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Does land use affect mammal diversity in savannah ecosystems?

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Abstract

I investigated to what extent differences in land use affect the diversity of large mammals including species richness and distributions, how animal communities differ between areas with different land use as well as the distribution of red listed mammal species in relation to land use. This is essential for the development of a sustainable balance between livestock- and wildlife-based economies in savannah ecosystems. This study was performed in the Kalahari through road-side counts both day and night in four different land use areas and on a wide range of mammal species. I have shown that the wildlife species richness differs between land use areas. Areas that have much domestic animals, i.e. Communal grazing areas and Fenced ranches, seem to have less wildlife than Wildlife management areas and National parks have. My results moreover indicate that species compositions differ between the land use areas. No clear animal community consisting of both wild and domestic animals could be shown and coexistence between indigenous herbivores and livestock are therefore not likely to occur. Type of land use as well as distance from village and pan seems to affect species distributions. Analyses also indicate that there are more red listed species and individuals of these species in undisturbed areas both during day and night. The results of this study may help in conducting wise land use and wildlife conservation in order to prevent further declines of the unique fauna of the Kalahari and also for obtaining a proper use of both livestock and wildlife for the benefit of the people of Botswana.

Foreword

I have undertaken a "Minor Field Study" financed mainly by the Swedish International Development Cooperation Agency (Sida) through the Committee of Tropical Ecology (ATE) at Uppsala University. This study is a part of an EU-project: Management and policy options for the sustainable development of communal rangelands and their communities in southern Africa, MAPOSDA Project No. ICA4-CT-2001-10050.

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Front page photo: Gemsboks in the Kgalagadi Transfrontier Park, Kaa (Tanja Viio).

1. Introduction

1.1 Animal communities in savannahs

The high faunal diversity and herbivore biomass in savannahs are directly linked to the high spatial heterogeneity of these ecosystems, apparently through ungulate habitat specificity that varies with body size (du Toit & Cumming 1999). A high diversity of large herbivores and their predators, by virtue of their very presence and actions, maintains an even higher diversity of niches for other species, both vertebrates and invertebrates (du Toit & Cumming 1999). Herbivores with large body size can tolerate poor vegetation quality better than smaller herbivores (Bell 1982) and larger species are thus able to feed in a wider range of habitats than smaller species (du Toit & Cumming 1999). The composition of large herbivore communities varies considerably across southern Africa (du Toit 1995). Community structure, in terms of the biomasses and types of plants and animals, is suggested to be determined by the balance between the availability of water and the availability of soil nutrients (Bell 1982). Herbivores are not only dependent on food quantity but also on food quality, which is strongly influenced by the interaction between mean annual rainfall and soil fertility (du Toit 1995). Soil quality and rainfall have actually been shown to have important effects on the carrying capacity for ungulates in African savannahs (Fritz & Duncan 1994).

The wildlife populations in Kalahari are characterised by high mobility in search of better quality food patches to satisfy water and energy demand (Verlinden 1997). Wildlife in Botswana is largely migratory; animals move in seasonal patterns and sequences (Wildlife Conservation Policy 1986). There is a wide variety of wildlife in the Kalahari and the populations fluctuate in numbers because they depend on the availability of prey and nutrients in a so-called bottom-up controlled food web (Campbell 1981, Begon et al. 1986).

1.2 Land use in Kalahari

Man has had a long association with the Kalahari, probably going back to the time of the early hominids. Until recent decades the Kalahari has been occupied by humans, practising lifestyles well adapted to the harsh conditions. Archaeological evidence indicates human occupation from the early Stone Age to the present day and within this time span societies have changed from a hunter-gatherer lifestyle to pastoralism and agriculture and on to multiple land use (Thomas & Shaw 1991). Domestic animals were in use in southern Africa over 2,000 years ago. Cattle are utilised in Kalahari, both in traditional livestock systems and in the expansion of organised ranching, and their effect upon the Kalahari environment is significant. Communal grazing areas (CGA) and Fenced ranches (FR) are normally used for livestock. The use of ground-water aquifers through borehole construction, which has provided year-round water, together with veterinary services, form the base for the expanded use of the Kalahari as a range land resource (Thomas & Shaw 1991). The major borehole-drilling programme started at about the same time as the erection of the first fences, in the 1950s (Campbell 1981).

Total preservation of the wildlife resources in Botswana is practised in both the National parks (NPs) and most Game reserves, which were established at independence in the 1960s and cover as much as about 18 percent of Botswana's total land area (Broekhuis 1997, Wildlife Conservation Policy 1986). See figure 2.1 for the distribution and size of National parks, Game reserves and Wildlife management areas in Botswana. Wildlife management areas (WMAs) are areas where sustained wildlife utilisation, e.g. controlled hunting, is the primary land use. Other land uses are permitted in WMA only if they are compatible with wildlife utilisation (Wildlife Conservation Policy 1986), such as low density livestock grazing (Botswana National Conservation Strategy 1990). WMAs function as buffer zones for the National parks and Game reserves in Botswana and are, at the same time, migratory corridors.

Without the WMAs some wildlife species could not survive in the parks and reserves. WMAs carry significant wildlife populations (Broekhuis 1997), but there is a continuing pressure to erode the WMAs in favour for cattle ranching (Broekhuis 1997, Thouless 1998). The WMAs are planned to constitute about 22 % of the land in Botswana (Broekhuis 1997). The concept of WMAs arose from Botswana's Tribal Grazing policy from 1975 that directed that there would be three zoning categories of state owned land. Those are Commercial Farming Areas, Communal Grazing Areas and Reserved Areas. The Wildlife management areas can be considered to belong to the category Reserved Areas (Wildlife Conservation Policy 1986).

Some previous studies conducted in the southern Kalahari have focused on how the distribution and species composition of mammal communities are affected by environmental gradients, created by human disturbance, livestock grazing and the attraction to pans. These studies were primarily conducted within areas that now have the status of Communal grazing areas and Wildlife management areas (Bergström & Skarpe 1999, Granlund 2001, Wallgren 2001).

It is important to determine how wild mammal communities vary across different types of land use in Botswana and, thereby, how wildlife species are affected by various types and degrees of human impact (Broekhuis 1997).

1.3 Changes in savannah large mammal communities

Most savannahs are nowadays used for livestock grazing, and millions of people depend to various extents on such pastoral systems and, but to a smaller extent, on indigenous herbivore systems. In Africa, there are long-term increasing trends in livestock numbers (Skarpe 1991). The savannahs in Africa house more larger herbivores than savannahs on any other continent (Skarpe 1991), but there have been drastic reductions in the geographical distribution, population size and genetic diversity among indigenous large herbivores (du Toit & Cumming 1999). The reduction in wild animals is not confined to Africa – twenty-four percent of all mammal species on earth are threatened according to the 2002 IUCN red list. Large concentrations of wild mammals in Africa are now found only in National parks and other reserves, which cover about seven percent of the African land area (Happold 1995).

In the dry savannahs of the Kalahari, Botswana, there have also been a dramatic decline in many wildlife populations during the last 150 years (Campbell 1981). Species such as elephant, buffalo, zebra, hippo and rhino have disappeared (Campbell 1981) but the area still contains globally significant populations of a number of ungulate species (Thouless 1998). However, several studies have revealed a massive decline of Kalahari wildlife populations during the last 20 years (Crowe 1995, Williamson & Williamson 1984). This is true for ostrich and almost all species of antelopes (Granlund 2001, Wallgren 2001), but especially severe for wildebeest and hartebeest (Bonificia 1992, Crowe 1995, Spinage & Matlhare 1992, Thouless 1998). Not all ungulates have decreased in numbers, steenbok may have increased (Granlund 2001, Thouless 1998, Wallgren 2001). It is less documented if predators and smaller herbivores, scavengers, insectivores and omnivores also have decreased in numbers in the Kalahari. However, a great decline of prey species as well as persecution of large carnivores (for example lions) by farmers who suffer livestock losses may logically have led to a decline in predators (Castley et al. 2002, Crowe 1995).

1.4 Causes of the declines of wildlife in the Kalahari

There are probably many reasons for the reductions of large wild mammals observed in the Kalahari during the last decades. High natural mortality in animal populations during drought is recurrent in the Kalahari, leading to fluctuations in numbers of some species (Mordi 1989, Williamson & Williamson 1984). However, the most common explanations for the declines of wildlife are all associated with people or livestock. There is no natural surface water in the

Kalahari and during droughts wildlife needs access to permanent water on the periphery of the Kalahari in order to survive. Herbivores like wildebeest, hartebeest and eland used to move long distances to find water or good forage but many of them are nowadays hindered by fences and settled areas (Crowe 1995, Spinage & Matlhare 1992, Thouless 1998). Fences in Kalahari include those along international boundaries and main roads, around ranches as well as veterinary cordon fences which were erected all over Botswana to prevent the spread of foot and mouth disease in cattle (Bonificia 1992). These fences presumably caused the drastic reduction of the Kalahari wildebeest population in the drought in the early 1980s (Spinage 1992, Williamson & Williamson, 1984). Hartebeests were also reduced in the same drought probably because of farm fences (Spinage 1992). Habitat loss is probably the greatest threat to wildlife in the long term in unprotected parts of the Kalahari (Thouless 1998). There is reduced access for wildlife to key habitats, like pans, which are shallow depressions that provide mineral licks, nutrient-rich vegetation and temporary surface water (Thomas & Shaw 1991). Pans are increasingly used by people and livestock and the number of wild animals are seriously reduced (Campbell 1981, Parris 1970, Parris & Child 1973). Changes in vegetation composition due to livestock grazing may also contribute to the observed decline of wildlife (Bergström & Skarpe 1999, Skarpe 1986). Other habitat changes that are often negative for wildlife are new roads and tracks into once inaccessible areas (Williamson & Williamson, 1984). The last but not least problem touched upon is hunting. Both legal (licensed) hunting and poaching may reduce certain wildlife populations (Mordi 1989, Thouless 1998, Wildlife Conservation Policy 1986, Williamson & Williamson 1984). Predators are also a subject for problem animal control efforts (Crowe 1995).

1.5 Objectives

The main aims of my study was

- to assess to what extent differences in land use affect the diversity of large mammals including species richness and distributions
- to assess to what extent livestock and wild large herbivores can coexist in the same area
- examine how animal communities differ between areas with different land use.
- to assess particularly the distribution of red listed mammal species in relation to land use

Such knowledge is essential for the development of a sustainable balance between livestock- and wildlife-based economies in savannah ecosystems. The increasing interest in diversification of utilisation and management of savannah rangelands including economic uses of other range land products than livestock also creates a need for this kind of knowledge. The rapidly growing ecotourism is largely based on wildlife resources and so is the lucrative hunting tourism. In addition, various forms of subsistence hunting and selling of wildlife based products are important (Wildlife Conservation Policy 1986). Comparisons of land use areas regarding mammal species in the Kalahari have not been performed earlier. Most wildlife surveys in the Kalahari have been done during daytime and also mostly on larger mammals. The field observations in this study were performed both day and night in different land use areas and on a wide range of mammal species.

2. Study area

2.1 Kalahari environment

The geological Kalahari is called the Mega Kalahari and impinges on the territories of nine countries, from South Africa and Namibia in the south to the more northern situated Gabon and Congo. Mostly Kalahari Sand, which is included in the Kalahari Group of sediments, mantles the Mega Kalahari and this makes it the largest continuos sand sheet on earth. The core area of the Mega Kalahari is the semi-arid to arid true Kalahari, with its centre in Botswana (Thomas & Shaw 1991). The climate is characterised by hot summers and winters with warm days and cold nights. Rainfalls mainly occur in summer (October to April) and the high rates of evaporation result in a moisture deficit in all but the wettest months. Although sand is not usually regarded as a good medium for plant growth it has high infiltration rate and maintains moisture from rainfall in arid to semi-arid environments. So despite the mean moisture deficit and the absence of surface water, the Kalahari is a well-vegetated arid to semi-arid shrub savannah (Thomas & Shaw 1991). The vegetation, which grows on nutrient poor Kalahari sand, is mainly a shrub savannah and not a desert (Skarpe 1986). The great flatness and the high altitude (more than 1000 m above sea level) are also major features of the Kalahari (Thomas & Shaw 1991*)*.

