Examensarbete
i ämnet biologi

2010:3

Distribution and community composition of mammals in relation to land use in Botswana

Malin Gustafsson

Sveriges lantbruksuniversitet
Fakulteten för skogsvetenskap
Institutionen för vilt, fisk och miljö
Examensarbete i biologi, 30 hp, D-nivå, Samhällsvetenskapsprogrammet

Umeå 2010

Examensarbete
i ämnet biologi

2010:3

Distribution and community composition of mammals in relation to land use in Botswana

Däggdjurssamhällenas utbredning och sammansättning i förhållande till markanvändning i Botswana

Malin Gustafsson

Keywords: Land use, Community composition, Species richness, Savanna ecology, Herbivory

Handledare: Roger Bergström, Christina Skarpe, Märtha Wallgren
Examinator: Inga-Lill Persson

30 hp, D-nivå
Kurskod EX0317

SLU, Sveriges lantbruksuniversitet
Fakulteten för skogsvetenskap
Institutionen för vilt, fisk och miljö

Swedish University of Agricultural Sciences
Faculty of Forestry
Dept. of Wildlife, Fish, and Environmental Studies

Umeå 2010

Abstract

The savannas of Botswana are heterogeneous ecosystems where the animal species richness has a clear link to the spatial heterogeneity as well as to plant species richness and interspecies interactions, like competition. The human population has increased exponentially with the introduction of new foreign productive systems of land use and large herds of livestock. There has been a change from wild to domestic herbivore dominance with heavily grazed savannas and an increase of woody vegetation, which often show signs of low species richness. This study investigates the effects that different land uses have on mammal communities in northern Botswana and compares the results with previous studies from the mentioned study area and an additional area in southern Botswana. Mammals, wild and domestic, from the size of tree squirrel and larger and ostriches were recorded along 11 predetermined transects in four land use types; Communal Grazing Areas, Fenced Ranches, Wildlife Management Areas and National Parks. This study indicates that decline in species richness in an area can many times be connected to an increase in human presence. The limited number of wild species observations in the unprotected areas is an indication of how the human population and high densities of domestic animals are influencing the wildlife in those areas. The herbivores are shown to have a very evident impact on the vegetation. In this study woody vegetation of all heights are positively correlated to the areas holding large herds of domestic livestock. Land use types are shown to be the most influential environmental variables in both study areas, independent of season or patterns of precipitation. It is evident that different land use regimes affect mammal communities and vegetation structures differently.

Keywords: land use, community composition, species richness, savanna ecology, herbivory

Foreword

The nature and wildlife of southern Africa constitute a very important part of the African spirit. Many people from around the world dream of a chance to journey through the open savannas, not to mention the role these areas have in the lives of the people living of the land. Pastoralism represents a possibility for humans to live in the dryer parts of this region where the resource of domestic animals is vital to support human life. Changes in vegetation structure and species composition are possible effects of heavy livestock grazing. In order to keep the savannas of southern Africa in a state close to what we have seen through-out human history, it is now more than ever time to consider the way we influence this biome. In 1987 the United Nations World Commission on Environment and Development published the report *Our Common Future*, where the term **sustainable development** was manifested; “*meeting the needs of the present without compromising the ability of future generations to meet their needs*”. Today there are many ongoing projects with a goal to utilize the resources of southern Africa in a more sustainable way, but the need for education, development and conservation is still immediate.

Introduction

Background

Ecology

A savanna is a heterogeneous ecosystem with a mosaic of burnt patches, grazed patches and woody areas, where the inherent ability to change is a key factor (Skarpe 1991). A savanna is defined by the dominant herbaceous layer of grass and it usually holds some kind of woody stratum, which differs in structure in space and time. However it is not only the spatial heterogeneity, but many different spatial and temporal dynamics like e.g. variation in soil moisture and nutrients, occurrence of pans, fire and herbivory and the variation in precipitation, that together forms the savanna biome (Skarpe 1992; Bergström & Skarpe 1999).

The semi-arid savanna biome of southern Africa is home to many of the world's most known and appreciated mammal species. It carries one of the greatest diversities of large ungulates found on the earth today (du Toit & Cumming 1999). The animal species diversity of a savanna has a clear link to the spatial heterogeneity of the area (du Toit & Cumming 1999). The web of species interactions within a savanna ecosystem can be described as a dynamic multispecies structure where organisms, from plants to large herbivores, highly affect their surrounding through different feedback loops (du Toit & Cumming 1999; McNaughton & Georgiadis 1986). The plant biomass is for example one important determinant of mammal species richness in a certain area (Hopcraft *et al.* 2009; Andrews & O'Brien 2000). Climatic factors like seasonal variation in precipitation and temperature account for much of the species variation. An area where there is a high seasonal variation in moisture and temperature usually holds fewer mammal species than one with more stable conditions (Andrews & O'Brien 2000). The above ground primary production is primarily limited by the quantity of available moisture and climatic variations may have both long and short term influences on primary production and the carrying capacity of the ecosystem (Coe *et al.* 1976). When moisture increases in an area the primary production generally follows. The vegetation grows faster, but with the unchanged availability in nutrients it becomes less nutritious (Olff *et al. 2002*).

Species coexist in dynamic communities where interactions like competition, herbivory and predation, as well as different types of facilitations stand for an important part in determining the species community compositions (du Toit 2003). All mammal species have a range of different preferences with which they more or less are affecting the environment they live in and every mammal species is affected by a multitude of other species in their surroundings. There are usually detectable ecological gradients affecting the variation of the species community compositions. By examining the species composition and possible variables affecting this composition, e.g. human land use, cover of woody vegetation and distance to water, it is possible to identify and interpret ecological gradients (Lepš & Šmilauer 2003). In the sparse vegetation of the dry savannas of southern Africa forage availability is a limiting factor for large herbivores and competition within and among herbivore populations is a common feature (Skarpe 1992; Coe *et al.* 1976). The annual precipitation predicts the available quantity of forage and thus the total area needed for herbivore populations to survive (Coppolillo 2000). Small herbivores need more nutritious forage than large herbivores, which in turn require larger quantities of food (Coe *et al.* 1976; Demment & Van Soest 1985). The highest herbivore species diversity is expected in areas with sufficient moisture availability to sustain a high primary productivity without a decrease in nutritional content (Olff *et al.* 2002). Predators and prey influence each other in numerous ways, for example in situations of a decline in prey species density the predator population may change preference to a more abundant prey species in order to uphold the population size (Owen-Smith *et al.* 2005).

Humans and livestock

There have been people living in rural communities supported by savanna resources for thousands of years (Huntley 1982). Today millions of humans use the plains and many are dependent on the land as grazing areas for domestic herbivores (Skarpe 1991). During the last century the human population has expanded and increased exponentially with the introduction of new foreign productive systems of land use (du Toit 2002). The expanding human population on the African savannas has affected the indigenous herbivores in numerous ways, e.g. habitat fragmentation and decrease in population size and genetic diversity (du Toit & Cumming 1999). As a consequence of the changes in land use and the increase of areas utilised by humans, the wild indigenous herbivores have become severely repressed, and to a large extant replaced by cattle (Huntley 1982). The change from wild to domestic herbivore dominance has resulted in an altered herbivory, from a diverse mix of grazers and browsers into a situation where today the majority are preferential grazers, mainly cattle (du Toit & Cumming 1999).

Several factors have contributed to this opportunity for man to bring large herds of livestock in to unexploited areas, which have extensively changed the species composition in some of the mentioned areas. Increased water accessibility through wells, dams and drilled boreholes as well as programmes for the eradication of tsetse flies have made it possible to keep domestic herbivores in these previously unexploited areas. The land now supports a larger herbivore biomass than ever before (du Toit & Cumming 1999). This development, with greater concentration of herbivores than what the ecosystem originally held, is most likely the main cause of the rangeland degradation one can detect in many parts of today’s savannas.

Grazing and browsing herbivores add to the effect of variation in precipitation on the grass productivity and can also influence the ratio of grass and woody vegetation (du Toit & Cumming 1999). In stressed areas the vegetation composition often changes due to changes in competitive hierarchies as a result of a heavy grazing pressure. For domestic species less palatable vegetation like woody species become more dominating as palatable grasses are reduced (Skarpe 1992). Heavily grazed savannas with an increase of woody vegetation often show signs of low species diversity (Blaum *et al.* 2007). High coverage of *Acacia mellifera* indicates an area exposed to heavy grazing and vegetation change (Skarpe 1990).

Humans usually have certain direct effects on the flora and fauna of the area they populate. They may hunt for food and protection of livestock and many times these hunts are illegal (Verlinden *et al.* 1998). Human presence itself brings a form of fragmentation in to an unexploited area with e.g. agricultural activities, burns and roads, not to mention the unfamiliar noises and smells originated from a human settlement. With an increase in human activities and population size the land use and resource conflicts will become more common and the rangeland degradation will progress further. Many wildlife species are vulnerable to changes in their environment and they might not be able to co-exist with an intensified land use (Njoroge *et al.* 2009; Wallgren *et al.* 2009; Blaum *et al*. 2007; Moleele & Mainah 2003).

Conservation

An expanding human population and high concentrations of cattle are limiting the possibilities of coexistence between humans and wildlife in southern Africa. Many conservation projects aim to mediate and even convert the current situation. In order to truly give the indigenous flora and fauna a chance to recover there need to be sufficient room for this heterogeneity to subsist throughout fluctuations in climate, livestock grazing and other ecological disturbances (Sinclair *et al*. 2007). There is a worldwide support for involving local communities in conservation projects with an aim of getting the best possible ecologic and socioeconomic response for sustainable resource use and biological diversity (Twyman 2001). Areas with dense human populations and with elevated levels of habitat change are needed to supplement protected areas. It is unrealistic to obtain any conservation goals without a common plan that reaches all parts of a region (Fjeldså *et al*. 2004). Community-based wildlife management ought to involve controlled consumptive use of wildlife, like ecotourism (du Toit 2002). The use of land and resources in the African savannas should be planned for in conservation measures that work trough methods with a long-term time span. By research in the region we can gain knowledge of the optimal way to farm the land and hold livestock with minimised pressure on wildlife (Moleele & Mainah 2003).

Objectives

The purpose of this study was to relate mammal community composition to land use and to seasonal and regional variation in precipitation and plant productivity in dry savannas of the Kalahari, Botswana. My focus was to examine effects of land use and the relationships between wildlife and domestic animals in northern Botswana during the wet season. I will also compare that information with the data previously gathered in the same area during the dry season (Magnus Persson, in prep., and Henrik Träff, in prep.) and data from the south-western parts of the country (Jakobsson 2006; Carlsson 2006; Viio 2003; Wallgren 2001). With this report it is my hope to assist in the work on wildlife conservation and land use in Botswana and in the rest of the world.

I focused my study on the following questions:

- How do different land uses affect mammal community composition in terms of species number and functional types in northern Kalahari?
- Are there differences between the dry and the wet season in this respect? If so, do these differences agree with previous results from southern Kalahari?
- Are there structural differences in vegetation between different land use types and if so, are such differences related to characteristics of the mammal communities?

