HABITAT USE BY GREAT ONE-HORNED RHINOCEROS (*Rhinoceros unicornis* L.) AND OTHER SYMPATRIC SPECIES IN KAZIRANGA NATIONAL PARK, ASSAM, INDIA

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By

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CERTIFICATE

This is to certify that **MS. GITANJALI BANERJEE** of the Wildlife Institute of India has carried out an original piece of work titled **"HABITAT USE OF GREAT ONE-HORNED RHINOCEROS (*Rhinoceros unicornis* L.) AND OTHER SYMPATRIC SPECIES IN KAZIRANGA NATIONAL PARK, ASSAM, INDIA"** in partial fulfillment of the M.Sc. (Wildlife Science) degree of Saurashtra University. These investigations were carried out under our supervision at the Wildlife Institute of India from November 2000 to June 2001. We also certify that this work has not been submitted for any other degree to any university.

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One thing I have learnt in a long life; that all our science,
measured against reality, is primitive and childlike-
and yet it is the most precious thing we have.

- *Albert Einstein*
(1879-1955)

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In retrospect I remember Kaziranga as a truly magical place. I think of the verdant green grasslands resplendent in the morning light and its unique denizens with fond memories. Fieldwork was never easy but I had a marvelous time. I would like to acknowledge the people who made it possible for me to carry out this study.

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This is a scientific effort, dry and impersonal. At the heart of it the exotic sights, sounds and mysteries of Kaziranga lie concealed. It is these that enamour me and whet my interest.

SUMMARY

A study on the habitat use by the Great One horned rhinoceros (*Rhinoceros unicornis*) and three other sympatric ungulates was carried out in Kaziranga National Park (KNP), Assam during December 2000 to April 2001. KNP supports more than half the world's population of the Indian Rhinoceros, a highly endangered species. Since this park also supports a high diversity and density of herbivores coexisting in a typical floodplain habitat, it was an ideal place to conduct the following study. The study aimed to determine how 4 large herbivore species rhino, wild buffalo, swamp deer and hog deer achieve spatial and temporal separation across two seasons. The study also investigated how nutritive content of the forage determines habitat selection by these species. KNP was an ideal place to study habitat use patterns by these four sympatric species due to the seasonal variation of forage quality caused by the practice of annual burning. Sampling for animal abundance within each habitat type over two seasons was done by monitoring transects. Feeding observations were obtained by scan sampling. Laboratory analysis was done to determine the nutritive content of the available forage during winter and summer.

Seasonal and spatial differences observed in habitat occupancy patterns by the ungulate species within KNP seem to be a way of partitioning resources in order to minimize competition. During the winter season all ungulates selected the short grasslands for feeding. The wild buffalo and the swamp deer showed no variation in the habitat occupancy patterns showing a positive selection for the short grasslands. However, rhinos and hog deer were observed to prefer the tall, burnt and sprouting grasslands in summer for feeding during summer. When habitat occupancy patterns were correlated with the nutritive value of the forage it was found that all ungulates tracked high crude protein levels in available forage. Rhinos and hog deer formed an association that exploited areas that have high crude protein and low silica content. Wild buffaloes and swamp deer show less flexibility in habitat occupancy patterns and were observed to feed in short grasslands where there was a relatively high amount of crude protein available during both the seasons. The study revealed that crude protein played an important role in determining habitat use by hog deer, which shows a linear relationship with crude protein. Forage volume, an indicator of available food played a significant role in determining habitat use patterns for the large bodied ungulates, namely the rhino and the wild buffalo which is in keeping with their physiology and body requirements.

There seems to be partitioning of space by the ungulates on the basis of body size and dietary separation. Rhino and hog deer were observed to formed one guild whereas wild buffalo and swamp deer formed another one. These two groups differed in the pattern of habitat occupancy suggesting that ecological separation in Kaziranga National Park, perhaps occurs on the basis of differential use of the habitat by ungulates that have a similar body size. There was an observed complementation of body sizes within each association. A large bodied ungulate associated with another ungulate that was much smaller in size and therefore, had different ecological needs.

Thus, fire as a management tool in the tall wet grasslands has important connotations. Increased levels of crude protein content and reduction in ash content as well as fibre levels in the fresh sprouting forage species is attributed to fire. Currently the management practice of annual burning seems to be beneficial for rhinos and hog

deer. Its effect on species such as wild buffalo and swamp deer was not apparent during the course of this study. Possible, they do not perceive a need to feed within the burnt tall grasslands during summer in order to exploit areas with higher amounts of crude protein since the crude protein content within the short grasslands are enough to sustain their requirements. This is merely a short-term effect. The long-term aspect of using fire to manage the tall grasslands comes with a plethora of attendant issues needs to be studied further.

Time was a limiting factor during this study and a long-term study is necessary to bear out the trends that were observed as a result of this study.

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1. INTRODUCTION

1.1 Background

The flood plains of the Brahmaputra in northeastern India and the Ganges in North India represent a unique grassland ecosystem owing to their dynamic nature, high productivity and the diversity of ungulates supported by them. The landscape in this region is dominated by hygrophilous grasslands (Puri *et al.* 1989). They owe their origin to the Miocene period subsequent to the upliftment of the Himalayas, establishment of the current monsoon pattern and beginning of fluvial deposition, 20 million years before present (Wadia, 1966). In terms of productivity the grasslands of this region rank the highest amongst the terrestrial ecosystems of the world (Eisenberg & Seidensticker 1976, Yadava & Singh 1977, Lehmkuhl 1989). Annual flooding and recurrent fires have helped to maintain these grasslands in a state of dynamic equilibrium. Fire, an anthropogenic factor in this habitat, stimulates the growth of several grasses that are more palatable and nutritious and can withstand grazing by ungulates, while flooding replenishes the soil with nutrients and allows the regeneration of flood adapted species. These two key factors of the tall wet grassland habitat operate at the landscape level creating mosaics of seral stages that are exploited by the resident ungulate populations according to their body requirements.

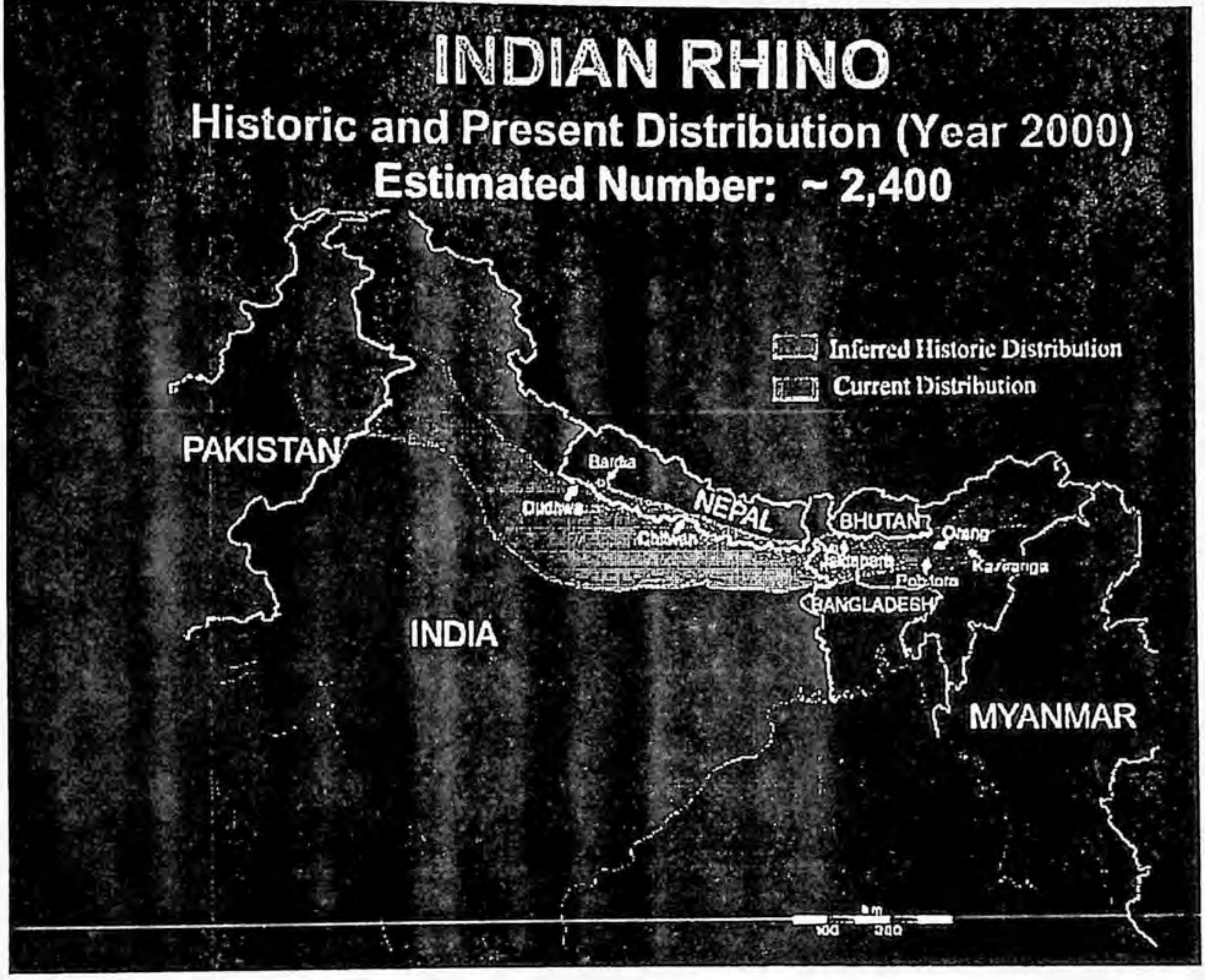
The wild herbivores, particularly grazing ungulates, have coexisted in this habitat across the span of their evolutionary history. Multispecies assemblies coexist in the area for a variety of different reasons despite a potential for intense competition. The sympatric herbivores resort to spatial, temporal and dietary separation in their habitat use (Lamprey 1963, Bell 1970, Jarman 1972, Seidensticker 1976, Sinclair & Norton - Griffith 1982, Green 1987, Sankar 1994, Khan 1996, Putman 1996). Such separation is largely predetermined by the quality of the available food. All animals are known to selectively graze on more palatable and nutritious species compared to coarse and less palatable species (Gwynne and Bell 1968, Bell 1970, 1971). Tolerance to low quality forage depends on the body size and gut physiology of the ungulates. Resource partitioning is brought about by highly selective feeding behaviour. At one end of the spectrum larger herbivores require an abundant supply of food even though it might be relatively poor in quality, whereas small herbivores such as the hog deer (*Axis porcinus*) are highly selective grazing on fresh, nutritious and highly palatable grasses that sprout after fire or frequent grazing. More generalist species such as the Great one horned rhinoceros (*Rhinoceros unicornis*) that can tolerate a poorer quality diet with a higher amount of plant structural components may move into areas dominated by tall and coarse grasses.

The Brahmaputra floodplains with their multi species assemblage provide an opportunity to test whether seasonal variation in the nutrient content of forage caused by the practice of annual burning affects the distribution pattern of sympatric ungulates. The present study deals with the habitat use by rhinos and other sympatric ungulates over two seasons *viz.* winter and summer from December 2000 to May 2001. It also aims to record whether there is any influence of nutrient content in the available forage on the seasonal distribution of ungulates of different body sizes across the major habitats.