2.1.1 Key habitat

The Kalahari lacks permanent surface water. However, in the wet season water is collected in the pans during rain. This water usually persists only for a few weeks (Parris & Child 1973), during that time they serve as typical game water holes (Parris 1970). Instead of Kalahari Sand the bottoms of the pans consist of saline clay soils (without vegetation) or hard grey soils (able to have a good vegetation cover). Consequently the pans have a relatively high mineral content and usually serves as “salt licks” where antelope eat the soil (Parris & Child 1973). Pans form a suitable habitat especially for springbok. Burrowing animals such as ground squirrels prefer the pans as well as bat-eared foxes that favour to dig their burrows in the hard soil. Predators such as lions, cheetahs, hyenas and wild dogs show up at pans, too (Parris 1970).

2.2 Land use areas studied

The centre of the selected study area are the Matsheng villages in the Kalahari in south-western Botswana (Fig. 2.1). There are 15 small villages in the Matsheng areas that inhabit just over 6,000 humans (year 1991) and the main villages include Hukuntsi, Tshane, Lehututu and Lokgwabe (Arntzen et al. 1998). Hukuntsi (24°04’S 21°40’E) is the largest Matsheng village and had approximately 2,500 inhabitants in 1991 (Arntzen et al. 1998). The study was conducted within the Kgalagadi district but also in the adjacent parts of the Ghanzi district. The four types of land use areas studied were Communal grazing areas (CGA), Fenced ranches (FR), Wildlife management areas (WMA) and the National parks (NP) (Fig. 2.1). The National park studied was Kgalagadi Transfrontier Park that is situated both in Botswana and South Africa with no fenced border in between.

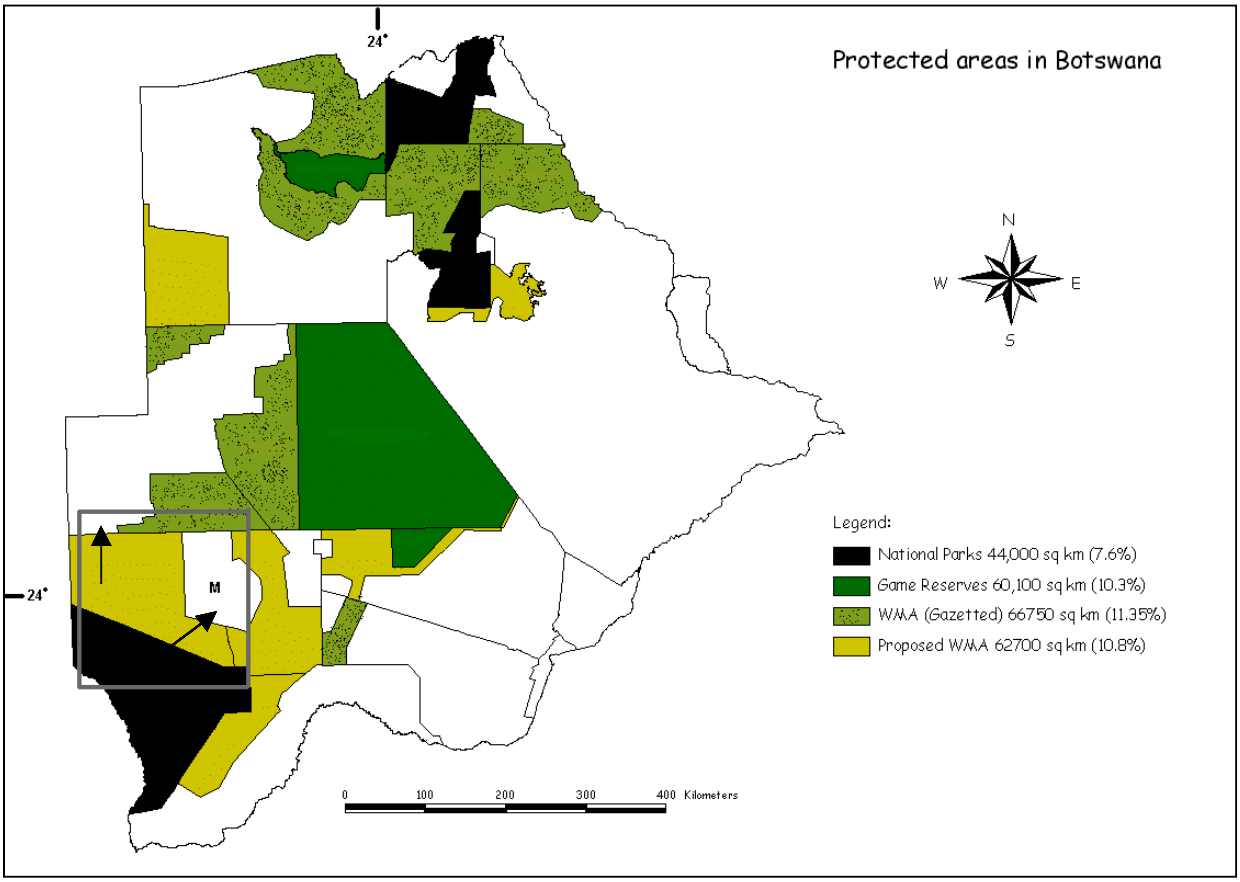


Figure 2.1. Protected areas in Botswana. After Broekhuis 1997. The framed square in south-east of Botswana shows the study area. The black part in the square is the Kgalagadi Transfrontier Park and the arrows indicate where the surveyed Fenced ranches are located. The capital letter M (in the square) shows where the Matsheng villages are centred.

3. Methods

3.1 Field methods

The ecological fieldwork was conducted during the dry season, from 12th of July to 21st of September 2002. The animals were counted from a four-by-four vehicle along transects in the study areas. The transects followed existing sand tracks which made it easier to drive. The road-side counts were made both day and night to include both diurnal and nocturnal animals in the study. Bergström & Skarpe (1999), Granlund (2001) and Wallgren (2001) have previously used similar methods, in the same area. The survey included mammals of the size of mongoose and larger, as well as ostrich. I chose these animals in my study since they are important from many aspects and because all species can be surveyed by road-side counts.

3.1.1 Road-side counts

Totally 110 road-side counts were performed, 56 were driven during the day and 54 during the night (Appendix). Seven transects each were driven both in CGAs and WMAs. Approximately there were two road counts per transect day and night, respectively, in these areas. Five FRs were included in the study, with one transect per ranch. There were ten to twelve road counts totally per transect on the ranches. It was only possible to drive two transects in the NP and with ten repetitions per transect. Because the land use areas were of different sizes the transects are not of equal length and the total length driven per land use area were not equal either. To facilitate possible future comparisons start and end points for the transects were partly the same as previous road count studies in the Kalahari (Bergström & Skarpe 1999, Granlund 2001, Wallgren 2001). Other start and end co-ordinates were chosen for practical reasons.

3.1.2 Procedure of the road-side counts

Three persons performed the road counts. One person was driving the vehicle at an average speed of 25 km/h and the other two stood on the back of the vehicle watching for animals at each side of the track. The person driving spotted animals straight ahead. We did not use binoculars when the car was moving, so the animals were spotted by eyesight only. During night-time two spotlights were used, one on each side of the car. The spotlights were swept back and forth repeatedly from straight-ahead to a 90-degree angle from the car. The spotlight reflected the eyes of the mammals and they were therefore more easily seen. A car battery was used for the spotlights. Each time an animal was seen we stopped the car. After identification to species level the number of individuals and time of observation were recorded. A GPS (Global positioning system) was used to record position and driven kilometres for each observation. Date, weather and period of day (night or day) were also documented for the road count. Since the vegetation in Kalahari is rather open one could see animals approximately 300 m away from the vehicle. The visibility was slightly better on pans. The transects were driven in both directions and during both night and day repeatedly. The day road counts were performed between 08.00 and 17.00 and the night road counts between 20.00 and 05.00 to prevent variation because of activities at dusk and dawn. The starting time for both day and night road counts in each transect was varied as much as possible. The dates for the transects were scattered randomly over the dry season, this to lower the variation between the different land use areas due to season. Because of limitation in the budget and high monthly fees for working in the Kgalagadi Transfrontier Park, we only drove in the National park during a concentrated time period. This means that the variation in time in the data from the National parks is not as varied as for the other land use areas.

3.2 Statistical methods

Kruskal-Wallis was used for all analysis of variance. All tests have been applied to a 5 % significance level and adjusted for ties. In some of the variance analyses I have used each transect as a replicate. However, to be able to statistically test for difference I have divided the four land use types into two categories, protected areas (WMA and NP) and unprotected (CGA and FR), to get more replicates. Broekhuis (1997) has earlier used these categories in the same way.

3.2.1 Species diversity

To analyse if there was a difference in diversity between the land use areas I have used observed number of species per transect (Appendix) in protected (NP and WMA) and unprotected (CGA and FR) areas, respectively. This is a simple measure of species richness. Night and day data were separated in the analyses to reveal possible differences between nocturnal and diurnal species richness if animals moved on a daily basis between areas with different land use. Alpha diversity (within habitat diversity) and beta diversity (among habitat diversity) (Hunter 1996) were also calculated. Alpha diversity is also a kind of measure of species richness but tested for in another way. The alpha diversity is in my study the mean number of species observed in each transect "site" in every land use area. I choose the sites to be 7.8 km long and the "left-over" sites that are not as long as 7.8 km were not included at all in that analysis. The beta diversity is the total number of species observed in each land use divided by the alpha diversity. The beta diversity is thus a sort of "variance measure" of the diversity in the land use areas. Day and night data were separated, and beta diversity for both domestic and wild species together and wildlife alone, was calculated.

3.2.2 Community structure and land use

Community patterns in space can be studied with gradient analyses, ordination or classification of communities (Begon et al. 1996). Ordination is a mathematical treatment that allows samples, in this case transect sites to be organised graphically so that those that are most similar in both species composition and relative abundance will appear closest together. Samples that differ greatly in the relative importance of a similar set of species or that possess quite different species, appear far apart. The axes of the graphs represent dimensions that effectively summarise species patterns. Species are displayed at their point of gravity based on their occurrence in the samples. The correlations with environmental factors, revealed by the analysis, give information about the kind and strength of the relationship between community compositions and underlying environmental factors. The results of the ordination emphasise that under a particular set of environmental conditions, a predictable combination of species is likely to occur (Begon et al 1996, Jongman et al 1995).

I used ordination methods to analyse how the species in Kalahari were arranged in relation to each other and to the different land use areas including distance to village and pan.

3.2.2.1 Selection of ordination technique

The ordination techniques that are most popular with community ecologists are direct and indirect gradient analyses. Indirect gradient analyses include Principal Components Analysis (PCA), Correspondence Analysis (CA) and Detrended Correspondence Analysis (DCA). The direct gradient tools are Canonical ordination techniques that are designed to detect the patterns of variation in the species data that can be explained by the observed environmental variables. Canonical ordination thus combines aspects of regular ordination with aspects of regression. The canonical form of CA is Canonical correspondence analysis (CCA). An important difference between indirect and direct gradient analysis is that indirect methods show all variation in the data set, regardless of whether the variation is correlated to the observed environment variables or not. The direct gradient analyses only show the variation that is explained by the measured environmental variables (Jongman et al 1995).