Methods

This report constitutes one of the concluding parts of a large-scale and extensive study of a complete mammal community in the Kalahari savanna. The study was financed by SIDA (SWE-2006-136), involving the PhD-thesis “Mammal community structure in a world of gradients” (Wallgren 2008). Three previous MSc studies were conducted in Botswana and included in the same extensive study, resulting in a number of reports (Magnus Persson, in prep., and Henrik Träff, in prep.; Jakobsson 2006; Carlsson 2006; Viio 2003).

Study area

In Botswana the annual precipitation decreases along a north-east south-west gradient (Scholes *et al.* 2002). The annual average in rainfall decreases from ca. 600 mm in the northeast to ca. 200 mm in the southwest (Thomas & Shaw, 1991; Department of Meteorological Services, Republic of Botswana). My study was conducted in northern Botswana; in the Ngamiland district around the city of Maun (19˚59’S, 23˚25’E) and in Savuti (18˚34’S, 24˚03’E) in the southern part of Chobe National Park. These areas are situated in the eastern parts of the sand filled Kalahari Basin. In north-eastern Botswana the mean annual rainfall is 450-600 mm (Department of Meteorological Services, Republic of Botswana). The area is semi-arid savanna woodland significantly influenced by the vicinity of the Okavango delta, the world’s largest inland delta. The Okavango regulates to a large extent the moisture regime in the area (Ramberg *et al.* 2006). The vegetation consists of a matrix of semi-arid savanna woodlands with e.g. open recently burnt planes of grass, small forested areas and pans.

The Kalahari is located about 1000 metres above sea level on a sand-covered almost flat plateau; the Kalahari Basin. It covers to a large extent the country of Botswana as well as parts of South Africa and Namibia. In Botswana the climatic year can be divided in to a warm wet season (October to April) and a cool dry season (May to September). The maximum daily temperatures range from 20 to 35°C and the minimum daily temperatures range from 7 to 20°C (Central Statistics Office 2008). There usually are occasions of the temperature dropping below 0°C in night time during the coldest months of the year. Kalahari was for a long time assumed to be a dry area with infertile soils where only a small number of plant and animal species could exist (Skarpe 1986). In reality the area is a heterogeneous mosaic with a range of habitats in different moisture regimes.

The moisture gradient is noticeable when the study area of my study is compared to the previously studied Matsheng area (24°04'S, 21°40'E) in the Kgalagadi district in the south-western part of the country. Here the semi-arid savanna receives an average annual rainfall of 250-350 mm (Department of Meteorological Services, Republic of Botswana). The vegetation consists mainly of open shrub savanna with a field layer of perennial grasses and occasional trees dispersed over the area (Skarpe 1986). Pans, which may temporarily be filled with water during the rains (Parris & Child 1970), constitute an important landscape element in this dry area. They usually have different vegetation than the savanna areas surrounding the pans (Bergström and Skarpe 1999) and they are popular areas extensively used by wildlife if not inhabited by humans (Wallgren 2001).

Botswana became independent in 1966 and since then its human population has undergone a shift from mainly living in small rural communities towards urbanization around the major towns (Central Statistics Office 2009). During the same period of time, boreholes have made it possible for people in rural areas to increase livestock holdings. Cattle are the single most common mammal in Botswana; it accounts for about 68.5% of the total animal biomass (Central Statistics Office 2005).

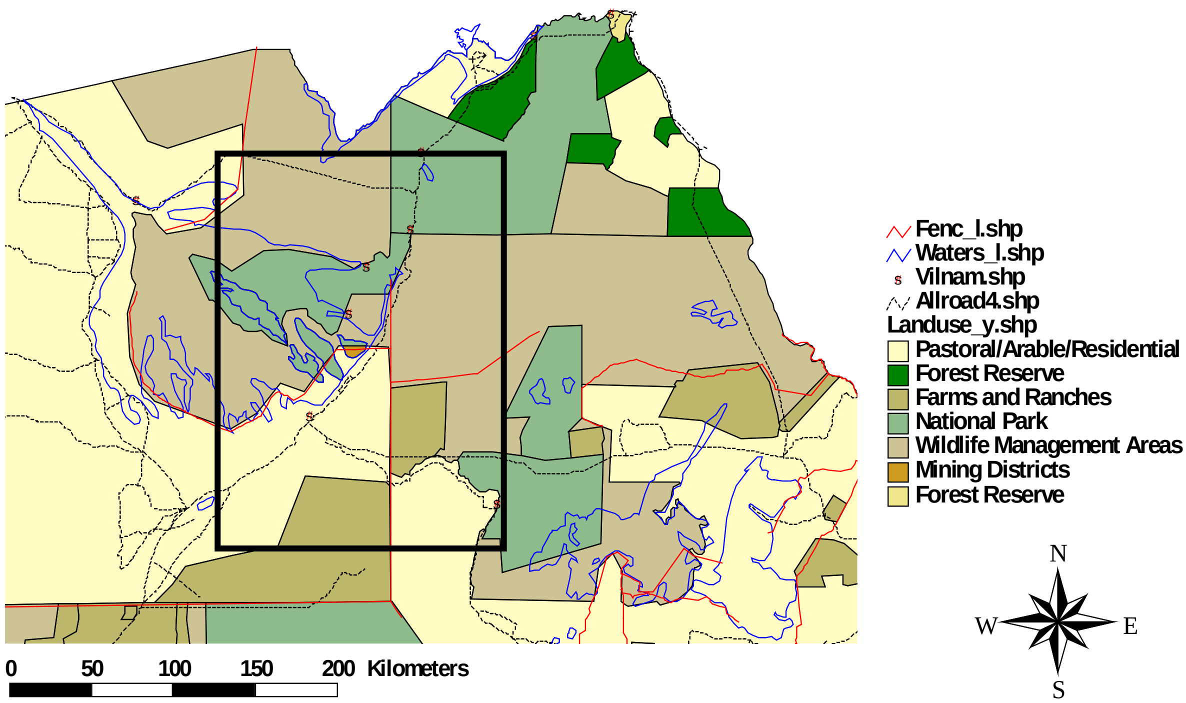

Figure 1. Map showing northern Botswana. The study area was situated in the area marked on the map with a black square.

Land use types

In order to observe and examine mammal species distribution, diversity and community composition the field work was conducted in four land use types: Communal Grazing Areas (CGA), Fenced Ranches (FR), Wildlife Management Areas (WMA) and National Parks (NP). These land use types were first identified in conservation planning during the second part of the 1970's (Wildlife Conservation Policy 1986).

CGA are communally managed areas surrounding all old, traditional human settlements, from small communities to large villages. They hold free ranging cattle of varying but usually high population densities, depending on the size of the human population inhabiting the area. FR are blocks of land, usually 4x4 km or larger, situated within the CGA and leased from the government for livestock production. These areas hold large quantities of domesticated herbivores and are usually grazed all year around without any recess periods. CGA and FR are in this paper referred to as livestock areas or unprotected areas. Generally the vegetation of both CGA and FR show impact of human-related activities like higher ratio of woody vegetation and unpalatable grass and forbs (Moleele & Mainah 2003; Verlinden 1997). The total animal biomass is very high, but a large part of the biomass is domestic herbivores (Central Statistics Office 2005).

WMA are vast areas outside the CGA, often linked to rural villages or other types of local communities, where the aim is to unite wildlife conservation with communities sustainable in economic as well as ecologic values. Small human settlements and limited numbers of livestock can be accepted in these protected areas, as well as tourism and even a controlled harvest of wildlife. The WMA's in my study are connected to The Sankuyo Tshwaragano Management Trust and the Sankuyo village. NP, i.e. in this study the Chobe National Park, are fully protected areas where people have only limited access, holding neither settlements nor livestock. It is not allowed to hunt in the parks and tourist may only explore these areas during daylight hours. WMA and NP are in this paper referred to as wildlife areas or protected areas. In Botswana both WMA and NP are utilized in the flourishing tourist industry. In absence of domestic mammal species rich wildlife communities are found. For example, the second largest part of the total animal biomass of Botswana is the African elephant (*Loxodonta africana*), which stands for about 11.8% of total animal biomass (Central Statistics Office, 2005). Chobe National Park holds a very large elephant population, maybe the largest one found on earth today.

Field methods

My study was conducted during the wet season of 2008, January to April, in the same areas as were observed during the dry season study (Magnus Persson, in prep., and Henrik Träff, in prep.). Transects driven, as described below, were with some exceptions the same as in the previous study. The vehicle used was a 4 wheel drive, 1994 Toyota Hilux. In the four land use types described above a total of eleven transects were driven repeatedly, day and night in both directions, with a speed around 25 km per hour. There were four CGA transects, three FR transects, three WMA transects and one NP transect. A total of 2 959 km of transect were driven (Table 1) divided into 135 transect tours. To drive approximately the same distance in total in each land use type all transects were driven a specific number of times.

Table 1. Land use type, number of repetitions (rep.) and total number of kilometres driven: in day time, night time and in total.

Land use type	Rep. Day	Rep. Night	Rep. Tot	Day (km)	Night (km)	Total km driven
Communal grazing area	13	12	25	353	379	732
Fenced ranches	33	33	66	333	337	670
Wildlife management area	15	13	28	443	353	796
National park	8	8	16	387	374	761
Total	69	66	135	1 516	1 443	2 959

The transect roads ranged from frequently used bush roads to small tracks (here after called roads) in dense grass or sand. The driver spotted animals on the road and the two persons standing in the back of the vehicle looked for animals on each side. All mammals spotted along the road were recorded, from 0.2 kg, i.e. the size of tree squirrel (*Paraxerus cepapi*) and larger, as well as ostriches (*Struthio camelus*). Transects were driven in day time between 08.00 and 17.00 and in night time between 20.00 and 05.00. No work was done during dusk or dawn in order to avoid the time of day when both diurnal and nocturnal mammals are active. The plan was to drive along the same transects as were used during the dry season study, but in some cases the routes had to be changed as a result of large pools of water, muddy areas or dense high grass. All together changes have been made with the intention to minimize the transect modification.

The animals were spotted by eye, during nighttime with the help of spotlights. By moving the spotlights in 90 degrees sweeping motions from straight ahead to the side of the vehicle it was possible to detect animals when the light reflected in the eyes of an individual. When an animal was detected the vehicle was stopped and time, species and number of animals were recorded. Species were determined according to Smithers (2000). When animals of the same species stood closer than 30 m from each other they were recorded as one group.

Vegetation study

In addition to the animal species data collected a vegetation analysis was performed once along each transect. Every second kilometer the vehicle was stopped and a circular area with a 100 meter radius surrounding the vehicle was examined. The following vegetation properties were recorded: not recently bunt, burnt last year or burnt this year (registered as % of total area coverage), cover and mean height of green grass, cover and mean height of wilted grass, cover of forbs and woody vegetation in three height ranges (< 0.5 m, 0.5-3 m and >3 m) and cover of *A. mellifera*. Coverage was registered as % of total area and height was registered with 0.1 m accuracy.