The tall wet grasslands with their resident fauna such as the Indian rhino once stretched in an unbroken sweep across the entire floodplain belt of the Ganges and the Brahmaputra (Fig. 1.1). Today these grasslands are reduced to small patches within the original range due to extensive fragmentation and loss of habitat. Kaziranga

National Park in Assam supports the highest population of Indian rhinos in one such habitat island that is as yet relatively undisturbed by human encroachment and anthropogenic pressures. Thus, understanding resource partitioning in terms of habitat use in relation to the nutritive quality of the forage is of direct relevance in the conservation and management of such areas since the species composition of herbivore communities is dynamic. Ecosystem responses to internal and external pressures can be effectively predicted and controlled after gaining such an understanding. This is vital for the long-term management and conservation of threatened species such as the Great one horned rhinoceros and its habitat. Keeping this view, the present study was undertaken during December 2000-April 2001.

Fig 1.1 Past and present distribution of the Great One horned Rhinoceros and the tall wet grasslands.



1.2 Objectives

The study had the following objectives:

1. To determine how 4 large herbivore species (rhino, wild buffalo, swamp deer and hog deer) dependent on the floodplain grasslands achieve spatial and temporal separation across two seasons.
2. To investigate how nutritive content of the forage determines habitat selection by these species.

In order to achieve the above objectives, the following questions were framed-

Habitat Use by Rhinos and sympatric species

1. What are the different habitat types within the study area based on vegetation structure that rhinos and sympatric species use for feeding?
2. How do different species utilize the habitat types for feeding across winter and summer?
3. What are the seasonal trends in habitat usage?

To determine the effect of nutrient content in the available forage on habitat use

1. Is there any seasonal difference in the nutritive value of forage across habitat types?
2. How does the nutritive value of the forage influence habitat selection by each species?

1.3 Review of literature

Heterogeneity of environment and resources in space and time may facilitate prolonged coexistence of species that would otherwise compete to exclusion in a more homogeneous environment (Putman, 1996). Forage quality has been found to be an important determinant of habitat use by herbivores. Plant species composition, structure and phenology are influenced a great deal by the burning of grasslands. Physical structure and growth phase of the food species and their seasonal variation are of vital importance to ungulates. Body size, metabolic requirements and rumen physiology consideration suggest that large ungulates must consume and digest abundant, low quality food whereas small animals consume food of high nutrient quality (Bell 1971). It has been pointed out that for plant foods, quality and abundance are often inversely co-related (Putman 1996). During the early growing season plant Nitrogen concentration and digestibility is presumably the greatest. As the growing season progresses the plant Nitrogen becomes diluted and structural components increase reducing digestibility and diet quality. Dietary selection follows size related trends, as it is a function of consumer size and food quality. Selection appears to be a product of evolutionary strategy related to body size, morphology and physiology (Bell 1971) and tactical choices based on the current food quantity and quality (Schwartz and Ellis 1981).

Sympatric ungulates differ in the mode of their exploitation of the environment. Factors including the mouth structure, gut physiology and function as well as the body size cause vast differences in the diet, grazing behaviour and grouping patterns. These diverse adaptive patterns lead to niche separation and habitat selection, which determine ungulate community structure (Putman 1996, Vesey-Fitzgerald 1960, Lamprey 1963, Gwynne and Bell 1968, Bell 1971, Jarman 1974, Schwartz and Ellis 1981). Ungulate diet selection, foraging behaviour, feeding ecology and community structure can be related to the body size, morphology and physiology.

Grzimek and Grzimek (1960) were the first to recognize that neither all areas nor all grass species were equally used by ungulates. Chemical analysis revealed that the preferred food species had higher protein and digestibility and this has been found to be strongly influenced by season (Putman 1996).

When soil moisture is abundant as in the flood plains, tall grasses flourish. This has two important consequences. First, the vegetation may grow out of reach of the animals, and secondly much of the production will be of structural tissues rich in insoluble lignin, cellulose and hemi-cellulose that are of low value as food to ungulates. This affects the quality of food available for wild ungulates over the season. Seasonal changes in forage quality causes shifts in habitat use (Klein 1970, Schaller 1967, Dinerstein 1980). Flood also influences the habitat by creating mosaics of water bodies such as ox bow lakes, silted banks, clay beds, swamps and other micro sites. Ungulates vary in their ability to exploit such microhabitats. Certain grassland patches are used more frequently by ungulates compared to other areas that may result in soil compaction and creation of meadow conditions or "grazing lawns" (Karki, 1997).

Protected Area managers have been using fire as an important tool to stimulate growth of more palatable and nutritious grasses that have little structural matter and are consequently high quality ungulate food in the floodplain grassland habitat (Deb

Roy 1986). Prescribed burning has been found to benefit especially megaherbivores (Martin 1975, Dinerstein 1979, Johnsingh 1986). Under proper regime, not only does it stimulate higher productivity of palatable grasses with higher protein content and releases minerals bound in grasses but also helps to maintain the grasslands and prevents serious outbreaks of wildfires in peak summer by reducing fuel loads. Seasonal and spatial differences among plant communities in species composition, production and food quality induced by a fire regime allows redistribution of ungulates thereby reducing pressure on smaller habitat patches (Jarman and Sinclair 1979).

Resource selection by ungulates has been intensively studied in the Serengeti ecosystem (Jarman and Sinclair 1979) and in the tropical ecosystem (Mathur 1991, Schaaf 1978, Mishra 1982) based on habitat as well as forage resources. Resource relations amongst African ungulates concentrate mostly on describing separation by habitat (Lamprey 1963, Bell 1970, Jarman 1972, Sinclair 1979), by food species (Jarman 1971) or plant parts (Gwynne and Bell 1968, Bell 1970, Sinclair 1979). One of the pre requisites for management of a wildlife area for the long-term conservation of a species can be achieved only after gaining an understanding of the habitat requirements of the species (Soule 1986). Recent studies on the large ungulate-habitat relationships have been done based on the habitat requirement of the species (Ben Shahar & Skinner 1988). A few studies have been done in the Indian context (Schaller 1967, Dinerstein 1979, Green 1985, Mathur 1991, Sinha and Sawarkar 1993,Sankar 1994, Biswas 1999).

There is very little published literature on habitat use by rhinos. Most of the earlier publications were based on observations made by sportsmen or naturalists e.g., Ali (1927). Gee (1953,1959,1963) conducted a survey on rhinos in Kaziranga National Park and in Royal Chitwan National Park addressing the ecology and behaviour of rhinos. The first study on the movement patterns and the feeding behaviour of the rhino was done by Berg (1933) in Jaldapara Wildlife Sanctuary, Northwest Bengal. Laurie (1978) and Dinerstein (1979) conducted landmark studies on the ecology of herbivores in the *Terai* grasslands of Nepal. Laurie (1978) found much seasonal variation in the food availability and the resultant movement of rhinos between different habitat types. The rhinos were observed feeding on abundant fibrous food supplemented by a wide variety of other plants. Grasses constituted 70-89% of its diet according to the season in Royal Chitwan National Park (Laurie 1978). Other studies have revealed that leaves and branches of shrubs, trees, submerged and floating aquatic plants and agricultural crops are also consumed (Brahmachary *et al.* 1969, Joshi 1986). Jnawali (1995) also confirmed the diverse diet of rhinos with more than 60% of its diet being constituted of grasses. More recent studies addressing the ecology of the species includes the work by Dinerstein and Price (1991) on the demography and habitat use by rhino in Royal Chitwan National Park. Sinha and Sawarkar (1993) studied the habitat use and seasonal variation in the range of movement in case of reintroduced rhinos in Dudhwa National Park, India. Plant resources and their utilization by different herbivores, including the rhino was studied by Banerjee (1993) in Jaldapara Wildlife Sanctuary. Jnawali and Wegge (1993) looked at the space and habitat use by the reintroduced rhino population in Royal Bardia National Park in Nepal.

Karki (1997) looked at the effects of grazing and management intervention in Royal Bardia National Park and concluded that ungulate concentration in habitat patches leads to the formation of grazing lawns that are characterized by growth of very short grasses differing in composition from the neighbouring areas. These patches recovered once grazing pressures declined. Ghosh (1997) looked at the effect of fire in the *chaurs* of Corbett National Park. Biswas (1999) looked at the habitat use by hog deer including sympatric species such as rhinos in the *duar* grasslands of Jaldapara Wildlife Sanctuary across areas of natural grasslands and managed grasslands. *Chaurs* are the anthropogenic grasslands in the *Bhabbar* tract characterized by relatively shorter (0.5-1.5 m) grasses. *Duar* grasslands of West Bengal are intermediate between the *chaurs* and *Terai* grasslands in terms of moisture and height.

PA's within the floodplain grasslands lack planned research and monitoring programmes which is essential for sound and effective management. The existing research contributions have largely been in the form of lists, inventories, ecological surveys and a species oriented approach towards a few selected endangered mammals and birds (Mathur, 2000).

The overall review of literature reveals that the *Terai* grasslands especially in terms of use by sympatric ungulates have received scant attention. Therefore, the following study was undertaken in Kaziranga National Park (KNP) located in the floodplains of the Brahmaputra. KNP forms the last stronghold of the Great one horned rhinoceros. The purpose was to study how resources in terms of space and food are partitioned in this ecosystem. The information generated was considered to be of vital importance for the management of the rhinoceros and sympatric species. It would also validate the need to conduct further studies of its kind in such an ecosystem in the future.