The indirect methods PCA and CA are suitable to detect different types of underlying data structures. PCA relates to a linear response model in which the abundance of any species either increases or decreases with the value of each of the potential environmental variables. CA is less strict than PCA and related to an unimodal response model when species have the best performance around some environmental optima. In CA, any species occurs in a limited range of values of each of the latent variables. Unimodal models are more general than monotonic ones and Jongman et al. (1995) suggest to start by using an unimodal model. If the lengths of the ordination axes for an unimodal model are less than about 2 S.D. most of the response curves will be monotonic and PCA might be used. If the ordination lengths in Detrended correspondence analysis (DCA) are greater than about 4 S.D. the data are strongly non-linear (Jongman et al. 1995, ter Braak and Smilauer 1998). My gradient length in DCA was 4.124 S.D. during day and 3.896 SD during night. Species data with many zeroes are often best analysed with an unimodal method (ter Braak and Smilauer 1998). My data include many zeroes, because of many sites where several of the species do not exist. These broad outlines including the seemingly non-linear response curve (Fig. 3.1) indicate that the species in my study show an unimodal response and therefore I have used correspondence analysis for the ordinations in the statistical package Canoco (version 4). The ordination axes in CA differ in importance and one would wish the scores to be spread out most along the most important axes, which is the first axis.

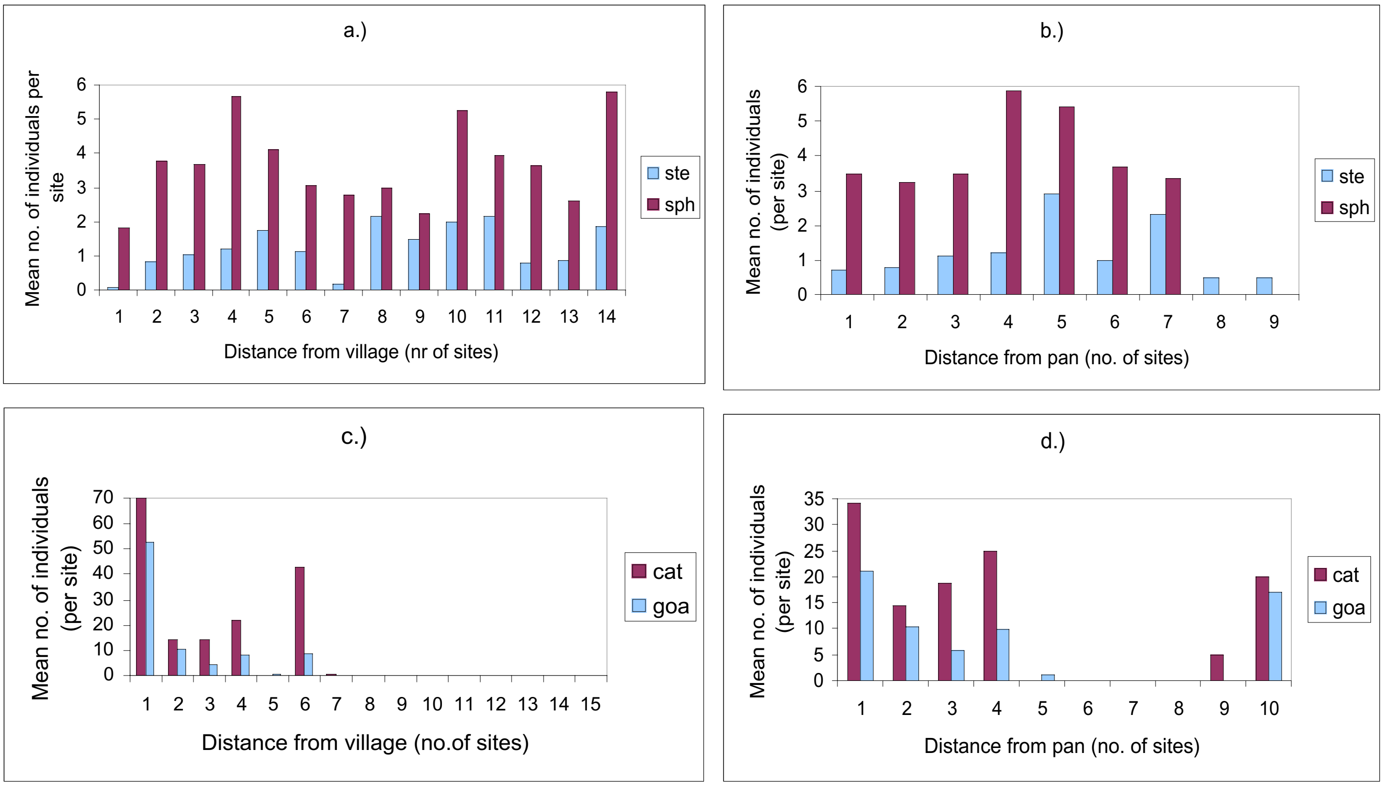


Figure 3.1. The species in this study do not seem to have a linear response to the environmental variables village (a. c.) and pan (b. d), but rather an unimodal response. This is illustrated firstly with the two most commonly observed wild species during night, steenbok (ste) and springhare (sph) (a. b). Secondly it is illustrated by the two most commonly observed domestic species during day, cattle (cat) and goat (goa) (c. d). Each site is 7.8 km long.

The statistical significance of the relationship between the species and the whole set of environmental variables can be evaluated using a Monte Carlo permutation test in CCA. The Monte Carlo permutation test was used to see which of the measured environmental variables that were most important to explain the variation in my data set. The permutation test is obtained by repeatedly shuffling the samples and it uses the *F*-ratio as test statistic. I did a stepwise selection procedure where the explanatory variable best fitting the species data is selected first and then the next best fitting variable is added. Before each addition, the significance of the explanatory effect of the candidate variable is evaluated using the Monte Carlo Permutation test.

3.2.2.2 Environmental variables

The four land use types CGA, FR, WMA and NP are all nominal environmental variables. Nominal environmental variables can in the ordination diagram naturally be represented as a point at the centroid of the sites belonging to that class. Classes of a nominal variable consisting of sites with high values for a species are then positioned close to the point of that species. Each nominal variable must be represented by a series of dummy variables each representing a category 1 or 0 depending on whether the sampling unit belongs or does not belong to the category (Jongman et al.1995, Ter Braak and Smilauer 1998).

Other environmental variables included are distance to village and pan. Villages are situated mainly in CGAs but some bushmen settlements do exist in WMAs. Pans are naturally occurring all over Kalahari and can thus exist in any of the four land use types. Distances from pan and village (in number of sites à 7.8 km) were used and represented in the ordination diagrams. Pans and villages can possibly have interaction effects with the nominal environmental variables, but because of the explanatory stepwise procedure of environmental variables in the Monte Carlo permutation test (see above) the interaction effects are not analysed exclusively.

3.2.2.3 Ordination analyses performed

I used 7.8 km sites for the ordination analyses. To be able to include the shortest transect of 3.9 km in the ordinations I doubled the numbers of animal observations in that transect. Since the sites are driven with unequal repetitions the number of observations of a species per site were divided with number of repetitions of that site. I analysed the unimodal data with indirect gradient analysis including the environment variables in Correspondence Analysis in Canoco. Hill's scaling and downtrending of rare species were the options I used. First I performed a CA including the 107 sites (à 7.8 km) and thirty-eight species. Second, I separated the day and night observations for the analyses to reveal differences in species compositions in night and day. The night data contained thirty-one species. The Correspondence analysis of the day data contained twenty-five species. The forward selection option in CCA was used to test the importance of the environmental variables using a Monte Carlo permutation test.

3.2.3 The distribution of red listed mammals

The IUCN red list of threatened species judges the conservation status of species on a global scale in order to highlight taxa threatened with extinction, and therefore promote their conservation. Observed mammal species that are listed in the 2002 IUCN red list was used in the analyses. The recorded wild mammals that are listed at "lower risk: conservation dependent" are gemsbok, kudu, red hartebeest, springbok and spotted hyena. Brown hyena is listed at "lower risk: near threatened". Lions is at higher risk of extinction, "vulnerable c2ai", which means that lions have got a population size estimated to number fewer than 10000 individuals, a continual decline in number of mature individuals and no sub-population estimated to contain more than 1000 mature individuals.

To analyse the possible difference in observed red listed species in the four land use areas I have counted observed number of species per transect, day and night separated. The number of all individuals of each observed red listed species was also counted in each transect and divided with total driven kilometres in that transect before the variance analysis. The proportion of the observations of each red listed species that was done in each of the four land uses categories, during day and night, respectively, was also calculated.

4. Results

4.1 Species diversity

Totally, I recorded thirty-eight species of mammals of the size of mongoose and larger as well as ostrich in the Kalahari study area in the dry season of 2002 (Table 4.1). Eight of these were domestic species. Table 4.1 shows order, family, common names, code names used in this study, scientific name as well as average body mass for all observed species. The smallest wild species recorded were slender mongoose, yellow mongoose, ground squirrel, suricate and striped polecat. The largest were cattle, blue wildebeest, gemsbok, kudu, red hartebeest and lion. Table 4.2 is a list of all counted individuals during the road side counts in each land use area as well as total number of counted species. 16 553 individuals were counted in total and 12 826 of them were domestic animals. No domestic animals at all were observed in the NP and in the WMAs there were much fewer observations of livestock than in CGAs and FRs. The domestic species together accounted for 77 % of the individuals observed (Table 4.2). Cattle were by far the most commonly observed species, followed by goat, springbok and springhare (Table 4.2). The most counted wild animal during night was springhare in all land use types. During day, springbok was the most common wild animal in WMA, NP and CGA but in FR ground squirrel was most common during daytime.

Table 4.1. Order and family as well as the body mass for all studied species. Nomenclature and taxonomy for mammals follow Skinner & Smithers 1990 and for ostrich Gordon, Lindsay and Maclean 1984. Red listed species are marked with an asterisk (*).

WILDLIFE	**Common name**	**Code name**	**Scientific name**	**Mass (kg)**
Artiodactyla				
Bovidae	Blue wildebeest	wil	*Connochaetes taurinus*	180-250
	Common duiker	cdu	*Sylvicapra grimmia*	18-21
	Gemsbok*	gem	*Oryx gazella*	210-240
	Kudu*	kud	*Tragelaphus strepsiceros*	180-250
	Red hartebeest*	rhb	*Alcelaphus buselaphus*	120-150
	Springbok*	spr	*Antidorcas marsupialis*	37-41
	Steenbok	ste	*Raphicerus campestris*	11
Suidae	Warthog	war	*Phacochoerus aethiopicus*	45-105
Carnivora				
Canidae	Bat-eared fox	bfx	*Otocyon megalotis*	3-5
	Black-backed jackal	bbj	*Canis mesomelas*	6-10
	Cape fox	cfx	*Vulpes chama*	2,5-4
Felidae	African wild cat	awc	*Felis lybica*	2,5-6,0
	Caracal	car	*Felis caracal*	7-19
	Leopard	leo	*Panthera pardus*	17-90
	Lion*	lio	*Panthera leo*	110-225
Hyaenidae	Brown hyena*	bhy	*Hyena brunnea*	42-47
	Spotted hyena*	shy	*Crocuta crocuta*	60-80
Mustelidae	Honey badger	hbg	*Mellivora capensis*	8-14
	Striped polecat	spc	*Ictonyx striatus*	0,5-1,4
Viverridae	Slender mongoose	smg	*Galerella sanguinea*	0,37-0,8
	Small-spotted genet	sgn	*Genetta genetta*	1,5-2,6
	Suricate	sur	*Suricata suricatta*	0,62-0,96
	Yellow mongoose	ymg	*Cynictis penicillata*	0,45-0,9
Protelidae	Aardwolf	aaw	*Proteles cristatus*	6-11
Lagomorpha				
Leporidae	Cape hare/ Scrub hare	har	*Lepus capensis/saxatilis*	1,4-4,5
Rodentia				
Hystricidae	Porcupine	por	*Hystrix africaeaustralis*	10-24
Pedetidae	Springhare	sph	*Pedetes capensis*	2,5-3,8
Sciuridae	Ground squirrel	gsq	*Xerus inauris*	0,5-1
Tubulidentata				
Orycteropodidae	Aardvark	aav	*Orycteropus afer*	40-70
Struthioniformes				
Strutionidae	Ostrich	ost	*Struthio camelus*	59-81
LIVESTOCK				
Artiodactyla				
Bovidae	Cattle	cat	*Bos taurus*	450
	Goat	goa	*Capra hircus*	26-42
	Sheep	she	*Ovis aries*	25-36
Camelidae	Camel	cam	*Camelus dromedarius*	450-650
Carnivora				
Canidae	Dog	dog	*Canis familiaris*	12-75
Felidae	Domestic cat	doc	*Felis catus*	3-6
Perissodactyla				
Equidae	Donkey	don	*Equus asinus*	275
	Horse	hor	*Equus caballus*	350-700

Table 4.2. Number of animals counted day and night for each species in the different land use areas.