Statistical methods

The data set containing records of observed species, mammals > 0.2 kg and ostrich, and vegetation was examined statistically. Data on animal species community composition and ecological gradients are likely to be multivariate. Every animal in the species community is affected by a range of different factors, e.g. environmental variables, sometimes correlated. Multivariate methods are tools by which the data can be handled in a manageable way (Jongman *et al.* 1995). A statistical sampling unit is in this report referred to as a site. Each site represents a 2 km or 10 km segment of one transect. Initially all transects were divided into 2 km segments. In some cases larger sample units were needed in order to obtain manageable data. New site compilations with 10 km segments were then created. Analyses were run with either 2 km or 10 km sites. The numbers of observed individuals for all species included in this study were compiled for each site. The vegetation data was recorded once every second kilometre and could easily be connected to the animal species data set. When more than one vegetation sampling was done in one site the mean of the samples was calculated. The species data recorded during the wet season in the northern and southern study area were arranged in groups of functional types according to feeding type and body size (Appendix II). This was done in order to be able to compare the northern and southern areas where the species compositions differ widely (Smithers 2002).

Multivariate analyses

Gradient analysis is a way to examine continuity trough statistical methods were species community composition is put in relation to environmental gradients. There are two types of multivariate analysis methods; *direct gradient analysis* and *indirect gradient analysis*. The direct gradient analysis shows only the variation explained by linear combinations of the provided environmental variables in an ordination. In direct gradient analysis the recorded environmental variables are included in the analysis as well as the response variables (species). The indirect gradient analysis considers the total variation of the species data. Environmental variables are not part of the ordination, but may be shown in biplots with the best fit.

In this study the indirect gradient analysis is used to examine the total variation in the data set with the help of the program package CANOCO 4.5. The significance of the recorded environmental variables for the variation of species composition was tested using the Monte Carlo permutation test in a forward selection operation in the direct gradient analysis, Canonical correspondence analysis (CCA) (Lepš & Šmilauer *2003*). The tests were performed in two steps in order to separate the land use variables and the environmental variables. This method gives an insight to what effect the environmental variables have on the examined species when the effects of different land uses are not taken into account.

Ordinations are techniques to arrange statistical sampling units of a data set along gradients. Species and sites are organized along axes representing the greatest variation in the species community composition and ordination diagrams make it possible to visualize structural resemblances. The ordination technique appropriate to use is depending on the data set and the objectives of the study. Principal components analysis (PCA) and Correspondence analysis (CA) are indirect ordination techniques frequently used in community ecology research. In PCA the data is examined trough a linear response model where population densities are assumed to follow the increasing and decreasing values of the latent environmental variables. In CA the data is examined through a unimodal response model where examined species are assumed to have a single optimum along a gradient (Jongman *et.al. 1995*).

Whether to use linear or unimodal species response models can be explored by examining the lengths of gradients in a Detrended correspondence analysis (DCA) for indirect gradient analysis or a Detrended canonical correspondence analysis (DCCA) for direct gradient analysis. If the longest gradient (showing the beta diversity of the community composition) is shorter than 3.0 S.D., the best choice is a linear method. When the longest gradient exceeds 4.0 S.D., which is the case in this study, the proper choice is to use a unimodal method, e.g. CA or CCA. If the longest gradient falls in the range between 3.0 and 4.0 S.D., both linear and unimodal methods can be used. Concisely, CA is an indirect unimodal ordination method used to examine heterogeneous data revolving many species (Lepš & Šmilauer *2003*). This method was the one most appropriate for the data set of this study.

Results

Species richness under different types of land use

During this study 43 mammal species, 36 wild and 7 domestic, and ostrich were registered (Table 2). A total number of 22 844 animals were sighted in 3 086 observations. Domestic mammals were exclusively seen in CGA and FR. Fourteen wild mammal species were observed only in protected areas (i.e. WMA and NP) and five wild species were solely found in areas with cattle. The species with the highest number of observed individuals are all medium to large herbivores and this is true for both wild, i.e. impala (*Aepyceros melampus*) and plains zebra (*Equus quagga*) and domestic species, i.e. cattle (*Bos taurus*) and goat (*Capra hircus*).

As mentioned the study shows clear differences in species richness in the protected areas, WMA and NP, compared to the areas exploited by humans, CGA and FR (Appendix I). There were fourteen wild species exclusively recorded in the protected areas, where domestic mammal species were completely absent. Only a few wild species were recorded exclusively in the study areas holding livestock production. FR holds a much larger livestock biomass; this study shows above 2.5 times more individuals of cattle there, compared to CGA. There were twice as many wild species exclusively recorded in the CGA compared to the FR. The species differences in-between the protected areas were much less noticeable, although there were a few more species exclusively recorded in the NP. The numbers of observed individuals in the NP are four times higher than in the WMA.

Species distributions in relation to environmental variables

The variance explained by the examined environmental variables stands for 78.6% of the total variance in the data set from the wet season in northern Botswana. The examined environmental variables were tested with the Monte Carlo permutation test in two steps (Table 3). The first step included the land use variables in the test and two of them, WMA and NP, were significant. No other variables were significant in this test. In step two the land use variables were excluded. In this test three variables were significant: distance to pans and heights of wilted and green grass.

Table 3. Significant environmental variables, codes used in the statistical analysis and the p-value, f-value and explained variance (%) of the significant environmental variables in the Monte Carlo permutation test.

Significant environmental variables	Code	P-value	F-value	Variance explained
Land use types included				
National Park	NP	0.0020	10.43	0.45
Wildlife Management Area	WMA	0.0020	15.13	0.58
Land use types excluded				
Distance to pan	Pan	0.0080	2.45	0.11
Height of wilted grass	H of WG	0.0260	1.86	0.08
Height of green grass	H of GG	0.0340	2.18	0.10

Table 2. Species, codes and no. of individuals per land use type observed in northern Botswana during the wet season.

Common species name	Scientific name	Code	No. of observed individuals/land use			
Wild species			**CGA**	**FR**	**WMA**	**NP**
African elephant	*Loxodonta africana*	ele	2		52	373
African wildcat	*Felis silvestris*	awc	3	1	16	11
Banded mongoose	*Mungos mungo*	bmg				7
Bat-eared fox	*Otocyon megalotis*	bfx	3			11
Black-backed jackal	*Canis mesomelas*	bbj	4	15		3
Blue wildebeest	*Connochaetes taurinus*	wil				344
Cape fox	*Vulpes chama*	cfx			1	2
Cape/Scrub hare	*Lepus capensis/saxatilis*	har	13	11	4	27
Common duiker	*Sylvicapra grimmia*	cdu	4	1	2	2
Dwarf mongoose	*Helogale parvula*	dmg			2	
Giraffe	*Giraffa camelopardalis*	gir			66	134
Ground squirrel	*Xerus inauris*	gsq		3		
Hippopotamus	*Hippopotamus amphibius*	hip	1			
Honey badger	*Mellivora capensis*	hbg	2			
Impala	*Aepyceros melampus*	imp			1 074	2 485
Kudu	*Tragelaphus strepsiceros*	kud		7	27	26
Large spotted genet	*Genetta tigrina*	lsg	1	1	10	7
Leopard	*Panthera pardus*	leo			1	2
Lion	*Panthera leo*	lio			1	2
Ostrich	*Struthio camelus*	ost	8	5		79
Plains zebra	*Equus burchelli*	zeb			64	2 361
Porcupine	*Hystrix africaeaustralis*	por	3	2	3	0
Roan	*Hippotragus equinus*	roa				1
Sable	*Hippotragus niger*	sab				1
Side-striped jackal	*Canis adustus*	ssj	1			
Slender mongoose	*Galerella sanguinea*	smg		1	3	1
Small spotted genet	*Genetta genetta*	sgn	3	3	8	4
Southern lesser bushbaby	*Galago moholi*	bub	40	6	23	20
Spotted hyena	*Crocuta crocuta*	shy			1	9
Springhare	*Pedetes capensis*	sph	23	27	43	166
Steenbok	*Raphicerus campestris*	ste	6	10	28	14
Striped polecat	*Ictonyx striatus*	spc	1	1		
Tree squirrel	*Paraxerus cepapi*	tsq	2		20	7
Tsessebe	*Damaliscus lunatus*	tse			2	25
Warthog	*Phacochoerus aethiopicus*	war			6	71
Wild dog	*Lycaon pictus*	wdg				8
Yellow mongoose	*Cynictis penicillata*	ymg	2	1		
			122	95	1 457	6 203
Domestic species						
Cattle	*Bos taurus*	cat	2 649	7 319		
Domestic cat	*Felis catus*	doc	2			
Domestic dog	*Canis familiaris*	dog	50	88		
Donkey	*Equus asinus*	don	202	654		
Goat	*Capra hircus*	goa	1 062	2 614		
Horse	*Equus caballus*	hor	39	121		
Sheep	*Ovis aries*	she	14	103		
			4 018	10 899		
Total number of observed individuals / land use type:			4 140	10 994	1 457	6 203

The CA ordination diagram (Figure 2) shows the relationships between the recorded species and the significant environmental variables. There is a general trend in land use types, where the protected areas, NP and WMA, are positively correlated to each other and negatively correlated to the domestic species. Distance to pan and height of wilted and green grass are positively correlated to the wildlife areas and species connected to those areas and negatively correlated to areas with livestock dominance.

Sites divided into land use types are displayed in the CA ordination diagram (Figure 3), showing species communities in relation to the significant environmental variables. Sites that are placed close together in the ordination diagram represent similar species compositions. A cluster of sites are considered to represent a community. The CGA and FR sites are clustered (Cluster 1). All domestic species and the wild species only observed outside of protected areas (marked in a circle with a dart in Figure 1) are found in this cluster; ground squirrel (*Xerus inauris*), honey badger (*Mellivora capensis*), hippopotamus (*Hippopotamus amphibius*), striped polecat (*Ictonyx striatus*), and side-striped jackal (*Canis adustus*). This species community show a clear positive correlation to CGA and FR. The omnivorous black-backed jackal (*Canis mesomelas*) also shows a positive correlation to the unprotected areas. The sites of the protected areas, WMA and NP, have a wider distribution compared to the sites of the unprotected areas, but can nevertheless be divided into species communities. A majority of the wild species recorded in this study are positively correlated to protected areas and both NP and WMA show a wide-ranging high species richness.

There are a few medium to large-sized herbivores dominating each land use type. The species communities of the livestock areas seem to consist of a very similar assembly of mammal species and both areas are clearly dominated by the domestic herbivores. In the wildlife areas wild medium to large-sized herbivores are present, often in high densities. Herbivore species positively correlated to the WMA species community (Cluster 2) are giraffe (*Giraffa camelopardalis*), kudu (*Tragelaphus strepsiceros*) and impala. African elephant and blue wildebeest (*Connochaetes taurinus*) are positively correlated to the species community of the NP (Cluster 3). The protected areas also hold populations of large carnivores, a functional type not recorded in any of the unprotected areas.

