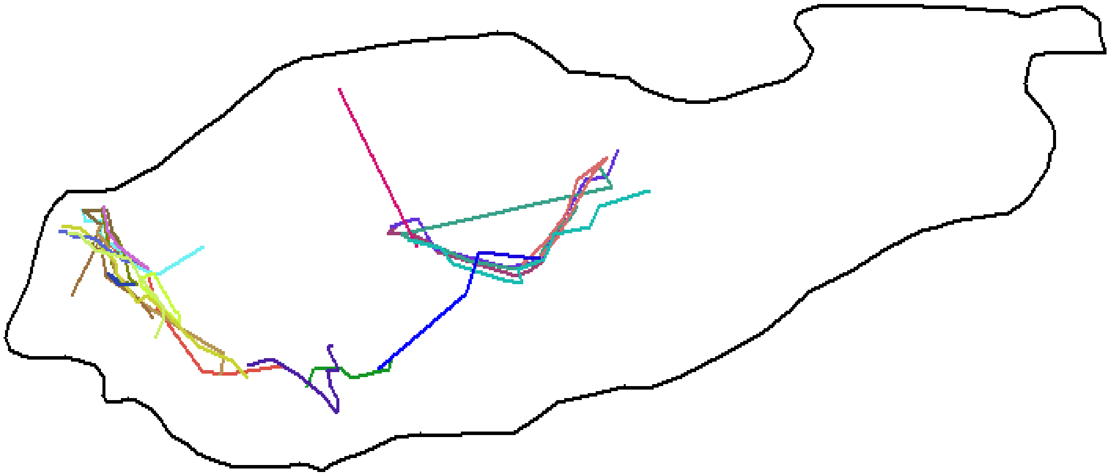
Both actual and randomly generated routes were overlaid onto the monthly energy grids. Routes consisted of arcs (i.e. segments) and needed to be converted to points so that matching grid locations could be extracted. For creating evenly distributed points on the arcs, the ARCVIEW® extension '*Convert Shapes to Points*' was used (Huber, 2000). Randomly generated points were sorted and duplicate points occurring in a single underlying grid were removed.

To extract matching energy information from underlying monthly grids, an ARCVIEW® spatial join was used to link the generated points to the underlying grid. The result was a combined table of points with energy values that could be exported and analysed in Microsoft Excel and SPSS.

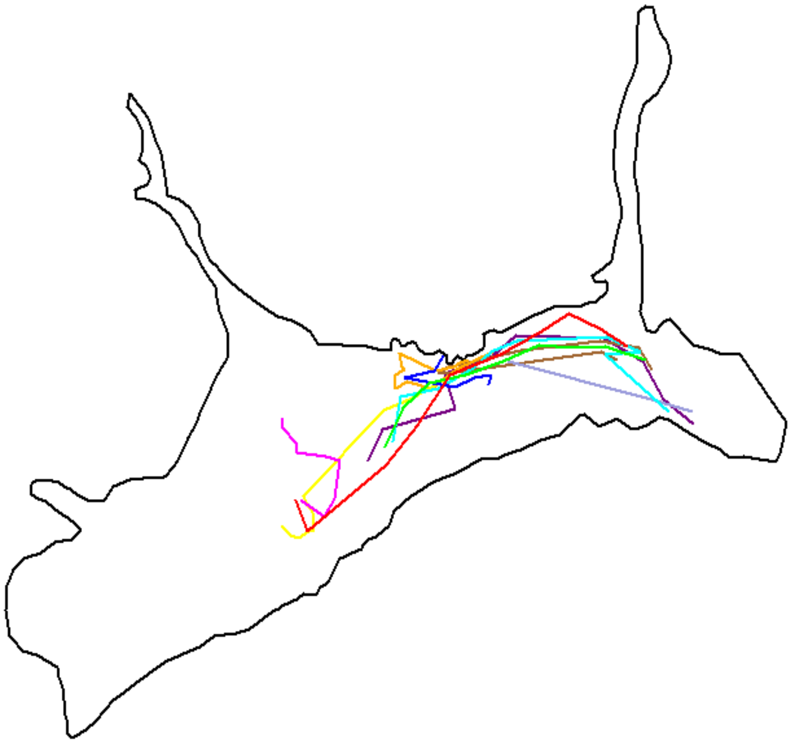
I compared energy values for an observed route taken by the vervets to both the upper 95% CIs and mean of all the random routes generated for that particular route. This gave an indication of whether that observed route was maximizing access to energy. The resulting energy figures for the observed routes and their associated random routes were compared for all observed routes in each respective home range.

Seasonal day ranges

I used all full day routes recorded (Donga *n*=43, Picnic *n*=21) over the study period for day range calculations (refer 3.3 Methods). Seasonal day ranges were determined by overlaying the dry (1 May to 31 October) and wet (1 November to 30 April) seasons routes over the respective troops' home ranges (Figure 7.6).



(a)



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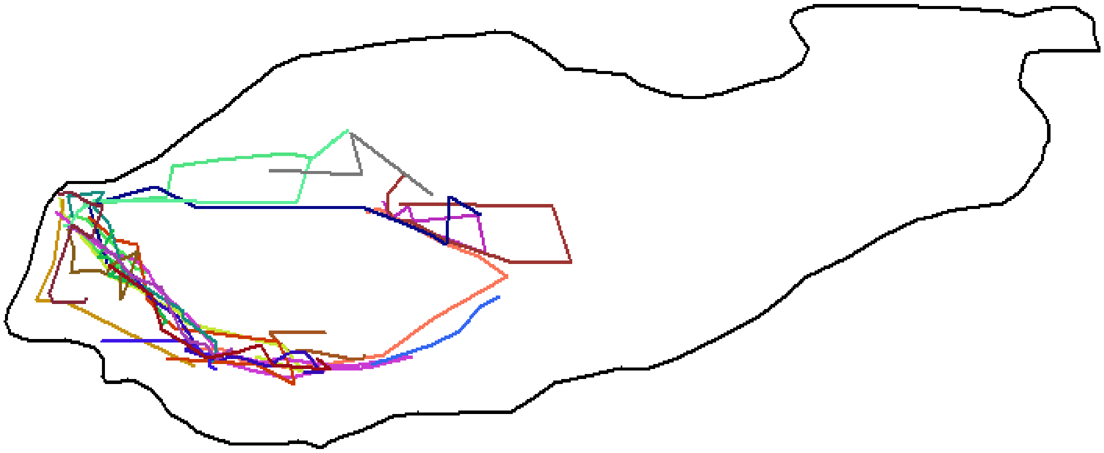

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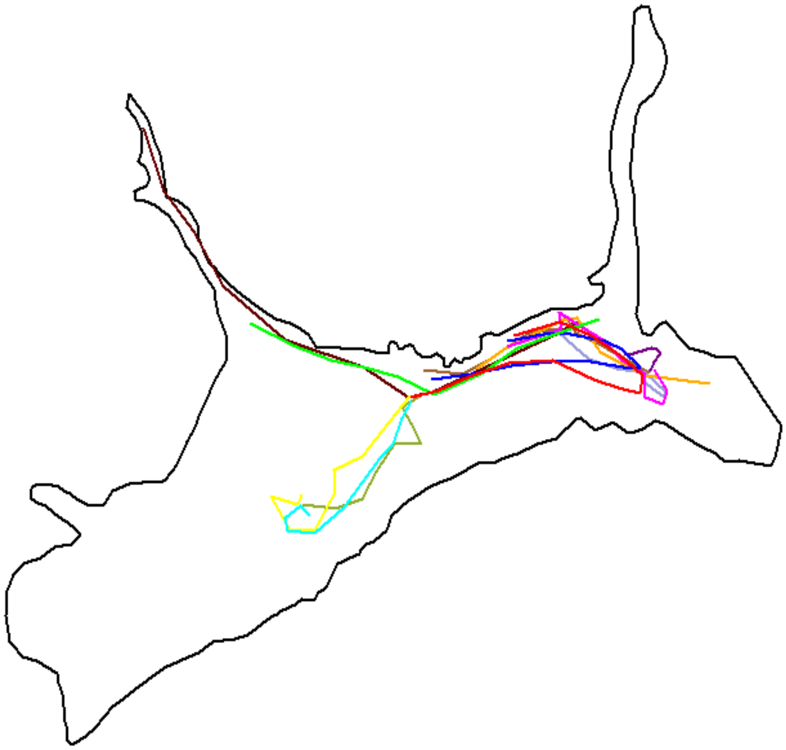


(d)

Figure 7.6. Troop seasonal day ranges depicting actual routes taken for Donga droop during the dry season (a), for the Picnic troop during the dry season (b), for the Donga troop during the wet season (c) and for the Picnic troop during the wet season (d). Only data from full day follows are presented.

7.2.3 *Relationship between time spent in grids and energy*

I calculated time spent in energy grids for all actual routes taken by both vervet troops by extracting GPS time signatures from all scan data collected for the troops. The relationship between time spent in the various grid cells and available energy in such grids was determined.

7.2.4 *Home range energy*

Overall energy for the two home ranges was calculated by extracting and accumulating monthly energy values for the various plant communities occurring in the respective home ranges.

7.3 Results

7.3.1 *Home range energy*

Figure 7.7 depicts available resource energy for the Donga and Picnic home ranges. Resource energy values have been averaged for plant community sizes for the two home ranges, providing per hectare values.

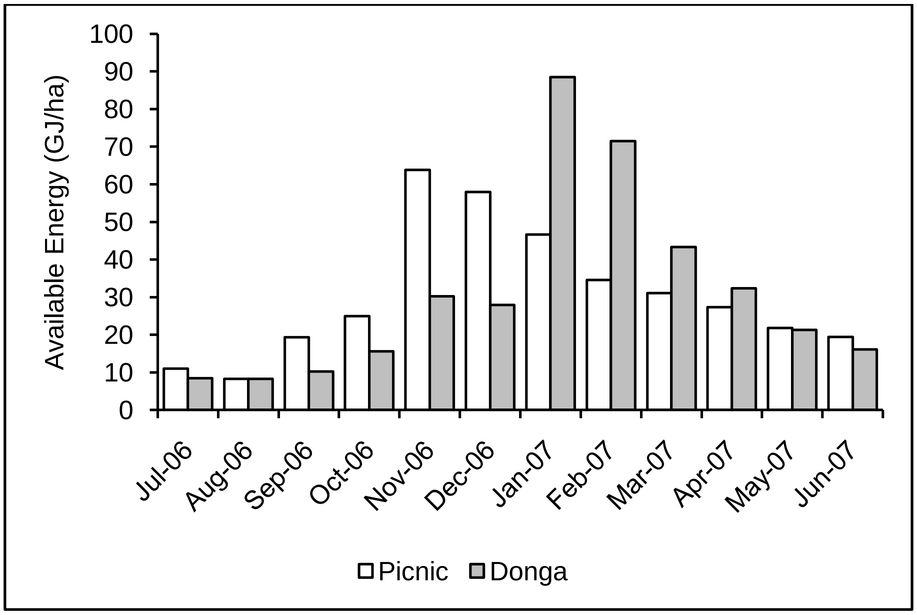


Figure 7.7. Available resource energy (GJ) for the two home ranges for the study period.

A comparison of monthly resource energy for combined seasons for the two home ranges showed no significant differences ($t_{22} = -0.072$, $P = 0.94$).

Across home range seasonal comparisons of available resource energy showed that for both the dry season ($t_{10} = 1.216$, $P = 0.25$) and the wet season ($t_{10} = -0.451$, $P = 0.66$) there were no significant differences between the two home ranges.

Within home range seasonal comparisons of available resource energy showed that for both the Picnic ($t_5 = 4.012$, $P < 0.01$) and the Donga ($t_5 = 2.951$, $P = 0.03$) home ranges there were significant differences between the dry and wet seasons.

7.3.2 *Day range lengths and areas*

Overall average day range length (Table 7.1) for the Donga troop was 621m (minimum 248 and maximum 1030m), and for the Picnic troop was 832m (minimum 550 and maximum 1161m).

Overall average day range area (Table 7.1) for the Donga troop was 0.37ha (minimum 0.15 and maximum 0.62ha), and for the Picnic troop was 0.50ha (minimum 0.33 and maximum 0.70ha).

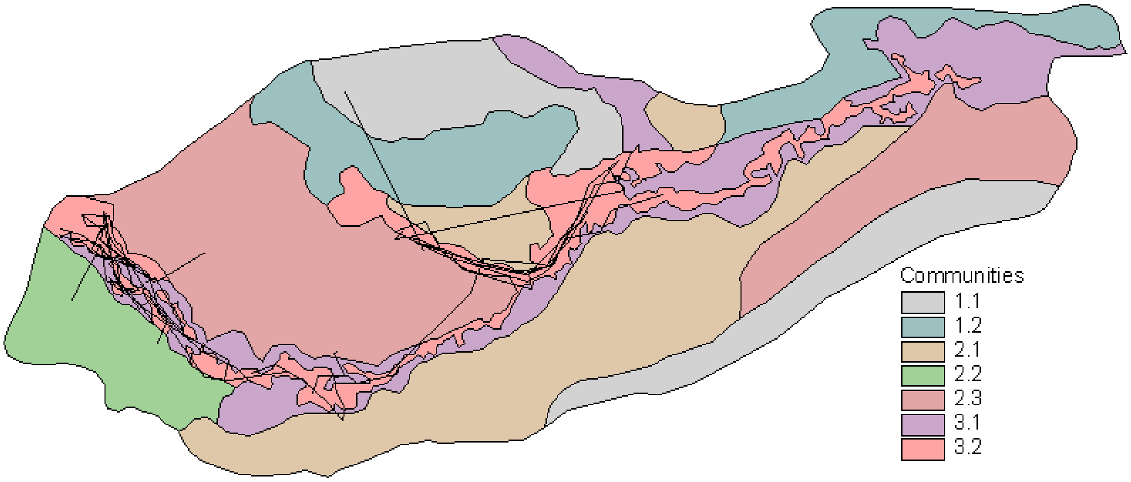
Table 7.1. Average day range lengths and areas by month for the two study troops for the study period.

	Avg day range length (m)		Avg day range area (ha)	
Date	**Picnic**	**Donga**	**Picnic**	**Donga**
Jul-06	1148 (*n*=1)	445 (*n*=3)	0.69 (*n*=1)	0.27 (*n*=3)
Aug-06	1051 (*n*=1)	676 (*n*=3)	0.63 (*n*=1)	0.41 (*n*=3)
Sep-06	581 (*n*=2)	682 (*n*=3)	0.35 (*n*=2)	0.41 (*n*=3)
Oct-06	1161 (*n*=1)	664 (*n*=6)	0.70 (*n*=1)	0.40 (*n*=6)
Nov-06	940 (*n*=2)	674 (*n*=3)	0.56 (*n*=2)	0.40 (*n*=3)
Dec-06	1052 (*n*=1)	710 (*n*=3)	0.63 (*n*=1)	0.43 (*n*=3)
Jan-07	743 (*n*=3)	1030 (*n*=4)	0.45 (*n*=3)	0.62 (*n*=4)
Feb-07	550 (*n*=2)	817 (*n*=3)	0.33 (*n*=2)	0.49 (*n*=3)
Mar-07	708 (*n*=2)	428 (*n*=5)	0.42 (*n*=2)	0.26 (*n*=5)
Apr-07	652 (*n*=2)	577 (*n*=3)	0.39 (*n*=2)	0.35 (*n*=3)
May-07	629 (*n*=2)	496 (*n*=4)	0.38 (*n*=2)	0.30 (*n*=4)
Jun-07	772 (*n*=2)	248 (*n*=3)	0.46 (*n*=2)	0.15 (*n*=3)

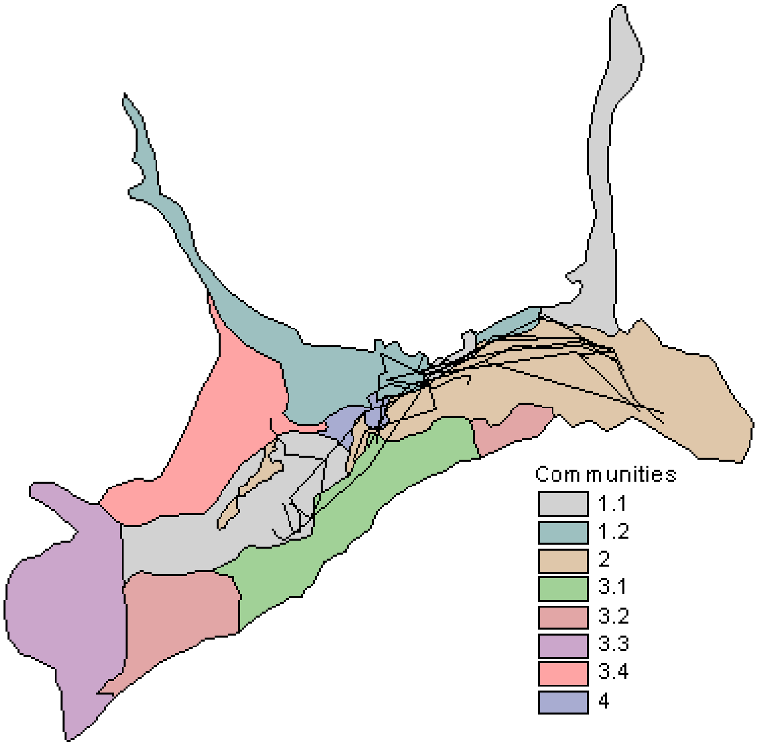
Overall average day range lengths (832±226m, *n*=21 for the Picnic vs. 621±202m, *n*=43 for the Donga) and areas (0.50±0.14ha, *n*=21 for the Picnic vs. 0.37±0.12ha, *n*=43 for the Donga) were significantly longer (t_{22} = -2.420, P = 0.02) and larger (t_{22} = -3.384, P = 0.03) for the Picnic troop when compared with those of the Donga troop.