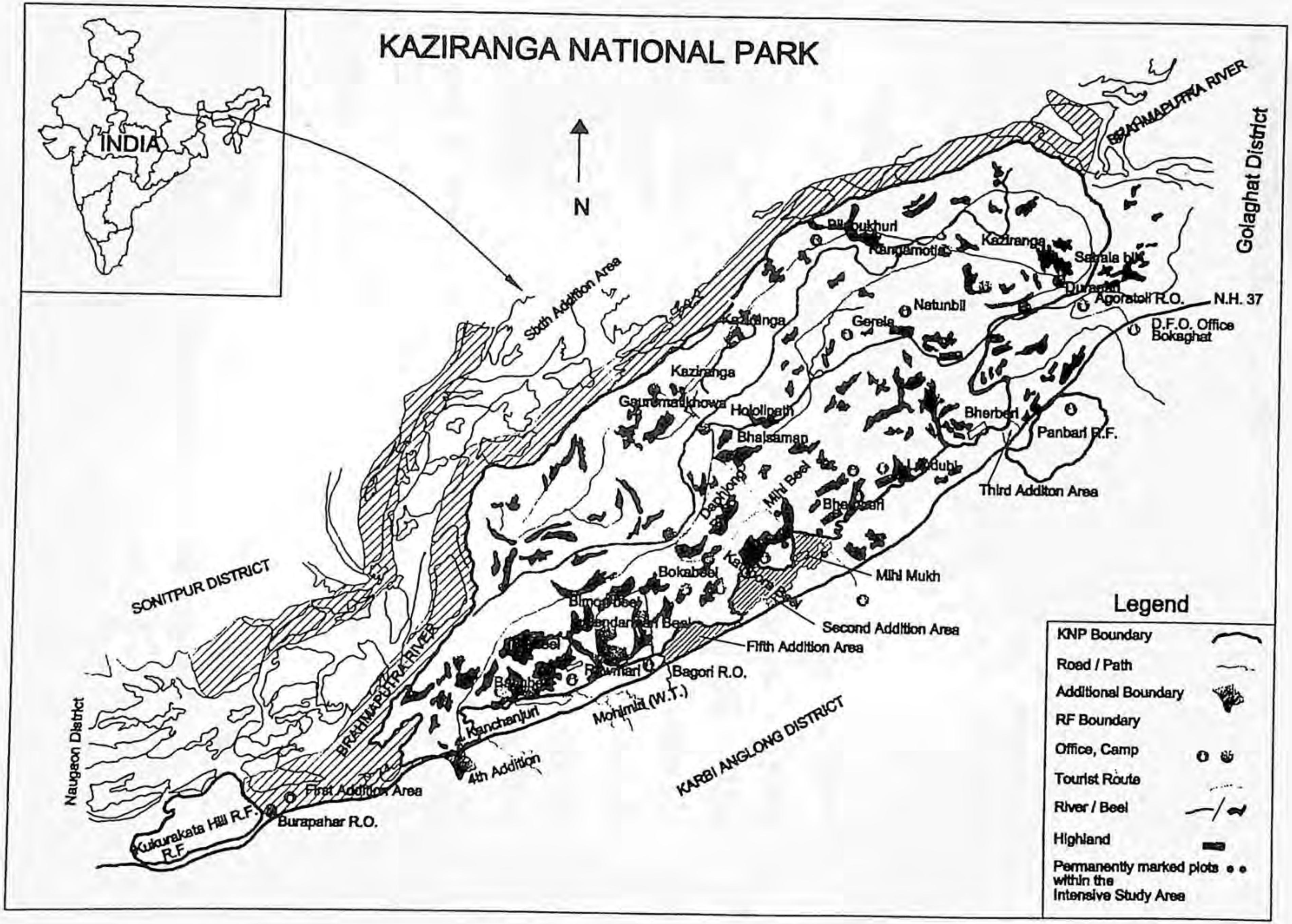
2. STUDY AREA

2.1 Introduction

The study was conducted in Kaziranga National Park (KNP; 26°30'-26°45'N, 93°05'-93°40'E), Assam, Northeast India. The park is situated in Naugaon and Golaghat districts on the southern flood plains of the Brahmaputra River at the foot of the Karbi Anglong Hills and north of the National Highway no.37. Its boundary for the most part follows the Mora Diphlu River (Fig 2.1). In the heart of the Assam, KNP is one of the last areas in northeastern India relatively undisturbed by debilitating anthropogenic pressures. It sustains the largest population of the Indian rhino and is one of the last strongholds of this endangered species.

Kaziranga is placed under the 9A biotic province of biogeographic zone of India (Rodgers and Panwar, 1992). The habitat consists primarily of tall, dense grasslands interspersed with open forests, numerous small lakes or 'Beels' and interconnecting streams that join the Brahmaputra draining from east to west. Three-quarters or more of the area is submerged annually by the floodwaters of the Brahmaputra. The area of the park is ca. 428.7 km^2. However there is constant change in the exact area due to erosion and accretion on the northern boundary caused by the Brahmaputra during floods. By 1990 an overall reduction of 23.6 km^2 particularly along the Bagori and Agoratoli ranges followed by a slight gain of 7.7 km^2 was noted (Kushwaha and Unni, 1986). In 1997 the total park area was found to be 407.9km^2 (Table 2.1).

429.93



KAZIRANGA NATIONAL PARK

Table 2.1: Dynamics of Landmass and Waterbodies During 1967-1997 in Kaziranga National Park*

Year	Park area (in km^2.)	Area of wetlands (in km^2.)	%age area to Park area
1967-68	428.7	36.6	8.5
1990	400.2	23.5	5.9
1997	407.9	27.4	6.7

* From Baruah (1998)

2.2 History of Kaziranga National Park

Kaziranga was declared a Reserve Forest in January 1908 with an initial area of 226.2 km^2 when the population of the Great One- horned rhinoceros dipped to an alarming number of 12 individuals. It was declared a game sanctuary in 1916 and a wildlife sanctuary in 1926 with the prime objective of conservation of the Indian rhinoceros. In 1952, the Executive Committee of the Indian Board for Wildlife recommended that the area be declared a national park. Subsequently the Assam Rhinoceros Bill was passed in 1954 and steps were initiated to conserve the rhino and its habitat. In February 1974 it was declared a national park that marked the beginning of active wildlife management. Kaziranga was declared a World Heritage Site in 1985 because of its unique habitat and fauna.

2.3 Topography

Kaziranga lying at an altitude of 65 m has a flat terrain with a gentle east to west slope (Kushwaha and Unni, 1986). The park has rich alluvial deposits due to recurrent floods that occur annually. It has numerous waterbodies locally known as "Beels" scattered all over the landscape. Beels have often been created by the changing courses of tributaries of the Brahmaputra that extensively criss-cross the National Park. The Beels constitute a very important habitat for all animals particularly the herbivores since they support short grass communities at their edges dominated by important forage species. They also provide water for drinking and wallowing (Laurie, 1978). The park is criss-crossed by several river channels. The Bhengrai and Jiya Diphlu rivers run east to west through the middle of the Park and the Mori Diphlu makes up most of the southern boundary. The Karbi Anglong hills flank the park on the south.

2.4 Climate

The climate of the area is sub-tropical monsoon type. There are three distinct seasons. Summer is dry and windy extending from February to May with an average maximum temperature of 37 ^{0}C and a minimum temperature of 19 ^{0}C. Monsoons are hot and humid and bring heavy rain between the months of June to September. The average rainfall ranges between 1500-2500 mm (Baruah, 1998). Winter extends from October to January with an average maximum temperature of 25 ^{0}C and an average minimum temperature of 10 ^{0}C. Mild winter showers occur during the month of January. Dew and thick fog are common during this period of the year.

2.5 Soil and Geology

Kaziranga has rich deposits of alluvium brought in by annual flooding of river Brahmaputra. Older deposits of alluvium date back to the Pleistocene period and consist of sand, pebbles, clay and silts with formations of impure calcium carbonate. Older deposits of alluvium in elevated areas are relatively unaffected by flood.

Alluvium of new origin is light in colour consisting of sand, silt, clay and pebbles. It is generally poor in calcium deposits (Baruah, 1998).

Recurrent floods heavily influence soil deposits within the park. The park is a mosaic of clayey soils as well as deposits of fresh sand in topsoil. Difference in soil conditions spurs growth of different vegetation communities and affects vegetation dynamics.

2.6 Vegetation

The different vegetation types of KNP are patchworked together to form an intimate mosaic. The vegetation of KNP comprises alluvial grasslands that are divisible into tall and short grass communities interspersed by tropical moist deciduous to semi-evergreen forests. Champion and Seth (1968) have described these grasslands as eastern wet alluvial grasslands (4D/2S2). Hajra (1978) classified the vegetation of the park into the following categories: (i) Alluvial inundated grasslands, (ii) Tropical wet evergreen forest (iii) Tropical semi-evergreen forest and (iv) Aquatic vegetation. Grasslands cover about two thirds of the park area (Kushwaha and Unni, 1986). They predominate in the west, with tall 'elephant' *Saccharum arundinaceum* grasses on the higher ground and short grasses on the lower ground surrounding the 'Beels'. They have been maintained by annual flooding and burning over thousands of years. A brief description of major physiognomic type follows:

i. **Tall grasslands** occupy more than 40% of the park and form the single largest land cover (Kushwaha and Unni, 1986). These grasses often reach a height of 4 to 5 metres. They are burnt every year during winter to prevent woodland succession. Some of the dominant grass species are *Saccharum arundinaceum*, *Saccharum spontaneum, Saccharum narenga, Phragmites karka, Arundo donax, Imperata cylindrica, Vetiveria zizanioides* and *Themeda arundinacea.* There are extensive patches of *Alpinia allughas* (Family Zingiberaceae) within areas dominated by tall grasses.

ii. **Short grasslands** surround the "Beels" and are the preferred grazing grounds for all major herbivore species in KNP. The major grass species are *Cynodon dactylon, Chrysopogon aciculatus, Andropogon sp., Eragrotis sp.*, *Hemarthria compressa, Carex sp., Cyperus, Kyllinga and Fimbristylis sp.*

iii. **Open Savannah grasslands** form an ecotone between tall grasslands and woodlands. Amidst the grasses are numerous forbs and scattered trees of *Bombax ceiba, Albizia procera, Dillenia pentagyna, Careya arborea and Emblica officinalis.*

The woodlands comprise 29.3 % of the total area of park (Kushwaha and Unni, 1986). They are found in the highlands and elevated areas. Grasses form a relatively low proportion of the vegetation in woodlands.

iv. **Tropical semi-evergreen forests:** The dominant species of tropical semi-evergreen forests are *Albizia procera, Bombax ceiba, Bridelia retusa, Bischoffia javanica, Crataeva unilocularis. Lagerstroemia parviflora, Leea indica* and *Trewia nudiflora.* They often support luxuriant and impenetrable thickets of cane (*Calamus tenuis*).

v. **Tropical evergreen forests** flourish on high grounds relatively unaffected by annual flooding. Common trees found here are *Alstonia scholaris*, *Dillenia indica, Garcinia tinctoria, Ficus* spp.. *Litsea nitida, Stereospermum* *personatum* and *Syzygium cumini*. There is thick undergrowth dominated by *Calamus tenuis* , *Alpinia allughas, Polygonum spp.* and *Solanum spp.*

vi. **Aquatic/Semi-aquatic vegetation** occupies the frequently inundated areas and banks of lakes, streams and "nullahs" interspersed between grasslands and woodlands (Kushwaha and Unni, 1986). Several species of submerged and floating plants such as *Paspalum paspaloides, Azolla pinnata, Ceratophyllum demersum, Cyperus sp, Enhydra sp., Hydrilla verticillata, Hygrorhiza aristata, Ipomea sp., Leersia hexandra, Pistia stratiotes, Polygonum spp., Scirpus sp., Typha elephantina,* and *Nymphaea sp. Eichhornia crassipes* (commonly known as water hyacinth) is a noxious weed occupying a significant percentage of open waters in most of the waterbodies within KNP.

vii. Apart from these vegetation categories there is a grassland of 6 sq. km approx. within the second addition area adjoining KNP. This grassland is primarily dominated by *Vetiveria zizanioides* along with other species such as *Cynodon dactylon* and forb species such as *Desmodium bipinnata* .

2.7 Fauna

Kaziranga National Park supports a rich diversity of fauna. It sustains the largest population of the Great One horned rhinoceros (*Rhinoceros unicornis*) and wild buffalo (*Bubalus bubalis*) in the subcontinent. The other sympatric ungulate species found here are the Asian elephant (*Elephas maximus*), gaur (*Bos gaurus*), swamp deer (*Cervus duvauceli*) and hog deer (*Axis porcinus*). Sambar (*Cervus unicolor*) and Indian muntjac (*Muntiacus muntjak*) are forest dwelling species and relatively low in number. Livestock are sympatric with the rhinos along the fringes of the park.

Other species inhabiting the park are the tiger (*Panthera tigris*), sloth bear (*Melursus ursinus*), jungle cat (*Felis chaus*), Indian porcupine (*Hystrix indica*), hoolock gibbon (*Hylobates hoolock*) and capped langur (*Presbytes pileatus*). All three species of otters are found here, namely the common otter (*Lutra lutra*), smooth Indian otter (*Lutra perspicillata*) and the clawless otter (*Aonyx cinerea*). The Gangetic dolphin (*Platanista gangetica*) is frequently sighted in the River Brahmaputra and in the Diphlu near its confluence with the Brahmaputra when the rivers are in full spate during the floods (*pers. obs.*).