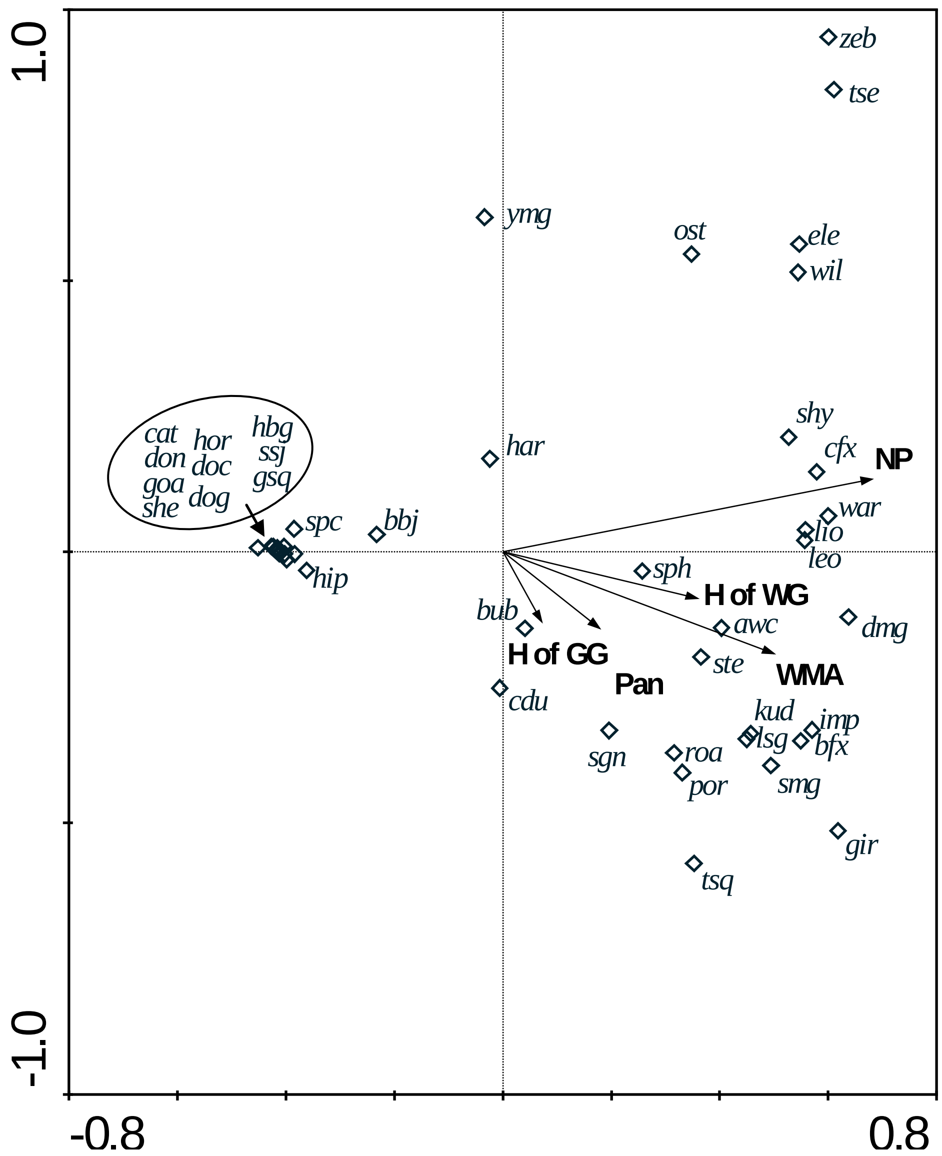

Figure 2. CA biplot of species in relation to significant environmental variables during the rainy season in northern Botswana. Species codes in table 2. Environmental variable codes in Table 3.

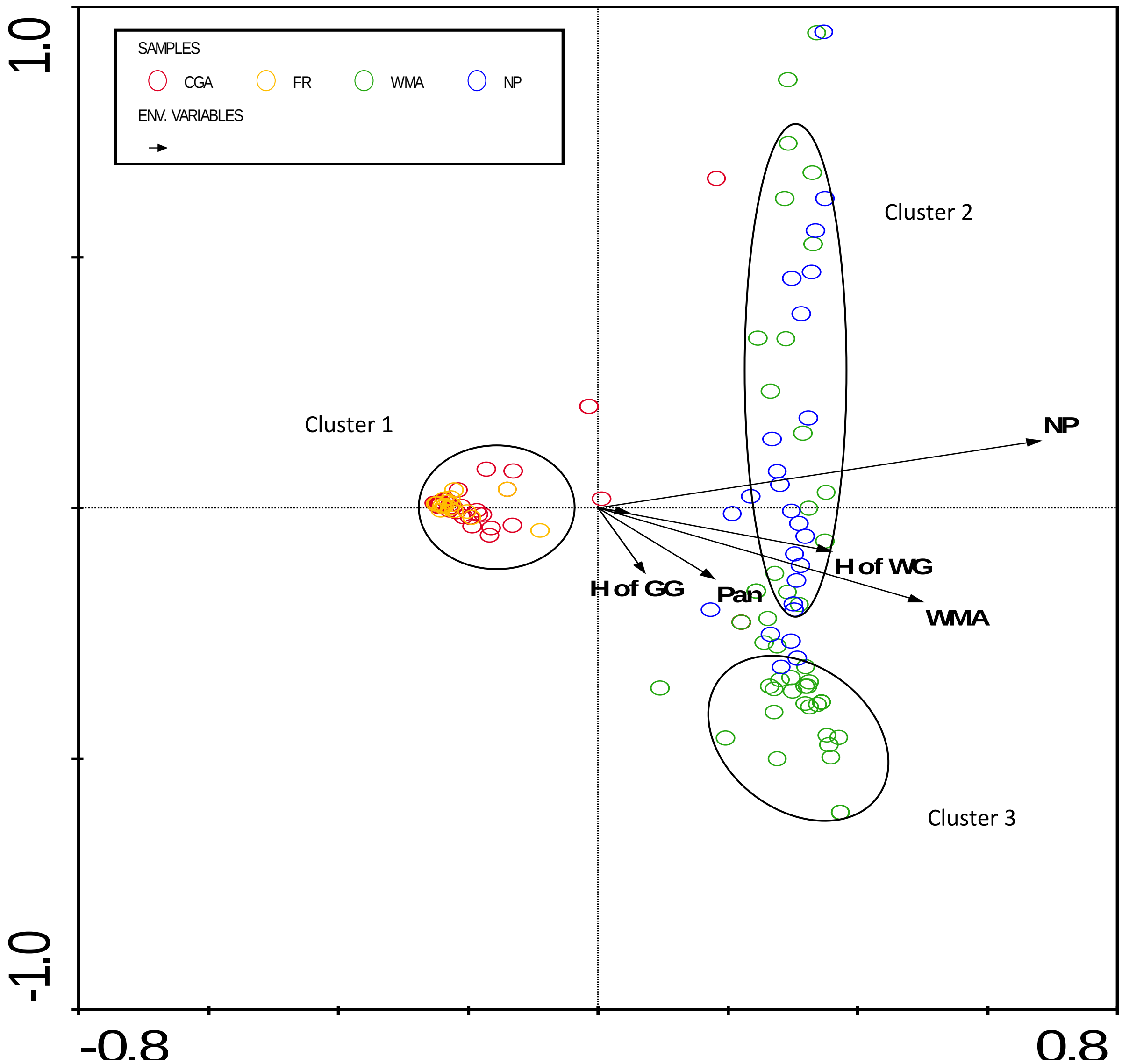

Figure 3. The wet season sites in northern Botswana in relation to significant environmental variables displayed in a CA biplot. Each symbol represents a 2 km site. Environmental variable codes in Table 3.

Dry and wet season in the northern Kalahari

In the CA ordination diagram showing the relationships between community composition in the dry and wet season in the northern study area (Figure 3) sites are displayed in relation to the significant environmental variables. The wet season data are compared to the data set collected during the dry season in the same area (Magnus Persson, in prep., and Henrik Träff, in prep.). A number of environmental variables were significant when tested in two steps with the Monte Carlo permutation test; including and excluding land use variables (Table 4).

Table 4. Significant environmental variables, codes used in the statistical analysis and the p-value, f-value and explained variance (%) of the significant environmental variables in the Monte Carlo permutation test.

Significant environmental variables	Code	P-value	F-value	Variance explained
Land use types included				
National Park	NP	0.0020	13.28	0.24
Wildlife Management Area	WMA	0.0020	20.72	0.36
Cover of forbs and woody vegetation < 0.5 m	CFW 0.5	0.0080	2.53	0.04
Cover of woody vegetation 0.5 - 3.0 m	CW 0.5-3.0	0.0180	2.01	0.03
Cover of green grass	C of GG	0.0320	1.70	0.03
Cover of woody vegetation > 3.0 m	CW 3	0.0180	1.73	0.03
Land use types excluded				
Cover of forbs and woody vegetation < 0.5 m	CFW 0.5	0.0020	4.88	0.09
Cover of wilted grass	C of WG	0.0020	5.79	0.11
Cover of woody vegetation > 3.0 m	CW 3	0.0020	3.06	0.06
Height of green grass	H of GG	0.0200	2.25	0.04
Height of wilted grass	H of WG	0.0020	3.37	0.06

The species distributions in the wet season seem to be more diffuse and mixed with regards to allocation of land use types compared with the dry season. This shows that the dry season species composition has a more evident land use type partition, especially in the protected areas.

There are three distinguishable clusters in Figure 4:

1. The WMA cluster – contains a wide distribution of species from many functional types. Herbivore species connected to the WMA species community are, e.g. zebra and buffalo (*Syncerus caffer*). Other species showing a strong relation to the same community are brown hyena (*Hyaena brunnea*), side-striped jackal (*Canis adustus*) and dwarf mongoose (*Helogale parvula*).
2. The NP cluster – also shows a wide distribution of species from many functional types, but this species community contain many large herbivores, e.g. African elephant, giraffe, kudu, roan (*Hippotragus equinus*) and sable (*Hippotragus niger*).
3. The livestock cluster – contains mainly domestic species. The exceptions are ground squirrel (*Xerus inauris*) and hippopotamus.