7.3.3 *Seasonal day range lengths and areas*

Average dry season day range length for the Donga troop (Figure 7.8a) was 525m (minimum 106 and maximum 1489m), and for the Picnic troop (Figure 7.8b) was 814m (minimum 384 and maximum 1161m). Average wet season day range length for the Donga troop (Figure 7.8c) was 695m (minimum 317 and maximum 1437m), and for the Picnic troop (Figure 7.8d) was 748m (minimum 164 and maximum 1512m).


Communities
1.1
1.2
2.1
2.2
2.3
3.1
3.2

(a)


Communities
1.1
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4

(b)

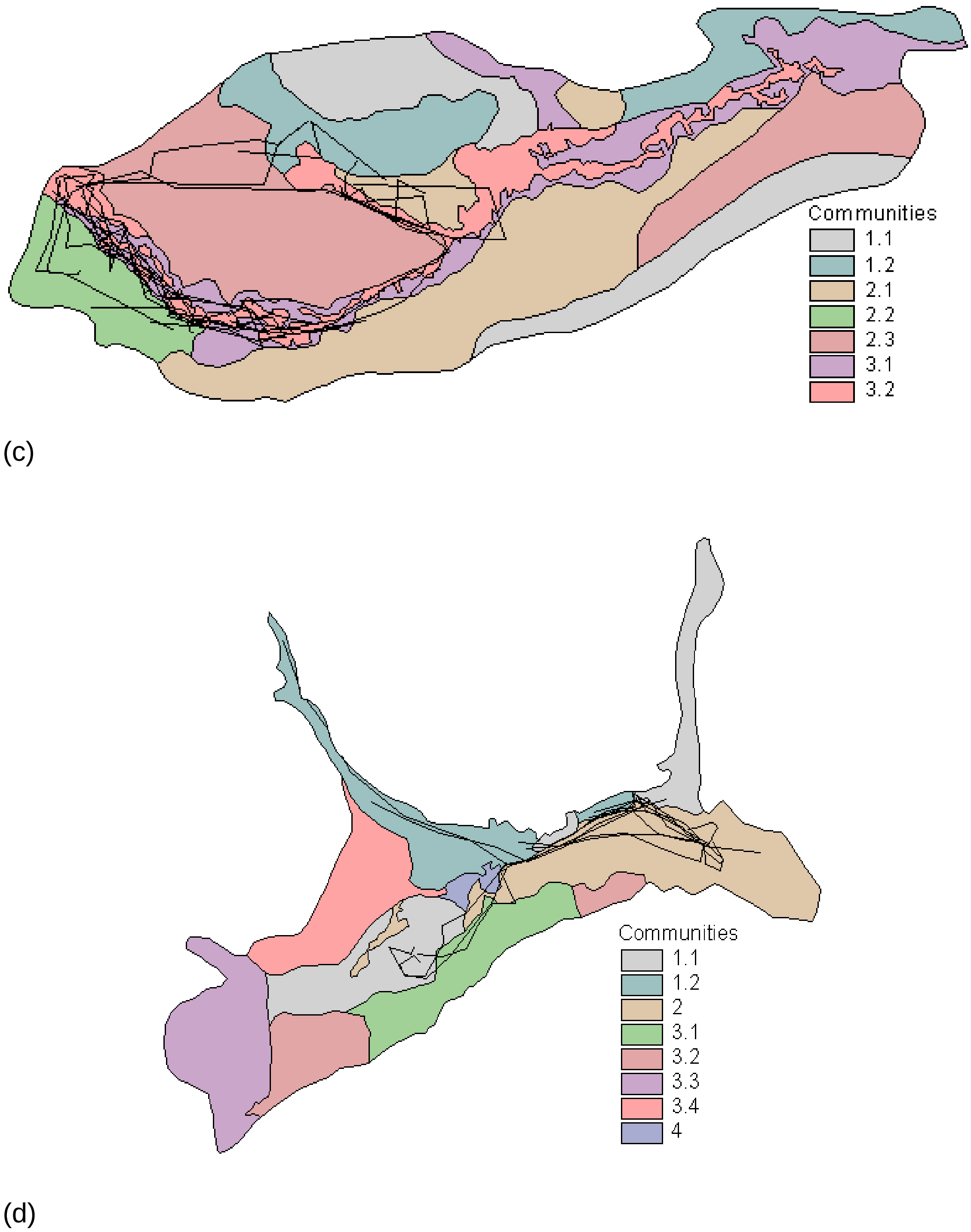
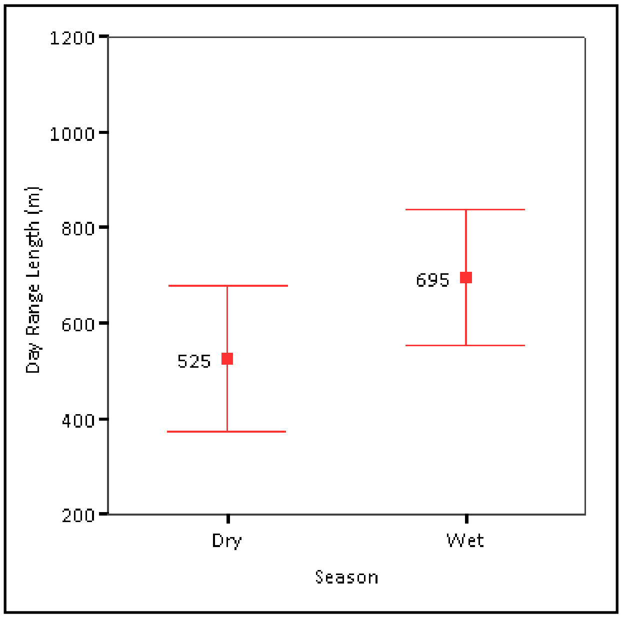


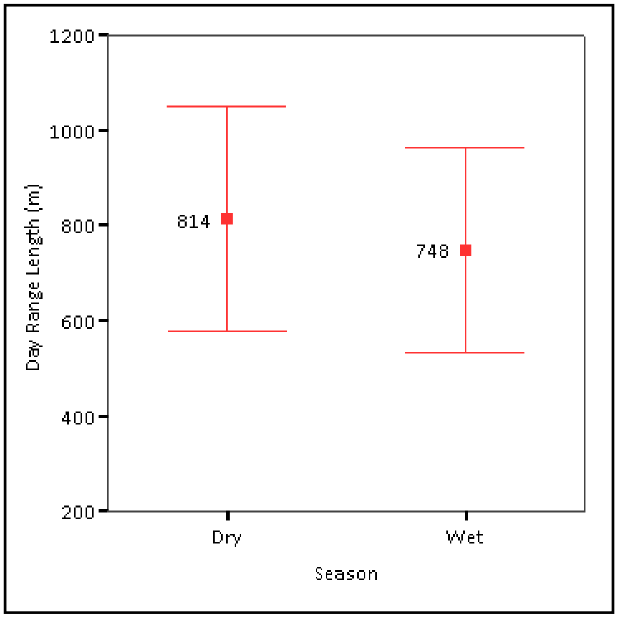
Figure 7.8. Troop average seasonal day ranges depicting day ranges overlaid onto plant communities for the Donga dry season (a), Picnic dry season (b), Donga wet season (c) and the Picnic wet season (d). Refer to 4.3.2 and 4.3.4 in the Phytosociology chapter for plant community descriptions.

Across troop seasonal day range length differences were significant for the dry season ($t_{29} = -2.190$, $P = 0.04$), but not for the wet season ($t_{31} = -0.456$, $P = 0.65$).

Figure 7.9 depicts seasonal day range lengths for both troops.



(a)

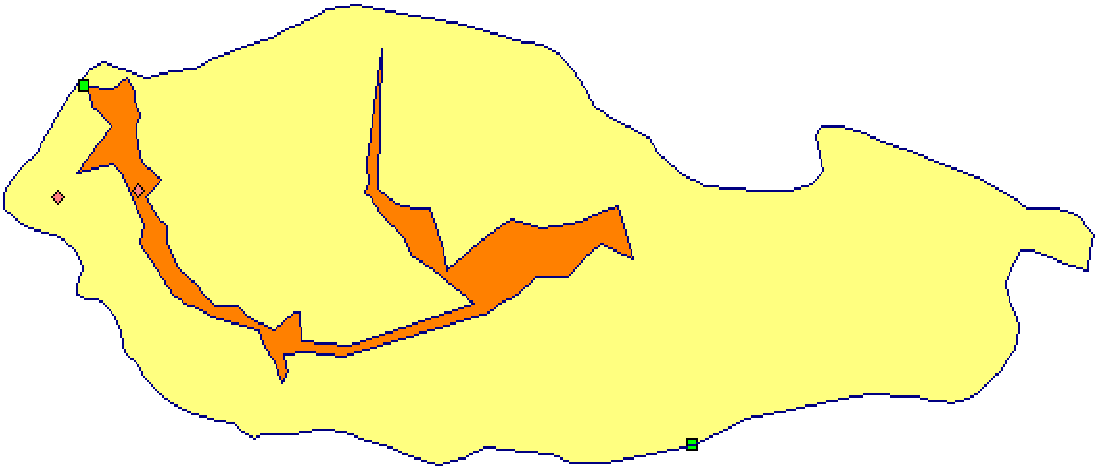


(b)

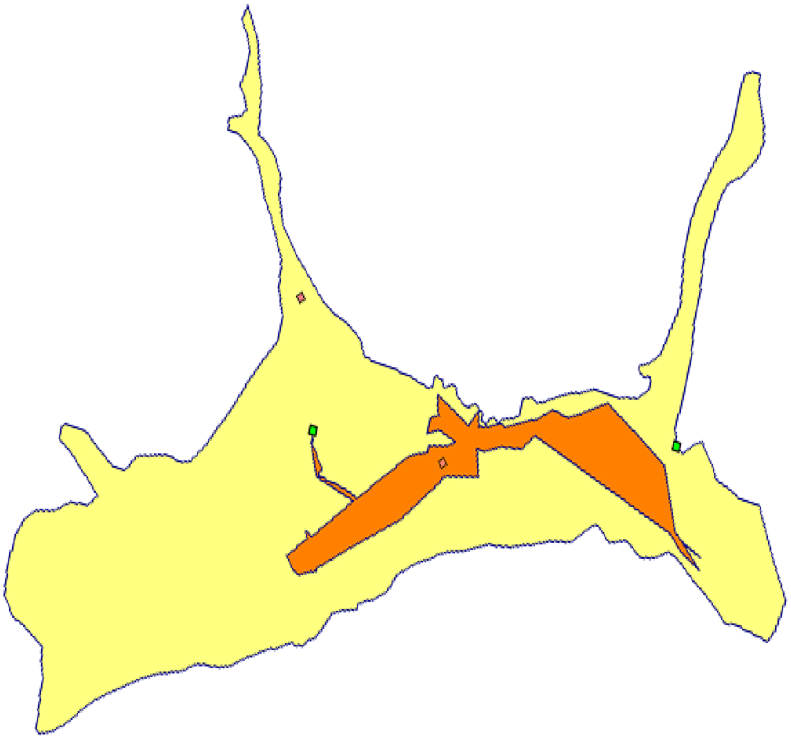
Figure 7.9. Seasonal day range lengths (meters) for the Donga troop (a) and the Picnic troop (b). Error bars indicate 95% CI for the mean.

Within troop seasonal day range length differences were not significant for either the Donga troop (t_{20} = -1.423, P = 0.17) or the Picnic troop (t_8 = 0.230, P = 0.82).

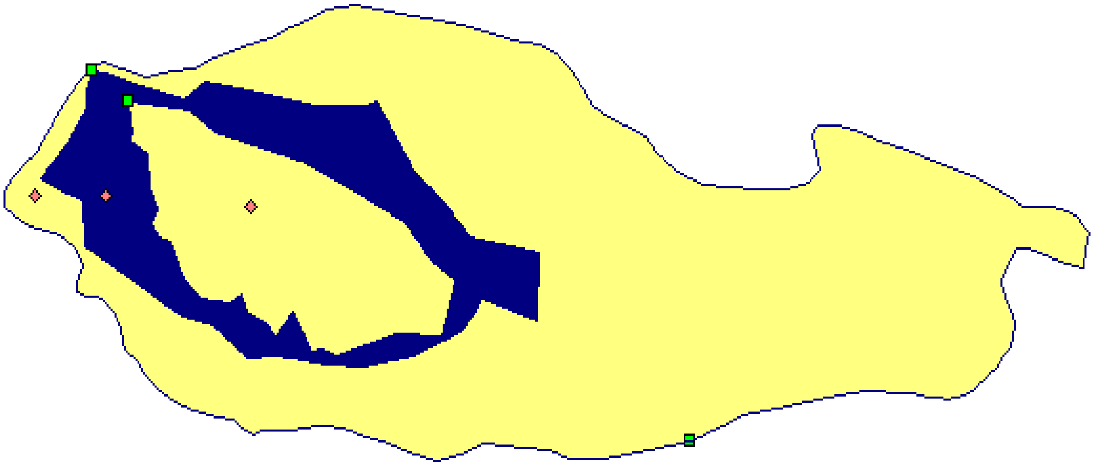
Average dry season day range area for the Donga troop (Figure 7.10a) was 0.32ha (minimum 0.06 and maximum 0.89ha), and for the Picnic troop (Figure 7.10b) was 0.49ha (minimum 0.23 and maximum 0.70ha). Average wet season day range area for the Donga troop (Figure 7.10c) was 0.42ha (minimum 0.19 and maximum 0.86ha), and for the Picnic troop (Figure 7.10d) was 0.45ha (minimum 0.10 and maximum 0.91ha).