Species	CGA		FR		WMA		NP		*All*		
	Day	Night	Day	Night	Day	Night	Day	Night	*Day*	*Night*	***Total***
Wildlife:											
Aardvark	0	0	0	0	0	4	0	1	0	5	**5**
Aardwolf	0	0	0	0	0	2	0	0	0	2	**2**
African wild cat	0	5	0	6	0	16	0	14	0	41	**41**
Bat-eared fox	0	10	0	4	0	21	0	24	0	59	**59**
Black-backed jackal	0	15	0	5	9	20	3	17	12	57	**69**
Blue wildebeest	0	0	0	0	23	0	64	44	87	44	**131**
Brown hyena	0	2	0	1	0	4	0	3	0	10	**10**
Cape fox	0	1	0	7	0	21	0	7	0	36	**36**
Cape / Scrub hare	2	23	0	21	0	30	1	18	3	92	**95**
Caracal	0	2	1	0	0	1	0	1	1	4	**5**
Common duiker	1	1	0	2	3	6	2	0	6	9	**15**
Gemsbok	0	0	0	1	21	7	76	36	97	44	**141**
Ground squirrel	28	0	115	0	59	0	11	0	213	0	**213**
Honey badger	0	3	0	0	0	0	1	0	1	3	**4**
Kudu	0	0	0	0	12	0	3	0	15	0	**15**
Leopard	0	0	0	0	0	3	0	4	0	7	**7**
Lion	0	0	0	0	0	3	2	0	2	3	**5**
Ostrich	28	0	0	0	32	1	12	0	72	1	**73**
Porcupine	0	2	0	3	0	5	0	1	0	11	**11**
Red hartebeest	9	4	7	11	63	20	65	22	144	57	**201**
Slender mongoose	2	0	2	0	6	0	4	0	14	0	**14**
Small-spotted genet	0	2	0	3	0	17	0	4	0	26	**26**
Spotted hyena	0	0	0	0	0	0	0	6	0	6	**6**
Springbok	97	37	1	3	295	54	369	67	762	161	**923**
Springhare	0	206	0	81	0	386	0	207	0	880	**880**
Steenbok	20	37	12	38	123	136	86	53	241	264	**505**
Striped polecat	0	1	0	0	0	2	0	0	0	3	**3**
Suricate	43	0	2	0	92	0	47	0	184	0	**184**
Warthog	0	0	0	0	4	0	0	0	4	0	**4**
Yellow mongoose	11	0	18	0	14	0	1	0	44	0	**44**
Tot	**241**	**351**	**158**	**186**	**756**	**759**	**747**	**529**	**1902**	**1825**	**3727**
Domestic:											
Camel	0	0	0	0	1	1	0	0	1	1	**2**
Cattle	2932	684	3060	1117	70	27	0	0	6062	1828	**7890**
Dog	54	10	60	14	22	6	0	0	136	30	**166**
Domestic cat	0	1	0	1	0	1	0	0	0	3	**3**
Donkey	466	44	138	16	83	23	0	0	687	83	**770**
Goat	1690	237	657	323	393	61	0	0	2740	621	**3361**
Horse	94	22	103	29	28	0	0	0	225	51	**276**
Sheep	109	0	217	0	32	0	0	0	358	0	**358**
Tot:	**5345**	**998**	**4235**	**1500**	**629**	**119**	**0**	**0**	**10209**	**2617**	**12826**
All total:	**241**	**351**	**158**	**186**	**756**	**759**	**747**	**529**	***1902***	***1825***	***16553***

There was a significant difference in wildlife species richness between unprotected and protected areas, during both day and night (Table 4.3). More wild species were observed in protected areas than unprotected (Fig. 4.1a and b).

Table 4.3. Tests for difference in wildlife species richness in protected areas versus unprotected areas

Time	Significance	n	H	df	p
day	**	22	8.15	1	0.004
night	**	21	17.16	1	0.007

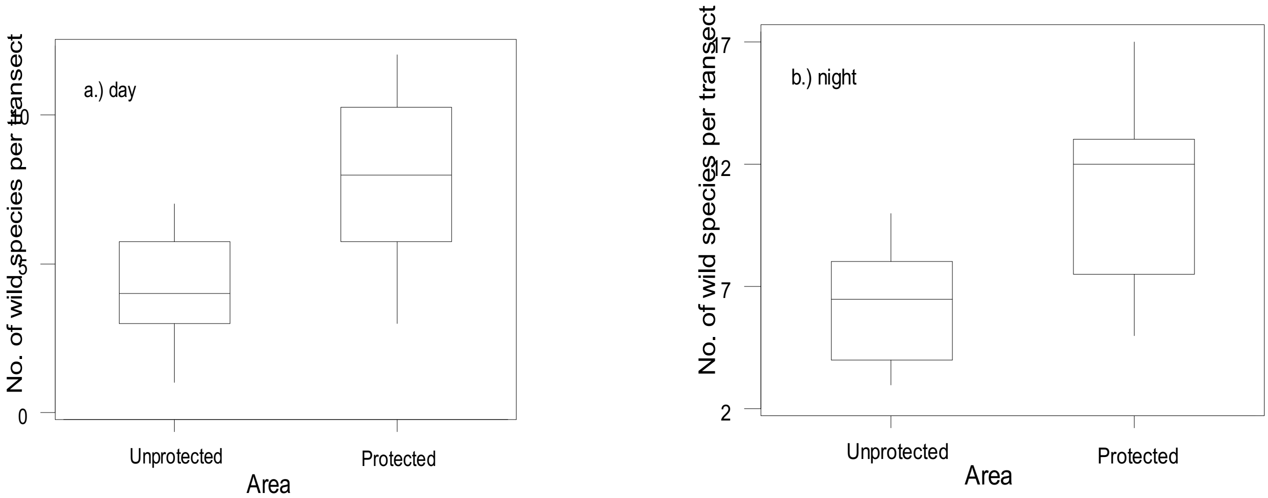


Figure 4.1. There were more wild species observed in protected areas than unprotected both day a) and night b). The figures are box-and-whisker plots with the median as a line drawn across the box. By default, the bottom of the box is at the first quartile (Q1), and the top is at the third quartile (Q3) value. The whiskers are the lines that extend from the top and bottom of the box to the adjacent values. The adjacent values are the lowest and highest observations that are still inside the region defined by the following limits: Lower Limit:Q1 - 1.5 (Q3 - Q1) Upper Limit:Q3 + 1.5 (Q3 - Q1) (2000 Minitab, Inc).

Significantly more wild species were observed during nights, compared with days, when tests were performed on all counts and on counts from unprotected areas (Table 4.4 and Fig. 4.1 a, b). A similar trend was noted for counts from protected areas.

Table 4.4. Tests for difference in number of observed wild species between day and night.

Area	Significance	n	H	df	p
All	*	43	4.21	1	0.040
Protected	NS	19	3.43	1	0.064
Unprotected	*	24	4.44	1	0.035

There were large differences in alpha diversity of wild species between the four different land use areas (Fig. 4.2) (n=178, H=55,92, DF=3, P=0,000). Largest alpha diversity was in NP, followed by FR, WMA and lastly, CGA.

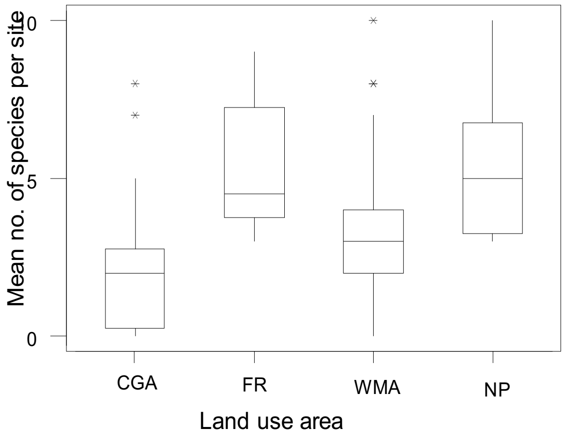


Figure 4.2. There was a significant difference in the alpha diversity between the four different land use areas. NP had the largest alpha diversity., followed by FR, WMA and CGA. Outliers are points outside of the lower and upper limits (Fig. 4.1) and are plotted with asterisks (*).

Beta diversity for all species was highest in WMA and lowest in FR (Fig. 4.3 a) and for wild species highest in CGA and lowest in FR (Fig. 4.3 b). The total number of observed wild species in respective land use areas seem to be larger in NP and WMA than CGA and FR, both day and night, but seemingly more during night (Fig. 4.3 c).