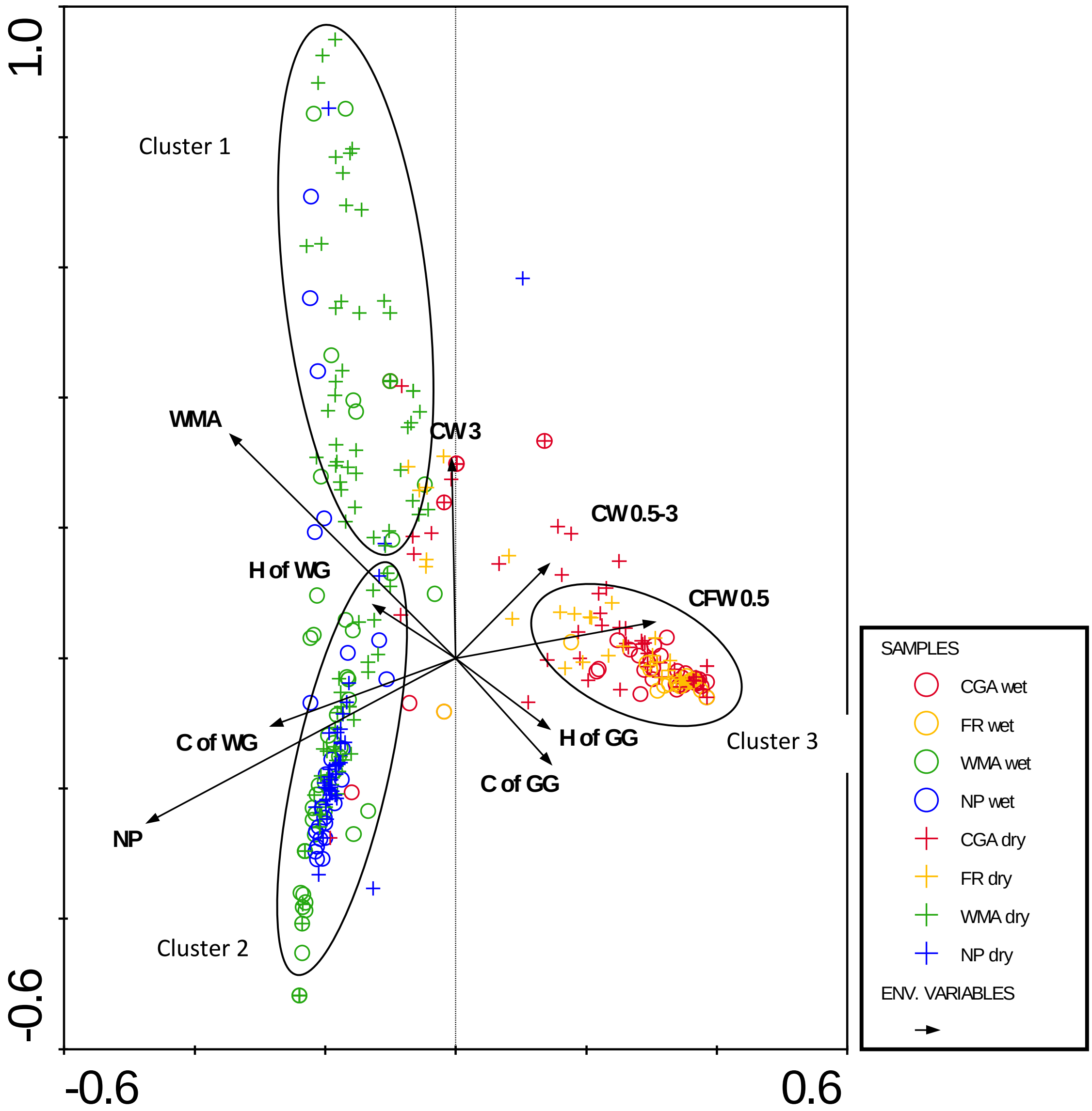

Figure 4. The relation between wet and dry season sites in northern Botswana in relation to significant environmental variables displayed in a CA biplot. Each symbol represents a 2 km site. Environmental variable codes in Table 3.

In tune with the previous ordinations from the wet season this one shows a clear connection between WMA and NP sites in opposition to CGA and FR sites, which in turn are positively correlated to each other. The wildlife areas show a clear positive correlation to height and cover of wilted grass. Height and cover of green grass on the other hand is positively correlated with livestock areas. This is a different pattern compared to the results from the wet season data. Cover of forbs and woody vegetation of small to medium height is also positively correlated to the livestock areas.

Functional types – wet season in the northern and southern study area

The CA ordination diagram shows 10 km sites from this current study compiled in northern Kalahari and the rainy season in southern Kalahari (Carlsson 2006; Jakobsson 2006) presented per land use type (Figure 4). Each site corresponds to a composition of functional types (Appendix II). Sites that are placed close together have a similar assemblage of functional types and that involves a similar community composition. The sites from the southern study area are overall placed much closer together compared to the sites from the northern study area. This indicates that the communities of the northern Kalahari are more homogenous than those of the southern Kalahari.

Table 5. Significant environmental variables, codes used in the statistical analysis and the p-value, f-value and explained variance (%) of the significant environmental variables in the Monte Carlo permutation test.

Significant environmental variables	Code	P-value	F-value	Variance explained
Land use types included				
National Park	NP	0.0020	21.37	0.32
Wildlife Management Area	WMA	0.0020	18.48	0.27
Cover of green grass	C of GG	0.0020	9.57	0.14
Cover of woody vegetation > 3.0 m	CW 3	0.0040	4.51	0.06
Land use types excluded				
Height of wilted grass	H of WG	0.0020	10.55	0.16
Distance to pan	Pan	0.0020	4.15	0.06
Cover of woody vegetation > 3.0 m	CW 3	0.0120	3.17	0.05
Cover of green grass	C of GG	0.0220	2.30	0.03
Height of green grass	H of GG	0.0200	2.34	0.04

The sites of the wet season data are divided into three clusters (Figure 5);

1. The livestock cluster - containing the sites from the livestock areas mixed with a few WMA sites.
2. The southern wildlife cluster - with a majority of the southern wildlife area sites.
3. The northern wildlife cluster - with a majority of the northern wildlife area sites.

The sites from the northern study area show in general a more diffuse distribution, though they are in a similar pattern as the southern sites, i.e. sites from unprotected areas are positively correlated to each other and negatively correlated to the sites from the protected areas and the other way around is true for the protected areas. WMA sites are clearly positively correlated to cover and height of wilted grass. The southern WMA and NP sites are positively correlated to pans. CGA and FR sites from both study areas are positively correlated to cover and height of green grass and woody vegetation with height above 3 m. The functional type of large herbivores is positively correlated to the areas where livestock production is conducted. Small herbivores and insectivores are positively correlated to WMA and large carnivores and omnivores are positively correlated to NP.

Vegetation structure in the land use types

There is a clear pattern in vegetation structure when comparing the study areas of northern and southern Kalahari. The data also shows that the areas hold many similarities in vegetation structure when comparing seasons or different land use types. The sites of the wildlife areas have vegetation structures with many resemblance; they have in general a positive correlation to wilted grass and distance to pans. Likewise, the sites of the livestock areas clearly hold vegetation with a resemblance in structure and they are positively correlated to height and cover of green grass and cover of forbs and woody vegetation. The only clear difference is that height of green grass is positively correlated to the protected areas in the northern study area during rainy season, but positively correlated to the livestock areas when comparing areas or seasons.

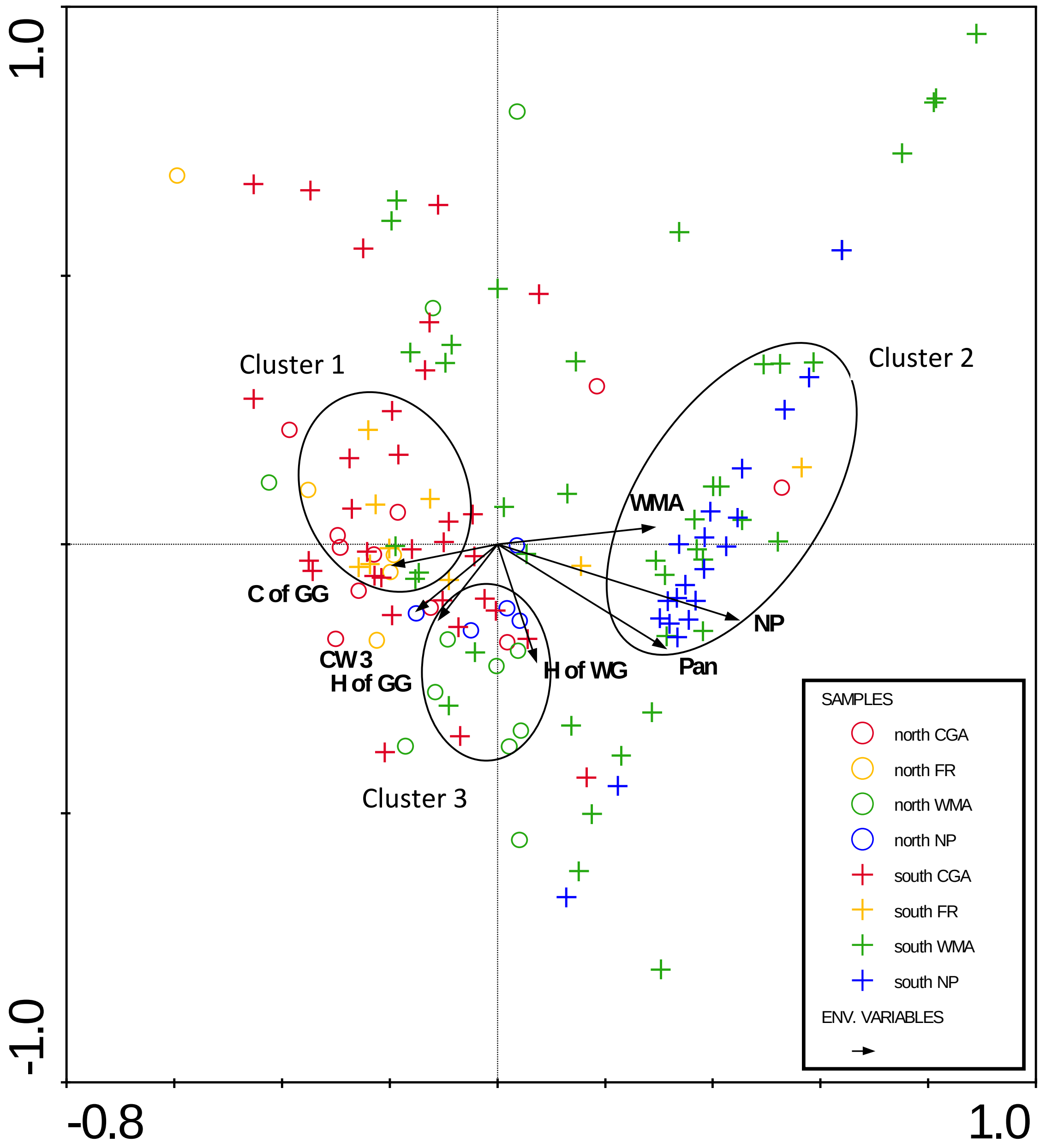

Figure 5. The relation between wet season sites in northern and southern Botswana in relation to measured environmental variables displayed in a CA biplot. Each symbol represents a 10 km site. Environmental variable codes in Table 3.

Discussion

Mammal communities in northern Botswana, wet season

The species most frequently recorded in this study in northern Botswana during wet season were medium and large herbivore species, both wild and domestic. Domestic herbivores were clearly the dominating species in livestock areas. Also in the wildlife areas, where no livestock was recorded, wild medium and large size herbivores were the dominating species. The wild herbivores belong to the same functional groups as the domestic herbivores and they may compete for the same recourses. Wild herbivores, especially large species, face many obstacles when the presence of man and cattle increases (Wallgren 2008; Blaum *et al*. 2007). The wild grazers and browsers may compete with the domestic species for forage, water and space and they are many times hunted by humans as they can represent a significant protein source for people inhabiting the area. This has an effect on the wild herbivore community with a possible decline in species richness. When comparing the sites of livestock areas there are some differences even though they are strongly clustered. CGA held less than half the number of domestic herbivores compared to the cattle ranches and there were recorded twice as many wild mammal species.

There were no large wild carnivores recorded in the unprotected areas. The results of this study support the idea that large carnivores are declining and maybe even absent in unprotected areas. Species respond very differently to changes in their environment, but there are traits and responses that are common among species in a functional type. Some functional types, like large carnivores, are usually more easily disturbed than others (Woodroffe 2000). Large carnivores are top predators particularly sensitive to habitat fragmentation since they are in need of large areas to subsist. They constitute a threat to livestock and compete with humans for prey species which leads to the deliberate killing of many carnivore individuals (Woodroffe *et al*. 2007). Top predators are an important part of a mammal community and they play a key role in any ecosystem. Decreasing predator diversity can e.g. affect herbivore biomass and through that plant productivity (Otto *et al.* 2008).