The avifauna of KNP includes species such as the Bengal Florican *Houbaropsis bengalensis*, Swamp francolins *Francolinus gularis*. Pallas fishing eagle *Haliaeetus leucoyphus*, grey headed fishing eagle *Icthyophaga icthyaetus* , greater adjutant storks *Leptoptilos dubius*, lesser adjutant storks *Leptoptilos javanicus* and black necked stork *Ephippiorhyncus asiaticus*. A large number of raptors are commonly sighted in the park. Large numbers of waterfowl visit the park during the winter month (Narayan *et al*., 1989).

Common reptilian species sighted included the python, king cobra, common cobra, bronze backed snakes, coral snakes and the water monitor lizard.

2.8 Floods in Kaziranga

Flooding is an annual phenomenon in KNP. Every year the river Brahmaputra floods its banks and inundates extensive areas of the park. Floods prove to be a "necessary evil" for KNP. Floods are beneficial because they bring in rich deposits of silt that is essential for the maintenance of grasslands. The receding floodwaters also flush out the water hyacinth from the waterbodies depending on the current in the water. Due to the long spells of inundation the water table in KNP is high throughout the year. Flood proves to be a bane for KNP as well because of the heavy toll it takes in terms of animal mortality within the park. In the last decade increasing levels of floods have been a cause of concern to the park management. Due to various reasons, mainly deforestation in the upper catchment areas the intensity of floods is on the rise. Extensive flooding forces the rhinos and other grassland dependent species to seek refuge in higher areas such as the Mikir hills where they become vulnerable to poaching. There have also been incidents in the past where animals were killed by speeding vehicles on National Highway 37 while they were moving up to the hills in search of higher grounds during peak monsoon (Anon 1988, Choudhury 1987).

The management strategy adopted by KNP authorities has been the creation of highlands where animals can seek shelter during the high floods. Some highlands were constructed in 1998 with the help of the army after the devastating flood. However, there may be a requirement for many more highlands with bigger dimensions to be constructed to provide shelter to marooned animals during the flood season. Research and monitoring is required to record and determine the effect of such highland construction.

2.9 Fire

Controlled burning of grasslands is a well-established practice in KNP. Fire helps in the maintenance of grasslands in the following ways: (i) Apart from arresting succession from grassland to forest, fire is believed to increase productivity of grasses, (ii) burning helps in providing high quality forage within grassland which is preferred by herbivores, (iii) it prevents succession from shorter *Imperata cylindrica* dominated swards to taller grassland communities dominated by mature stands of *Saccharum arundinaceum, S. narenga* and other species and woodland species that are less favoured by obligate grassland ungulates, (iv) burning also enhances visibility that facilitates anti poaching surveillance, especially in tall grass areas.

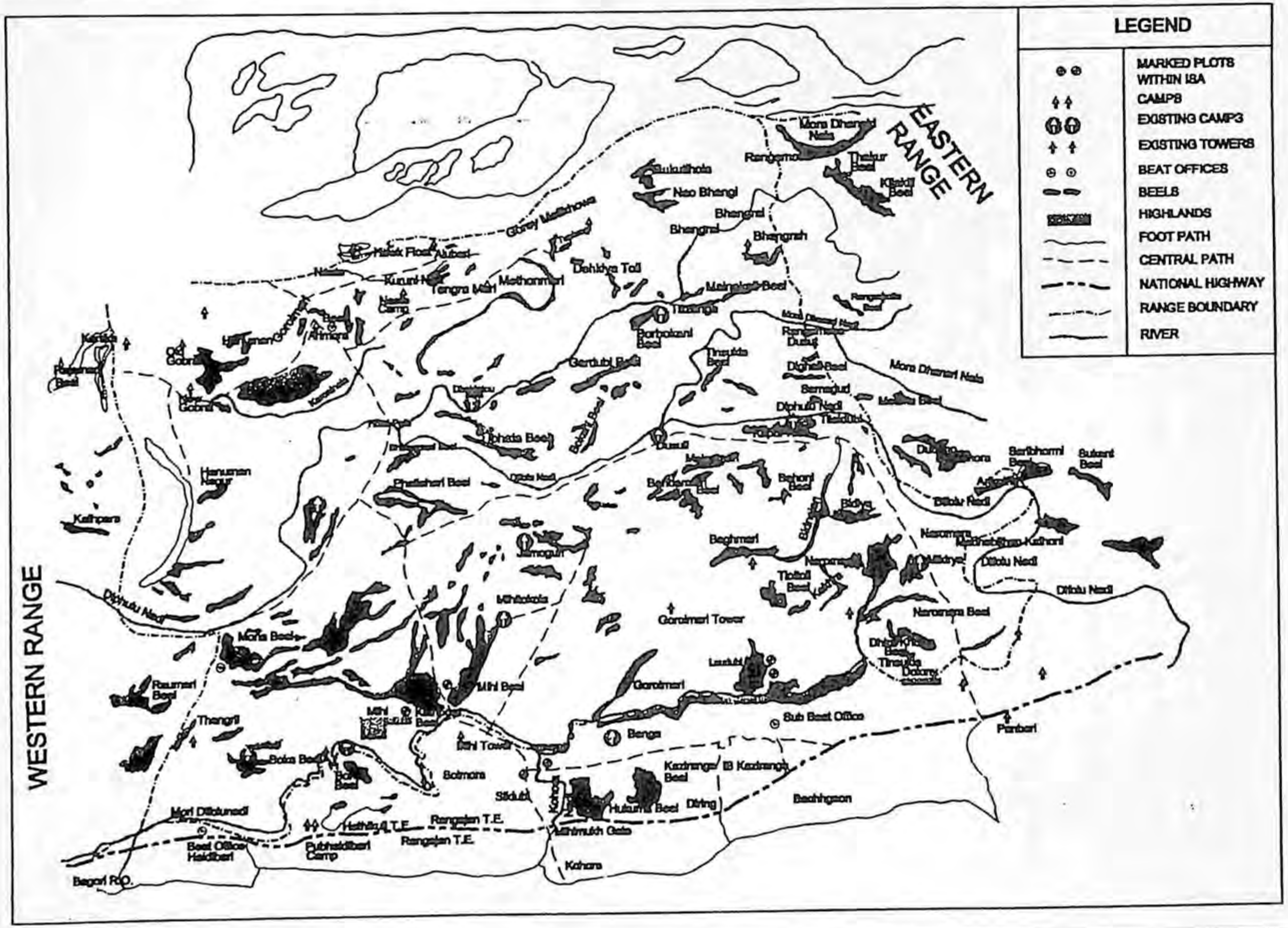
Grasslands are burnt in patches to ensure that there is prolonged availability of forage. The low-lying, moist pockets, semi-evergreen formations are immune to fire. Vegetation regrowth is phenomenally fast in the prevailing conditions. Patch burning prevents the over concentration of herbivores in heavily grazed short grassland areas since overgrazing in a small patch may be detrimental to such patches. The mosaic pattern of new growth interspersed with tall grass for cover is beneficial for ungulates and such areas have the highest ungulate density and diversity.

Almost the entire area dominated by grasslands within KNP is burnt in the post flood season between January and February but it may extend until April depending on the moisture regimes and grass phenology.

2.10 Intensive study area

A rapid reconnaissance survey was carried out within Kaziranga National Park in the Central (Kohora range) in December 2000 for the purpose of selecting an intensive study area. Based on the characterization of grassland vegetation, herbivore diversity and abundance, habitat types and areas extensively used by feeding ungulates were identified. The vegetation was classified into three categories on the basis of vegetation community structure and height.

Map of Kohora Range showing intensive study site



Since the study was a short term one and time was a limiting factor, the intensive study area (ISA) was selected within the Central (Kohora) range (Figure 2.2) in areas that are utilized by a high abundance of herbivores and logistically easily accessible. The ISA covered an area of 40 sq. km and had an adequate representation of all the grassland types (Section 2.6) used by the four ungulates that were being studied. Woodland and wetland as a component of habitat was not considered for analysis during this study due to lack of observations of feeding ungulates during the course of sampling.

Sampling sites were also selected in the Sildubi area that constitutes the second addition area of the park. Livestock grazing greatly influences this patch of grassland particularly during the dry, summer months when there is a lack of forage in the neighbouring areas. *Vetiveria zizanioides* formed a significant portion of the vegetation community in this area.

3. STUDY METHODS

The study was carried out between December 2000 and April 2001 in the intensive study area (ISA) selected within the Central (Kohora) range in Kaziranga National Park. The habitat types within the ISA were roughly mapped using a Suunto compass and a laser rangefinder (*Bushnell Yard Pro*) and were broadly designated as (a) Tall grassland (b) Short grassland and (c) *Vetiveria* dominated grassland.

3.1 Field methods

3.1.1 Habitat availability

Habitat use was largely determined by the availability of forage for herbivore species (Laurie 1978, Putman 1996). The habitat availability was quantified for summer and winter seasons within the intensive study area as detailed below.

Quantification of vegetation

Systematic random sampling was followed for quantification of vegetation parameters following Mueller-Dombois and Ellenberg (1974). Lehmkuhl (1990) has found 25 m^2 area adequate for sampling grassland vegetation in Royal Chitwan National Park. Rawat et al. (1997) used 5 m^2 (<75 m^2 area) for cover and other categories. Based on information gathered from literature a 5-m radius circular plot was randomly laid within each grassland type within the ISA and the next 9 plots were laid at a distance of 30 m from each subsequent plot. A total of 60 plots were permanently marked within the tall, short and *Vetiveria* dominated grasslands. The following parameters were recorded every fortnight:

i) **Species composition** Species present within the plot as well as percentage cover of each species within the plot on the basis of ocular estimation,

ii) **Height** of the grass and forb/herb species was recorded. Percentage cover and height was recorded to get an index of forage volume and biomass. Forage volume was calculated by multiplying the area of the quadrat with the mean height of the grass species. Since the floodplain grassland is a very dynamic ecosystem the biomass values that were collected only once in each season were not used because they would be a poor representative of the forage volume available. Forage volume was used as an index of available forage.

iii) **Phenology** of the grasses and forbs and herbs was scored on a 5 point scale, ranging from 0 (mostly dry plant), 1 (presence of old inflorescence/flowers), 2 (flowering), 3 (presence of fruits), 4 (presence of fresh shoots).

3.1.2 Habitat use by ungulates over two seasons

Data on habitat use was collected by monitoring transects. Scan samples were done to collect information on activity and relative use of the habitat types by herbivore species across the two seasons (Lehner 1979).

Laying and monitoring of transects

Data on habitat use was collected through direct observations from four fixed transects. Transects were established within the ISA to traverse all different habitat types present. Transect lengths varied between 9 to 12 km and were monitored on elephant back and by vehicle during daylight hours. Transect monitoring was repeated every 15 days during dawn (1 hour after sunrise), late mornings (around 10-

11 in the morning) and dusk (1-2 hours before sunset) to record animal activity. Total transect length that was monitored during winter was 667.5 km and during summer a total distance of 547 km was monitored. On every sighting the following parameters were noted down: (a) Species, (b) Group size: two or more animals of the same species in case of wild buffaloes and deer species were considered as a single group, (c) Habitat type: The habitat type in which the animals were first sighted (d) Activity: The activity exhibited by the animal at the time of observation. Data from all transects was pooled for the purpose of analysis to account for differences in body sizes of the ungulates affecting the probability of detection and differential visibility across all grassland types during winter and summer.