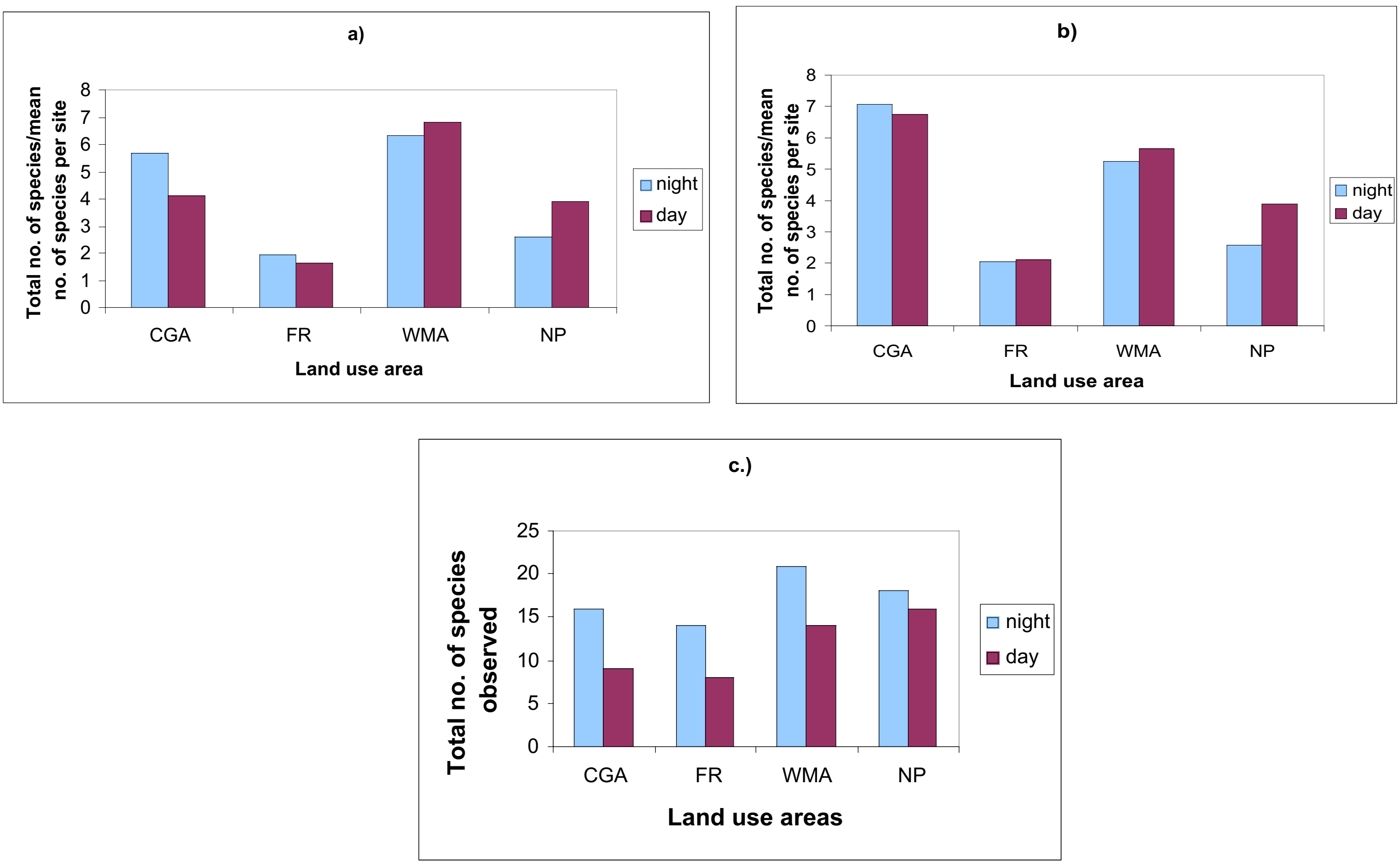


Figure 4.3. Beta diversity for all species was highest in WMA and lowest in FR a). Beta diversity for wild species is shown in b) and was highest in CGA and lowest in FR. The total numbers of wild species observed in the different land use areas are shown in c), and were highest in NP and WMA.

4.2 Community structure and land use

The species ordination diagram (Fig. 4.4) clearly separates the species according to land use types into two areas, WMA and NP are placed to the right along the first axis and CGA and FR are placed to the left along the first axis. The wildlife is situated furthest away from village (arrow d (village)) as well as only in the right side of the diagram. The livestock is placed on the left side, closest to the villages. Cattle are placed closest to Fenced ranches. Distance from pan (arrow d (pan)) explains some of the variation too, animals placed closest to pan seem to be ground squirrel, springbok and blue wildebeest.

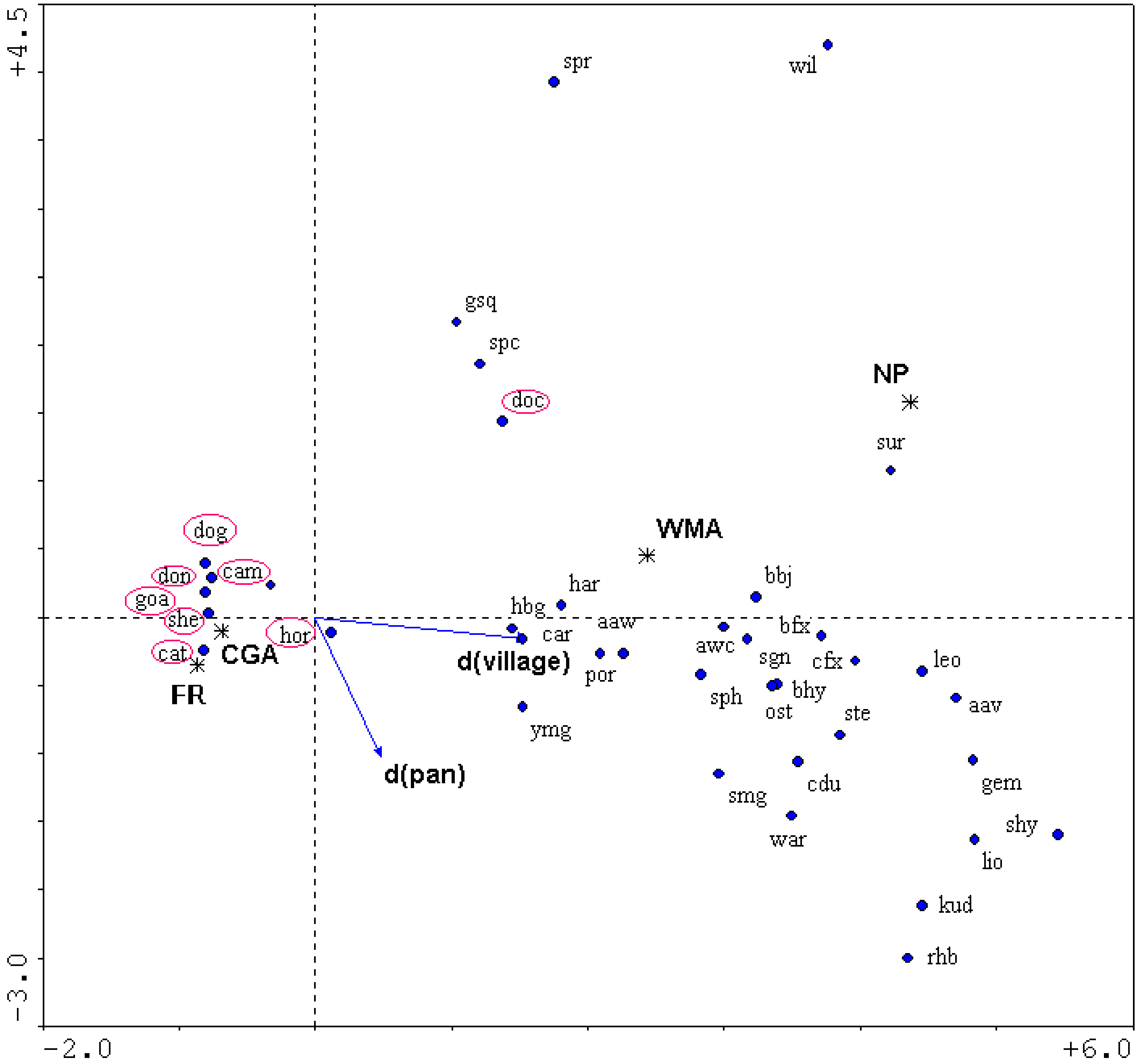


Figure 4.4. Species ordination diagram in CA displays the relation between observed species and between observed species and the environmental variables measured for day and night observations together. The land use types are represented as centroids but distances from pan as well as distance from village are represented as arrows. For full species names, see table 4.1. All domestic animals are encircled.

An ordination diagram was produced, showing all transect sites with a symbol for the land use type they belonged to (Fig. 4.5). Note that the sites from the NP and FR are very concentrated.

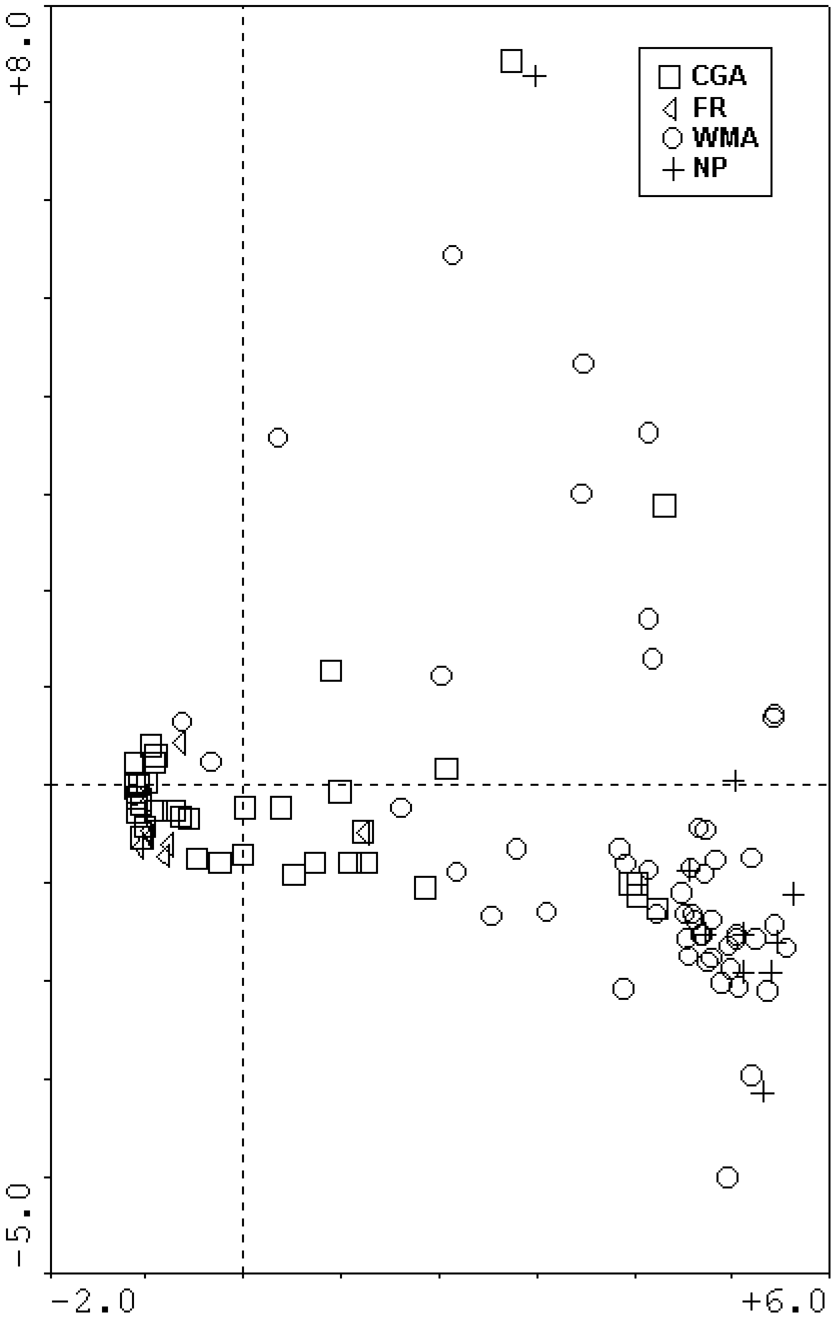


Figure 4.5. Site ordination diagram showing sites labelled with land use symbols.

The possible animal communities distinguished in my study sites (Fig. 4.6) were based on the species ordination diagram (Fig. 4.4) together with the site ordination diagram (Fig. 4.5). The clusters were subsequently subjectively drawn.