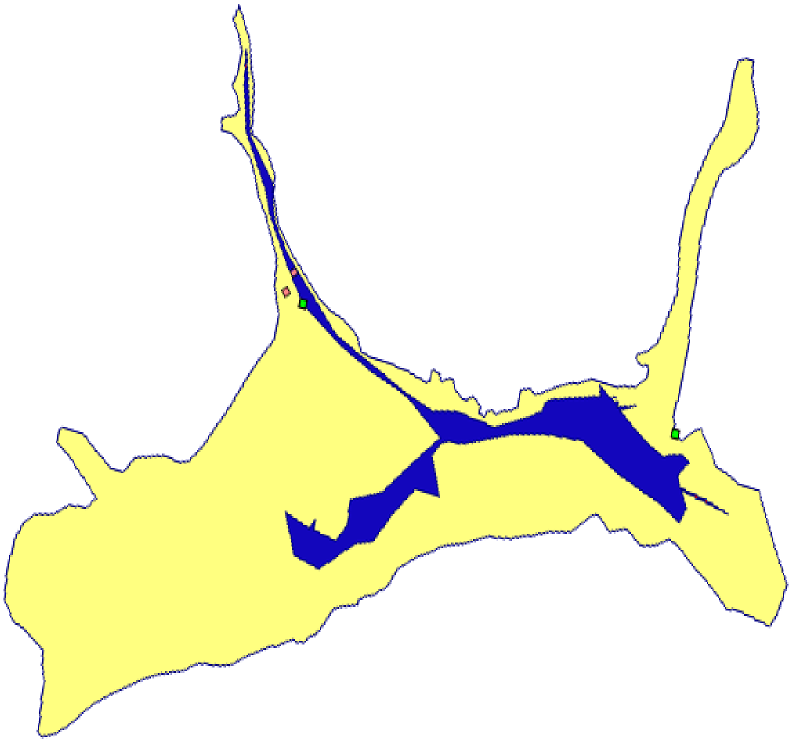
(a)



(b)



(c)

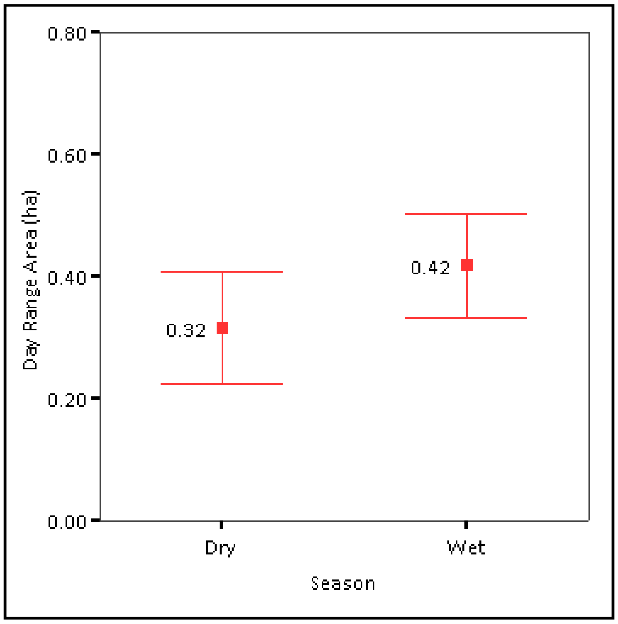


(d)

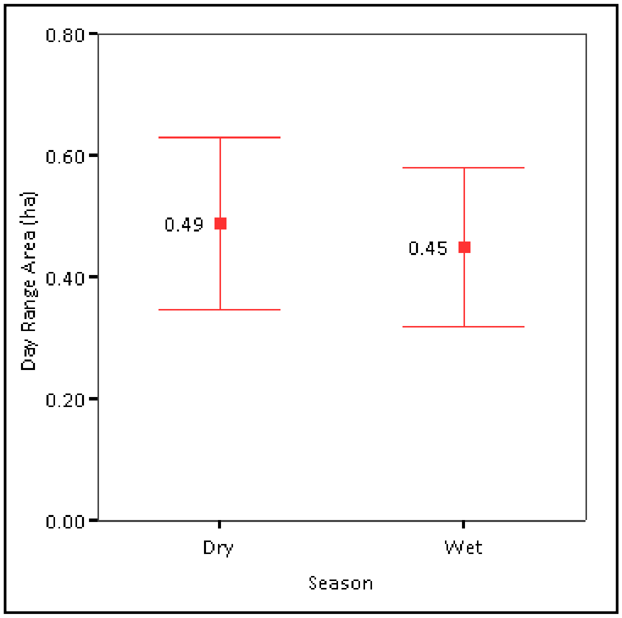
Figure 7.10. Troop average day range areas for the Donga dry season (a), Picnic Dry season (b), Donga wet season (c) and the Picnic wet season (d). Day range areas are depicted in orange for the dry season and blue for the wet season.

Inter troop seasonal day range area differences were significant for the dry season (t_{29} = -2.190, P = 0.04), but were not for the wet season (t_{31} = -0.456, P = 0.65).

Figure 7.11 depicts seasonal day range areas for both troops.



(a)



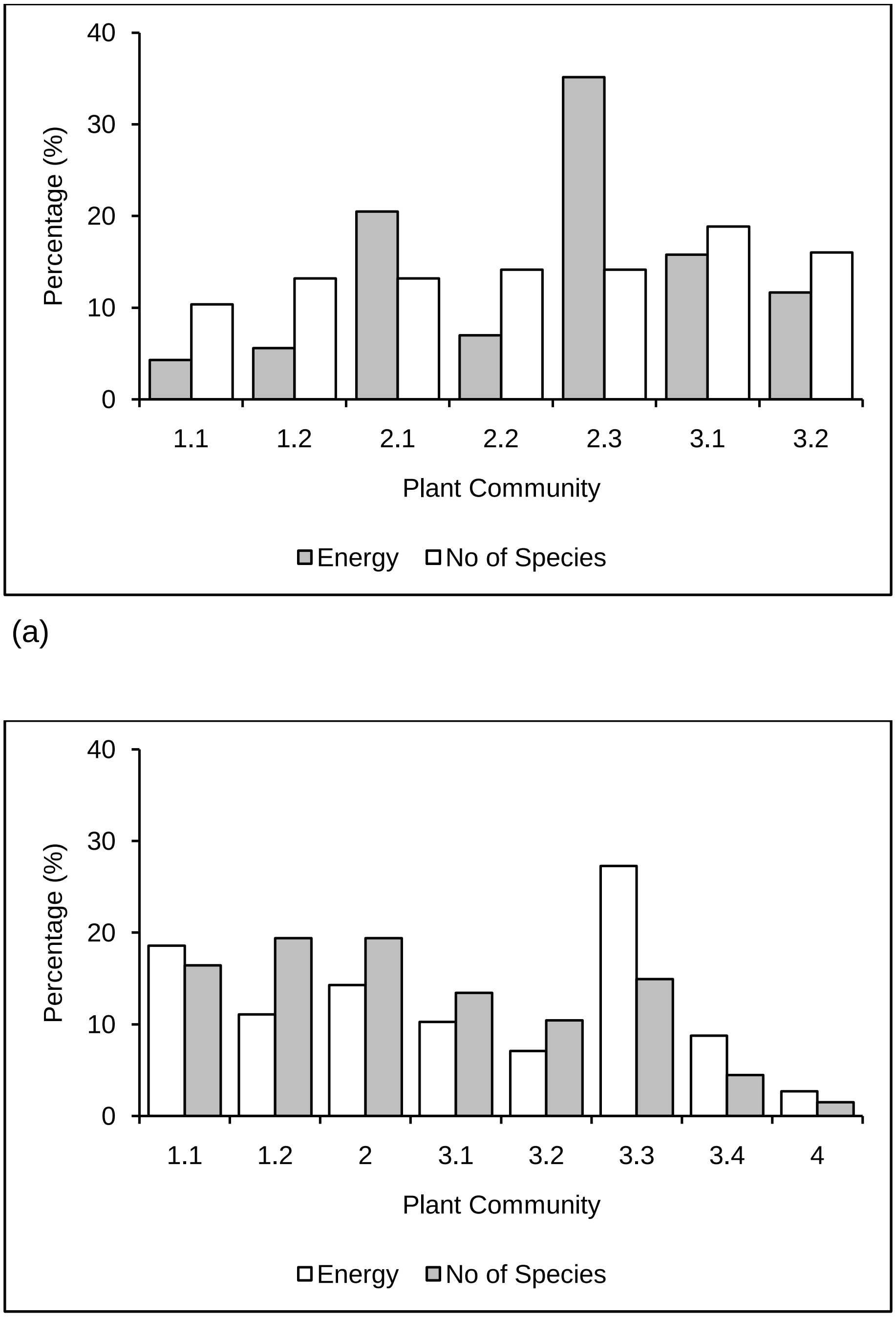
(b)

Figure 7.11. Seasonal day range areas (hectares) for the Donga troop (a) and the Picnic troop (b). Error bars indicate 95% CI for the mean.

Within troop seasonal day range area differences were not significant for either the Donga troop (t_{20} = -1.423, P = 0.17) or the Picnic troop (t_8 = 0.230, P = 0.82).

7.3.4 *Energy vs. species diversity*

Figure 7.12 shows the amount of energy available (from 7.3.1 above) and the corresponding number of plant species present in the various plant communities of the Donga (Figure 7.12a) and the Picnic (Figure 7.12b) home ranges.



(a)

(b)

Figure 7.12. Contributions of available energy (GJ/ha) and numbers of plant species to the various plant communities of the Donga (a) and the Picnic (b) home ranges.

There was a non significant weak positive correlation between the amount of energy available and number of species present in the plant communities of the Donga home range ($r_s = 0.473$, df = 5, $P = 0.28$).

There was a significant positive correlation between the amount of energy available and number of plant species present in the plant communities of the Picnic home range ($r_s = 0.755$, df = 6, $P = 0.03$).

7.3.5 *Shortest routes*

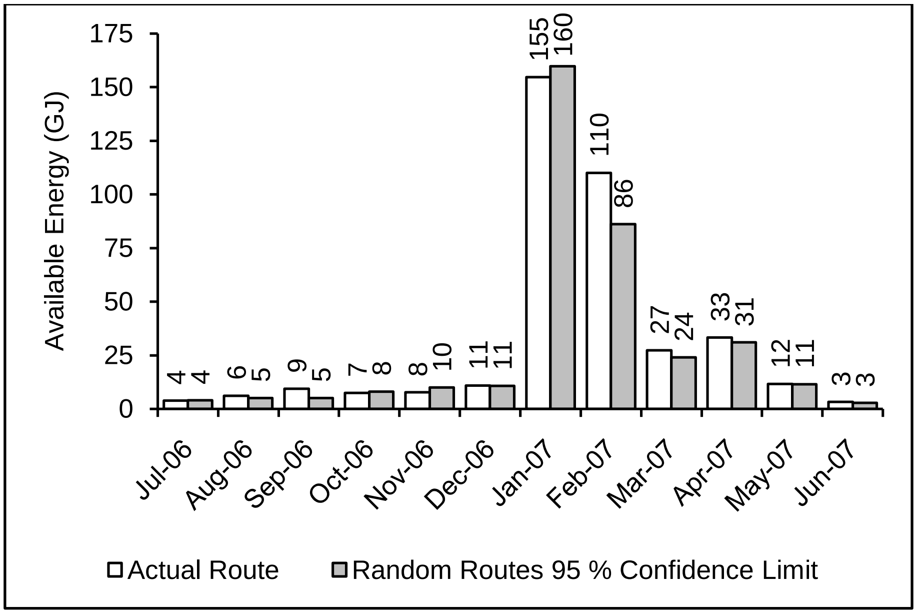
Actual routes taken provided significantly more energy than the shortest straight-line routes between the start and end points of actual routes for both the Picnic troop ($t_{20} = 4.632$, $P < 0.01$) and the Donga troop ($t_{42} = 2.083$, $P = 0.04$). Lengths of actual routes taken were significantly longer than the shortest straight-line route lengths between the start and end points of actual routes for both the Picnic troop ($t_{20} = 5.618$, $P < 0.01$) and the Donga troop ($t_{42} = 6.430$, $P < 0.01$). Refer to Appendix 3 for data table.

7.3.6 *Time spent vs. available energy in grid cells*

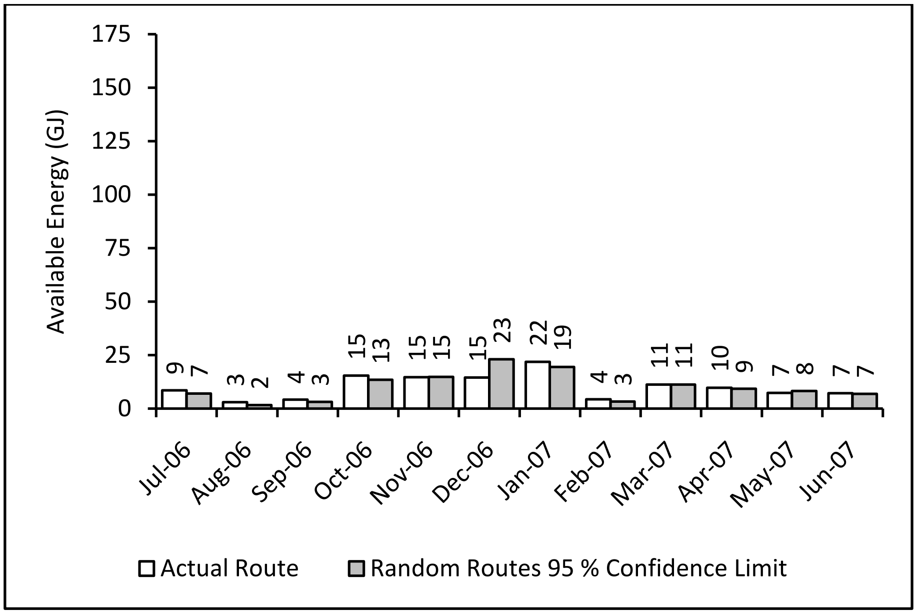
For the Donga troop there was a significant negative correlation between the energy available in a grid cell and the amount of time spent in it ($r_s = -0.074$, df = 1090, $P < 0.01$). For the Picnic troop this correlation was in the same direction but was not statistically significant ($r_s = -0.057$, df = 715, $P = 0.13$).

7.3.7 *Within troop actual and random route energy*

Results from a comparison of average monthly energy values for the actual and random routes are shown in Figure 7.13 (refer to Appendix 3 for data table).



(a)



(b)

Figure 7.13. Comparison of average actual daily routes energy values (GJ) to random routes 95% confidence limits for the Donga (a) and the Picnic (b).

Differences for the Donga troop (Figure 7.13a) were not significant (binomial test, based on z approximation, 1-tailed: *P* = 0.18). The actual routes followed by the Donga troop did not provide significantly more or less energy than any other potential routes the troop could have taken. For the Picnic troop (Figure 7.13b), differences were significant (binomial test, based on z approximation, 1-tailed: $P = 0.03$). The actual routes followed by the Picnic troop provided significantly more energy than any other routes the troop could have taken.

7.3.8 *Within troop actual and random route energy seasonal variations*

For the Donga troop there was a significant difference between available route energy for the wet and dry seasons for both the actual routes taken ($t_{20} = -3.144$, $P < 0.01$) and random routes generated from the actual routes ($t_{20} = -3.455$, $P < 0.01$).

For the Picnic troop differences between available route energy for the wet and dry seasons were not significant for both the Picnic actual routes taken ($t_8 = -1.599$, $P = 0.15$) and the random routes generated from the actual routes ($t_8 = -1.975$, $P = 0.08$).

7.3.9 *Across troop actual route energy variations*

Energy values of the actual routes taken over the entire study period for the two troops were compared and it was found that there were no significant differences between the Donga and Picnic routes ($t_{62} = 1.729$, $P = 0.09$).

7.3.10 *Across troop actual route energy seasonal variations*

Seasonal comparisons of actual routes energy values for the two troops showed that for the dry season there were no significant differences between the two troops ($t_{29} = -0.004$, $P = 0.99$), even though Picnic routes were markedly longer than those of the Donga (refer to 7.3.2 above). For the wet season there was a significant difference ($t_{31} = 2.131$, $P = 0.04$), with Donga routes yielding more energy than those from the Picnic, despite Picnic routes still being slightly longer than those of the Donga.

7.4 Discussion

Results show that habitat structure, variability between the troop's home ranges, and seasonality influences how the two troops utilize available resources that are temporally and spatially distributed.

Available resource energy for combined seasons for the two home ranges is not significantly different. When comparing available resource energy by season across the two home ranges, differences for both the wet and dry seasons are not significant. Within home range seasonal comparisons show significant differences.

Comparisons of overall average day range lengths and areas for the two troops show that both day range lengths and areas are noticeably longer and larger for the Picnic troop compared with those for the Donga troop. Longer day range lengths and larger day range areas for the Picnic troop are attributed to differences in the two troops' home ranges. The Picnic home range has fewer available resources, with the result that the troop has to travel longer distances and cover a greater area.

The Donga environment is more stable and heterogeneous than the Picnic environment (refer Table 4.7). The general physical variability within and between the two home ranges contributes to different plant species associations occurring in the respective areas (refer Tables 4.1 and 4.3). The greater numbers and diversity of plant species in the Donga home range provides for an increased diversity of food types available to the troop, compared to the Picnic troop.

The Donga home range is more dense (47% tree cover), containing larger sized trees, compared to those found in the Picnic area (31% tree cover). Flora for the Donga home range is represented by 43 families constituting 94 genera that contain 127 species, compared to the flora for the Picnic home range that is represented by 34 families constituting 72 genera and containing 94 species (refer Tables 4.5 and 4.6). Several plant resource species are common to both home ranges, but they vary substantially in life form, size and density (refer to 4.3.2 and 4.3.4 in the Phytosociology chapter).

Bush encroachment is visible in the Picnic home range plant communities, with several stands of similar size and age shrubs including *Acaia caffra, A. karroo, Dichrostachys cinerea, Lippia javanica* and *Solanum panduriiforme* occurring in areas where incorrect grazing practices were previously undertaken (refer Table 4.3). This and widespread erosion found in the Picnic home range (refer Table 4.7 and section 4.3.4 in the Phytosociology chapter) provide testimony to previous human interference, contributing towards both the instability and homogeneity of the Picnic environment.

An interesting observation for the Donga troop is that they travelled further and covered larger areas during the wet season compared to the Picnic troop. Diminishing resources during the dry season caused the Picnic troop in turn to travel further and cover larger areas to meet daily requirements. I did not anticipate this and attribute it to the presence of several large *Lannea discolor* trees occurring in the Donga home range (refer Table 4.1). These trees provided a preferred resource in the form of fruit during the wet season, resulting in the Donga troop travelling into non-preferred habitat to utilize this resource. In addition to their preference for the *Lannea discolor* fruit, and possibly contributing towards such a preference, is that the resource is also energy rich (19.9 KJ/g), compared to the average energy content (17.7 KJ/g) for all other resources consumed during the study period, and for which monthly phenological data has been collected (refer Table 6.2). No *Lannea discolor* trees were present in the Picnic troop's home range (refer Table 4.3).