Feeding observations

Apart from the data obtained by monitoring the marked transects, scan sampling was done from vantage-points such as watchtowers or "machans" overlooking each site within the ISA. Scan sampling was done every 10 minutes from dawn to dusk to record animal abundance and activity within the intensive study area. Each of the 6 study sites was sampled twice in every 15 days. This amounted to a total of 36 days of observation for each of the three habitat types.

The following parameters were recorded for each day of observation:

(a) Species, (b) Habitat type, (c) Activity exhibited by the animal at the time of observation. Activity was classified into the following categories:

i) Grazing which included all activities such as foraging, inspection and chewing of food. Any other activity in the midst of feeding such as movement that lasted less than one minute between bouts of feeding was also included in this category.

ii) Others which included moving, resting and wallowing.

In keeping with the objectives only feeding observations were considered for analysis.

3.1.3 Quantification of nutrient content in the available forage

The above ground vegetation was harvested from 6 quadrats measuring one m^2 each for each of the grassland types and their replicates in the month of December prior to burning of the grasslands. The species were then separated, weighed, sun-dried and weighed again to get dry matter weights. The samples were then stored in paper bags until the end of the field study. The similar procedure was repeated towards the end of April during the post fire season.

3.2 Laboratory methods

Nutrient Analysis

All dried samples were subsequently oven dried at 60 ^{0}C for 24 hours which was found to be adequate for drying the samples to a constant weight. For each grassland type, composite samples for major grasses and forbs were prepared by taking approximately equal weights and grinding the samples together. This was then sieved for laboratory analysis. Replicates were run for all samples and the mean values were used for analysis. For the purpose of analysis composite samples of the food plants were analyzed for each of the study areas. The following assays were carried out:

i. **Nutrients:**

a) Nitrogen content was determined by the Kjeldahl method (Wilde *et al.* 1964). Percentage of crude protein was calculated by multiplying the values of nitrogen expressed as percentage dry weight with a constant factor of 6.4. Values were expressed as % Crude protein.

b) Silica content was estimated by evaluation of total acid insoluble ash content (Horwitz, 1980). The proportion of residue left after the combustion of organic matter in a sample of known weight is the ash content for that sample and was expressed as % Acid insoluble ash.

ii Digestion inhibitors

a) Lignocellulose and silica content was estimated by Acid detergent fibre (ADF) (Van Soest, 1963).

b) Fibre content was estimated by Neutral detergent fibre (NDF) (Goering and Van Soest, 1970).

c) Lignin (Morais & Nascimento,1991)

3.3 Statistical Analysis

3.3.1 Habitat use by rhinos and sympatric species

Data on habitat use were gathered by direct observations of feeding animals on transect routes and scan sampling. Since there was differential visibility on transect routes across habitats and seasons the total number of feeding observations for each species within each habitat was converted into proportions of feeding ungulates for each habitat type.

Proportional use of a habitat (say H_{bi}) by a species (say Sp. A) was calculated by:

$$H_{bi} = \frac{\Sigma \text{ feeding observations of Sp. A in Habitat } H_{bi}}{\Sigma \text{ Feeding observations of Sp. A in Habitats } H_{bi} + H_{bj} + H_{bk}} * 100$$

Similarly proportional use was calculated for all habitat types for each species.

Data obtained from all scan samples were also recorded for each habitat type. Results from individual transects and scan samples were pooled according to season to present a seasonal overview of habitat use.

Statistical analyses for patterns in habitat use were performed by employing non-parametric tests using the log likelihood ratio test on the observed proportions (Zar 1984).

3.3.2 Estimation of forage quality

Forage quality in the pre fire and post fire season as well as nutrient contents were estimated by comparing the data on habitat use across two seasons and correlating it with the differences in nutrient content observed within each habitat type and between two seasons.

a) Assessment of seasonal variation in the nutritive value of forage.

A Principal Component Analysis (PCA) was done to explore whether there were any interrelationships between the variables (i.e. nutrients) and to compare them across habitats and the two seasons i.e. winter and summer.

b) Interrelationships between the habitat selection and nutritive value of forage

Scatter plots were made to explore interrelationships between each of the nutrients and relative abundance of rhinos, wild buffaloes, swamp deer and hog deer. Regression equations were fitted for the non-linear and linear relationships that were obtained between nutrients and relative abundance of animal species.

Based on the trends observed above a principal component analysis was done to see if there were any relationships between nutrients, relative abundances of animals and forage volume.

Values for relative animal abundances, crude protein, silica (ash), lignocellulose and fibre content (ADF), fibre content (NDF) and lignin were transformed by using z scores in order to bring all the variables down to a comparable scale. Multi-dimensional scaling was used to combine these two disjunct matrices i.e. animal abundance as well as nutrients during both the seasons. This procedure was carried out using SPSS for Windows (8.0) (Norussis 1990) and a composite idea of the interrelationships of the study species with nutrient values was obtained.

A non metric multi dimensional scaling model was fitted on the basis of the transformed values plotted along a two dimensional axis in order to look at a more holistic picture of inter relationships between nutrients and relative animal abundances. No effort was made to name the dimensions since the purpose of the exercise was to gain a composite picture of the interrelationships between the factors.

4. RESULTS

4.1 Habitat use by Rhinos and other sympatric species

During the **winter season** all four ungulates showed a positive selection for the short grasslands (Fig. 4.1). High percentages of all four ungulate species were found feeding in the short grasslands throughout the winter season (Table 4.1). Tall grasslands were used to the highest extent by rhinos (29.5 %). Wild buffaloes were also observed feeding within the tall grass habitat though in relatively smaller numbers (11.7 %). Swamp deer were not observed utilizing the tall grassland during the entire season. A small percentage of hog deer (14.9 %) were observed feeding within this habitat type. The *Vetiveria* dominated grassland was utilized to the largest extent by swamp deer (24.7 %). A very small percentage of rhinos (5.6 %) and wild buffaloes (3.06 %) were observed utilizing the *Vetiveria* grassland. Hog deer did not utilize the *Vetiveria* dominated grassland during winter (0.895 %).

During the **summer season** a high degree of utilization of the short grasslands by wild buffalo (98.943 %) and swamp deer (96.875 %) was recorded (Fig 4.2). There was a significant *decrease* in the percentage of utilization of the short grassland habitat by rhinos (57.704 %) and hog deer as compared to the winter season (29.428 %). Tall grassland habitat was utilized to the greatest extent by hog deer for feeding during the summer (70.571 %). Rhinos were also observed feeding within the tall grassland patches in higher percentages as compared to the winter season (41.639 %). Wild buffalo and swamp deer were not observed to utilize the tall grasslands for feeding till the end of fieldwork towards the end of summer.

The tall grassland patches had been burnt at the beginning of the summer season between the second week of February and the beginning of March. Hog deer and rhinos were observed feeding in large numbers on the flush of green grass that sprouted in the grassland patch within a short time after the fire.

There was a sharp decline in the usage of the *Vetiveria* dominated grassland patch by all species during the summer season. A very small percentage of swamp deer were observed to utilize these grasslands (3.125 %).. Except for some sporadic feeding observations the other species did not use this habitat type for feeding during the entire season.

There was a significant difference in the use of each of the three habitat types by all four species during winter and summer (Table 4.3). When comparisons were made to assess differences between use of the three habitat types for each individual ungulate species during summer and winter, significant differences between utilization of the different habitat types for rhino, wild buffalo and swamp deer were observed (Table 4.4).

Seasonal trends in habitat use

Based on data on feeding observations collected through scan sampling, seasonal trends in habitat usage were assessed for each species. All observations were grouped into two categories *viz.* feeding and other activities. Data on feeding observations within each habitat type were analyzed to observe any differences in the patterns of habitat use between summer and winter.

Rhinos selected the short grassland for feeding to a greater extent in winter (95.27 %) as compared to 60.59 % use of short grassland in summer (Fig. 4.3). There was a significantly greater utilization (p=0.00) of the tall grassland for the purpose of feeding in summer as compared to winter. The *Vetiveria* grassland was used to a very small extent during the winter season for feeding. No observations of rhinos in the *Vetiveria* grassland were recorded during the summer. These observed differences in habitat use across two seasons were found to be significant according to the log likelihood ratio test (Table 4.5).

Wild buffaloes utilized the short grasslands for feeding to the largest extent compared to other habitat types in both winter and summer. Tall grasslands were utilized to a marginally greater (9.10 %) extent during the late summer period. The *Vetiveria* dominated grassland was avoided by wild buffaloes during the winter and summer season (Fig. 4.4).

Swamp deer utilized the short grassland habitat type for feeding to the largest extent in both summer and winter in comparison to the other habitat types. The tall grasslands were not used for feeding in both summer and winter. A sharp decline in the use of the *Vetiveria* dominated grasslands was noted in summer as compared to use of this grassland type in winter (Fig. 4.5)

Hog deer showed major changes in the observed habitat use patterns during the summer. Significant proportions of feeding time were spent within the short grasslands during summer and winter. Burnt, tall grassland patches were used for feeding to a much greater extent in summer as compared to winter. *Vetiveria* dominated patches were not used by hog deer for feeding in the summer and utilized to an insignificant degree during winter (Fig 4.6).

Log likelihood ratio tests showed that the differences observed in habitat use patterns were significantly different for rhinos and hog deer (Table 4.5) but there was no significant difference in the use of the different habitats by wild buffalo and swamp deer during the winter and summer season.

4.2 Seasonal variation in forge quality and quantity

4.2.1 Forage quality

Based on the laboratory analysis of the forage from the different grassland types, several interesting trends emerged.

i) **Crude protein (CP)** levels were found to be the highest in the short grasslands (10.45 %) during the winter (Fig. 4.7). CP content of the available forage in the *Vetiveria* grasslands was 7.89 % followed by the tall grasslands that had the lowest level of crude protein (6.05 %). During the summer, tall grasslands with their fresh growth of grass had the highest levels of CP (11.96 %). A slight decrease in CP was observed in the short grasslands (8.21 %) and within the *Vetiveria* dominated grasslands (6.22 %).

ii) Lignin showed an almost inverse pattern as compared to CP as expected (Fig. 4.8). During the winter season lignin content of the tall grass was the highest (9.68 %) followed by the *Vetiveria* grassland (7.20 %). Lignin content of the forage available in the short grassland had the lowest value (5.15 %).

During the summer lignin content was almost the same in the short grasslands (7.22 %) and the *Vetiveria* grasslands (7.30 %). Lignin had the lowest value in the tall grassland in the summer (4.69%) due to the sprouts of fresh grass during the post fire period.

iii) Ash content, an indicator of silica and trace elements was high in the short grasslands (17.58 %) during winter meaning that the grasses were older and coarser during this season (Fig. 4.9). *Vetiveria* dominated grasslands also had a relatively high ash content (10.68 %) as compared to the tall grass (6.05 %).

Silica content was lower in all the grassland types during the summer as compared to winter. Short grasslands had 8.51 % of silica content whereas the *Vetiveria* grassland had a relatively higher amount of silica (9.72 %). Tall grasslands had the least amount of silica (2.50 %).

iv) Lignocellulose and silica content measured by neutral detergent fibre (NDF) was the highest in the *Vetiveria* dominated grassland (76.62 %) and in the tall grassland (76.02 %) during the winter season (Fig. 3.10). Short grasslands had 61.56 % of NDF content.