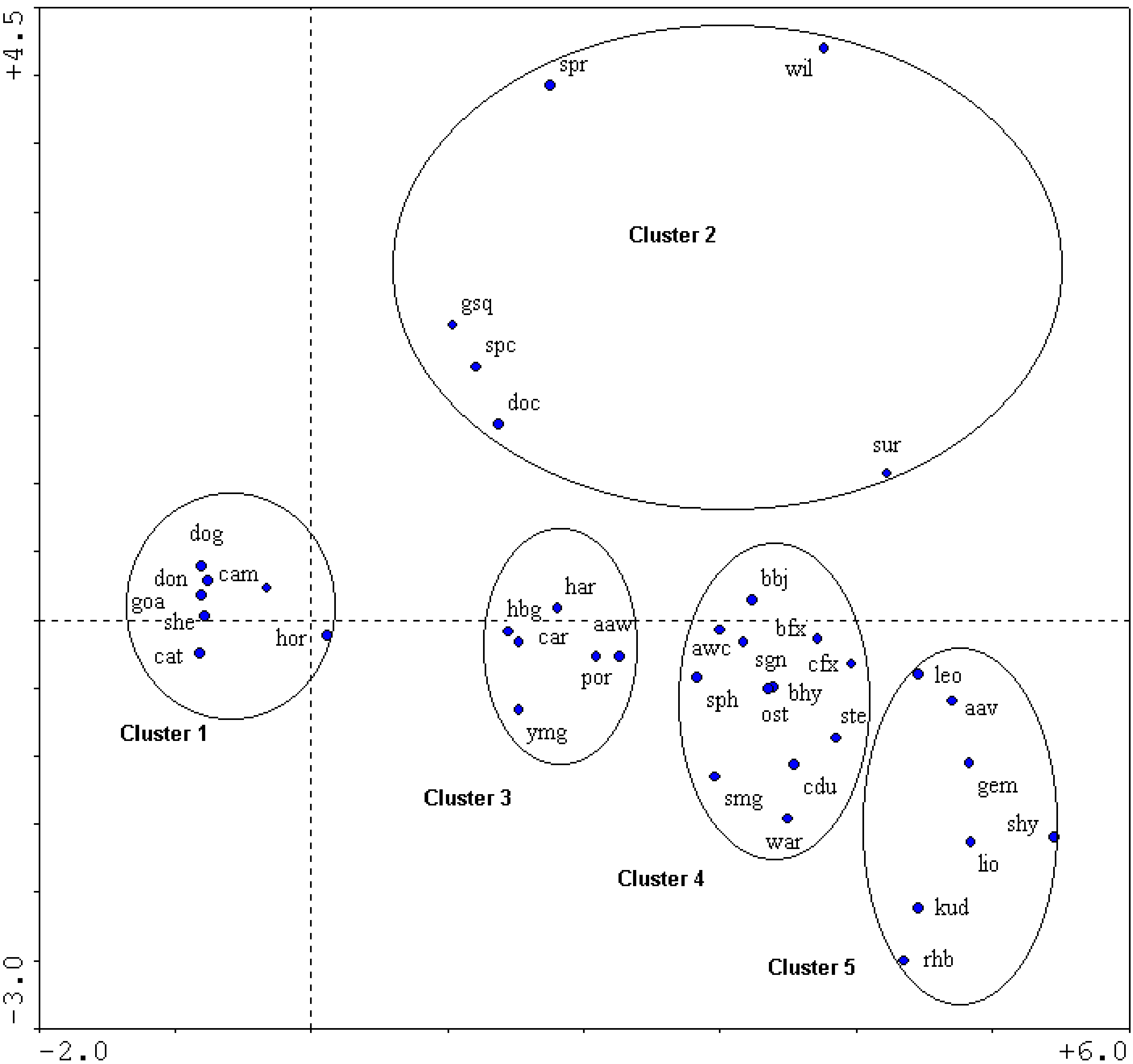


Figure 4.6. Species ordination diagram for all observed species, same as Figure 4.4 but with clusters distinguished, encircled and marked Cluster 1-5.

Clusters distinguished were:

1. cattle, camel, dog, donkey, goat, horse and sheep
2. blue wildebeest, domestic cat, ground squirrel, striped polecat, springbok, suricate
3. aardwolf, caracal, hare, honey badger, porcupine, yellow mongoose
4. african wild cat, bat-eared fox, black-backed jackal, brown hyena, cape fox, common duiker, ostrich, slender mongoose, small-spotted genett, springhare, steenbok, warthog
5. aardvark, gemsbok, leopard, lion, kudu, red hartebeest, spotted hyena

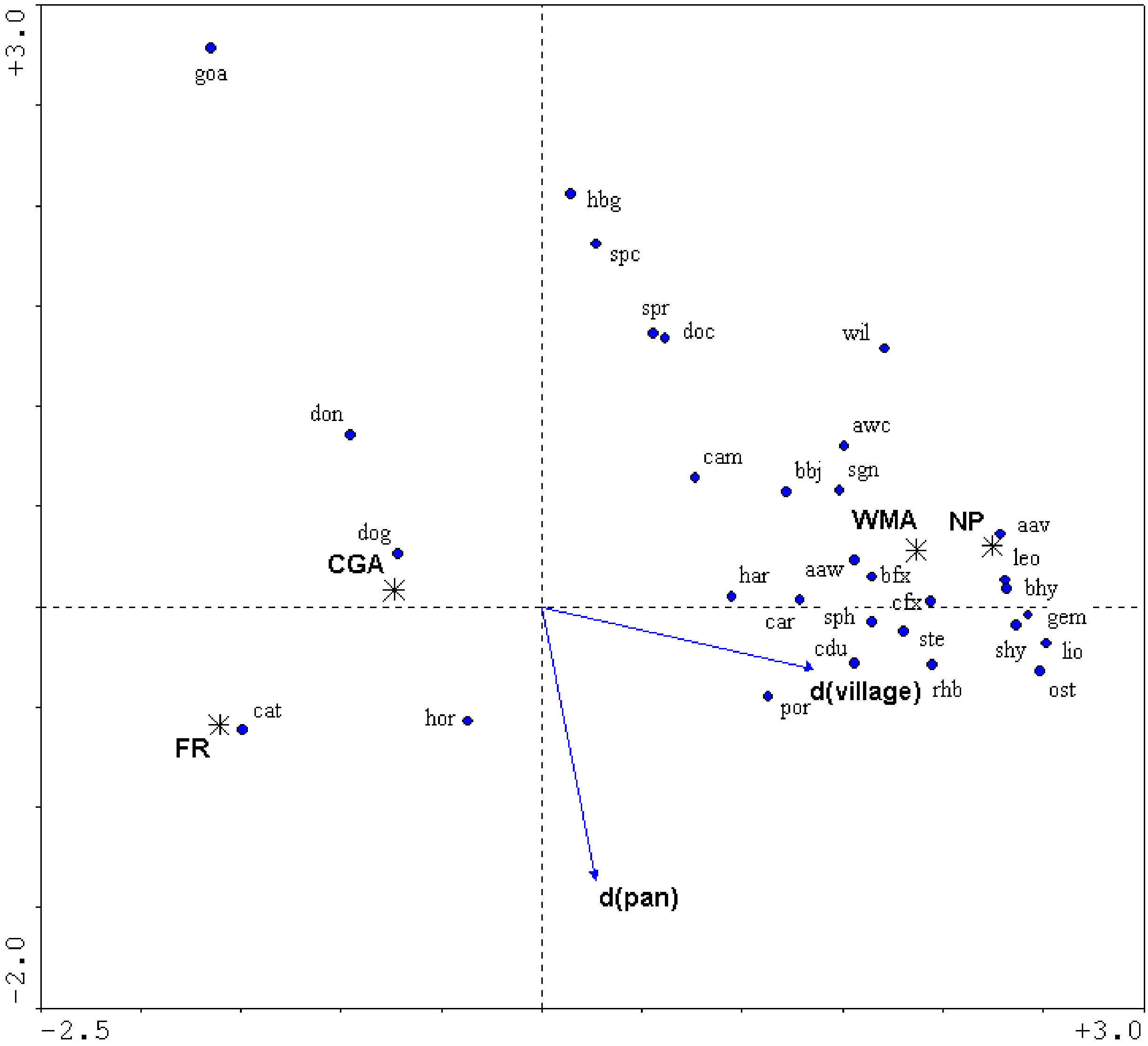


Figure 4.7. Species ordination diagram in CA displays the relation between observed species during night and between observed species and the environmental variables measured.

As in figure 4.4, the night species ordination diagram (Fig. 4.7) clearly separates the species along a land use gradient, with WMA and NP placed to the right along the first axis and CGA and FR to the left. The wildlife are situated furthest away from village (arrow d (village)) as well as only in the right side of the diagram. The livestock are placed mainly in the left side, closest to the villages. Animals related, in the diagram, to pan are springbok, striped polecat, honey badger and goat.

WMA is the variable that explains most of the variance in my night data, as much as 32%, followed by distance to village, FR, distance from pan and NP (Table 4.5). All these, except for NP, are significant environmental parameters to explain the animal distribution during night. As much as 73 % of all variance in this data set are explained by the measured variables.

Table 4.5. Data variance explained by environmental variables during night.

Env. Variable	p-value	F	Variance explained (%)
WMA	0.005	10.64	32
d(village)	0.005	6.31	18
FR	0.010	3.74	11
d(pan)	0.005	3.18	9
NP	0.140 NS	1.46	3

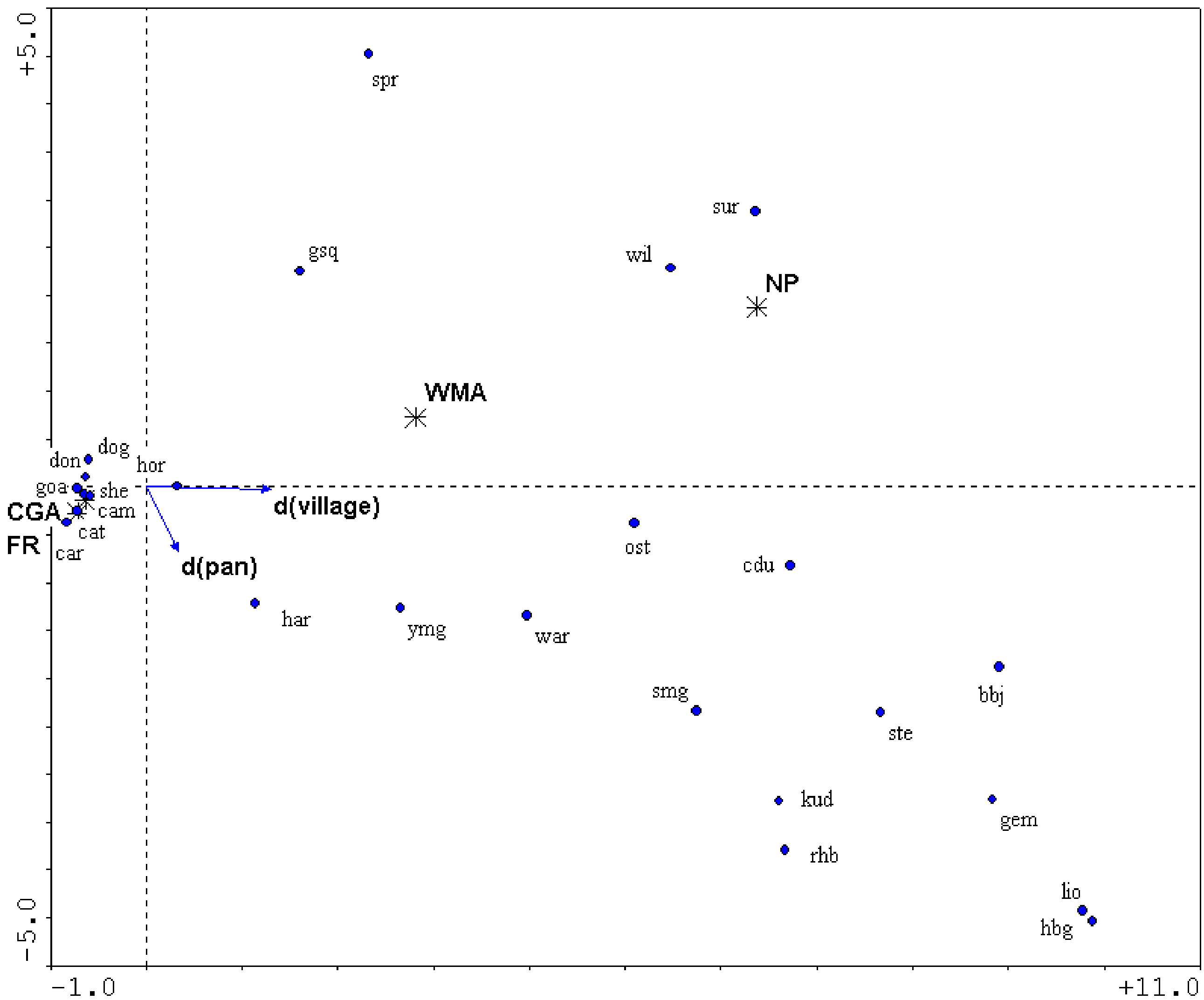


Figure 4.8. Species ordination diagram in CA displays the relation between observed species during day and between species and the environmental variables measured. The land use types are represented as centroids but distances from pan as well as distance from village are represented as arrows.