The amount of available resource energy encountered in the two home ranges is positively correlated with the number of plant species. As the number of plant species increase, there are associated increases in available resource energy.

A comparison of available resource energy for actual routes taken to shortest straight-line distances between the starting and ending points of such routes, shows that for both troops, actual routes provide significantly more resource energy than the shortest straight-line routes do. In addition, for both troops, actual routes taken are significantly longer than the shortest straight-line distances between the starting and ending points for such actual routes. This indicates that the troops are actively deciding on the routes they follow, otherwise they would simply follow the shortest straight-line routes between a route's starting and ending points.

Concerning time spent in grid cells and available energy: for both troops there are negative correlations between time spent in grid cells and available energy. When the troops encounter high energy grids they spend less time in such grids because there are more available resources that can be harvested in less time, compared to grids with less energy and available resources, where more time needs to be spent finding and harvesting resources. Increased energy leads to reduced foraging effort that indicates a time minimization foraging strategy.

Within troop comparisons of available resource energy for actual routes taken to randomly generated routes show that for the Donga troop, actual routes followed do not provide significantly more or less energy than any random route they could have taken would, indicating a rich, stable environment where the troop can forage at random to fulfill daily dietary requirements. For the Picnic troop actual routes selected do provide significantly more energy than any random route could, indicating that the troop are attempting to maximize available energy in a less stable and homogenous environment with less resource variety and availability.

Interestingly, troop seasonal variations show that for the Donga troop during the wet season, actual routes taken provide significantly more energy than their dry season routes do. This is not the case for Picnic routes where seasonal differences are not significant. Initially it appears that both troops are maximizing available energy, the Picnic troop more noticeably during the dry season when fewer resources are available, and the Donga troop during the wet season when more resources are available. These results appear contradictory. However, longer wet season routes for the Donga troop are not due to energy maximization (as there is an increased variety of resources to select from), but rather due to their resource rich environment and the troop having more options available to them, where they travel slightly further to utilize preferred resources.

Comparisons of seasonal route energy across the two troops show no significant differences for the dry season, but for the wet season Donga routes yield significantly more available resource energy than Picnic routes do. The differences between the two troops can be related to habitat differences between their home ranges (refer Table 4.7), either in the distribution of available foods, or in the physical structure of their habitats (as presented in the previous chapters), suggesting that habitat structure influences the way in which vervets utilize constantly changing spatial and temporal resources available to them.

Overall, both troops' movements are influenced by monthly resource availability. The Picnic troop live in a relatively homogenous, resource restricted environment that does not offer much variety and choice with regards to route selection, placing greater pressure on them to choose routes that maximize access to energy. The Donga environment is more heterogeneous and productive with actual routes not providing more available resource energy than any alternative random route could. The Donga troop is not restricted to fixed routes by their energy requirements, therefore having the freedom to exploit more of their habitat.

According to Lee & Hauser (1998), vervet resource selection is primarily determined by availability. Vervets are regarded as generalist feeders that tend to maximise available energy. However, when there are constraints on food availability, it may become impossible for them to pursue such a strategy (Leighton, 1993). The way in which the Loskop vervets utilise energy available to them is relatively predictable, with their route selection being driven by resource availability. In terms of foraging effort, time minimizers decrease their foraging effort as food supplies increase, meeting their metabolic requirements quicker, while energy maximizers maintain a similar foraging effort independent of changing food supplies (Schoener, 1971; Pyke *et al.*, 1977; Barton *et al.*, 1992; Gaynor, 1994). From the negative correlations between time spent and available energy in grid cells (refer 7.3.6), it is suggested that both troops are minimizing foraging effort and are following time minimizing strategies.

Aforementioned results suggest a paradox concerning foraging strategies, with the effects of seasonal route length dynamics and actual vs. random route energy comparisons indicating energy maximization, while the relationship between times spent in grid cells and available energy indicating a time minimizing strategy. A more feasible explanation is that vervets are overall time minimisers that become energy maximisers in less heterogeneous environments constrained by low diversity and seasonality, especially during periods of food scarcity (Milton, 1984; Sourd & Gautier-Hion, 1986).

It must be kept in mind that primates choose foods, not energy or other nutrients in their dietary selections, and that any conclusions drawn from route or movement analyses are at the most relative concerning resource availability and factors influencing such. Environmental fluctuations are common and often unpredictable, resulting in conclusions that show current trends or momentary snapshots of events and behaviours that are likely to change with time.

Route selection, home range utilization and boundary configurations fluctuate annually based on seasonality, and resulting resource availability. The only inherent characteristic of temperate areas is that change will occur in them. The impact such changes have is dependent on the overall stability of an area: the more stable the area, the more resilient it will be.

CHAPTER 8

CONCLUSION

Energy availability is an ‘*ultimate*’ limiting factor for all primate species. Lee & Hauser (1998), have shown that a reduction in food resources (energy availability) due to habitat degradation, leads to local group extinction, high mortality rates and low reproductive rates in vervets, which can culminate in an eventual population crash, as predicted by Struhsaker (1973, 1976).

The purpose of this study was to examine whether two vervet monkey troops living in a seasonally affected environment optimize the resource energy available to them or not. How variations in habitat structure affects troop ranging patterns and the foraging strategies employed by the two troops was also considered.

A phytosociological investigation of the two troop’s home ranges revealed that there were floristic and structural habitat variations between the areas. The Donga home range was more heterogeneous and stable compared to the Picnic. Both areas had sufficient resources to maintain the troops living in them.

Dietary choices made by the two troops were examined and results showed that seasonality and variations in local habitat structure influenced choices. The Donga troop had more resource species to choose from and took advantage of these, utilizing 36 different plant species compared to 21 for the Picnic.

Having established that there were habitat and floristic variations between the two troop’s home ranges, and that these variations resulted in dietary differences between the troops, the next step was to look at the phenology of the various tree resource species available to them so that monthly energy grids could be generated for route and energy analyses. The caloric content of resource items consumed by the two troops was determined, phenology data for resource tree species was presented, and the influence of abiotic factors on phenology was discussed.

Using resource item energy values and temporal data for resource species selected by the two troops, a series of monthly energy grids was created. Actual routes followed by the two troops were used to generate random routes, and route energy for both sets of routes were extracted from underlying monthly energy grids. Route and energy analyses were undertaken and results showed that for the two troops there were seasonal variations in energy availability and route dynamics. The Picnic troop travelled longer distances and covered larger areas compared to the Donga troop. Actual and shortest route comparisons showed that both troops were actively selecting the daily routes they followed and were not randomly moving through their home ranges. Results from comparisons of time spent in areas containing higher energy than surrounding areas revealed that both troops spent less time in high energy areas. Comparisons of available resource energy for actual and random routes reflected the underlying variability between the two troop's home ranges, with the Donga troop's actual routes not providing more or less energy than any random route could, and the Picnic troop's actual routes providing significantly more energy than any random route could. Actual vs. random route energy comparisons further accentuated the underlying differences between the two home ranges in terms of habitat structure and dietary preferences.

From the aims for this study, the overall results show that variations in habitat structure for the two troops home ranges affects the way in which they utilize their respective territories in terms of time spent and available resource energy. Energy analyses show that foraging strategies employed by the two troops are optimal in terms of utilizing available resources, with the troops switching between time minimizing and energy maximization based on resource availability, precipitated by seasonality and underlying habitat variability. Having flexible foraging strategies is what allows the troops (and vervets in general) to survive in environments where fluctuations in resource availability are common.

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APPENDICES

Appendix 1: Flora list for LDNR as at June 2007 (1071 plant taxa).

The Flora list was created from hard copies of reserve archives, field observations and Theron's thesis (1973). Plant species suffixed with an asterix (*) were recorded in the Donga home range and those suffixed with a hash (#) were recorded in the Picnic home range.

Family	***Species***
ACANTHACEAE	*Barleria crossandriformis*
ACANTHACEAE	*Barleria elegans*
ACANTHACEAE	*Barleria galpinii*
ACANTHACEAE	*Barleria lancifolia*
ACANTHACEAE	*Barleria mackenii*
ACANTHACEAE	*Barleria macrostegia*
ACANTHACEAE	*Barleria obtusa*
ACANTHACEAE	*Barleria pretoriensis*
ACANTHACEAE	*Barleria rotundifolia**
ACANTHACEAE	*Barleria saxatilis*
ACANTHACEAE	*Blepharis maderaspatensis subsp. Maderaspatensis*
ACANTHACEAE	*Blepharis subvolubilis var. subvolubilis*
ACANTHACEAE	*Blepharis transvaalensis*
ACANTHACEAE	*Chaetacanthus burchellii*
ACANTHACEAE	*Chaetacanthus setiger*
ACANTHACEAE	*Crabbea angustifolia*
ACANTHACEAE	*Crabbea hirsuta*
ACANTHACEAE	*Crossandra greenstockii**
ACANTHACEAE	*Dicliptera clinopodia*

ACANTHACEAE	*Dyschoriste transvaalensis*
ACANTHACEAE	*Hypoestes aristata var. aristata*
ACANTHACEAE	*Hypoestes forskaolii*
ACANTHACEAE	*Isoglossa grantii*
ACANTHACEAE	*Justicia anagalloides*
ACANTHACEAE	*Justicia betonica#*
ACANTHACEAE	*Justicia flava*
ACANTHACEAE	*Justicia odora*
ACANTHACEAE	*Justicia protracta subsp. protracta*
ACANTHACEAE	*Lepidagathis scabra*
ACANTHACEAE	*Ruellia cordata*#*
ACANTHACEAE	*Ruellia patula*
ACANTHACEAE	*Sclerochiton triacanthus*
ACANTHACEAE	*Thunbergia atriplicifolia*#*
ACANTHACEAE	*Thunbergia natalensis*
AIZOACEAE	*Corbichonia decumbens*
AIZOACEAE	*Gisekia pharnacioides var. pharnacioides*
AIZOACEAE	*Limeum viscosum subsp. viscosum var. kraussii*
AIZOACEAE	*Mollugo nudicaulis*
AIZOACEAE	*Psammotropha mucronata var. foliosa*
ALLIACEAE	*Agapanthus nutans*
AMARANTHACEAE	*Achyranthes aspera var. aspera*
AMARANTHACEAE	*Aerva leucura*
AMARANTHACEAE	*Alternanthera pungens*
AMARANTHACEAE	*Alternanthera sessilis*
AMARANTHACEAE	*Amaranthus thunbergii*
AMARANTHACEAE	*Gomphrena celosioides*
AMARANTHACEAE	*Kyphocarpa angustifolia*

AMARANTHACEAE	*Pupalia lappacea var. lappacea*
AMARYLLIDACEAE	*Boophane disticha#*
AMARYLLIDACEAE	*Crinum bulbispermum*
AMARYLLIDACEAE	*Crinum lugardiae#*
AMARYLLIDACEAE	*Haemanthus humilis subsp. hirsutus*
AMARYLLIDACEAE	*Scadoxus puniceus*
ANACARDIACEAE	*Lannea discolor**
ANACARDIACEAE	*Lannea edulis var. edulis#*
ANACARDIACEAE	*Lannea gossweileri subsp. tomentella*
ANACARDIACEAE	*Ozoroa insignis subsp. reticulata*
ANACARDIACEAE	*Ozoroa paniculosa var. paniculosa*#*
ANACARDIACEAE	*Ozoroa paniculosa var. salicina*
ANACARDIACEAE	*Ozoroa sphaerocarpa R.& A.Fern.#*
ANACARDIACEAE	*Rhus dentata**
ANACARDIACEAE	*Rhus gerrardii*
ANACARDIACEAE	*Rhus gracillima var. gracillima*
ANACARDIACEAE	*Rhus leptodictya*#*
ANACARDIACEAE	*Rhus magalismontana subsp. magalismontana*
ANACARDIACEAE	*Rhus montana*
ANACARDIACEAE	*Rhus pyroides var. pyroides*#*
ANACARDIACEAE	*Rhus zeyheri*
ANACARDIACEAE	*Sclerocarya birrea subsp. caffra*#*
ANEMIACEAE	*Mohria caffrorum*
ANEMIACEAE	*Mohria vestita*
ANTHERICACEAE	*Chlorophytum aridum*
ANTHERICACEAE	*Chlorophytum bowkeri*
ANTHERICACEAE	*Chlorophytum cooperi*

APIACEAE	*Alepidea setifera*
APIACEAE	*Annesorhiza flagellifolia*
APIACEAE	*Centella asiatica*
APIACEAE	*Heteromorpha trifoliata*
APIACEAE	*Polemanniopsis marlothii*
APIACEAE	*Sium repandum*
APOCYNACEAE	*Acokanthera oppositifolia*
APOCYNACEAE	*Ancylobothrys capensis*
APOCYNACEAE	*Carissa bispinosa subsp. bispinosa*#*
APOCYNACEAE	*Diplorhynchus condylocarpon*#*
APOCYNACEAE	*Rauvolfia caffra*
APOCYNACEAE	*Stropanthus speciosus**
AQUIFOLIACEAE	*Ilex mitis var. mitis*
ARACEAE	*Stylochiton natalensis*
ARALIACEAE	*Cussonia paniculata subsp. paniculata*
ARALIACEAE	*Cussonia spicata*
ARALIACEAE	*Cussonia transvaalensis*
ARECACEAE	*Phoenix reclinata*
ASCLEPIADACEAE	*Asclepias aurea*
ASCLEPIADACEAE	*Asclepias brevipes*
ASCLEPIADACEAE	*Asclepias burchellii*
ASCLEPIADACEAE	*Ceropegia ampliata var. ampliata*
ASCLEPIADACEAE	*Duvalia polita var. parviflora*
ASCLEPIADACEAE	*Gomphocarpus fruticosus*

ASCLEPIADACEAE	*Gomphocarpus glaucophyllus*
ASCLEPIADACEAE	*Gomphocarpus tomentosus*
ASCLEPIADACEAE	*Gymnema sylvestre*
ASCLEPIADACEAE	*Orbeopsis melanantha*
ASCLEPIADACEAE	*Pachycarpus schinzianus*
ASCLEPIADACEAE	*Pentarrhinum insipidum*
ASCLEPIADACEAE	*Periglossum angustifolium*
ASCLEPIADACEAE	*Periglossum kassnerianurn*
ASCLEPIADACEAE	*Sarcostemma viminale subsp. Viminale*
ASCLEPIADACEAE	*Secamone alpini*
ASCLEPIADACEAE	*Secamone filiformis*
ASCLEPIADACEAE	*Stapelia gigantea*
ASCLEPIADACEAE	*Tenaris chlorantha*
ASCLEPIADACEAE	*Tenaris rubella*
ASPARAGACEAE	*Asparagus africanus*#*
ASPARAGACEAE	*Asparagus angusticladus*
ASPARAGACEAE	*Asparagus buchananii*
ASPARAGACEAE	*Asparagus cooperi*
ASPARAGACEAE	*Asparagus densiflorus*#*
ASPARAGACEAE	*Asparagus suaveolens**
ASPARAGACEAE	*Asparagus transvaalensis*#*
ASPARAGACEAE	*Asparagus virgatus#*
ASPHODELACEAE	*Aloe arborescens*
ASPHODELACEAE	*Aloe castanea*
ASPHODELACEAE	*Aloe greatheadii var. davyana*
ASPHODELACEAE	*Aloe marlothii subsp. marlothii*
ASPHODELACEAE	*Aloe zebrina*
ASPHODELACEAE	*Anthericum cooperi*
ASPHODELACEAE	*Anthericum longistylum*

ASPHODELACEAE	*Bulbine angustifolia*
ASPHODELACEAE	*Bulbine capitata*
ASPHODELACEAE	*Haworthia koelmaniorum*
ASPHODELACEAE	*Haworthia macmurtryi*
ASPHODELACEAE	*Kniphofia ensifolia subsp. ehsifolia*
ASPHODELACEAE	*Trachyandra saltii var. sallii*
ASPLENIACEAE	*Aspleniurn aethiopicum*
ASPLENIACEAE	*Ceterach cordatum*
ASTERACEAE	*Achyrocline stenoptera*
ASTERACEAE	*Adenostemma caffrum*
ASTERACEAE	*Ambrosia artemisiifolia*
ASTERACEAE	*Arternisia afra*
ASTERACEAE	*Aster bakerianus*
ASTERACEAE	*Athrixia elata*
ASTERACEAE	*Berkheya densifolia*
ASTERACEAE	*Berkheya insignis*
ASTERACEAE	*Berkheya radula*
ASTERACEAE	*Bidens formosa*
ASTERACEAE	*Bidens pilosa*
ASTERACEAE	*Blumea mollis*
ASTERACEAE	*Brachylaena rotundata*
ASTERACEAE	*Callilepis laureola*
ASTERACEAE	*Callilepis leptophylla*
ASTERACEAE	*Cineraria britteniae*
ASTERACEAE	*Cineraria canescens*
ASTERACEAE	*Cineraria parvifolia*
ASTERACEAE	*Conyza albida*
ASTERACEAE	*Conyza attenuata*
ASTERACEAE	*Conyza bonariensis*