Most wild mammal species react negatively to human induced disturbances, but some can be favoured by these changes in the environment. There were in this study a few species recorded most frequently in the unprotected areas, e.g. black-backed jackal, side-striped polecat and honey badger. These wild species may be positively affected by the presence of humans and livestock trough e.g. the absence of competition with large carnivores or increased forage availability in plantations. Wild species common in livestock areas do probably not compete with, nor do they constitute a threat to, the domestic species in the same extent as do other wild mammal species.

Kalahari – seasonal and regional variation in community composition

The combined data set covering wet and dry season in southern and northern Kalahari showed that the mammal communities of the wildlife areas held many similarities with much higher species richness compared to the livestock areas. This study indicates that decline in species richness in an area can many times be connected to an increase in human presence. Thus, my study showed that in African savannas land use can be a more important determinant of mammal community composition of species as well as functional types, than both season and precipitation. The results from my study coincide with the results from the previous studies conducted in the northern and southern study areas (Wallgren 2008; Magnus Persson, in prep., and Henrik Träff, in prep.; Jakobsson 2006; Carlsson 2006; Viio 2003).

The species composition of the wildlife community in the northern study area, close to the Okavango delta, was quite different from the species composition of the southern more dry study area (Appendix I). However, my study showed, through the examined functional types, that the patterns of species composition were similar in both study areas. The area in northern Botswana was expected to hold a higher species richness compared to the southern more dry and infertile study area. The compiled data of this study showed this prediction to be true. There were three times more wild species exclusively observed in the moister and more fertile northern study area, even though the sampling effort i.e. total driven km, and with that the chance to spot animals were higher in the southern study area. When comparing the wet and dry season in the northern study area the differences were much less noticeable. The species communities of the dry season are a bit more clearly connected to a certain land use type, whilst the communities of the wet season have a more diffuse dispersal. These results are maybe linked to the fact that the wet season has more abundant resource availability and through that probably less competition between mammal species.

There was an evident difference in species assembly when comparing the land use types; with high concentrations of medium and large-sized herbivores recorded in the livestock areas in both northern and southern Kalahari independent of season. Livestock production is strongly connected to the human cultures of the Kalahari and even if the productivity is poor there is a strong support for preserving the large herds. Sustainable livestock production requires cattle herds controlled with ecologically defendable methods (Skarpe 1991) e.g. controlled grazing pressure and altered forage areas. The medium and large-sized mammal herbivores were also the dominating functional types in the mammal communities of the wildlife areas. The wild herbivores dominated strongly, even though there were a few domestic mammals recorded in the protected areas in the south. The high animal abundance in the unprotected areas may exceed the areas carrying capacity with resource depletion as a possible consequence. High species richness of herbivores is usually followed by high species richness of carnivores (Owen-Smith *et al.* 2005). The limited number of wild species observations in the unprotected areas is an indication of how the human population and high densities of domestic animals are influencing the wildlife in those areas. Many wild species have difficulties to coexist with humans and cattle due to the disturbances, e.g. competition, fragmentation and hunting, previously mentioned in this report. When the human population expands into previously unexploited areas the effect will most likely be a decline in species diversity (Moleele & Mainah 2003; Parris & Child 1973).

The rich species composition of the WMAs can be an indication of how to connect protected areas with areas inhabited by humans. The WMAs, where people are living and to some extent holding livestock, are many times bordering the fully protected NP areas and may constitute important buffer zones (Twyman 2001). Non-consumptive or low-consumptive use of nature and wildlife, e.g. ecotourism and trophy hunting, are means for people to utilize their surrounding areas with a minimized influence (du Toit 2002). It might be a good strategy to allow a small and monitored harvest of wildlife and in return find a human community aware of and hopefully interested in their surrounding nature. A recent study conducted in northern Kenya showed that wildlife species richness was higher in an area with more cattle where wildlife were favored, compared to an area with less cattle where wildlife were not favored (Georgiadis *et al.* 2007). It is important to have a flexible conservation approach and to focus the main fraction of the protection management to where it has the best effect (Brashares *et al.* 2001; Chanda *et al.* 2003). This differs widely among different areas. Conservation efforts need sufficient room in space and time (Sinclair *et* al. 2007). The heterogeneity of an area with a mosaic of burns and grazing disturbance and unpredictable precipitation patterns can only be maintained if there is enough space and time for the natural processes to proceed.

Structural vegetation patterns

The study areas of northern and southern Kalahari showed a very similar pattern in vegetation structure. By examining the data sets divided in to land use types it was clear that areas affected by human population and livestock production were very different from areas protected from exploitation, regardless of season or yearly average rainfall. The results of this study show that height and cover of wilted grass were generally positively correlated with the protected areas. Height and cover of green grass on the other hand was positively correlated with the areas heavily affected by grazing and browsing domestic herbivores. As a consequence of the grazing pressure a large proportion of the grass in areas inhabited by humans, if not all of it, is consumed. This affects not only the green grass but the wilted grass too. During the months when this study was conducted the annual vegetation change was clearly visible. In the end of January the heavy rains had fuelled the vegetation growth, showing areas of dense high grass. Rapidly the vegetation of the unprotected areas, especially the ranch areas, was affected by grazing animals. In the end of the study period, i.e. the end of the rainy season, there was only sand to be found in many places previously covered by grass.

In the study areas the large herbivores had a very evident impact on the vegetation. Areas affected by an intense grazing pressure show an increase in woody vegetation (Skarpe 1991). In this study woody vegetation of all heights was positively correlated to the areas holding large herds of domestic livestock. Forage was probably a limiting factor in these areas with high mammal biomass. The growing season of the woody vegetation usually starts some time before the grass starts growing (Bergström 1992). During this time the preferential grazers will probably feed on browse. Herbivores generally have a preference for either grazing or browsing, but most species can alter their feeding behaviour and browse may at some points be an important part of the diet of both wild and domestic grazing herbivores (Bergström 1992). Moisture is perhaps the key limiting factor in the Kalahari ecosystems and vegetation productivity decreases with a decline in precipitation along a soil-moisture gradient. African herbivore densities and distributions depend primarily on the availability of water and forage (Belsky 1995). During the last decades human populations have found ways to expand their livestock production into previously unexploited areas. This movement has resulted in an increase in total animal biomass of those areas, according to data from the Central Statistics Office of Botswana (2005). The land use types affected by the human population hold a higher number of animal individuals and show a decrease in wild species richness. Once humans settle in an area there usually follows an increased pressures on wild flora and fauna (du Toit 2002).

Conclusion

The compiled data of this study show that land use, in the form of protected wildlife areas or unprotected areas holding large populations of domestic herbivores, are the environmental variables with the most significant influences on the mammal communities of the areas. The areas with high species richness, WMA and NP, have a low total occurrence of animal individuals and show a minor indication of human induced disturbance. There are wild mammal species in the livestock areas, but fewer species and smaller populations have been recorded.

This study also shows the importance of protected areas in the work with nature conservation and indigenous mammal community preservation. It is evident that different land use regimes affect mammal communities and vegetation structures differently. The expanding human population and with it the increasing domestic stocks are requiring larger and larger areas to subsist. This has an extensive impact on an area with a heavy grazing pressure, change in vegetation structure and repressed wildlife as probable and noticeable consequences. Results from a number of previous studies performed in both study areas show indications of these consequences (Wallgren 2001; Viio 2004; Carlsson 2005; Jakobsson 2006) and the results from this study follow the same trends. The ambition to maintain high biodiversity and mitigate resource depletion in this dynamic area makes the issues of conservation and sustainable development crucial. Not to mention the enormous cultural and emotional values this part of the world add for local people and many more. The southern African wildlife communities need large areas to subsist and a reasonable amount of time to recover from recent habitat loss. It will require extensive joined efforts of the human population to improve the current ecological situation. These values and treasures must not be lost.

Acknowledgements

I want to thank Office of the President and Department of Wildlife and National Parks for granting me and my colleagues' research permits in Botswana and by that giving us the opportunity to experience and explore your beautiful country. I also feel gratitude towards SIDA and SLU External Relations for supporting this project and giving financial funding.

A special thank you to Josefine Muñoz, my fellow study partner and sweet friend, for introducing the idea of participation in this project and even more for putting up with me during times of hunger, wet sleeping bags and fear to drive the car. You are my guiding star. I also give my gratefulness to Karin Carlsson for valued assistance and new friendship. You filled the rides through Botswana with knowledge, adventure and laughter. Girls, our journey has given me innumerous memories and heaps of experience.

I give many thanks to Dr Märtha Wallgren for invaluable support and guidance. You have through this experience been the pillar for me to rely on. I would like to give my humble appreciation to Professor Roger Bergström and Professor Christina Skarpe. I am grateful for your patience, advice and helpful supervision. And thank you Dr Shimane Makhabu for supervision and support in Botswana. Thanks also to Magnus, Henrik, Karin, Tobias and Tanja for kindly sharing your data with me.

I want to thank the Sankuyo Tshwaragano Management Trust and the village of Sankuyo for the possibility to conduct research in the area. I am grateful for all advice and help in the field, through which I now know how to handle wet season driving and stubborn elephants. I want to give my gratefulness to the Seaman family for many helpful tips and tricks in the field, rescue when the car broke down and especially for giving me a place to call home.

In conclusion I want to give gratitude to my wonderful family and amazing friends. Without you all I would not have been where I am today. Your love and support means the world to me.

References

Andrews, P. and O'Brien, E. M. (2000) Climate, vegetation and predictable gradients in mammal species richness in southern Africa. *Journal of Zoology,* London 251, 205-231.

Belsky, A. J. (1995) Spatial and temporal landscape patterns in arid and semi-arid African savannas. In: Hansson, L., Fahrig, L. and Merriam, G. (Eds.) *Mosaic Landscapes and Ecological Processes,* p. 31-56.

Bergström, R. and Skarpe, C. (1999) The abundance of large wild herbivores in a semi-arid savanna in relation to season, pans and livestock. *African Journal of Ecology,* vol. 37, no.1.

Bergström, R. (1992) Browse characteristics and impact of browsing on trees and shrubs in African savannas. *Journal of vegetation science* 3:315-324.

Blaum, N., Rossmanith, E., Popp, A. and Jeltsch, F. (2007) Shrub encroachment affects mammalian carnivore abundance and species richness in semiarid rangelands. *Acta Oecologica* 31, 86-92.

Carlsson, K. (2005) Mammal communities in the southern Kalahari: differences between land use types and seasons. *Master thesis, Uppsala University.*

Central Statistics Office (2009) Botswana Demographic Survey 2006. *Government Printer*, Gaborone.

Central Statistics Office (2008) Botswana Environment Statistics. *Department of Printing and Publishing Service*, Gaborone.

Central Statistics Office, (2005) Wildlife Statistics 2004. *Department of Printing and Publishing Service,* Gaborone.

Chanda, R., Totolo, O., Moleele, N., Setshogo, M. and Mosweu, S. (2003) Prospects for subsistence livelihood and environmental sustainability along the Kalahari Transect: The case of Matsheng in Botswana's Kalahari rangelands. *Journal of Arid Environments* 54, 425-445.