The same trends as the night ordination showed are also shown during day (Fig. 4.8). The day species ordination diagram also clearly separates NP and WMA to the right of the first axis and CGA and FR to the left. Livestock were positioned to the left, closest to villages, and wildlife to the right. Caracal is the only wild animal positioned together with the domestic species. There was only one caracal observed during daytime during the field observations, and that was on a Fenced ranch. Springbok (together with ground squirrel), as in the night species ordination are also shown to be related to pans.

Distance to village is the variable that explains most of the variance in my day data, 29 %, followed by FR, CGA, NP and distance from pan (Table 4.6). All these except distance from pan are significant environmental parameters to explain the animal distribution during day. 87 % of all variance in this data set are explained by the measured variables.

Table 4.6. Data variance explained by the environmental variables during day.

Env. Variable	p-value	F	Variance explained (%)
d(village)	0.005	7.32	29
FR	0.005	6.95	26
CGA	0.005	4.66	16
NP	0.015	3.40	12
d(pan)	0.300 NS	1.14	4

4.3 The distribution of red listed mammals

There is a significant difference in observed numbers of red listed species (per transect) between protected areas and unprotected both during day (n=22, H=7,12, DF=1, P=0.008) and night (n=21, H=4,42, DF=1, P=0.035 (Fig. 4.11 a, b). NP seems to have more red listed species than any other land use area.

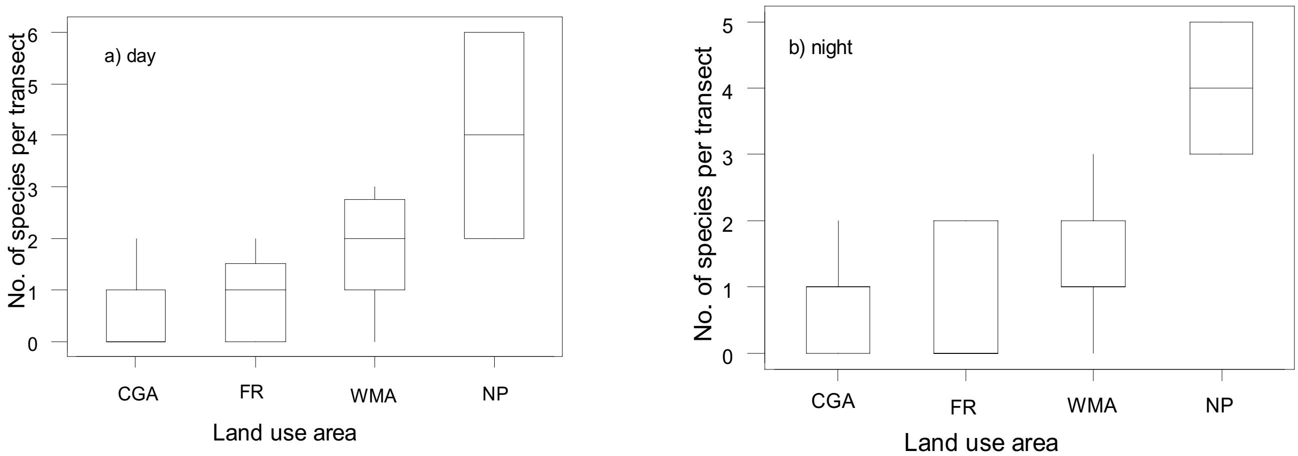
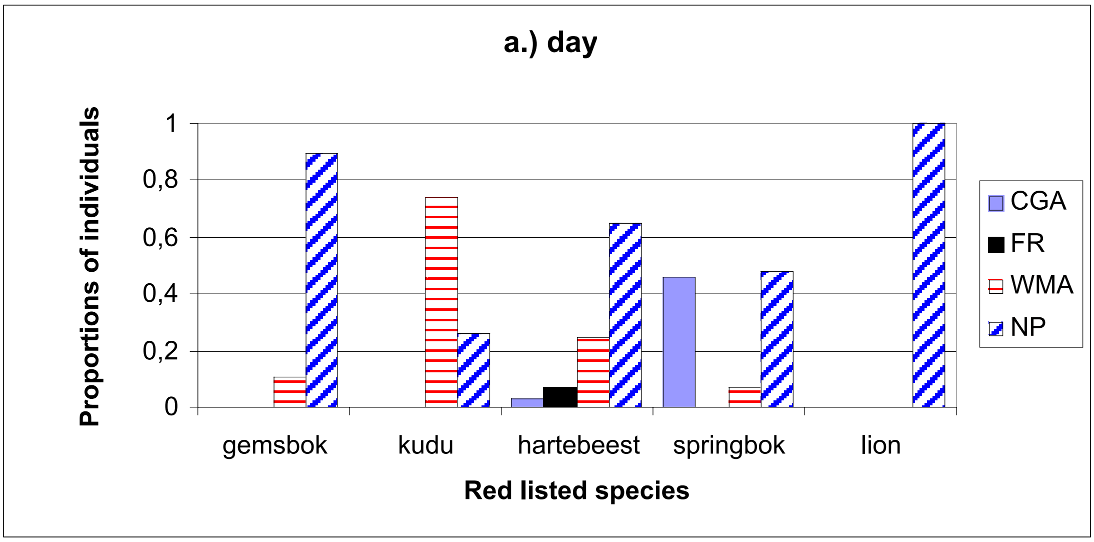


Figure 4.11. There is a large difference in number of red listed species both day a) and night b) between the land use areas. NP seems to have most red listed species.

A significant difference was also shown for numbers of individuals of red listed species per kilometre between protected and unprotected areas (N=43, H = 4,66 DF = 1, p= 0,031). The proportion of the observations of every red listed species which were done in each land use area is shown in Fig. 4.12 a. and b. During day-time a larger proportion of the red listed individuals were observed in NP and WMA than in CGA and FR (4.12 a.). Note that springbok is also observed in CGA during daytime. More red listed individuals seem to be observed in CGA and FR during night than during day. However, highest proportions of red listed individuals are still found in NP and CGA during night.



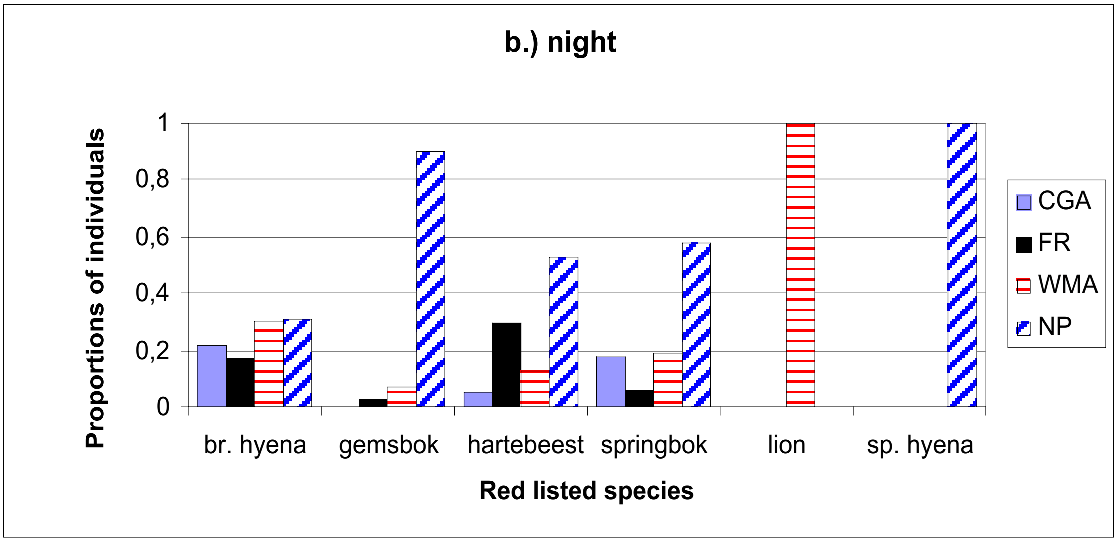


Figure 4.12. Proportions of red listed animals in respective land use type are shown during day a) and night b), respectively. Proportions of individuals are based on mean no. per km. Total no. of observed individuals during day / night, respectively: gemsbok 97 / 44, kudu 15 / 0, hartebeest 144 / 57, springbok 762 / 161, brown hyena 0 / 10, lion 2 / 3 and spotted hyena 0 / 6. Individuals of red listed species seem to reside mostly in WMA and NP, especially during night.

5. Discussion

5.1 Species diversity
This study indicates that the wildlife species richness differs between land use areas in the Kalahari. Areas with much domestic animals, i.e. Communal grazing area (CGA) and Fenced ranches (FR), seem to have less wildlife than Wildlife management areas (WMA) and the National park (NP). Competition from domestic species and disturbances like hunting and other activities from village peoples may affect wild animals' distribution (Parris & Child 1973). One expressed view is that a shift from wildlife to livestock is "an ecological mismatch" (du Toit & Cumming 1999). These authors suggest that most indigenous large herbivore communities in African savannahs are dominated by four or five large species, which are most vulnerable to hunting and also least matched for substitution by domestic species. According to Skarpe (1991) the basic differences between domestic and wild herbivores are not in the animals as such, but rather in the management of livestock. The domestic animals are often restricted in their movements and they are often kept in higher population densities than indigenous large herbivores. This may be explained by water supplementation and protection from natural predation and diseases. Livestock are perhaps "more of a constraint on the ecosystem and less of an interactive component of it" (Skarpe 1991, Skarpe 1992).

My data indicate that there are less differences in number of observed wild species between land use areas during night-time than during day-time. There are large differences between day and night in number of observed wild species in CGA and FR, where more species were seen during night than day. Human disturbance in CGA and FR is probably much less during night than day. Animals are probably more easily hunted during day than during night. Nocturnal animals are less active during day and may hide so that they are recorded to a lesser extent during day-time. Another possibility is that wild mammals that are active during night may stay in WMA and NP during day and move to CGA and FR during night when some livestock are kraaled and the villagers are asleep. The villages are noisier during day and may scare wildlife away more during day than during night.

The high beta diversity in WMA reflects large variations in both livestock and wildlife distributions. Since some settlements and cattle posts exist in WMA there are some local concentrations of domestic mammals. At the same time, many parts of WMA's are remote areas (e.g. close to Kgalagadi Transfrontier Park) and contain unsettled pans that support many wild animals. All these characters add to a high beta diversity. The high beta diversity in CGA for wild species only, may be explained by pronounced habitat differences along the gradient from the centres of cattle posts and villages to the virtually unaffected areas far from these elements. Some wild mammals may in fact also benefit from the activities in the CGA's. For example, large predators/scavengers may prey on livestock or eat carcasses. Further, water from boreholes set aside for livestock may tempt some wild animals, and insectivores may benefit from beetles and other creatures that use cattle dung (pers. obs.). Livestock may also facilitate foraging of smaller herbivores, like steenbok and springbok. Earlier studies in fact suggest that springbok are attracted to areas of shorter grass cover associated with pan areas but also livestock grazing (Verlinden 1997, Verlinden et al. 1998). All this may add to a high diversity variation within CGA and then the beta diversity consequently becomes high.