ASTERACEAE	Conyza pinnata
ASTERACEAE	Conyza podocephala
ASTERACEAE	Conyza scabrida
ASTERACEAE	Conyza ulmifolia
ASTERACEAE	Cotula anthemoides
ASTERACEAE	Denekia capensis
ASTERACEAE	Dicoma anomala
ASTERACEAE	Dicoma galpinii
ASTERACEAE	Dicoma zeyheri subsp. zeyheri
ASTERACEAE	Eclipla prostrata
ASTERACEAE	Emilia transvaalensis
ASTERACEAE	Ethulia conyzoides subsp. conyzoides
ASTERACEAE	Euryops pedunculatus
ASTERACEAE	Felicia fascicularis
ASTERACEAE	Felicia mossamedensis*#
ASTERACEAE	Felicia muricata subsp. muricata#
ASTERACEAE	Gazania krebsiana subsp. serrulata
ASTERACEAE	Geigeria brachycephala
ASTERACEAE	Gerbera ambigua
ASTERACEAE	Gerbera jamesonii*#
ASTERACEAE	Gerbera viridifolia subsp. viridifolia
ASTERACEAE	Gnaphaliurn confine
ASTERACEAE	Helichrysum argyrosphaerum
ASTERACEAE	Helichrysum athrixiifolium
ASTERACEAE	Helichrysum cephaloideurn
ASTERACEAE	Helichrysum coriaceurn
ASTERACEAE	Helichrysum difficile
ASTERACEAE	Helichrysum harveyanum
ASTERACEAE	Helichrysum nudifolium
ASTERACEAE	Helichrysum oxyphyllurn
ASTERACEAE	Helichrysum pallidum

ASTERACEAE	*Helichrysum setosum*
ASTERACEAE	*Helichrysum rugulosum*#*
ASTERACEAE	*Kleinia stapeliiformis*
ASTERACEAE	*Lactuca inermis*
ASTERACEAE	*Laggera crispata*
ASTERACEAE	*Lopholaena coriifolia*
ASTERACEAE	*Nidorella anomala*
ASTERACEAE	*Nidorella hottentotica*
ASTERACEAE	*Nidorella resedifolia subsp. resedifoiia*
ASTERACEAE	*Nolletia rarifolia*
ASTERACEAE	*Pegolettia senegalensis*
ASTERACEAE	*Pseudognaphalium oligandrum*
ASTERACEAE	*Pseudognaphalium undulatum*
ASTERACEAE	*Pulicaria scabra*
ASTERACEAE	*Schistostephium crataegifolium*
ASTERACEAE	*Schkuhria pinnata*
ASTERACEAE	*Senecio barbertonicus*
ASTERACEAE	*Senecio burchellii*
ASTERACEAE	*Senecio erubescens var. erubescens*
ASTERACEAE	*Senecio inaequidens*
ASTERACEAE	*Senecio inornatus*
ASTERACEAE	*Senecio isatidioides*
ASTERACEAE	*Senecio microglossus*
ASTERACEAE	*Senecio oxyriifolius*
ASTERACEAE	*Senecio venosus*
ASTERACEAE	*Senecio vimineus*
ASTERACEAE	*Sonchus dregeanus*
ASTERACEAE	*Sonchus oleraceus*
ASTERACEAE	*Stoebe vulgaris**
ASTERACEAE	*Tarchonanthus camphoratus*
ASTERACEAE	*Vernonia fastigiata*

ASTERACEAE	*Vernonia natalensis*
ASTERACEAE	*Vernonia oligocephala*
ASTERACEAE	*Vernonia poskeana subsp. botswanica*
ASTERACEAE	*Vernonia staehelinoides*
ASTERACEAE	*Vernonia steetziana*
ASTERACEAE	*Xanthium strumarium*
ASTERACEAE	*Zinnia peruviana*
BIGNONIACEAE	*Jacaranda mimosifolia*
BLECHNACEAE	*BIechnum punctulatum var. punctulaturn*
BORAGINACEAE	*Cynoglossum lanceolatum*
BORAGINACEAE	*Ehretia obtusifolia*
BORAGINACEAE	*Ehretia rigida**
BORAGINACEAE	*Myosotis sylvatica*
BORAGINACEAE	*Trichodesma physaloides*
BRASSICACEAE	*Lepidium bonariense*
BRASSICACEAE	*Rorippa fluviatilis var. fluviatilis*
BUDDLEJACEAE	*Buddleja salviifolia*
BUDDLEJACEAE	*Gomphostigrna virgatum*
BUDDLEJACEAE	*Nuxia congesta*
BUDDLEJACEAE	*Nuxia oppositifolia*
BURSERACEAE	*Commiphora africana var. africana*
BURSERACEAE	*Commiphora angolensis*
BURSERACEAE	*Commiphora glandulosa*
BURSERACEAE	*Commiphora marlothii*
BURSERACEAE	*Commiphora neglecta*

BURSERACEAE	*Commiphora pyracanthoides*
BURSERACEAE	*Commiphora schimperi**
BUXACEAE	*Buxus macowanii*
CABOMBACEAE	*Brasenia schreberi*
CACTACEAE	*Cereus jamacaru*
CACTACEAE	*Opuntia ficus-indica*#*
CAMPANULACEAE	*Wahlenbergia undulata*
CAPPARACEAE	*Boscia albitrunca var. albitrunca*
CAPPARACEAE	*Capparis tomentosa*
CAPPARACEAE	*Cleome hirta*
CAPPARACEAE	*Cleome maculata*
CAPPARACEAE	*Cleome monophylla*
CAPPARACEAE	*Cleome rubella*
CAPPARACEAE	*Maerua angolensis*
CAPPARACEAE	*Maerua cafra*
CAPPARACEAE	*Maerua rosmarinoides*
CARYOPHYLLACEAE	*Dianthus mooiensis subsp. kirkii*
CARYOPHYLLACEAE	*Dianthus zeyheri subsp. zeyheri*
CARYOPHYLLACEAE	*Polycarpaea corymbosa var. corymbosa*
CELASTRACEAE	*Cassine aethiopica*
CELASTRACEAE	*Cassine burkeana*
CELASTRACEAE	*Cassine transvaalensis*
CELASTRACEAE	*Gymnosporia albata**
CELASTRACEAE	*Gymnosporia buxifolia*#*

CELASTRACEAE	*Gymnosporia deflexa*
CELASTRACEAE	*Gymnosporia polyacantha*
CELASTRACEAE	*Gymnosporia tenuispina*
CELASTRACEAE	*Mystroxylon aethiopicum**
CELASTRACEAE	*Pleurostylia capensis*
CELASTRACEAE	*Pterocelastrus echinatus*
CHENOPODIACEAE	*Chenopodium ambrosioides*
CHRYSOBALANACEAE	*Parinari capensis subsp. capensis*
COLCHICACEAE	*Gloriosa superba*
COMBRETACEAE	*Combretum apiculatum subsp. apiculalum*#*
COMBRETACEAE	*Combretum erythrophyllum*#*
COMBRETACEAE	*Combretum hereroense subsp. hereroense var. hereroense**
COMBRETACEAE	*Combretum kraussii*
COMBRETACEAE	*Combretum rnoggii*
COMBRETACEAE	*Combretum molle*#*
COMBRETACEAE	*Combretum zeyheri*#*
COMBRETACEAE	*Terminalia brachystemma*#*
COMBRETACEAE	*Terminalia sericea*#*
COMMELINACEAE	*Aneilema hockii*
COMMELINACEAE	*Commelina africana var. lancispalha#*
COMMELINACEAE	*Commelina erecta*#*
COMMELINACEAE	*Cyanotis lapidosa*
COMMELINACEAE	*Floscopa glomerata*
CONVOLVULACEAE	*Convolvulus farinosus*

CONVOLVULACEAE	*Convolvulus thunbergii*
CONVOLVULACEAE	*Evolvulus alsinoides var. linifolius*
CONVOLVULACEAE	*Ipomoea albivenia*
CONVOLVULACEAE	*Ipomoea bolusiana*
CONVOLVULACEAE	*Ipomoea crassipes*
CONVOLVULACEAE	*Ipomoea gracilisepala*
CONVOLVULACEAE	*Ipomoea hochstetteri*
CONVOLVULACEAE	*Ipomoea magnusiana*
CONVOLVULACEAE	*Ipomoea obscura var. fragilis*
CONVOLVULACEAE	*Ipomoea ommaneyi*
CONVOLVULACEAE	*Ipomoea papilio*
CONVOLVULACEAE	*Ipomoea purpurea*
CONVOLVULACEAE	*Ipomoea sinensis subsp. blepharosepala*
CONVOLVULACEAE	*Ipomoea transvaalensis*
CONVOLVULACEAE	*Merremia kentrocaulos*
CONVOLVULACEAE	*Merremia tridentata subsp. angustifolia var. angustifolia*
CONVOLVULACEAE	*Seddera capensis*
CONVOLVULACEAE	*Seddera suffruticosa*
CONVOLVULACEAE	*Turbina oblongata*
CRASSULACEAE	*Andromischus umbraticola subsp. umbraticola*
CRASSULACEAE	*Cotyledon barbeyi*
CRASSULACEAE	*Crassula alba var. alba*
CRASSULACEAE	*Crassula capitella subsp. nodulosa*
CRASSULACEAE	*Crassula setulosa var. selulosa*
CRASSULACEAE	*Crassula swaziensis subsp. swaziensis var. swaziensis*
CRASSULACEAE	*Kalanchoe brachyloba**
CRASSULACEAE	*Kalanchoe paniculala*
CRASSULACEAE	*Kalanchoe rotundifolia*

CUCURBITACEAE	*Citrullus lanatus*
CUCURBITACEAE	*Coccinia adoensis#*
CUCURBITACEAE	*Corallocarpus bainesii*
CUCURBITACEAE	*Cucumella bryoniifolia*
CUCURBITACEAE	*Cucumella cinerea*
CUCURBITACEAE	*Cucumis anguria*
CUCURBITACEAE	*Cucumis hirsutus*
CUCURBITACEAE	*Cucumis zeyheri*
CUCURBITACEAE	*Momordica boivinii*
CUCURBITACEAE	*Zehneria scabra subsp. scabra*

CYATHEACEAE	*Cyathea dregei*

CYPERACEAE	*Bulbostylis burchellii*
CYPERACEAE	*Bulbostylis hispidula*
CYPERACEAE	*Bulbostylis humilis*
CYPERACEAE	*Bulbostylis oritrephes*
CYPERACEAE	*Carex cognata var. drakensbergensis*
CYPERACEAE	*Carex spicato-paniculata*
CYPERACEAE	*Coleochloa setifera*
CYPERACEAE	*Cyperus albostriatus*
CYPERACEAE	*Cyperus denudatus*
CYPERACEAE	*Cyperus distans*
CYPERACEAE	*Cyperus esculentus var. esculentus*
CYPERACEAE	*Cyperus lalifolius*
CYPERACEAE	*Cyperus leptocladus*
CYPERACEAE	*Cyperus margaritaceus*
CYPERACEAE	*Cyperus marginatus*
CYPERACEAE	*Cyperus obtusiflorus var. flavissimus*#*
CYPERACEAE	*Cyperus rupestris var. rupeslris*

CYPERACEAE	*Cyperus sexangularis*
CYPERACEAE	*Cyperus sphaerospermus*
CYPERACEAE	*Fimbristylis dichotoma*
CYPERACEAE	*Fimbristylis squarrosa*
CYPERACEAE	*Fuirena leptostachya*
CYPERACEAE	*Fuirena pubescens*
CYPERACEAE	*Fuirena stricta var. stricta*
CYPERACEAE	*Isolepis costata var. costata*
CYPERACEAE	*Isolepis fluitans*
CYPERACEAE	*Kyllinga alba*
CYPERACEAE	*Kyllinga erecta var. erecta*
CYPERACEAE	*Kyllinga melanosperma*
CYPERACEAE	*Lipocarpha chinensis*
CYPERACEAE	*Lipocarpha nana*
CYPERACEAE	*Mariscus albomarginatus*
CYPERACEAE	*Mariscus dregeanus*
CYPERACEAE	*Mariscus indecorus var. indecorus*
CYPERACEAE	*Mariscus rehmannianus*
CYPERACEAE	*Pycreus flavescens*
CYPERACEAE	*Pycreus macranthus*
CYPERACEAE	*Pycreus polystachyos var. polystachyos*
CYPERACEAE	*Pycreus pumilus*
CYPERACEAE	*Pycreus rehmannianus*
CYPERACEAE	*Rhynchospora brownii*
CYPERACEAE	*Schoenoplectus brachyceras*
CYPERACEAE	*Schoenoplectus muricinux*
CYPERACEAE	*Schoenoxiphium lehmannii*
DENNSTAEDTIACEAE	*Pteridium aquilinum*
DICHAPETALACEAE	*Dichapetalum cymosum*

DICRANACEAE	*Campylopus robillardei*
DIOSCOREACEAE	*Dioscorea dregeana*
DIOSCOREACEAE	*Dioscorea sylvatica var. brevipes*
DIPSACACEAE	*Scabiosa columbaria*
DRACAENACEAE	*Sansevieria aethiopica*
EBENACEAE	*Dioscorea sylvatica**
EBENACEAE	*Diospyros lycioides subsp. guerkei#*
EBENACEAE	*Diospyros lycioides subsp. sericea*
EBENACEAE	*Diospyros whyteana**
EBENACEAE	*Euclea crispa subsp. crispa*#*
EBENACEAE	*Euclea linearis*
EBENACEAE	*Euclea nalalensis subsp. natalensis*
EBENACEAE	*Euclea undulata var. myrtina*#*
ELATINACEAE	*Elatine triandra*
EQUISETACEAE	*Equisetum ramosissimum*
ERICACEAE	*Erica drakensbergensis*
ERIOCAULACEAE	*Eriocaulon abyssinicum*
ERIOCAULACEAE	*Eriocaulon maculaturn*
ERIOSPERMACEAE	*Eriospermum cooperi var. cooperi*
ERYTHROXYLACEAE	*Erythroxylum pictum#*

EUPHORBIACEAE	*Acalypha angustata*
EUPHORBIACEAE	*Acalypha indica var. indica*
EUPHORBIACEAE	*Acalypha segetalis*
EUPHORBIACEAE	*Acalypha villicaulis*
EUPHORBIACEAE	*Bridelia mollis**#
EUPHORBIACEAE	*Chamaesyce neopolycnemoides*
EUPHORBIACEAE	*Clutia pulchella var. pulchella*
EUPHORBIACEAE	*Croton gratissimus var. gratissimus*
EUPHORBIACEAE	*Croton gratissimus var. subgratissimus*
EUPHORBIACEAE	*Dalechampia capensis*
EUPHORBIACEAE	*Euphorbia cooperi var. cooperi**
EUPHORBIACEAE	*Euphorbia heterophylla*
EUPHORBIACEAE	*Euphorbia ingens**
EUPHORBIACEAE	*Euphorbia pseudotuberosa*
EUPHORBIACEAE	*Euphorbia schinzii*
EUPHORBIACEAE	*Euphorbia tirucalli*
EUPHORBIACEAE	*Euphorbia trichadenia var. trichadenia*
EUPHORBIACEAE	*Flueggea virosa subsp. virosa**#
EUPHORBIACEAE	*Jatropha capensis*
EUPHORBIACEAE	*Jatropha lagarinthoides*
EUPHORBIACEAE	*Jatropha latifolia var. latifoiia*
EUPHORBIACEAE	*Jatropha natalensis*
EUPHORBIACEAE	*Phyllanthus glaucophyllus*
EUPHORBIACEAE	*Phyllanthus maderaspatensis*
EUPHORBIACEAE	*Phyllanthus parvulus var. parvulus*
EUPHORBIACEAE	*Phyllanthus reticulatus*
EUPHORBIACEAE	*Pseudolachnostylis maprouneifolia var. maprouneifolia*
EUPHORBIACEAE	*Spirostachys africana**#
EUPHORBIACEAE	*Suregada africana*