Coe, M. J., Cumming, D. H. and Phillipson, J. (1976) Biomass and production of large African herbivores in relation to rainfall and primary production. *Oecologia* (Berlin) 22, 341-354.

Department of Meteorological Scervices (2003) Botswana's climat. *www.weather.info.bw*

du Toit, J. T. (2003) Large herbivores and savannas heterogeneity. In: du Toit, J. T., Rogers, K. H. and Biggs, H. C. (Eds.) *The Kruger experience: ecology and management of savanna heterogeneity*. Washington DC: Island Press. 519pp.

du Toit, J. T. (2002) Wildlife harvesting guidelines for community-based wildlife management: a southern African perspective. *Biodiversity and Conservation* 11, 1403-1416.

du Toit, J. T. and Cumming, D. H. M. (1999) Functional significance of ungulate diversity in African savannas and the ecological implications of the spread of pastoralism. *Biodiversity and Conservation* 8, 1643-1661.

Fjeldså, J., Burgess, N. D., Blyth, S. and de Klerk, H. M. (2004) Where are the major gaps in the reserve network for Africa's mammals? *Oryx* 38(1), 17-25.

Georgiadis, N. J., Olwero, J. G. N., Ojwang, G. and Romanach, S. S. (2007) Savanna herbivore dynamics in a livestock-dominated landscape. Dependence on land use, rainfall, density and time. *Biological conservation*137(3), 461-472.

Hopcraft, J. G. C., Olff, H. and Sinclair, A. R. E. (2009) Herbivores, resources and risks: alternating regulation along primary environmental gradients in savannas. *Trends in Ecology & Evolution* 25, 119-128.

Huntley, B. J. (1982) Southern African savannas. In: Huntley, B. J. and Walker, B. H. (Eds.) *Ecology of tropical savannas*. Berlin: Springer-Verlag, p. 101-119.

Jakobsson, T., (2006) Influence of land use intensity on mammal densities in an African savanna. *Master thesis, Uppsala University.*

Jongman, R. H. G., ter Braak, C. J. F and Van Tongeren, O. F. R. (1995) Data analysis in community and landscape ecology. *Cambridge University Press.*

Lepš, J. and Šmilauer, P. (2003) Multivariate analysis of ecological data using CANOCO. *Cambridge University Press.*

McNaughton, S. J. and Georgiadis, N. J. (1986) Ecology of African grazing and browsing mammals. *Annual reviews Ecol. Syst.* 17, 39-65.

Moleele, N. M. and Mainah, J. (2003) Resource use conflicts: the future of the Kalahari ecosystem. *Journal of Arid Environments* 54, 405-423.

Njoroge, P., Yego, R. Muchane, M. and Githiru, M. (2009) A survey of large and medium sized mammals of Arawale National Reserve, Kenya. *Journal of East African Natural History* 98(1): 119-128.

Olff, H., Ritcie M. E. and Prins, H. H. T. (2002) Global environmental controls of diversity in large herbivores. *Nature* vol. 415, February 2002.

Otto, S. B., Berlow, E. L., Rank, N. E., Smiley, J. and Brose, U. (2008) Predator diversity and identity drive interaction strength and trophic cascades in a food web. *Ecology* 89(3):888.

Parris, R. and Child, G. (1973) The importance of pans to wildlife in the Kalahari and the effect of human settlements on these areas. *Journal of the South African Wildlife Management Association* 3, 1-8.

Ramberg, L., Hancock, P., Lindholm, M., Meyer, T., Ringrose, S., Sliva, J., Van As, J. and VanderPost, C. (2006) Species diversity of the Okavango Delta, Botswana. *Aquatic Sciences* 68, 310-337.

Scholes, R. J., Dowty, P. R., Caylor, K., Parsons, D. A. B., Frost, P. G. H. and Shugart, H. H. (2002) Trends in savanna structure and composition along an aridity gradient in the Kalahari. *Journal of Vegetation Science* 13, 419-428.

Sinclair, A. R. E., Mduma, S. A. R., Grant, J., Hopcraft, C., Fryxell J. M., Hilborn, R. and Thirgood, S. (2007) Long-term ecosystem dynamics in the Serengeti: Lessons for conservation. *Conservation Biology* 21(3), 580-590.

Skarpe, C. (1992) Dynamics of savanna ecosystems. *Journal of Vegetation Science* 3, 293-300.

Skarpe, C. (1991) Impacts of grazing in savanna ecosystems. *Ambio* 20, 351-356.

Skarpe, C. (1990) Shrub layer dynamics under different herbivore densities in arid savanna, Botswana. *Journal of Applied Ecology* 27:873-885.

Skarpe, C. (1986) Plant community structure in relation to grazing and environmental change along a north-south transect in the western Kalahari. *Vegetatio* 68, 3-18.

Smithers, R., edited by Apps, P. (2000) Mammals of southern Africa – a field guide. *Struik Publishers.*

Thomas, D. S. G. and Shaw, P. A. (1991) The Kalahari environment. *Cambridge University Press.*

Twyman, C. (2001) Natural resource use and livelihoods in Botswana’s wildlife management Areas. *Applied Geography* 21, 45-68.

Verlinden, A., Perkins, J. S., Murray, M. and Masunga, G. (1998) How are people affecting the distribution of less migratory wildlife in the southern Kalahari of Botswana? A spatial analysis. *Journal of Arid Environments* 38, 129-141.

Viio, T., (2004) Does land use affect mammal diversity in the savanna ecosystems? *Master thesis, Uppsala University*.

Wallgren, M., Skarpe, C., Bergström, R., Danell, K., Bergström, A., Carlsson, K., Jakobsson, T. and Strand, T (2009) Influence of land use on the abundance of wildlife and livestock in the Kalahari, Botswana. Journal of Arid Environments 73: 314-321.

Wallgren, M., (2008) Mammal community structure in a world of gradients. Effects of resource availability and disturbance across scales and biomes. Acta Universitatis Agriculturae Sueciae. Ph D Thesis 2008:59. Swedish University of Agricultural Sciences, Umeå, Sweden.

WCED, World Commission on Environment and Development (1987) Our common future. *Oxford university press*, London.

Woodroffe, R., Frank, L. G., Lindsey, P. A., ole Ranah, S. M. K. and Romañach, S. (2007) Livestock husbandry as a tool for carnivore conservation in Africa’s community rangelands: a case-control study. *Biodivers Conservation* 16:1245-1260.

Woodroffe, R. (2000) Predators and people; using human densities to interpret declines of large carnivores. *Anim. Conservation* 3, 165-173.

Appendix I

The table contains a complete species lists covering the four conducted studies in northern and southern Kalahari during dry and wet season with total number of observed individuals / land use area.

Southern Botswana		**Dry season No. of individuals**				**Wet season No of individuals**			
Species	**Scientific name**	**CGA**	**FR**	**WMA**	**NP**	**CGA**	**FR**	**WMA**	**NP**
Aardvark	*Orycteropus afer*	0	0	4	1	1	0	0	1
Aardwolf	*Proteles cristatus*	0	0	2	0	0	0	1	0
African wildcat	*Felis silvestris lybica*	5	6	16	14	2	1	3	3
Bat-eared fox	*Ococyon megalotis*	10	4	21	24	0	6	34	48
Black-backed jackal	*Canis mesomelas*	14	5	29	20	7	27	13	27
Blue wildebeest	*Connochatetes taurinus*	0	0	23	108	0	0	40	2
Brown hyena	*Hyena brunnea*	2	1	4	3	0	0	2	3
Cape fox	*Vulpes chama*	1	7	21	7	2	1	9	14
Cape/Scrub hare	*Lepus capensis/saxatilis*	25	21	30	19	12	23	10	16
Cheetah	*Acinonyx jubatus*	0	0	0	0	0	0	0	1
Common duiker	*Sylvicapra grimmia*	2	2	9	2	3	2	2	6
Greater kudu	*Tragelaphus strepsiceros*	0	0	12	3	0	0	0	0
Ground Squirrel	*Xerus inauris*	28	115	59	11	23	7	23	15
Honey Badger	*Mellivora capensis*	3	0	0	1	1	0	0	1
Leopard	*Panthera pardus*	0	0	3	4	0	0	0	1
Lion	*Panthera leo*	0	0	3	2	0	0	4	8
Ostrich	*Struthio camelus*	28	0	33	12	50	15	72	32
Porcupine	*Hystrix africaeaustralis*	2	3	5	1	1	1	4	0
Side-striped jackal	*Canis adustus*	0	0	0	0	0	0	0	1
Slender mongoose	*Galerella sanguinea*	2	2	6	4	2	2	1	2
Small spotted genet	*Genneta genetta*	3	3	17	4	0	1	1	2
Spotted hyena	*Crocuta crocuta*	0	0	0	6	0	0	13	2
Springhare	*Pedetes capensis*	206	81	386	207	139	67	337	703
Steenbok	*Raphicerus campestris*	56	50	259	139	40	53	221	281
Striped polecat	*Ictonyx striatus*	1	0	1	0	0	0	0	0
Warthog	*Phacochoerus aethiopicus*	0	0	4	0	2	0	0	0
Yellow mongoose	*Cynictis penicillata*	11	18	14	1	7	7	5	2
Species observed only in the southern study area:									
Caracal	*Felis caracal*	2	1	1	1	0	0	1	0
Eland	*Taurotragus oryx*	0	0	0	0	0	0	3	0
Gemsbok	*Oryx gazella*	0	1	28	112	0	7	27	244
Red hartebeest	*Alcelaphus buselaphus*	13	18	82	87	7	1	165	56
Springbok	*Antidorcas marsupialis*	134	4	348	436	72	31	952	759
Suricate	*Suricata suricatta*	43	2	92	47	0	4	13	9