During the summer all the grassland types had almost similar levels of NDF, *Vetiveria* grasslands had the highest amount (69.86%) followed by the tall grassland (68.23 %) and 67.07% in the short grassland (Fig 4.10).

v) Fibre content of forage estimated by acid detergent fibre (ADF) was almost the same in the short grassland (40.28 %) and in the *Vetiveria* grassland (40.28 %) in winter. ADF was the highest in the tall grassland (50.95 %).

ADF values dropped to a small extent in the summer. ADF content of the *Vetiveria* grassland was highest (39.59 %). Short grasslands (37.74 %) and tall grasslands (37.79%) had almost similar ADF values (Fig 4.11).

4.2.2 Forage Volume

Forage volume was estimated by multiplying the quadrat size with the mean height of the palatable grasses species along with their percentage cover in order to get an index of Forage volume (FV). During the winter, FV was the highest in the tall grassland (85408 m^3) followed by the *Vetiveria* grassland (2218.41 m^3). Short grassland had the least forage volume (506.33 m^3).

In summer FV was found to be almost similar in the short grassland (1331.36 m^3), which showed a drastic increase from FV in winter and in the *Vetiveria* grassland (1210.47 m^3) that showed a decrease as compared to winter. FV was high in the tall grassland (1453.04 m^3) as well during this period (Fig. 4.12).

Results from the principal components analysis revealed that the nutrients differed significantly across the two seasons and amongst the habitat types (except for the *Vetiveria* grassland that showed that the nutritive content of the forage remained almost the same over both winter and summer). The Bartletts test of sphericity showed that the result was significant (Appendix I). Factors were extracted using the principal components method. The rotation method used was a Varimax with Kaiser normalization. Two factors explained 62.084 % of the variation observed. Factor 1 consisted of Crude protein on the negative axis along with Lignin, ADF and NDF on the positive axis. Ash content (an indicator of silica in the forage) formed factor 2.

Based on these two factors there was a remarkable separation of grassland types over summer and winter (Fig.4.13).

Vetiveria grassland did not show much variability in the nutrient content over the two seasons. Short grasslands in the winter had a higher content of CP than in summer. Tall grasslands, owing to coarse grasses had high ash (silica) content in winter and therefore, had a high amount of segregation on the CP axis. Thus, CP influenced the observed differences between nutritive value of forage in the tall grassland.

4.2.3 Interrelationships between the habitat selection and nutritive value of forage

Regression equations were fitted for the trends observed in the distribution of relative abundances of animal distribution with each nutrient. Several interesting trends were observed.

i) Crude protein: Rhinos showed a marginal linear relation with increased levels of crude protein within the forage. This is in accordance with information gleaned from the available literature. Hog deer showed a linear relation to increasing amounts of CP its abundances showed an increase with increasing levels of CP. This is an artifact of its being a concentrate feeder relying on high nutrient levels to meet its body requirements. Interestingly, wild buffaloes and swamp deer showed a similar response suggesting that they required an optimum amount of crude protein in their diets and increasing levels of crude protein beyond that amount did not influence habitat selection (Fig. 4.14).

ii) Lignin showed an inverse trend in comparison to CP, as expected. With increased levels of lignin, wild buffalo, swamp deer and hog deer showed an inverse relationship suggesting that as levels of lignin increased animal use of those areas decreased. Rhinos showed a decreased trend in habitat occupancy with increased lignin in grasslands until a certain level and then showed a slight increase in habitat use. This is reiterated by the fact that rhinos are hindgut-fermentors and are ultimately constrained by other factors such as forage volume and crude protein content (Fig 4.15).

iii) Ash content (indicating silica level) of forage showed another interesting trend. Rhino did not show any response to increasing levels of ash in the forage (r^2 = 0.0008). Hog deer showed an inverse non-linear trend with increasing levels of ash. Hog deer numbers decreased with increasing levels of ash till a certain level and increased after that critical level suggesting that hog deer traded off for some other factor at this point. The most interesting results were obtained for wild buffalo and swamp deer that paradoxically showed an increase in number with increasing amounts of ash content in the forage (Fig. 4.16). This implies that there was some other factor that was operating in combination to ash content in the grassland type that determined the habitat choice by these two species.

iv) NDF (Fig 4.17) and **ADF** (Fig. 4.18) showed declining trends in concordance with the distribution of animal species.

An important point that comes to fore is that each of these graphs cannot be considered in isolation to explain habitat selection patterns. In order to gain a comprehensive picture, the combined effect of these factors would have to be taken into account. A principal component analysis was done to determine the relative importance of each of these variables on habitat use. The rotation factor used was varimax with Kaiser normalization. It was found that three important factors emerged as a result of this analysis. Factor 1 was largely CP, factor 2 was silica (ash) content of the forage and factor 3 emerged as the forage volume. With increasing levels of CP there was a very strong association between hog deer and rhino abundance and a decrease in wild buffaloes and swamp deer feeding in such habitat types. Wild buffalo and swamp deer were seen to be feeding in areas with intermediate silica content (ash) in the forage. Forage volume interestingly showed that the two large bodied ungulates were responding to increase in the levels of forage volume, followed to some extent by swamp deer and there was not much effect on hog deer abundance (Appendix II).

Forage volume decreased within the *Vetiveria* grasslands (Fig 4.19.) in the summer. Short grasslands showed an increase in forage volume with the growth of fresh grass (Fig 4.20.) and there was a significant drop in forage volume within the tall grasslands (Fig. 4.21). In the winter there was a very high forage volume within the tall grasslands but most of it consisted of coarse unpalatable grass.

These two matrices (i.e. one for animal abundances and another for nutrient content) were put through a Multidimensional scaling procedure. This produced a holistic picture of the species relationships in terms of these two key resources.

No attempt was made at naming the dimensions since the interest lay in assessing the relative importance of each of nutrients on the distribution of individual species (Fig. 4.22). Crude protein was an important determinant in habitat selection by all ungulates. Two associations became apparent. Rhino and hog deer were seen to have a negative relation with silica content. Therefore, they were seen to feed in areas that had the least amount of silica and high crude protein levels. Wild buffalo and swamp deer tracked optimum levels of crude protein and less silica.

4.3 Summary

Important results that emerged as a result of this study are summarized below: -

- Fire was seen to have an important influence on forage quality. It causes a fresh flush of grass within the tall grassland during summer. Fresh grass has high crude protein levels and low levels of ash, which is tracked by rhino and hog deer.
- Short grassland had a relatively high level of crude protein and intermediate levels of ash during winter and summer. Wild buffalo and swamp deer were observed to select the short grasslands for feeding during both seasons.
- There was high forage volume within the tall grassland during winter but most of the forage was inaccessible to ungulates and consisted of coarse, unpalatable grass. During the summer season, the forage volume decreased drastically but the forage was highly nutritious and was selected by rhinos and hog deer for feeding during this period. Forage volume within the short grasslands and *Vetiveria* grassland increased during the summer season due to the increased presence of forbs that sprouted during this period. Increased forage volume as a result of fresh forbs was also responsible for high crude protein levels in these grasslands even during summer. High crude protein levels within the short grasslands made it a favourable foraging ground for swamp deer and wild buffalo.

Fig 4.1 Comparison of habitat use by Rhino, Wild buffalo, Swamp deer and Hog deer across three grassland types in winter.
(Grassland types: VGL= *Vetiveria* grasslands, SGL= Short grasslands, TGL= Tall grasslands)

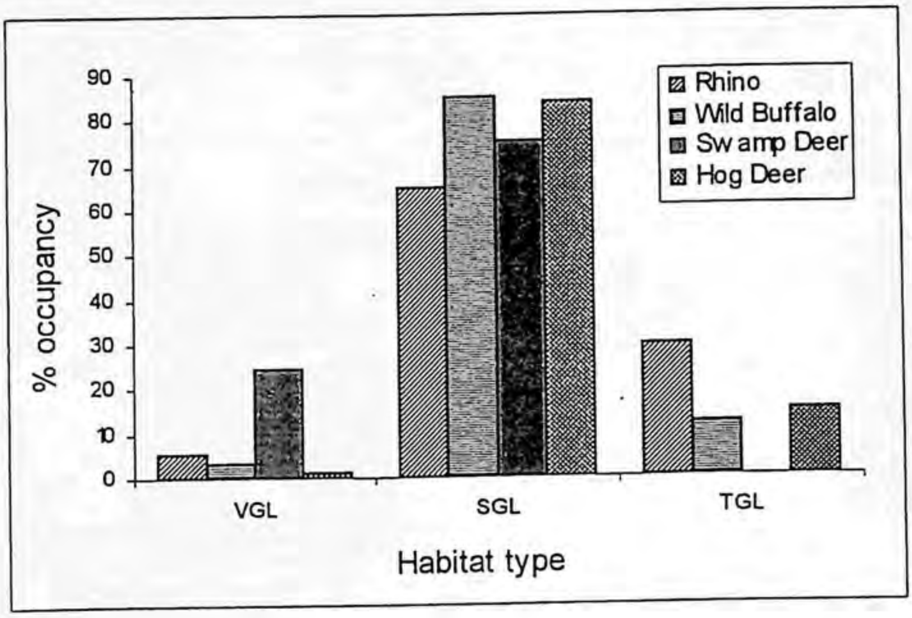
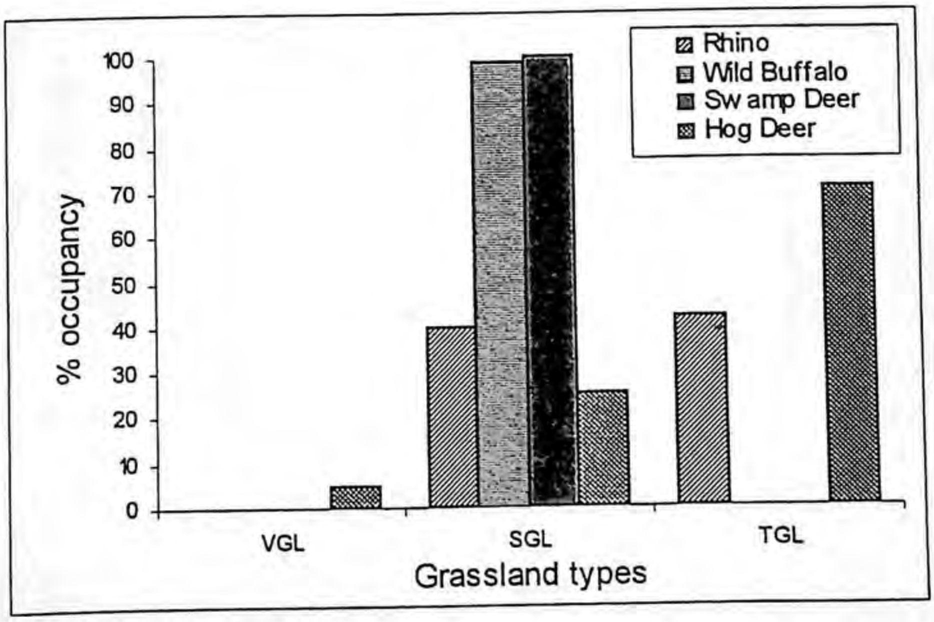