EUPHORBIACEAE	*Synadenium cupulare*
EUPHORBIACEAE	*Tragia rupestris*
EXORMOTHECACEAE	*Exormotheca pustulosa*
FABACEAE	*Abrus laevigatus*
FABACEAE	*Acacia ataxacantha**
FABACEAE	*Acacia burkei**
FABACEAE	*Acacia caffra*#*
FABACEAE	*Acacia dealbata**
FABACEAE	*Acacia decurrens*
FABACEAE	*Acacia gerrardii subsp. gerrardii var. gerrardii*
FABACEAE	*Acacia goetzei subsp. microphylla*
FABACEAE	*Acacia karroo*#*
FABACEAE	*Acacia mearnsii*
FABACEAE	*Acacia nigrescens*
FABACEAE	*Acacia nilotica subsp. kraussiana*#*
FABACEAE	*Acacia robusta subsp. robusta*#*
FABACEAE	*Acacia sieberiana var. woodii*
FABACEAE	*Acacia tortilis subsp. heteracantha**
FABACEAE	*Argyrolobium megarrhizum*
FABACEAE	*Argyrolobium nigrescens*
FABACEAE	*Argyrolobium speciosum*
FABACEAE	*Argyrolobium transvaalense*
FABACEAE	*Bauhinia galpinii*
FABACEAE	*Bolusanthus speciosus*
FABACEAE	*Burkea africana*
FABACEAE	*Canavalia virosa*
FABACEAE	*Chamaecrista absus*
FABACEAE	*Chamaecrista biensis*
FABACEAE	*Chamaecrista mimosoides*

FABACEAE	*Crotalaria globifera*
FABACEAE	*Crotalaria podocarpa*
FABACEAE	*Crotalaria sphaerocarpa subsp. sphaerocarpa*
FABACEAE	*Decorsea galpinii*
FABACEAE	*Dichilus strictus*
FABACEAE	*Dichrostachys cinerea subsp. africana var. africana*#*
FABACEAE	*Dichrostachys cinerea subsp. nyassana*
FABACEAE	*Dolichos trilobus subsp. transvaalicus*
FABACEAE	*Elephantorrhiza burkei*
FABACEAE	*Elephantorrhiza elephantina*
FABACEAE	*Eriosema cordatum*
FABACEAE	*Eriosema psoraleoides*
FABACEAE	*Erythrina lysistemon*
FABACEAE	*Indigastrum burkeanum*
FABACEAE	*Indigofera arrecta*
FABACEAE	*Indigofera alternans*
FABACEAE	*Indigofera daleoides var. daleoides**
FABACEAE	*Indigofera filipes*
FABACEAE	*Indigofera heterotricha*
FABACEAE	*Indigofera hilaris var. hilaris*
FABACEAE	*Indigofera ingrata*
FABACEAE	*Indigofera lydenburgensis*
FABACEAE	*Indigofera melanadenia*
FABACEAE	*Indigofera nebrowniana*
FABACEAE	*Indigofera oxytropis*
FABACEAE	*Indigofera setiflora*
FABACEAE	*Indigofera sordida*
FABACEAE	*Indigofera spicata var. spicata*
FABACEAE	*Indigofera tristoides*
FABACEAE	*Lotononis calycina*

FABACEAE	*Lotononis eriantha*
FABACEAE	*Lotononis listii*
FABACEAE	*Mundulea sericea**
FABACEAE	*Neonotonia wightii*
FABACEAE	*Neorautanenia ficifolius*
FABACEAE	*Ophrestia oblongifolia var. oblongifolia*
FABACEAE	*Otholobium polyphyllum*
FABACEAE	*Pearsonia cajanifolia subsp. cryptantha*
FABACEAE	*Pearsonia sessilifolia subsp. marginata*
FABACEAE	*Pearsonia sessilifolia subsp. sessilifolia*
FABACEAE	*Pearsonia uniflora*
FABACEAE	*Peltophorum africanum**
FABACEAE	*Psoralea pinnata*
FABACEAE	*Pterocarpus rotundifolius subsp. rotundifolius#*
FABACEAE	*Rhynchosia albissima*
FABACEAE	*Rhynchosia caribaea*
FABACEAE	*Rhynchosia confusa*
FABACEAE	*Rhynchosia komatiensis*
FABACEAE	*Rhynchosia minima var. minima*
FABACEAE	*Rhynchosia monophylla*
FABACEAE	*Rhynchosia nervosa var. nervosa*
FABACEAE	*Rhynchosia nitens*
FABACEAE	*Rhynchosia reptabunda*
FABACEAE	*Rhynchosia sordida*
FABACEAE	*Rhynchosia spectabilis*
FABACEAE	*Rhynchosia totta var. totta*
FABACEAE	*Senna bicapsularis#*
FABACEAE	*Senna italica subsp. arachoides*
FABACEAE	*Sesbania punicea*
FABACEAE	*Sesbania sesban subsp. sesban var. nubica*
FABACEAE	*Sphenostylis angustifolia*

FABACEAE	*Stylosanthes fruticosa*
FABACEAE	*Tephrosia burchellii*
FABACEAE	*Tephrosia elongata var. elongata*
FABACEAE	*Tephrosia longipes subsp. longipes var. longipes*
FABACEAE	*Tephrosia lupinifolia*
FABACEAE	*Tephrosia macropoda var. macropoda*
FABACEAE	*Tephrosia multijuga*
FABACEAE	*Tephrosia polystachya var. latifolia*
FABACEAE	*Tephrosia rhodesica var. evansii*
FABACEAE	*Tephrosia semiglabra*
FABACEAE	*Vigna frutescens*
FABACEAE	*Zornia linearis*
FISSIDENTACEAE	*Fissidens rufescens*
FLACOURTIACEAE	*Dovyalis zeyheri**
FLACOURTIACEAE	*Flacourtia indica**
FLACOURTIACEAE	*Scolopia zeyheri**
GENTIANACEAE	*Chironia purpurascens subsp. humilis*
GENTIANACEAE	*Sebaea exigua*
GENTIANACEAE	*Sebaea grandis*
GENTIANACEAE	*Sebaea leiostyla*
GERANIACEAE	*Monsonia angustifolia*
GERANIACEAE	*Monsonia burkeana*
GERANIACEAE	*Pelargonium alchemilloides*
GERANIACEAE	*Pelargonium luridum*
GERANIACEAE	*Pelargonium multicaule subsp. multicaule*

GESNERIACEAE	*Streptocarpus polyanthus subsp. comptonii*
GESNERIACEAE	*Streptocarpus vandeleurii*
GLEICHENIACEAE	*Gleichenia polypodioides*
HETEROPYXIDACEAE	*Heteropyxis natalensis**
HIPPOCRATEACEAE	*Salacia rehmannii*
HYACINTHACEAE	*Albuca angolensis*
HYACINTHACEAE	*Albuca glauca*
HYACINTHACEAE	*Bowiea volubilis*
HYACINTHACEAE	*Dipcadi marlothii*
HYACINTHACEAE	*Dipcadi rigidifolium*
HYACINTHACEAE	*Dipcadi viride*
HYACINTHACEAE	*Drimia ciliaris*
HYACINTHACEAE	*Drimiopsis atropurpurea*
HYACINTHACEAE	*Drimiopsis burkei*
HYACINTHACEAE	*Eucomis autumnalis subsp. autumnalis*
HYACINTHACEAE	*Ledebouria cooperi*#*
HYACINTHACEAE	*Ledebouria inquinata*
HYACINTHACEAE	*Scilla nervosa*
HYACINTHACEAE	*Urginea epigea*
HYACINTHACEAE	*Urginea modesta*
HYPERICACEAE	*Hypericum lalandii*
HYPERICACEAE	*Hypericum wilmsii*
HYPOXIDACEAE	*Hypoxis angustifolia var. angustifolia*
HYPOXIDACEAE	*Hypoxis hemerocallidea*
HYPOXIDACEAE	*Hypoxis iridifolia*

HYPOXIDACEAE	*Hypoxis rigidula var. rigidula*
ICACINACEAE	*Apodytes dimidiata subsp. dimidiata*
ICACINACEAE	*Cassinopsis ilicifolia*
ILLECEBRACEAE	*Corrigiola litoralis subsp. litoralis var. litoralis*
ILLECEBRACEAE	*Paronychia brasiliana var. pubescens*
ILLECEBRACEAE	*Pollichia campestris*
IRIDACEAE	*Babiana hypogea var. hypogea*
IRIDACEAE	*Freesia grandiflora*
IRIDACEAE	*Freesia laxa subsp. laxa*
IRIDACEAE	*Gladiolus crassifolius*
IRIDACEAE	*Gladiolus elliotii*
IRIDACEAE	*Gladiolus permeabilis subsp. edulis*#*
IRIDACEAE	*Gladiolus pole-evansii*
IRIDACEAE	*Gladiolus sericeovillosus subsp. calvatus*
IRIDACEAE	*Gladiolus woodii*#*
IRIDACEAE	*Moraea stricta*
IRIDACEAE	*Tritonia nelsonii*
JUNCACEAE	*Juncus dregeanus*
JUNCACEAE	*Juncus exsertus subsp. exsertus*
JUNCACEAE	*Juncus oxycarpus*
LAMIACEAE	*Acrotome hispida*
LAMIACEAE	*Aeollanthus buchnerianus*
LAMIACEAE	*Aeollanthus rehmannii*
LAMIACEAE	*Becium obovatum subsp. obovatum var. obovatum**
LAMIACEAE	*Hemizygia canescens*

LAMIACEAE	*Hemizygia petrensis*
LAMIACEAE	*Hemizygia pretoriae subsp. pretoriae*
LAMIACEAE	*Hemizygia transvaalensis*
LAMIACEAE	*Leonotis ocymifolia var. ocymifolia*
LAMIACEAE	*Leucas neuflizeana*
LAMIACEAE	*Ocimum gratissimum subsp. gratissimum var. gratissimum*
LAMIACEAE	*Orthosiphon fruticosus*
LAMIACEAE	*Orthosiphon suffrutescens*
LAMIACEAE	*Plectranthus dinteri*
LAMIACEAE	*Plectranthus fruticosus*
LAMIACEAE	*Plectranthus hadiensis var. tomentosus*
LAMIACEAE	*Plectranthus mutabilis*
LAMIACEAE	*Pycnostachys reticulata*
LAMIACEAE	*Scutellaria racemosa*
LAMIACEAE	*Stachys natalensis var. galpinii*
LAMIACEAE	*Tetradenia riparia*
LAMIACEAE	*Teucrium trifidum*
LENTIBULARIACEAE	*Utricularia arenaria*
LENTIBULARIACEAE	*Utricularia gibba*
LINACEAE	*Linum thunbergii*
LOBELIACEAE	*Cyphia assimilis var. assimilis*
LOBELIACEAE	*Cyphia elata var. elata*
LOBELIACEAE	*Lobelia erinus*
LOBELIACEAE	*Lobelia flaccida subsp. mossiana*
LOBELIACEAE	*Monopsis decipiens*
LORANTHACEAE	*Erianthemum ngamicum*

LORANTHACEAE	*Tapinanthus kraussianus subsp. kraussianus#*
LORANTHACEAE	*Tapinanthus leendertziae*
LORANTHACEAE	*Tapinanthus natalitius subsp. zeyheri*
LORANTHACEAE	*Tapinanthus oleifolius*
LORANTHACEAE	*Tapinanlhus rubromarginatus*
LYCOPODIACEAE	*Lycopodium cernium*
LYTHRACEAE	*Nesaea cordata*
MALPIGHIACEAE	*Sphedamnocarpus pruriens subsp. galphimiifolius*
MALPIGHIACEAE	*Sphedamnocarpus transvalicus*
MALPIGHIACEAE	*Triaspis hypericoides subsp. nelsonii*
MALVACEAE	*Anisodontea scabrosa*
MALVACEAE	*Cienfuegosia gerrardii*
MALVACEAE	*Hibiscus calyphyllus*
MALVACEAE	*Hibiscus cannabinus var. cannabinus*
MALVACEAE	*Hibiscus engleri*
MALVACEAE	*Hibiscus meyeri subsp. transvaalensis*
MALVACEAE	*Hibiscus micranthus var. micranthus*
MALVACEAE	*Hibiscus microcarpus*
MALVACEAE	*Hibiscus pusillus*
MALVACEAE	*Hibiscus vitifolius subsp. vitifolius*
MALVACEAE	*Hibiscus vitifolius subsp. vulgaris*
MALVACEAE	*Pavonia burchellii*
MALVACEAE	*Pavonia columella*
MALVACEAE	*Pavonia transvaalensis*
MALVACEAE	*Sida alba*
MALVACEAE	*Sida cordifolia**

MELIACEAE	*Melia azedarach*
MELIACEAE	*Turraea obtusifolia*
MENISPERMACEAE	*Cissampelos torulosa*
MENYANTHACEAE	*Nymphoides indica subsp. occidentalis*
MESEMBRYANTHEMACEAE	*Aptenia cordifolia var. cordifolia*
MESEMBRYANTHEMACEAE	*Delosperma gracile*
MESEMBRYANTHEMACEAE	*Delosperma herbeum*
MORACEAE	*Ficus abutilifolia*
MORACEAE	*Ficus cordata subsp. salicifolia*
MORACEAE	*Ficus craterostoma**
MORACEAE	*Ficus glumosa*
MORACEAE	*Ficus ingens var. ingens*
MORACEAE	*Ficus natalensis*
MORACEAE	*Ficus sur**
MORACEAE	*Ficus thonningii*
MYRICACEAE	*Myrica serrata*
MYROTHAMNACEAE	*Myrothamnus flabellifolius*
MYRSINACEAE	*Myrsine africana*
MYRSINACEAE	*Myrsine pillansii*
MYRTACEAE	*Psidiurn guajava*
NYMPHAEACEAE	*Nymphaea lotus*

NYMPHAEACEAE	_Nymphaea nouchali var. caerulea_
OCHNACEAE	_Ochna arborea var. oconnorii_
OCHNACEAE	_Ochna holstii_
OCHNACEAE	_Ochna inermis_
OCHNACEAE	_Ochna natalitia_
OCHNACEAE	_Ochna pretoriensis_
OCHNACEAE	_Ochna pulchra_
OCHNACEAE	_Ochna serrulata_
OLACACEAE	_Ximenia americana var. americana_
OLACACEAE	_Ximenia caffra var. caffra*#_
OLACACEAE	_Ximenia caffra var. natalensis_
OLEACEAE	_Chionanthus foveolatus subsp. foveolatus_
OLEACEAE	_Chionanthus foveolatus subsp. major_
OLEACEAE	_Jasminum breviflorum*_
OLEACEAE	_Jasminum quinatum_
OLEACEAE	_Jasminum stenolobum_
OLEACEAE	_Menodora africana_
OLEACEAE	_Olea capensis subsp. enervis_
OLEACEAE	_Olea europaea subsp. africana*_
OLINIACEAE	_Olinia emarginata_
ONAGRACEAE	_Ludwigia adscendens subsp. diffusa_
ONAGRACEAE	_Ludwigia octovalvis_
ONAGRACEAE	_Ludwigia palustris_
ONAGRACEAE	_Oenothera jamesii_
ONAGRACEAE	_Oenothera rosea_

ORCHIDACEAE	*Eulophia angolensis*
ORCHIDACEAE	*Eulophia ovalis subsp. ovalis**
ORCHIDACEAE	*Eulophia speciosa*
ORCHIDACEAE	*Eulophia streptopetala*
ORCHIDACEAE	*Eulophia welwitschii*
OSMUNDACEA	*Osmunda regalis*
OXALIDACEAE	*Oxalis corniculata*
OXALIDACEAE	*Oxalis depressa*
OXALIDACEAE	*Oxalis obliquifolia*
PAPILIONOIDEAE	*Robinia pseudoacacia**
PASSIFLORACEAE	*Adenia digitata*
PEDALIACEAE	*Ceratotheca triloba*
PEDALIACEAE	*Dicerocaryum eriocarpum*
PEDALIACEAE	*Dicerocaryum senecioides subsp. senecioides*
PEDALIACEAE	*Pterodiscus speciosus*
PEDALIACEAE	*Sesamum alatum*
PEDALIACEAE	*Sesamum triphyllum var. triphyllum*
PERIPLOCACEAE	*Cryptolepis cryptolepioides*
PERIPLOCACEAE	*Cryptolepis oblongifolia*
PERIPLOCACEAE	*Cryptolepis transvaalensis*
PERIPLOCACEAE	*Raphionacme galpinii*
PERIPLOCACEAE	*Stomatostemma monteiroae*
PHYTOLACCACEAE	*Lophiocarpus polystachyus*
PHYTOLACCACEAE	*Lophiocarpus tenuissimus*

PIPERACEAE	*Peperomia retusa var. bachmannii*
PITTOSPORACEAE	*Pittosporum viridiflorum*
PLUMBAGINACEAE	*Plumbago zeylanica*
POACEAE	*Agrostis lachnantha var. lachnantha*
POACEAE	*Alloteropsis semialata subsp. semialata*
POACEAE	*Andropogon chinensis*
POACEAE	*Andropogon eucomus*
POACEAE	*Andropogon huillensis*
POACEAE	*Andropogon schirensis*
POACEAE	*Anthephora pubescens*
POACEAE	*Aristida adscensionis*
POACEAE	*Aristida canescens subsp. canescens*
POACEAE	*Aristida congesta subsp. barbicollis*
POACEAE	*Aristida congesta subsp. congesta**
POACEAE	*Aristida diffusa subsp. burkei*
POACEAE	*Aristida junciformis subsp. junciformis*
POACEAE	*Aristida meridionalis*
POACEAE	*Aristida pilgeri*
POACEAE	*Aristida scabrivalvis subsp. scabrivalvis*
POACEAE	*Aristida stipitata subsp. graciliflora*#*
POACEAE	*Aristida transvaalensis*
POACEAE	*Bambusa balcooa*
POACEAE	*Bewsia biflora*
POACEAE	*Bothriochloa bladhii*
POACEAE	*Bothriochloa insculpta#*
POACEAE	*Bothriochloa radicans*
POACEAE	*Brachiaria brizantha*#*