Northern Botswana		Dry season No. of individuals				Wet season No of individuals			
Species	**Scientific name**	**CGA**	**FR**	**WMA**	**NP**	**CGA**	**FR**	**WMA**	**NP**
Species observed in both study areas:									
Aardvark	*Orycteropus afer*	1	1	1	2	0	0	0	0
Aardwolf	*Proteles cristatus*	0	0	0	1	0	0	0	0
African wildcat	*Felis silvestris lybica*	1	2	18	29	3	1	16	11
Bat-eared fox	*Ococyon megalotis*	2	3	5	21	3	0	0	11
Black-backed jackal	*Canis mesomelas*	0	8	12	21	4	15	0	3
Blue wildebeest	*Connochatetes taurinus*	0	0	13	333	0	0	0	344
Brown hyena	*Hyena brunnea*	0	1	0	0	0	0	0	0
Cape fox	*Vulpes chama*	1	0	2	0	0	0	1	2
Cape/Scrub hare	*Lepus capensis/saxatilis*	34	3	26	39	13	11	4	27
Cheetah	*Acinonyx jubatus*	0	0	1	2	0	0	0	0
Common duiker	*Sylvicapra grimmia*	14	21	4	1	4	1	2	2
Greater kudu	*Tragelaphus strepsiceros*	5	30	15	75	0	7	27	26
Ground Squirrel	*Xerus inauris*	0	3	0	0	0	3	0	0
Honey Badger	*Mellivora capensis*	0	0	4	0	2	0	0	0
Leopard	*Panthera pardus*	0	0	1	4	0	0	1	2
Lion	*Panthera leo*	0	0	3	4	0	0	1	2
Ostrich	*Struthio camelus*	13	37	3	82	8	5	0	79
Porcupine	*Hystrix africaeaustralis*	0	0	0	2	3	2	3	0
Side-striped jackal	*Canis adustus*	0	0	1	0	1	0	0	0
Slender mongoose	*Galerella sanguinea*	2	5	3	7	0	1	3	1
Small spotted genet	*Genneta genetta*	6	9	22	2	3	3	8	4
Spotted hyena	*Crocuta crocuta*	0	0	4	15	0	0	1	9
Springhare	*Pedetes capensis*	33	10	329	1 625	23	27	43	166
Steenbok	*Raphicerus campestris*	19	86	96	99	6	10	28	14
Striped polecat	*Ictonyx striatus*	0	0	2	4	1	1	0	0
Warthog	*Phacochoerus aethiopicus*	0	1	22	58	0	0	6	71
Yellow mongoose	*Cynictis penicillata*	1	2	1	8	2	1	0	0
Species observed only in the northern study area:									
African buffalo	*Syncerus caffer*	0	0	26	0	0	0	0	0
African elephant	*Loxodonta africana*	7	0	1	451	2	0	52	373
Banded mongoose	*Mungos mungo*	0	0	0	40	0	0	0	7
Dwarf mongoose	*Helogale parvula*	0	1	21	12	0	0	2	0
Giraffe	*Giraffa camelopardalis*	0	0	90	218	0	0	66	134
Hippopotamus	*Hippopotamus amphibius*	0	0	0	0	1	0	0	0
Impala	*Aepyceros melampus*	0	0	838	2 013	0	0	1 074	2 485
Large spotted genet	*Genneta tigrina*	6	1	21	14	1	1	10	7
Roan	*Hippotragus equinus*	0	0	0	1	0	0	0	1
S. Lesser Bushbaby	*Galago moholi*	28	1	62	20	40	6	23	20
Sable	*Hippotragus niger*	0	0	0	0	0	0	0	1
Serval	*Felis serval*	0	0	1	0	0	0	0	0
Tree Squirrel	*Paraxerus cepapi*	34	0	45	24	2	0	20	7
Tsessebe (Topi)	*Damaliscus lunatus*	0	0	6	4	0	0	2	25
Vervet Monkey	*Cercopithecus aethiops*	0	0	0	2	0	0	0	0
White-tail. mongoose	*Ichneumia albicauda*	2	0	4	0	0	0	0	0
Wild dog	*Lycaon pictus*	0	0	0	1	0	0	0	8
Zebra	*Equus burchelli*	0	0	1 039	0	0	0	64	2 361

Domestic species		Dry season No. of individuals				Wet season No of individuals			
Species	**Scientific name**	**CGA**	**FR**	**WMA**	**NP**	**CGA**	**FR**	**WMA**	**NP**
Southern Botswana:									
Cattle	*Bos taurus*	3 613	4 177	97	0	3 293	11 024	1 145	0
Domestic cat	*Felis catus*	1	1	1	0	0	5	0	0
Domestic dog	*Canis familiaris*	62	74	28	0	13	164	26	0
Donkey	*Equus asinus*	500	152	105	0	341	505	78	0
Dromedary (Camel)	*Camelus dromedarius*	0	0	2	0	0	3	0	0
Goat	*Capra hircus*	1 890	980	454	0	2 274	3 984	432	0
Horse	*Equus caballus*	106	125	28	0	105	307	49	0
Sheep	*Ovis aries*	109	221	32	0	91	623	10	0
Northern Botswana:									
Cattle	*Bos taurus*	1 339	2 216	0	0	2 649	7 319	0	0
Domestic cat	*Felis catus*	2	0	0	0	2	0	0	0
Domestic dog	*Canis familiaris*	53	9	0	0	50	88	0	0
Donkey	*Equus asinus*	106	93	0	0	202	654	0	0
Goat	*Capra hircus*	927	888	0	0	1 062	2 614	0	0
Horse	*Equus caballus*	13	50	0	0	39	121	0	0
Mule	*Equus asinus x caballus*	0	2	0	0	0	0	0	0
Sheep	*Ovis aries*	1	5	0	0	14	103	0	0

Appendix II

The table contains a record of species recorded during the wet season in northern and southern Kalahari, codes used in the study and functional type based on food preference and body mass.

Common species name	Scientific name	Code	Food pref.	Body mass (kg)	Size	Funktional type
Herbivore species						
African elephant	*Loxodonta africana*	ele	herbivore	2 500.0-6 000.0	L	LH
African buffalo	*Syncerus caffer*	buf	herbivore	530.0-900.0	L	LH
Cattle	*Bos taurus*	cat	herbivore	300.0-400.0	L	LH
Dromedary (Camel)	*Camelus dromedarius*	cam	herbivore		L	LH
Eland	*Taurotragus oryx*	ela	herbivore	460.0-840.0	L	LH
Giraffe	*Giraffa camelopardalis*	gir	herbivore	700.0-1 400.0	L	LH
Hippopotamus	*Hippopotamus amphibius*	hip	herbivore	970.0-2 000.0	L	LH
Horse	*Equus caballus*	hor	herbivore	250.0	L	LH
Kudu	*Tragelaphus strepsiceros*	kud	herbivore	120.0-305.0	L	LH
Plains zebra	*Equus burchelli*	zeb	herbivore	290.0-340.0	L	LH
Blue wildebeest	*Connochatetes taurinus*	wil	herbivore	180.0-250.0	M	MH
Donkey	*Equus asinus*	don	herbivore	140.0	M	MH
Gemsbok	*Oryx gazella*	gem	herbivore	210.0-260.0	M	MH
Goat	*Capra hircus*	goa	herbivore	30.0	M	MH
Impala	*Aepyceros melampus*	imp	herbivore	32.0-66.0	M	MH
Mule	*Equus asinus x caballus*	mul	herbivore	360.0-450.0	M	MH
Red hartebeest	*Alcelaphus buselaphus*	rhb	herbivore	105.0-156.0	M	MH
Roan	*Hippotragus equinus*	roa	herbivore	250.0-270.0	M	MH
Sable	*Hippotragus niger*	sab	herbivore	210.0-230.0	M	MH
Sheep	*Ovis aries*	she	herbivore	30.0	M	MH
Springbok	*Antidorcas marsupialis*	spr	herbivore	30.4-48.0	M	MH
Tsessebe	*Damaliscus lunatus*	tse	herbivore	126.0-140.0	M	MH
Cape/Scrub hare	*Lepus capensis/saxatilis*	har	herbivore	1.4-4.5	S	SH
Common duiker	*Sylvicapra grimmia*	cdu	herbivore	15.3-25.4	S	SH
Ground squirrel	*Xerus inauris*	gsq	herbivore	0.5-1.0	S	SH
Porcupine	*Hystrix africaeaustralis*	por	herbivore	10.0-24.0	S	SH
Springhare	*Pedetes capensis*	sph	herbivore	2.9-3.9	S	SH
Steenbok	*Raphicerus campestris*	ste	herbivore	3.9-13.2	S	SH
Tree squirrel	*Paraxerus cepapi*	tsg	herbivore	0.7-2.7	S	SH
Carnivore species						
Cheetah	*Acinonyx jubatus*	che	carnivore	43.0-60.0	L	LC
Leopard	*Panthera pardus*	leo	carnivore	32.0.90.0	L	LC
Lion	*Panthera leo*	lio	carnivore	69.0-260.0	L	LC
Spotted hyena	*Crocuta crocuta*	shy	carnivore	60.0-88.0	L	LC
Brown hyena	*Hyaena brunnea*	bhy	carnivore	40.0-47.0	M	MC
Caracal	*Felis caracal*	car	carnivore	7.2-20.0	M	MC
Domestic dog	*Canis familiaris*	dog	carnivore	15.0-25.0	M	MC
Honey badger	*Mellivora capensis*	hbg	carnivore	8.0.14.5	M	MC
Serval	*Felis serval*	ser	carnivore	8.6-13.5	M	MC
Wild dog	*Lycaon pictus*	wdg	carnivore	24.0-30.0	M	MC
African wild cat	*Felis silvestris lybica*	awc	carnivore	2.4-6.4	S	SC
Cape fox	*Vulpes chama*	cfx	carnivore	2.3-4.2	S	SC
Domestic cat	*Felis LHus*	doc	carnivore	3.0-6.0	S	SC

Common species name	**Scientific name**	**Code**	**Food pref.**	**Body mass (kg)**	**Size**	**Funktional type**
Omnivore species						
Black-backed jackal	*Canis mesomelas*	bbj	omnivore	5.4-12.0		O
Large grey mongoose	*Herpestes ichneumon*	lmg	omnivore	2.4-4.1		O
Large spotted genet	*Genetta tigrina*	lsg	omnivore	1.0-3.2		O
Lesser bushbaby	*Galago moholi*	bub	omnivore	0.1-0.2		O
Ostrich	*Struthio camelus*	ost	omnivore	90.0-100.0		O
Side-striped jackal	*Canis adustus*	ssj	omnivore	7.2-12.1		O
Small spotted genet	*Genetta genetta*	sgn	omnivore	1.4-2.6		O
Striped polecat	*Ictonyx striatus*	spc	omnivore	0.4-1.5		O
Warthog	*Phacochoerus aethiopicus*	war	omnivore	44.0-104.0		O
Vervet monkey	*Cercopithecus aethiops*	ver	omnivore	3.4-8.0		O
Insectivore species						
Aardvark	*Orycteropus afer*	aav	insectivore	40.0-65.0		I
Aardwolf	*Proteles cristatus*	aaw	insectivore	5.2-10.7		I
Banded mongoose	*Mungos mungo*	bmg	insectivore	1.0-1.6		I
Bat-eared fox	*Ococyon megalotis*	bfx	insectivore	3.0-5.4		I
Dwarf mongoose	*Helogale parvula*	dmg	insectivore	0.2-0.4		I
Slender mongoose	*Galerella sanguinea*	smg	insectivore	0.4-0.8		I
Suricate	*Suricata suricatta*	sur	insectivore	0.6-1.0		I
White-tailed mongoose	*Ichneumia albicauda*		insectivore	3.2-5.5		I
Yellow mongoose	*Cynictis penicillata*	ymg	insectivore	6.0		I

SENASTE UTGIVNA NUMMER

2009:1	Användande av avskjutningsstatistik i Förvaltning. Påverkar tidigare jakt CPUE? Författare: Mirja Lindberget
2009:2	En riskanalys av älg nära väg. Författare: Anneli Stigsdotter
2009:3	Produktion av fodermärgkål och klövviltets utnyttjande av viltåker och omgivande skog. Författare: Lovisa Nilsson
2009:4	Vad är de uppskattade totala fångsterna av svenskt fiske i Östersjön 1950-2007? Författare: Lo Persson
2009:5	Brown bear (*Ursus arctos)* den site concealment in relation to human activity in Scandinavia. Författare: Ellinor Sahlén
2010:1	Enumerating Atlantic salmon smolt production in River Vindelälven based on habitat availability and parr densities. – Consequences of using different density estimation methods. Författare: Stefan Ågren
2010:2	Hunter demography, trends and correlates of hunting participation in Sweden. Författare: Erik Lindberg

Hela förteckningen på utgivna nummer hittar du på www.vfm.slu.se