Fig 4.2 Comparison of habitat use by Rhino, Wild buffalo, Swamp deer and Hog deer across three grassland types in summer .
(Grassland types: VGL= *Vetiveria* grasslands, SGL= Short grasslands, TGL= Tall grasslands)



Seasonal variation in habitat use by individual species across different grassland types

(Grassland types: VGL= *Vetiveria* grasslands, SGL= Short grasslands, TGL= Tall grasslands)

Fig 4.3

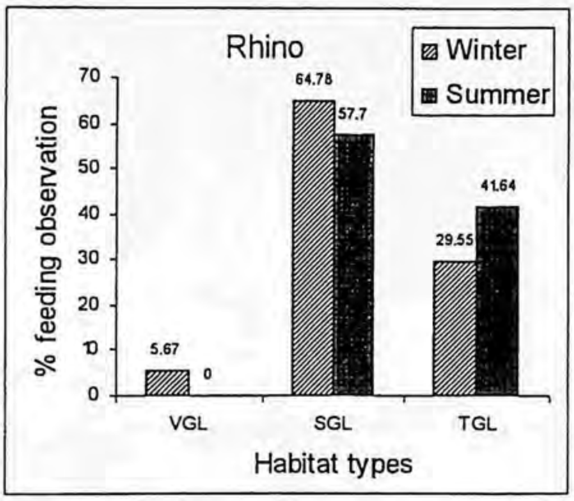


Fig 4.4

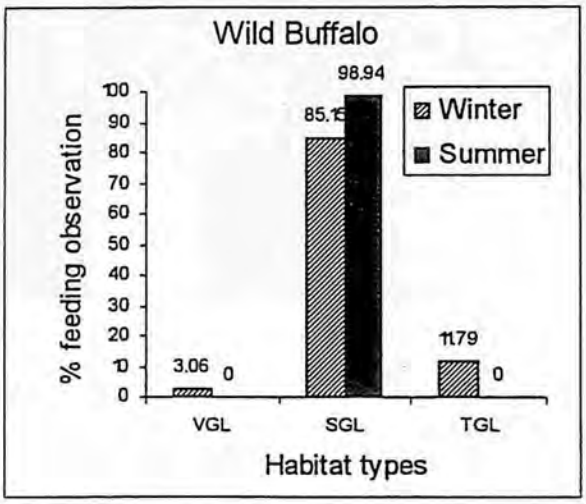


Fig 4.5

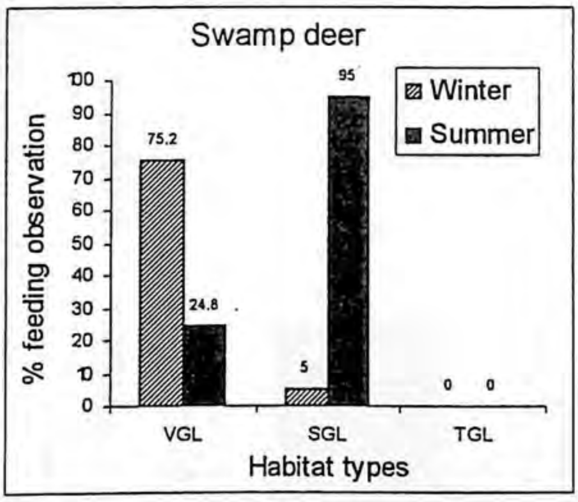


Fig 4.6

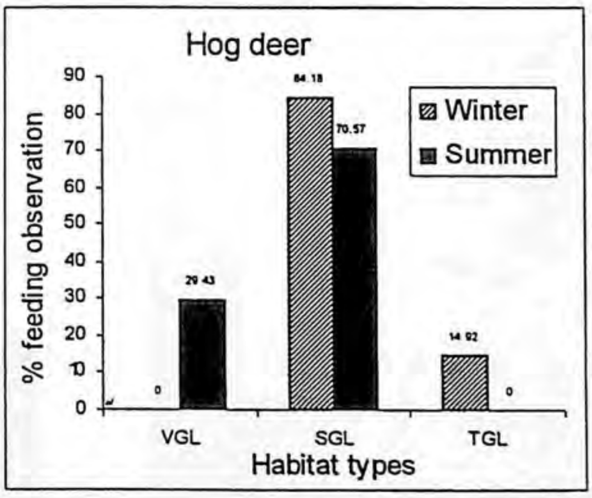


Fig. 4.7 Seasonal variation in Crude Protein (as % content) across all grassland types
(VGL= *Vetiveria* grassland, SGL= Short grassland, TGL = Tall grassland)

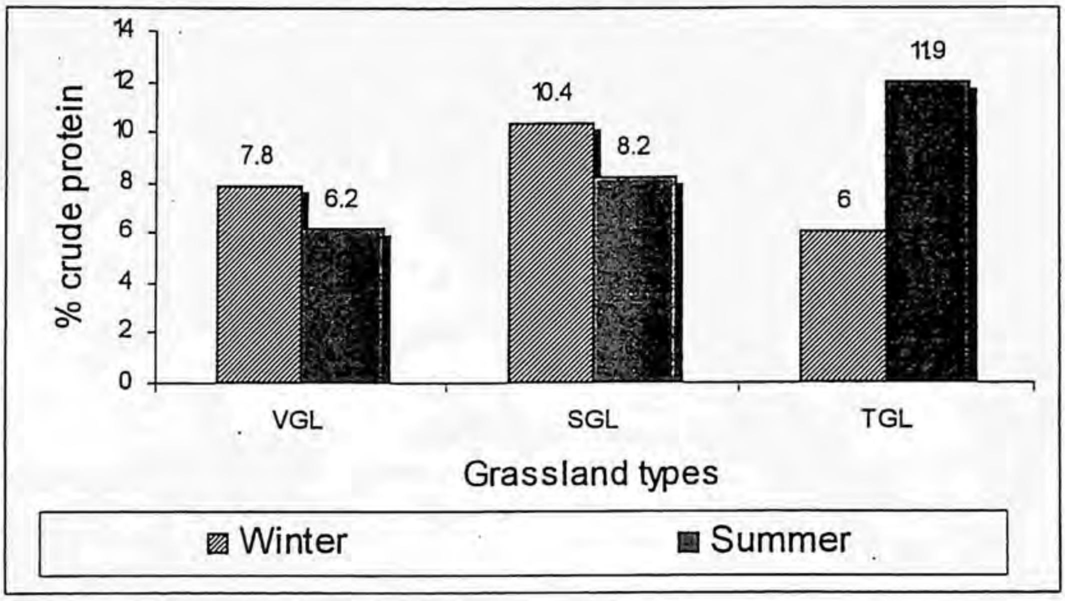


Fig. 4.8 Seasonal variation in lignin (as % content) across all grassland types
(VGL= *Vetiveria* grassland, SGL= Short grassland, TGL = Tall grassland)

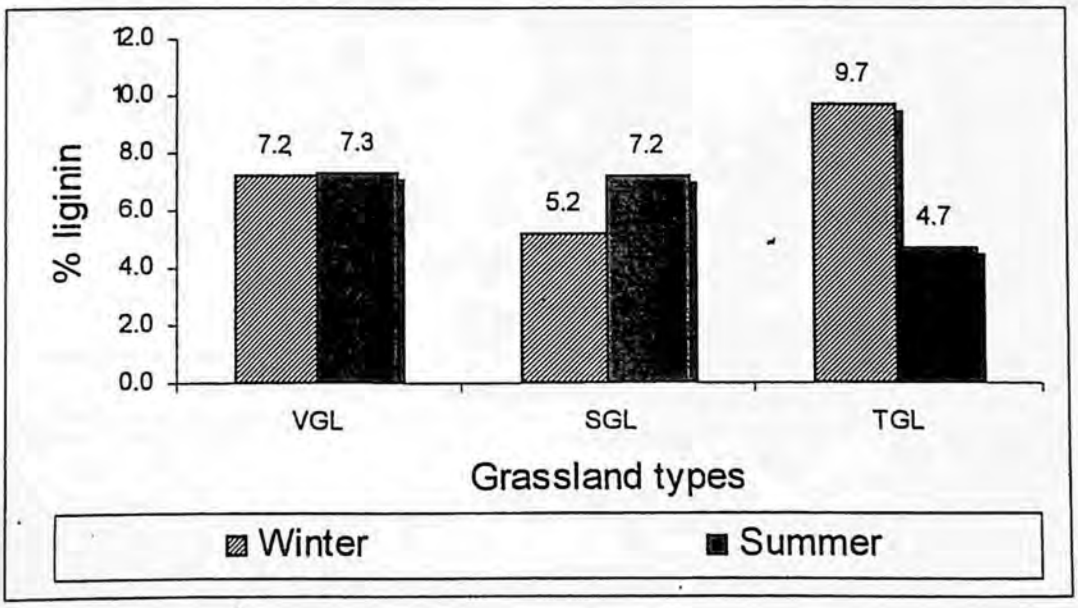


Fig 4. 9 Seasonal variation in ash (as % content) across all grassland types
(VGL= *Vetiveria* grassland, SGL= Short grassland, TGL = Tall grassland)

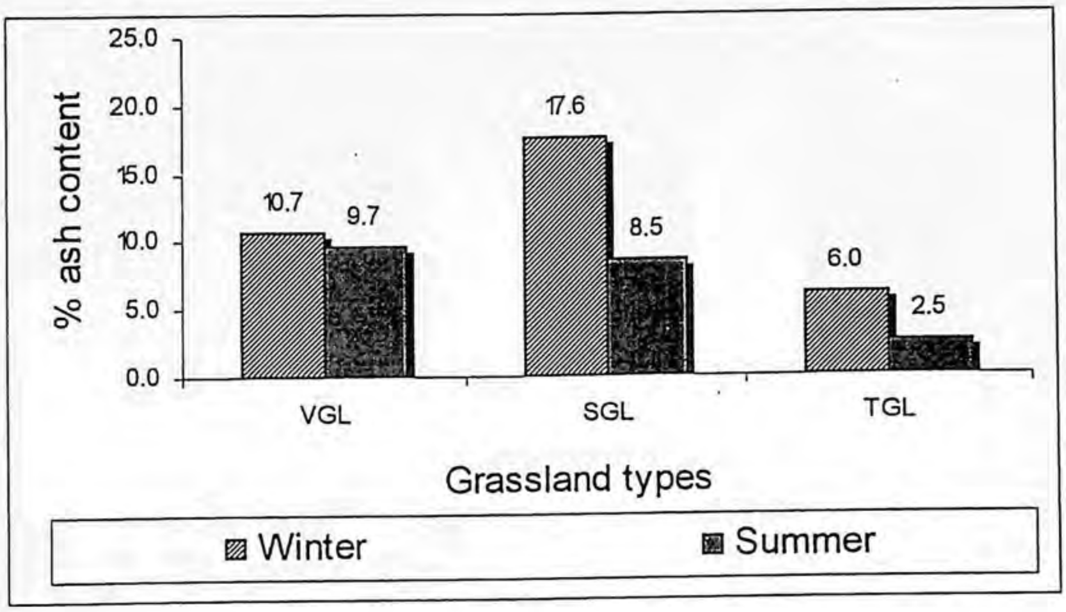


Fig 4.10 Seasonal variation in NDF (as % content) across all grassland types
(VGL= *Vetiveria* grassland, SGL= Short grassland, TGL = Tall grassland)