POACEAE	*Brachiaria deflexa*
POACEAE	*Brachiaria nigropedata*
POACEAE	*Cenchrus ciliaris*#*
POACEAE	*Chloris virgata*
POACEAE	*Cymbopogon excavatus*
POACEAE	*Cymbopogon plurinodis*#*
POACEAE	*Cymbopogon validus*
POACEAE	*Cynodon dactylon*
POACEAE	*Dactyloctenium australe*
POACEAE	*Diandrochloa namaquensis*
POACEAE	*Digitaria argyrograpta*
POACEAE	*Digitaria brazzae*
POACEAE	*Digitaria debilis*
POACEAE	*Digitaria diagonalis var. diagonalis*
POACEAE	*Digitaria eriantha*#*
POACEAE	*Digitaria eylesii*
POACEAE	*Digitaria longiflora*
POACEAE	*Digitaria milanjiana*
POACEAE	*Digitaria monodactyla*
POACEAE	*Digitaria sanguinalis**
POACEAE	*Digitaria scalarum*
POACEAE	*Digitaria velutina*
POACEAE	*Diheteropogon amplectens*
POACEAE	*Diplachne eleusine*
POACEAE	*Echinochloa haploclada*
POACEAE	*Echinochloa jubata*
POACEAE	*Echinochloa stagnina*
POACEAE	*Eleusine coracana subsp. africana*
POACEAE	*Elionurus muticus**
POACEAE	*Enneapogon cenchroides*
POACEAE	*Enneapogon pretoriensis*

POACEAE	*Enneapogon scoparius*
POACEAE	*Enteropogon macrostachyus*
POACEAE	*Eragrostis aspera*
POACEAE	*Eragrostis barbinodis*
POACEAE	*Eragrostis barrelieri*
POACEAE	*Eragrostis capensis*
POACEAE	*Eragrostis chloromelas*#*
POACEAE	*Eragrostis cilianensis*
POACEAE	*Eragrostis curvula*
POACEAE	*Eragrostis cylindriflora*
POACEAE	*Eragrostis gummiflua**
POACEAE	*Eragrostis heteromera*
POACEAE	*Eragrostis hierniana*
POACEAE	*Eragrostis lappula*
POACEAE	*Eragrostis lehmanniana*#*
POACEAE	*Eragrostis micrantha#*
POACEAE	*Eragrostis nindensis*
POACEAE	*Eragroslis pallens*
POACEAE	*Eragroslis pilosa*
POACEAE	*Eragrostis plana*
POACEAE	*Eragrostis pseudosclerantha*#*
POACEAE	*Eragrostis racemosa**
POACEAE	*Eragrostis rigidior*
POACEAE	*Eragrostis rotifer*
POACEAE	*Eragrostis superba*#*
POACEAE	*Eragrostis trichophora*
POACEAE	*Eragrostis virescens*
POACEAE	*Eustachys paspaloides#*
POACEAE	*Fingerhuthia africana*
POACEAE	*Heteropogon contortus*#*
POACEAE	*Hyparrhenia dregeana*

POACEAE	*Hyparrhenia filipendula var. filipendula*
POACEAE	*Hyparrhenia filipendula var. pilosa*
POACEAE	*Hyparrhenia gazensis*
POACEAE	*Hyparrhenia hirta*#*
POACEAE	*Hyparrhenia tamba*
POACEAE	*Hyparrhenia variabilis*
POACEAE	*Hyperthelia dissoluta*#*
POACEAE	*Imperata cylindrica*
POACEAE	*Ischaemum fasciculatum*
POACEAE	*Leersia hexandra*
POACEAE	*Leptocarydion vulpiastrum*
POACEAE	*Loudetia flavida*
POACEAE	*Loudetia simplex*#*
POACEAE	*Melinis nerviglumis*#*
POACEAE	*Melinis repens subsp. repens**
POACEAE	*Miscanthus junceus*
POACEAE	*Monocymbium ceresiiforme*
POACEAE	*Mosdenia leptostachys*
POACEAE	*Oplismenus hirtellus*
POACEAE	*Panicum coloratum var. coloratum*
POACEAE	*Panicum deustum**
POACEAE	*Panicum dregeanum*
POACEAE	*Panicum maximum*#*
POACEAE	*Panicum natalense*
POACEAE	*Panicum schinzii**
POACEAE	*Panicum subalbidum*
POACEAE	*Paspalum dilatatum*
POACEAE	*Paspalum distichum*
POACEAE	*Paspalum scrobiculatum*
POACEAE	*Pennisetum clandestinum*
POACEAE	*Pennisetum macrourum*

POACEAE	*Perotis patens*
POACEAE	*Phragmiles australis*
POACEAE	*Pogonarthria squarrosa*#*
POACEAE	*Schizachyrium jeffreysii*
POACEAE	*Schizachyrium sanguineum*
POACEAE	*Schmidtia pappophoroides*
POACEAE	*Setaria appendiculata*
POACEAE	*Setaria incrassata*
POACEAE	*Setaria lindenbergiana*
POACEAE	*Setaria megaphylla*
POACEAE	*Setaria nigrirostris*
POACEAE	*Setaria plicatilis*
POACEAE	*Setaria sphacelata var. sericea*#*
POACEAE	*Setaria ustilata*
POACEAE	*Setaria verticillata*
POACEAE	*Sorghastrum friesii*
POACEAE	*Sorghastrum stipoides*
POACEAE	*Sorghum bicolor subsp. arundinaceum*
POACEAE	*Sorghum halepense*
POACEAE	*Sporobolus africanus**
POACEAE	*Sporobolus consimilis*
POACEAE	*Sporobolus fimbriatus#*
POACEAE	*Sporobolus pectinatus*
POACEAE	*Sporobolus pyramidalis*
POACEAE	*Sporobolus stapfianus*
POACEAE	*Themeda triandra*#*
POACEAE	*Trachypogon spicatus*#*
POACEAE	*Tragus berteronianus*#*
POACEAE	*Tricholaena monachne*
POACEAE	*Trichoneura grandiglumis var. grandiglumis*
POACEAE	*Triraphis andropogonoides*

POACEAE	*Tristachya biseriata*
POACEAE	*Tristachya rehmannii*
POACEAE	*Urelytrum agropyroides*
POACEAE	*Urochloa oligotricha#*
POLYGALACEAE	*Polygala africana*
POLYGALACEAE	*Polygala amatymbica*
POLYGALACEAE	*Polygala hottentotta*
POLYGALACEAE	*Polygala producta*
POLYGALACEAE	*Polygala rehmannii*
POLYGALACEAE	*Polygala sphenoptera var. sphenoptera*
POLYGONACEAE	*Oxygonum delagoense*
POLYGONACEAE	*Oxygonum dregeanum subsp. canescens var. linearifolium*
POLYGONACEAE	*Oxygonum sinuatum*
POLYGONACEAE	*Persicaria lapathifolia*
POLYGONACEAE	*Persicaria senegalensis*
POLYGONACEAE	*Persicaria serrulata*
POLYGONACEAE	*Polygonum aviculare*
POLYGONACEAE	*Polygonum meisnerianum*
POLYGONACEAE	*Polygonum plebeium*
PORTULACACEAE	*Anacampseros subnuda subsp. lubbersii*
PORTULACACEAE	*Portulaca kermesina*
PORTULACACEAE	*Portulaca oleracea*
PORTULACACEAE	*Portulaca quadrifida*
POTAMOGETONACEAE	*Potamogeton octandrus*
PROTEACEAE	*Faurea saligna*#*

PROTEACEAE	*Grevillea robusta*
PROTEACEAE	*Protea caffra subsp. caffra*
PROTEACEAE	*Protea welwitschii subsp. welwitschii*
PTERIDACEAE	*Actiniopteris dimorpha*
PTERIDACEAE	*Actiniopteris radiata*
PTERIDACEAE	*Adiantum capillus-veneris*
PTERIDACEAE	*Cheilanthes hirta var. hirta*
PTERIDACEAE	*Cheilanthes viridis var. glauca*
PTERIDACEAE	*Doryopteris concolor*
PTERIDACEAE	*Pellaea boivinii*
PTERIDACEAE	*Pellaea calomelanos var. calomelanos*#*
PTERIDACEAE	*Pellaea pectiniformis*
PTERIDACEAE	*Pteris friesii*
PTERIDACEAE	*Pteris vittata*
RANUNCULACEAE	*Clematis brachiata*
RANUNCULACEAE	*Ranunculus multifidus*
RHAMNACEAE	*Berchemia discolor*
RHAMNACEAE	*Berchemia zeyheri*#*
RHAMNACEAE	*Helinus integrifolius*
RHAMNACEAE	*Ziziphus mucronata subsp. mucronata*#*
RHAMNACEAE	*Ziziphus zeyheriana*
RICCIACEAE	*Riccia natalensis*
RICCIACEAE	*Riccia stricta*
ROSACEAE	*Cliffortia linearifolia*
ROSACEAE	*Rubus pinnatus*
ROSACEAE	*Rubus rigidus*

RUBIACEAE	*Agathisanthemum bojeri subsp. bojeri*
RUBIACEAE	*Anthospermum hispidulum*
RUBIACEAE	*Canthium gilfillanii**
RUBIACEAE	*Canthium mundianum*
RUBIACEAE	*Fadogia homblei*
RUBIACEAE	*Galopina circaeoides*
RUBIACEAE	*Hyperacanthus amoenus#*
RUBIACEAE	*Kohautia cynanchica*
RUBIACEAE	*Kohautia virgata*
RUBIACEAE	*Oldenlandia herbacea var. herbacea*
RUBIACEAE	*Otiophora calycophylla subsp. verdcourtii*
RUBIACEAE	*Otiophora cupheoides*
RUBIACEAE	*Pachystigma thamnus*
RUBIACEAE	*Pavetta gardeniifolia var. gardeniifolia*
RUBIACEAE	*Pavetta lanceolata*
RUBIACEAE	*Pavetta zeyheri*
RUBIACEAE	*Pentanisia angustifolia*
RUBIACEAE	*Pentanisia prunelloides subsp. prunelloides*
RUBIACEAE	*Psydrax livida*
RUBIACEAE	*Psydrax obovata subsp. elliptica*
RUBIACEAE	*Pygmaeothamnus zeyheri var. zeyheri*
RUBIACEAE	*Rothmannia capensis*
RUBIACEAE	*Sperrnacoce natalensis*
RUBIACEAE	*Tapiphyllum parvifolium**
RUBIACEAE	*Tricalysia lanceolata*
RUBIACEAE	*Vangueria infausta subsp. infausta#*
RUBIACEAE	*Vangueria madagascariensis*
RUTACEAE	*Calodendrum capense*
RUTACEAE	*Vepris lanceolata*

RUTACEAE	*Vepris reflexa*
RUTACEAE	*Zanthoxylum capense*
SALICACEAE	*Populus alba var. alba*
SALICACEAE	*Salix mucronata subsp. woodii*
SANTALACEAE	*Osyris lanceolata*
SANTALACEAE	*Thesium burkei*
SANTALACEAE	*Thesium costatum var. costatum*
SANTALACEAE	*Thesium junceum var. junceum*
SANTALACEAE	*Thesium magalismontanum*
SANTALACEAE	*Thesium resedoides*
SANTALACEAE	*Thesium transvaalense*
SAPINDACEAE	*Cardiospermum corindum*
SAPINDACEAE	*Cardiospermum halicacabum var. halicacabum*
SAPINDACEAE	*Dodonaea angustifolia*
SAPINDACEAE	*Pappea capensis*#*
SAPOTACEAE	*Englerophytum magalismontanum*
SAPOTACEAE	*Mimusops zeyheri**
SCROPHULARIACEAE	*Alectra orobanchoides*
SCROPHULARIACEAE	*Alectra sessiliflora var. sessiliflora*
SCROPHULARIACEAE	*Aptosimum elongatum*
SCROPHULARIACEAE	*Aptosimum procumbens var. elongatum*
SCROPHULARIACEAE	*Buchnera glabrata*
SCROPHULARIACEAE	*Cycnium adonense subsp. adonense*
SCROPHULARIACEAE	*Cycnium tubulosum*
SCROPHULARIACEAE	*Halleria lucida*
SCROPHULARIACEAE	*Ilysanthes dubia*

SCROPHULARIACEAE	*Jamesbrittenia burkeana*
SCROPHULARIACEAE	*Manulea parviflora var. parviflora*
SCROPHULARIACEAE	*Mimulus gracilis*
SCROPHULARIACEAE	*Nemesia fruticans*
SCROPHULARIACEAE	*Rhamphicarpa brevipedicellata*
SCROPHULARIACEAE	*Sopubia cana var. cana*
SCROPHULARIACEAE	*Striga asiatica*
SCROPHULARIACEAE	*Striga bilabiata var. bilabiata*
SCROPHULARIACEAE	*Striga gesnerioides*
SCROPHULARIACEAE	*Sutera burkeana*
SCROPHULARIACEAE	*Sutera palustris*
SCROPHULARIACEAE	*Zaluzianskya microsiphon*
SELAGINELLACEAE	*Selaginella dregei*
SELAGINELLACEAE	*Selaginella mittenii*
SOLANACEAE	*Datura sp.*
SOLANACEAE	*Nicotiana glauca*
SOLANACEAE	*Physalis peruviana*
SOLANACEAE	*Solanum aculesis var. hadiensis*
SOLANACEAE	*Solanum coccineum*
SOLANACEAE	*Solanum giganteum*
SOLANACEAE	*Solanum incanum*
SOLANACEAE	*Solanum panduriforme*#*
SOLANACEAE	*Solanum retroflexum*
SOLANACEAE	*Solanum rigescens*
SOLANACEAE	*Withania somnifera*
STERCULIACEAE	*Dombeya rotundifolia var. rotundifolia*#*
STERCULIACEAE	*Hermannia antonii*
STERCULIACEAE	*Hermannia boraginiflora*

STERCULIACEAE	*Hermannia parvula*
STERCULIACEAE	*Hermannia staurostemon*
STERCULIACEAE	*Hermannia tomentosa*
STERCULIACEAE	*Melhania acuminata var. acuminata*
STERCULIACEAE	*Melhania prostrate**
STERCULIACEAE	*Sterculia rogersii*
STERCULIACEAE	*Waltheria indica*
STRYCHNACEAE	*Strychnos cocculoides#*
STRYCHNACEAE	*Strychnos madagascariensis*#*
STRYCHNACEAE	*Strychnos pungens*
STRYCHNACEAE	*Strychnos usambarensis*
THELYPTERIDACEAE	*Thelypteris confluens*
THELYPTERIDACEAE	*Thelypteris gueinziana*
THELYPTERIDACEAE	*Thelypteris pulchra*
THYMELAEACEAE	*Gnidia caffra*
THYMELAEACEAE	*Gnidia capitata*
THYMELAEACEAE	*Gnidia kraussiana var. kraussiana*
THYMELAEACEAE	*Gnidia microcephala*
THYMELAEACEAE	*Gnidia sericocephala*
TILIACEAE	*Corchorus asplenifolius*
TILIACEAE	*Corchorus tridens*
TILIACEAE	*Grewia bicolor var. bicolor**
TILIACEAE	*Grewia flava*#*
TILIACEAE	*Grewia flavescens var. flavescens*#*
TILIACEAE	*Grewia monticola*#*
TILIACEAE	*Grewia occidentalis var. occidentalis**
TILIACEAE	*Grewia retinervis*

TILIACEAE	*Grewia rogersii*
TILIACEAE	*Grewia subspathulata*
TILIACEAE	*Triumfetta annua*
TILIACEAE	*Triumfetta pentandra var. pentandra*
TILIACEAE	*Triumfetta pilosa var. effusa*
TILIACEAE	*Triumfetta sonderi*
TURNERACEAE	*Tricliceras glanduliferum*
TYPHACEAE	*Typha capensis*
ULMACEAE	*Celtis africana*#*
ULMACEAE	*Chaetachme aristata**
ULMACEAE	*Trema orientalis*
URTICACEAE	*Girardinia diversifolia*
URTICACEAE	*Laportea grossa**
URTICACEAE	*Obetia tenax**
URTICACEAE	*Pouzolzia mixta*
VAHLIACEAE	*Vahlia capensis subsp. capensis*
VELLOZIACEAE	*Xerophyta retinervis*#*
VELLOZIACEAE	*Xerophyta viscosa*
VERBENACEAE	*Chascanum hederaceum var. hederaceum*
VERBENACEAE	*Chascanum pinnatifidum var. pinnatifidum*
VERBENACEAE	*Clerodendrum glabrum var. glabrum*
VERBENACEAE	*Clerodendrum louwalbertsii*
VERBENACEAE	*Clerodendrum myricoides*
VERBENACEAE	*Clerodendrum suffruticosum var. suffruticosum*

VERBENACEAE	*Clerodendrum ternatum var. ternatum*
VERBENACEAE	*Clerodendrum triphyllum var. triphyllum**
VERBENACEAE	*Duranta erecta*
VERBENACEAE	*Lantana camara*
VERBENACEAE	*Lantana rugosa*#*
VERBENACEAE	*Lippia javanica*#*
VERBENACEAE	*Lippia wilmsii*
VERBENACEAE	*Priva meyeri var. meyeri*
VERBENACEAE	*Verbena bonariensis*
VERBENACEAE	*Vitex rehmannii**
VISCACEAE	*Viscum combreticola*
VISCACEAE	*Viscum rotundifolium*
VITACEAE	*Cissus quadrangularis var. quadrangularis*
VITACEAE	*Cyphostemma cirrhosum subsp. transvaalense*
VITACEAE	*Cyphostemma humile subsp. humile*
VITACEAE	*Cyphostemma puberulum*
VITACEAE	*Cyphostemrna sandersonii*
VITACEAE	*Cyphostemma woodii*
VITACEAE	*Rhoicissus revoilii*
VITACEAE	*Rhoicissus tridentata subsp. cuneifolia*#*
XYRIDACEAE	*Xyris capensis*
ZAMIACEAE	*Encephalartos eugene-maraisii subsp. middelburgensis*
ZYGOPHYLLACEAE	*Tribulus terrestris*

Appendix 2: Mammals, reptiles and amphibians of LDNR.