5.2 Community structure and land use

Distribution of species

It appears to be large contrasts between the distribution of domestic species and of wild species. Livestock and wildlife do not seem to reside together and wild species seem to keep away from villages, FR and CGA, especially during day-time. The livestock is, not surprisingly, concentrated in FR and CGA. Earlier studies have shown that distance from villages and pans are important in affecting species distributions (Bergström and Skarpe 1999, Wallgren 2001). Many species of wildlife also tend to concentrate at or near pans (Parris & Child 1973, Bergström and Skarpe 1999). When pans are occupied by large permanent villages the number of wild animals using the pan is seriously reduced (Parris & Child 1973). Wildlife was on average first observed 10 km away from villages (Bergström & Skarpe 1999). My study confirms that pans and villages play a role in the distribution of mammal species but also clearly indicates that type of land use affects species distributions. Villages seem to have a larger role than pans in my study perhaps because some pans have become occupied by villages and/or cattle. Which other environmental variables may explain the rest of the variance in my data set? One study performed in the same area of Kalahari but in the wet season and based on aerial surveys revealed that distance to borehole, grass greenness, fire and tree cover explained wildlife and livestock distribution (Verlinden 1997). Boreholes both for cattle and for settlements were used in that analysis and since livestock are confined to boreholes they appear to be a highly useful index of human impact in the Kalahari. Another study performed in the dry season and the same area, showed that additional parameters like rain and cloudiness during day and time of season during night (Wallgren 2001), seemed to explain some of that data's variance. Perhaps some of these parameters referred to above could explain my variance too.

Species compositions

This study indicates that there are large differences in animal communities in the different land use areas. Five clusters of species forming animal communities were distinguished (Fig. 4.6). Cluster 1 may be seen as a "livestock-community" and cluster 2 as a "pan-community". Cluster 3, 4 and 5 might be seen as wildlife communities with different degrees of disturbance, where cluster 5 is a community furthest away from disturbance. It is difficult (if not impossible) to make conclusions in cases when only a few observations have been made of rare species.

The largest difference between day and night ordinations seems to be that wildlife are further away from villages, CGA and FR during days. It does not seem to be large differences between day and night considering species that have commonly been observed both periods. During day and night a distinctive cluster with only domestic animals (one exception) was found, the "livestock-community" or cluster 1. These animals reside mainly within CGA or FR and close to villages. No wildlife species seem to form a community together with the community of domestic species. Cluster 2, the "pan-community", can be interpreted as a community on or close to pans, with springbok and blue wildebeests observed both day and night. Suricate and ground squirrel were observed in day time. These animals are all commonly observed on pan habitats. The common species in this "pan-community" seem to be mostly determined by pan area and not first by type of land use. Cluster 3 seems to be in or around WMAs and far away from villages, but closer to CGA and FR than the other wildlife communities. This community includes for example yellow mongoose and hare and these animals are probably less affected by human disturbance. The species in cluster 4 are notably small herbivores, insectivores, and small carnivores. Cluster 5 is the community most far away from the villages, CGA, FR and also livestock. The largest carnivores (lion, leopard, spotted hyena and brown hyena) are found in this community, where also large herbivores like gemsbok, red hartebeest and kudu, as well as aardvark are found. Black backed jackal "change" to more remote areas from night to day. Black backed jackal are according to Stuart & Stuart (2001) mainly nocturnal when in conflict with man, but is frequently seen in protected reserves during day. This corresponds to my experience of more day observations of black backed jackal in NP than in any other area. According to the literature, steenbok are active at night mainly in disturbed areas (Stuart & Stuart 2001) but in the ordination diagram for night they are still far away from villages, CGA and FR.

Springbok, steenbok and common duiker (and ostrich) are suggested to be less influenced by human settlement than other wildlife species (Verlinden 1997). As said above, springbok are attracted to areas with shorter grass associated with pan areas but also with livestock grazing areas (Verlinden 1997, Verlinden et al. 1998). Livestock may consequently facilitate for springbok but a community with springbok and livestock was not confirmed by this study. Steenbok and common duiker are browsers and livestock may also facilitate foraging for these species (Wallgren 2001, Verlinden 1997, Verlinden et al. 1998). No community with these small ungulates and livestock could be indicated here. Therefore, no coexistence between wild herbivores and livestock seems to occur. My study, however, does not reject the possibility that springbok, steenbok and common duiker are less influenced by human settlements than other wildlife species. Why this study did not show any animal community consisting of both wild and domestic animals may be a result of hunting and poaching or other disturbances and not by avoidance by wildlife of livestock themselves. A study in southern Kalahari suggests that selective wildlife utilisation is a more important factor in the current distribution of common game species than avoidance of areas changed by livestock (Verlinden et al. 1998).

5.3 The distribution of red listed mammals

The ordination diagram (Fig 4.4) reveals that five of the seven red listed species are placed furthest away from CGA, FR and village. The other two red listed species are springbok, that are placed close to pan, and brown hyena, that are placed in the middle of most of the wild species. Variance analyses also show that there are more red listed species in NP and WMA areas than CGA and FR both during day and night. More individuals of these species were also observed in undisturbed areas. Proportions of red listed animals appeared to be largest in NP followed by WMA.

My study shows that gemsboks are confined to protected areas, WMA and areas without cattle and other studies are in agreement with this (Crowe 1995, Broekhuis 1997, Thouless 1998, Verlinden et al. 1998). Reasons for gemsbok being outside disturbed areas are probably not competition with cattle but hunting and poaching (Verlinden et al. 1998). My study indicates that hartebeest are found mostly in protected areas in the dry season and this has been found earlier (Verlinden et al. 1998). Springbok is mainly distributed outside protected areas (Broekhuis 1997, Thouless 1998) and my study does not reject that. Springbok prefer pan-like areas (Thouless 1998, Verlinden 1997, Verlinden et al. 1998) and this seems to be more important for the springbok than avoidance of disturbance.

5.4 What are the consequences of the mammal trends in Kalahari?

My study clearly indicates an effect of land use on richness and composition of wildlife species. How important then is species diversity? Can we lose a few, several or many species and still maintain productivity, nutrient cycling, community stability or resilience in the face of disturbance? Today, there is no simple answer and no one actually knows (Begon et al.1996).

Despite the generous allocations of protected areas to wildlife the fauna is still declining in the Kalahari (Crowe 1995, Mordi 1989, Thouless 1998). Since much of the Kalahari is protected it would be considered enough for preserving a sufficient representation of the wildlife. However, it has been argued that the Kalahari is different and that wildlife populations in the protected areas cannot be sustained unless they have access to the surrounding unprotected areas (Crowe 1995). Species that drink water regularly need to migrate during droughts or prolonged dry seasons. Many reserves and National parks are waterless and combined with the fact that fences prevent migration, the strategy is not enough (Mordi 1989). The general avoidance of livestock areas by gemsbok, wildebeest, hartebeest and eland suggests that populations of these species occurring in southern and central Kalahari might become separated if the area occupied by livestock increases along the boundary between the protected and unprotected areas (Crowe 1995, Verlinden 1997). The need to maintain the integrity of the protected areas by preventing livestock encroachment into them cannot be overstated, if the Kalahari is to retain significant herds of large herbivores (Verlinden 1997).

The Department of Wildlife and National Parks (DWNP) in Botswana bases its hunting quotas on aerial surveys (Bonificia 1992) and reduced wildlife populations means reduced legal subsistence hunting for local people and also reduced income from tourist hunting (Broekhuis 1997). Foreign tourists pay a lot of money to hunt or just view game animals in Botswana and less animals to shoot and photograph means reduced attractiveness for tourists. That means less income to the state from tourism but also a problem for many local people that are employed by safari companies and lodges. Also, with almost unlimited livestock increases, the productivity of the Kalahari will steadily decline until it supports neither livestock nor wildlife (Campbell 1981).

5.5 Conclusions

This is the first study of comparisons between land use areas in the Kalahari regarding large mammal species. I have shown that the wildlife species richness differs between land use areas. Areas that have much domestic animals, i.e. Communal grazing areas and Fenced ranches, seem to have less wildlife than Wildlife management areas and National parks. My results moreover indicate that species compositions differ between the land use areas. No clear animal community consisting of both wild and domestic animals could be shown and coexistence between indigenous herbivores and livestock is therefore not likely to occur. Type of land use as well as distance from village and pan seems to affect species distributions. Analyses also indicate that there are more red listed species and individuals of these species in NP and WMA areas than CGA and FR both during day and night.

To verify these conclusions further, additional field data from other methods like counts of track and dung (Verlinden et al.1998) or capture-recapture Lincoln-Petersen method (Castley et al. 2002) would be desirable. Comparison of data from different methods would for instance reduce the effect of the vehicle scaring animals away before they are observed, minimise observer bias and risk of double-counting. Also measures of other environmental variables as well as observations of other taxa would broaden the view of how type of land use affects species diversity, distributions and abundance. These results need also to be tested further on data sets from other savannah ecosystems.

The results of this study may help in conducting wise land use and wildlife conservation in order to prevent further declines of the unique fauna of the Kalahari and also for obtaining a proper use of both livestock and wildlife for the benefit of the people of Botswana.

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Appendix

Study areas, showing all driven transects with number of road counts, mean time for driving each road count, distance driven each road count and start and end coordinates for each transect. The names of the villages and other areas in the table are cited from maps of the area (Botswana 1:250 000), published by Department of Surveys and Lands, Gaborone, 1979.

Transects	**No. of road counts**		**Mean time per drive**	**Distance per drive**	**Start coordinates**		**End coordinates**	
	day	***night***	**(h:min)**	**(km)**	**south**	**east**	**south**	**east**
CGA Communal Grazing								
Hukuntsi NW	2	2	02:49	41,7	2358996	2145617	2348844	2124347
Hukuntsi SW	2	1	02:01	36,6	2359295	2144906	2406696	2125167
Lehututu	2	2	04:58	83,4	2354567	2149364	2319252	2144724
Logkwabe N	2	2	01:47	30,8	2406934	2146967	2422309	2152016
Ncojane E	2	2	01:00	21,2	2308844	2018152	2308760	2030081
Ncojane S	2	2	01:32	23,6	2319233	2020583	2308438	2017503
Tshane	2	2	02:06	25,6	2401295	2152444	2400253	2206620
Tot. per land use	**14**	**13**	**63**	**1015**				
WMA Wildlife Mgmt. areas								
Logkwabe S	2	2	03:20	58,7	2422308	2152016	2451037	2204797
Maitlo-a-Phuduhudu	2	2	03:56	73,4	2305359	2151574	2308438	2108843
Mosieding	2	2	01:07	21,4	2319252	2144724	2310122	2151019
Ngwatle	2	2	04:15	56,3	2348844	2124347	2341734	2053532
Tshotswa E	2	1	00:55	16,6	2406696	2125165	2408213	2115829
Tshotswa W	1	2	05:57	72,5	2408212	2115827	2421479	2037552
Tshotswa W half	1	0	02:21	29,2	2415986	2052738	2421479	2037552
Ukwi	2	2	05:50	82,0	2341734	2053532	2319251	2020591
Tot. per land use	**14**	**13**	**97**	**1463**				
FR Fenced ranches								
Logkw. ranch BB74	5	5	01:18	11,3	2413109	2155962	2413613	2201812
Logkw. ranch Zolcon	5	5	00:26	3,9	2419268	2151307	2420831	2149739
Ncojane ranch 10	6	6	00:48	8,3	2304884	2041876	2300867	2041047
Ncojane ranch 17	6	6	00:39	8,1	2309266	2042111	2304884	2041876
Ncojane ranch 23	6	6	00:22	4,1	2309331	2041938	2311408	2041850
Tot. per land use	**18**	**18**	**39**	**397**				
NP National park								
Kaa	5	5	01:53	30,6	2421536	2037529	2422605	2020759
Mabuasehube	5	5	02:38	45,5	2504961	2209277	2503677	2158998
Tot. per land use	**10**	**10**	**21**	**761**				
Total	***56***	***54***	***244***	***3636***				