Mammals

Common Name	***Scientific Name***
Aardvark	*Orycteropus afer*
Aardwolf	*Proteles cristatus*
African civet	*Civettictis civetta*
African wild cat	*Felis lybica*
Banded mongoose	*Mungos mungo*
Black backed jackal	*Canis mesomelas*
Blue wildebeest	*Connochaetes taurinus*
Brown hyaena	*Hyaena brunnea*
Buffalo	*Syncerus caffer*
Burchells zebra	*Equus burchellii*
Bushbuck	*Tragelaphus scriptus*
Bushpig	*Potamochoerus porcus*
Bushveld horseshoe bat	*Rhinolophus capensus*
Cape clawless otter	*Aonyx capensis*
Caracal	*Felis caracal*
Chacma baboon	*Papio ursinus*
Common duiker	*Sylvicarpa grimmia*
Common molerat	*Cryptomys hottentotus*
Dwarf mongoose	*Helogale parvula*
Egyptian or Common slit-faced bat	*Nycteris thebaica*
Eland (not seen in a while)	*Taurotragus oryx*
Fat mouse	*Steatomys pratensis*
Giraffe	*Giraffa camelopardalis*
Greater canerat	*Thryonomys swinderianus*
Hedgehog	*Atelerix frontalis*
Hippo	*Hippopotamus amphibius*
Honey badger	*Mellivora capensis*

House rat	*Rattus rattus*
Impala	*Aepyceros melampus*
Klipspringer	*Oreotragus oreotragus*
Krebs fat mouse	*Steatomys krebsii*
Kudu	*Tragelaphus strepsiceros*
Leopard	*Panthera pardus*
Lesser bushbaby	*Galago moholi*
Lesser red musk shrew	*Crocidura hirta*
Mountain reedbuck	*Redunca fulvorufula*
Tiny musk shrew	*Crocidura fuscomurina*
Namaqua rock mouse	*Aethomys namaquensis*
Natal multimammate mouse	*Mastomys natalensis*
Nyala	*Tragelaphus angasii*
Oribi (not seen in a while)	*Ourebia ourebi*
Porcupine	*Hystrix africaeaustralis*
Pouched mouse	*Saccostomus campestris*
Red veld rat	*Aethomys namaquensis*
Reddish grey musk shrew	*Crocidura cyanea*
Reedbuck	*Redunca arundinum*
Rock dassie	*Procavia capensis*
Rock elephant shrew	*Elephantulus myurus*
Sable	*Hippotragus niger*
Schreibers longfingered bat	*Miniopterus schreibersii*
Scrub hare	*Lepus saxatilis*
Serval	*Felis serval*
Short snouted elephant shrew	*Elephantulus rupestris*
Single-striped mouse	*Lemniscomys rosalia*
Slender mongoose	*Galerella sanguinea*
Small spotted genet	*Genetta genetta*
Spiny mouse	*Acomys spinosissimus*
Spotted necked otter	*Lutra maculicollis*

Steenbok	*Raphicerus campestris*
Striped mouse	*Rhabdomys pumilio*
Striped polecat	*Ictonyx striatus*
Sundevall's leaf-nosed bat	*Hipposideros caffer*
Tree mouse	*Thallomys paedulcus*
Tsessebe	*Damaliscus lunatus*
Vervet monkey	*Cercopithecus aethiops pygerythrus (senso lato)*
Vleirat	*Otomys irroratus*
Wahlbergs epaulleted fruit bat	*Epomorphorus wahlbergi*
Warthog	*Phacochoerus aethiops*
Waterbuck	*Kobus ellipsiprymnus*
White rhino	*Ceratotherium simum*
Woodland doormouse	*Graphiurus murinus*
Yellow house bat	*Scotophilus dinganii*

Reptiles

Nile crocodile	*Crocodylus niloticus*
Rock leguan	*Varanus exanthematicus*
Water leguan	*Varanus niloticus*
African Python	*Python sebae*
Berg adder	*Bitis atropos*
Bibrons blind snake	*Typhlops bibronii*
Black file snake	*Mehelya nyassae*
Black mamba	*Dendroaspis polylepis*
Black worm snake	
Blackheaded centipede eater	*Aparallactus guentheri*
Boomslang	*Dispholidus typus*
Brown house snake	*Lamprophis fuliginosus*
Brown water snake	*Lycodonomorphus rufulus*
Cape file snake	*Mehelya capensis*

Cape wolf snake	*Lycophidion capense*
Common egg-eater	*Dasypeltis scabra*
Common night-adder	*Causus rhombeatus*
Dwarf sand snake	*Psammophis angolensis*
Eastern tiger snake	*Telescopus semiannulatus*
Egyptian cobra	*Naja haje*
Garter snake	
Herald snake	*Crotaphopeltis hotamboeia*
Mole snake	*Pseudaspis cana*
Mozambique spitting-cobra	*Naja mossambica*
Puff adder	*Bitis arietans*
Rinkhals	*Hemachatus haemachatus*
Shield-nose snake	*Aspidelaps scutatus*
Shortsnouted sand snake	
Snouted night adder	
South-eastern green snake	
Southern stilleto snake	*Atractaspis bibronii*
Spotted bush snake	*Philothamnus semivariegatus*
Striped skaapsteker	*Psammophylax tritaeniatus*
Twig snake	*Thelotornis capensis*
Variagated wolf snake	*Lycophidion variegatum*
Natal green snake	*Philothamnus natalensis*
Yellowbellied sand snake	
Variable skink	*Mabuya varia*
Striped skink	*Mabuya striata*
Sundevals skink	*Lygosoma sundevallii*
Dwarf skink	
Spotted skink	
Bibrons thicktoed gecko	
Cape wedgesnouted worm lizard	
Greater roughscaled lizard	

Lesser roughscaled lizard
Ocellated sand lizard
Ornate longtailed lizard
Traansvaal girdled lizard
Traansvaal grass lizard
Transvaal crag lizard
Van Dams girdled lizard
Yellowthroated plated lizard

<u>Amphibians</u>

Bubbling kassina	*Kassina senegalensis*
Bushveld rain frog	*Breviceps adspersus*
Clicking stream frog	*Strongylopus grayii*
Common bullfrog (rarely seen)	*Pyxicephalus edulus*
Common clawed frog	*Xenopus laevis*
Common river frog	*Afrana angolensis*
Dainty frog	
Foamnest frog	*Chiromantis xerampelina*
Guttural toad	*Bufo gutturalis*
Natal sand frog	*Tomopterna natalensis*
Northern mottled toad	
Puddle frog	*Phrynobatrachus natalensis*
Raucous toad	*Bufo rangeri*
Red toad	*Schismaderma carens*
Russetbacked grass frog	
Striped sand frog	
Striped stream frog	*Strongylopus fasciatus*
Striped toad	
Transvaal pygmy toad	

Appendix 3: Troop actual, random and shortest route data.

		Actual Route		Random Route					Shortest Route	
Home Range	Route ID	Length (m)	Energy (MJ)	Mean Energy (MJ)	Min Energy (MJ)	Max Energy (MJ)	Standard Deviation	95 % Upper Confidence Limit	Length (m)	Energy (MJ)
Donga	200607a	620.15	7162.21	8063.43	6803.36	9232.88	485.38	8118.58	528.97	7171.75
Donga	200607b	379.10	2985.08	2909.87	2275.67	3913.90	283.29	2942.06	286.87	2152.57
Donga	200607c	334.47	1369.00	742.29	268.46	1636.72	281.11	774.22	72.22	284.02
Donga	200608a	1208.47	11394.09	7524.26	3624.46	12619.70	2144.80	7767.95	1002.91	6026.65
Donga	200608b	301.73	391.34	1414.65	318.27	4077.69	855.37	1511.84	24.29	298.25
Donga	200608c	518.06	6537.30	5785.71	3829.54	8392.55	971.77	5896.12	379.88	5063.77
Donga	200609a	714.59	10671.25	6451.27	1940.88	10701.65	2336.55	6716.75	549.76	5527.24
Donga	200609b	1031.85	14884.46	6421.59	2730.54	13322.73	2469.97	6702.22	105.15	1813.11
Donga	200609c	300.78	2393.93	1684.08	634.11	3115.69	552.45	1746.85	7.49	172.73
Donga	200610a	479.31	5149.15	6737.37	4122.14	10081.28	1287.60	6883.66	431.19	6442.85
Donga	200610b	372.04	2289.97	2534.30	1892.91	3756.99	420.84	2716.29	192.59	2066.42
Donga	200610c	585.00	7370.47	6866.80	5350.35	8926.68	672.94	6943.26	544.81	7034.31
Donga	200610d	1488.55	26546.35	25665.38	20928.57	30709.21	1904.58	25881.78	1273.69	21063.31
Donga	200610e	105.91	478.74	574.34	419.44	683.22	124.19	728.55	35.95	428.87
Donga	200610f	393.84	2464.62	2562.90	2362.48	2763.32	283.44	5109.48	389.53	2621.33
Donga	200611a	1161.96	12629.35	22228.30	10428.66	35748.52	5133.08	22811.51	512.43	16562.26
Donga	200611b	491.50	5831.35	3899.68	1736.96	7898.69	1241.07	4040.69	142.37	931.99
Donga	200611c	369.05	4449.70	2659.64	1292.32	5195.08	949.54	2767.53	103.21	1119.62
Donga	200612a	1038.26	16832.91	14279.47	5826.75	26159.73	3960.93	14729.50	67.88	485.72
Donga	200612b	658.84	13486.91	14348.37	11466.45	16781.17	1167.58	14481.03	602.98	14291.18
Donga	200612c	433.62	2231.77	2634.09	891.76	6552.17	1141.90	2763.83	47.38	625.00
Donga	200701a	848.97	179770.52	167406.40	100121.12	241390.90	29724.28	170783.62	582.40	141924.10
Donga	200701b	642.81	49904.22	85580.88	31331.13	157303.68	41739.25	103630.29	493.61	60715.62
Donga	200701c	1190.05	133503.67	141379.11	74588.07	200192.04	21392.85	143809.73	859.75	114084.12
Donga	200701d	1436.50	255129.04	212829.27	65748.17	363552.82	69590.06	220735.99	495.22	74171.54
Donga	200702a	1008.66	208372.17	123696.57	19343.18	221025.23	52459.66	129656.96	381.65	19611.02
Donga	200702b	777.50	43347.87	45515.97	38993.58	49523.03	1949.21	45737.43	688.83	45714.12
Donga	200702c	665.16	78432.59	80667.89	39440.43	150411.57	19719.11	82908.34	467.42	68033.39
Donga	200703a	364.41	10922.57	14313.16	7802.25	27369.07	4166.12	14786.50	246.13	12485.01
Donga	200703b	316.93	26828.00	17019.48	11972.93	27338.40	4136.89	17489.51	275.90	19481.94
Donga	200703c	476.61	11315.39	9255.64	2473.29	18034.42	3396.52	9641.54	153.86	1539.71
Donga	200703d	643.35	74419.48	63402.57	44768.73	83509.75	6310.77	64119.59	457.70	61100.52
Donga	200703e	341.14	12980.49	13692.25	12417.49	15116.03	750.12	14016.63	333.46	15096.20
Donga	200704a	527.82	39169.49	35164.09	25413.53	46124.38	3981.57	35616.47	473.13	38135.69
Donga	200704b	520.76	10009.37	7634.43	2706.91	13768.93	1996.98	7861.32	252.05	3313.59
Donga	200704c	683.51	50581.90	48697.93	34712.06	63661.23	5317.99	49302.15	525.85	47571.51
Donga	200705a	247.23	4795.78	4245.17	3407.08	5927.76	620.41	4357.80	202.93	3930.43
Donga	200705b	597.53	7075.82	7762.17	3214.65	14714.63	2229.98	8015.53	33.23	1993.28
Donga	200705c	696.07	16642.97	10447.28	5839.23	19039.22	2758.87	10760.74	560.57	7957.41
Donga	200705d	441.44	17731.57	22332.71	14639.79	34042.75	3820.25	22766.76	200.59	13341.81
Donga	200706a	198.42	1187.76	1153.48	559.04	1897.28	292.55	1186.71	190.15	1402.44
Donga	200706b	363.64	4746.05	3011.33	1781.68	4559.19	600.85	3079.59	303.90	2858.33
Donga	200706c	180.77	3513.79	3798.48	2366.46	5225.92	560.65	3862.18	169.93	4749.05
Picnic	200607a	1147.98	8570.68	6979.75	2783.30	10751.71	1510.78	7100.88	928.54	3227.40
Picnic	200608a	1051.01	3045.45	1585.56	298.01	3046.49	539.37	1628.81	92.71	201.78
Picnic	200609a	383.63	1873.68	1183.58	666.53	2888.18	320.88	1209.30	138.30	653.05
Picnic	200609b	779.29	6591.16	4988.64	2724.78	7260.70	1029.54	5071.19	699.73	5261.13
Picnic	200610a	1161.10	15419.24	13173.09	4216.80	20722.99	3674.04	13467.66	938.18	12774.88
Picnic	200611a	901.85	9672.15	11021.88	7129.46	19357.09	2471.57	11220.04	219.90	4693.56
Picnic	200611b	977.63	19800.99	18228.86	13513.46	23320.48	2378.03	18419.52	902.16	9222.69
Picnic	200612a	1052.23	14545.80	22399.71	10810.19	48452.61	7569.65	23006.62	311.22	9075.84
Picnic	200701a	1512.14	40569.71	33592.87	27704.65	39812.08	2093.87	33760.75	1222.83	25600.94
Picnic	200701b	553.04	24121.11	23615.83	16359.02	31208.96	2546.59	23820.00	413.39	18206.54
Picnic	200701c	164.21	878.74	898.27	544.41	1426.79	155.18	910.72	79.05	1462.25
Picnic	200702a	679.61	5995.17	5014.40	3216.36	7591.17	794.87	5078.13	576.06	4545.96
Picnic	200702b	419.76	2703.04	1476.30	643.24	4973.51	831.96	1543.01	255.21	1029.61
Picnic	200703a	694.29	4236.30	4961.35	2431.62	9126.56	1565.56	5086.87	595.50	3428.94
Picnic	200703b	722.10	18182.76	17066.67	9789.14	24138.89	2570.55	17272.77	380.57	13235.92
Picnic	200704a	679.52	5987.46	4149.78	2213.17	9267.35	1046.87	4233.72	382.80	2447.42
Picnic	200704b	624.43	13647.23	14104.79	9871.17	18433.39	1551.28	14229.17	401.72	8464.41
Picnic	200705a	583.52	4764.99	4044.56	2383.74	7161.34	716.67	4102.02	67.59	853.09
Picnic	200705b	673.72	9924.40	12098.02	7711.15	16734.99	2030.13	12260.79	563.83	12752.20
Picnic	200706a	445.07	3831.57	3541.17	2434.43	4889.32	438.96	3576.37	223.09	1827.39
Picnic	200706b	1098.21	10618.03	10151.00	5468.08	17294.14	2115.68	10320.63	705.56	5640.10