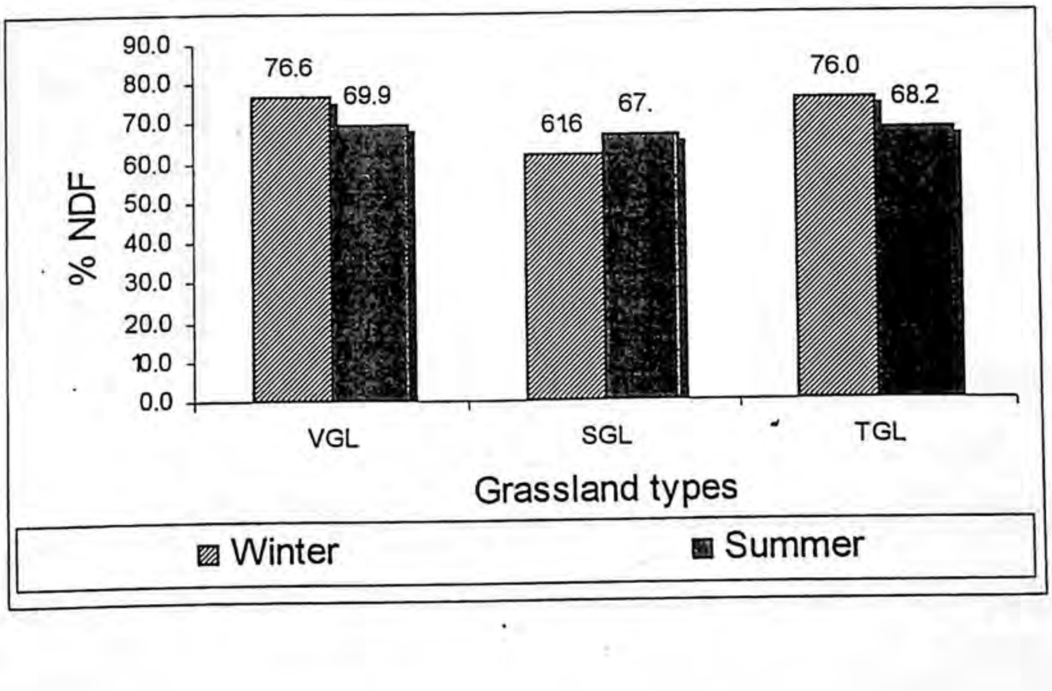


Fig 4.11 Seasonal variation in ADF (as % content) across all grassland types
(VGL= *Vetiveria* grassland, SGL= Short grassland, TGL = Tall grassland)

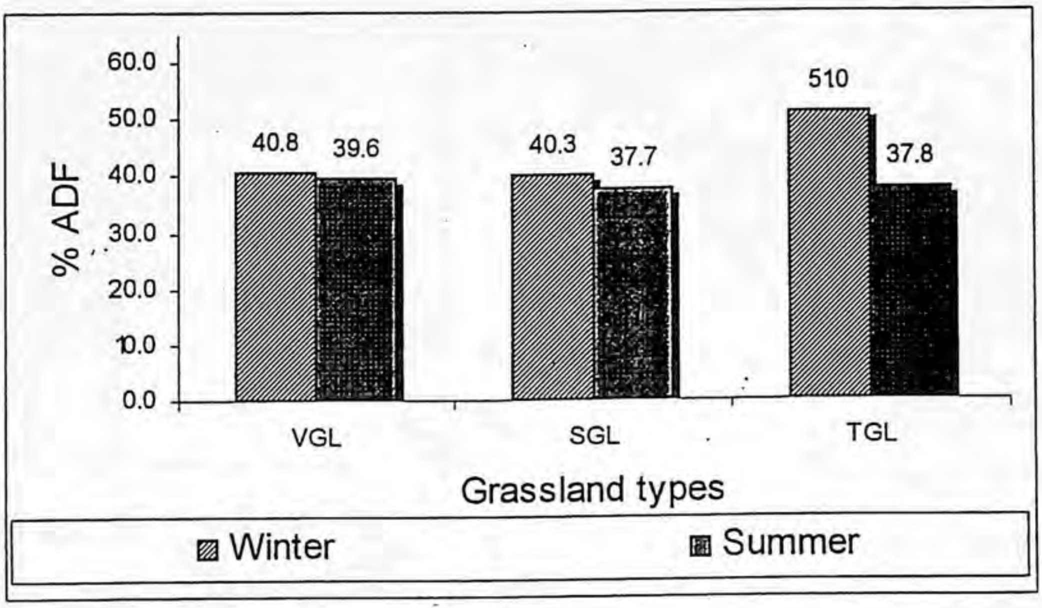


Fig 4.12 Seasonal variation in forage volume across all grassland types
(VGL= *Vetiveria* grassland, SGL= Short grassland)

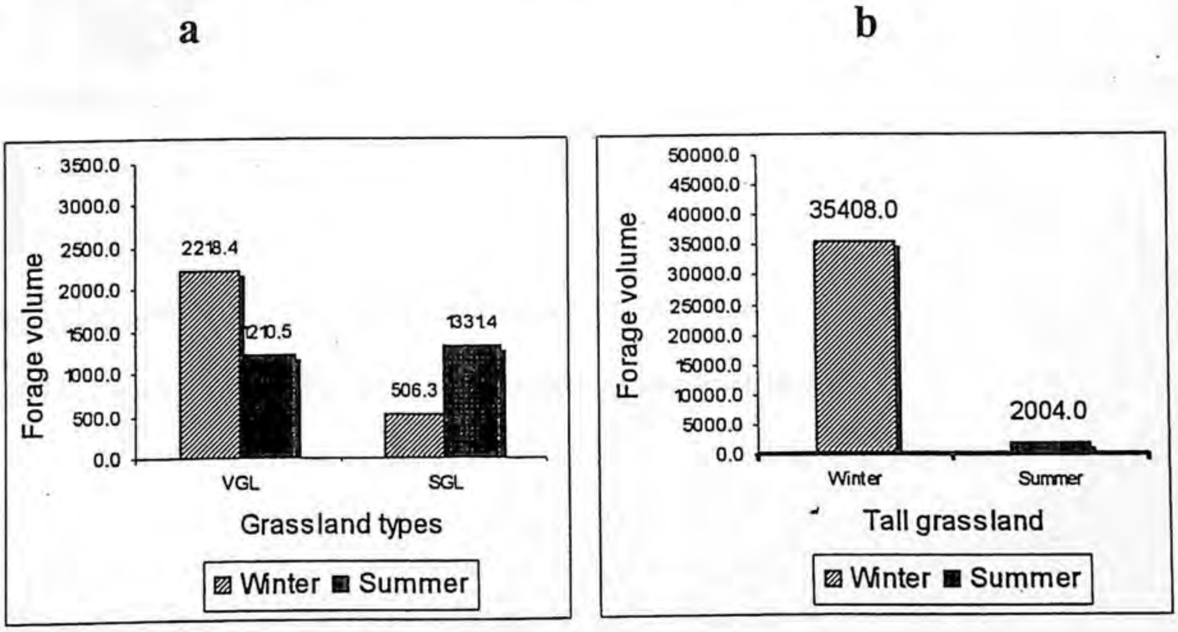
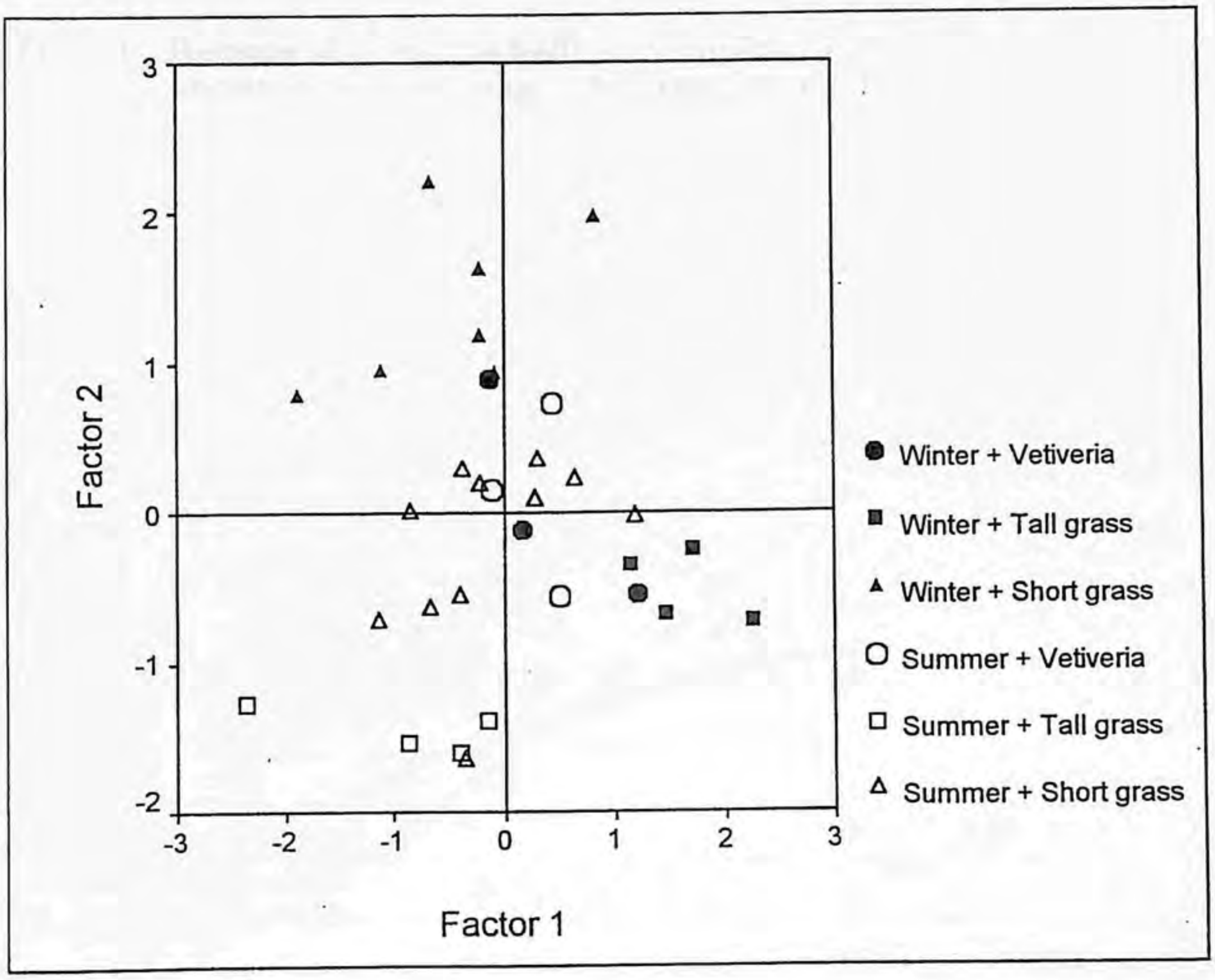


Fig 4.13 Factor matrix showing the segregation of grassland types during winter and summer on the basis of nutritive value of forage



Factor 1: Crude protein

Factor 2: Ash (indictor of silica content of forage)

Both factors explain 62.08 % of the observed variation

Fig 4.14 Response of rhino, wild buffalo, swamp deer and hog deer to crude protein levels in the forage in Kaziranga National Park.

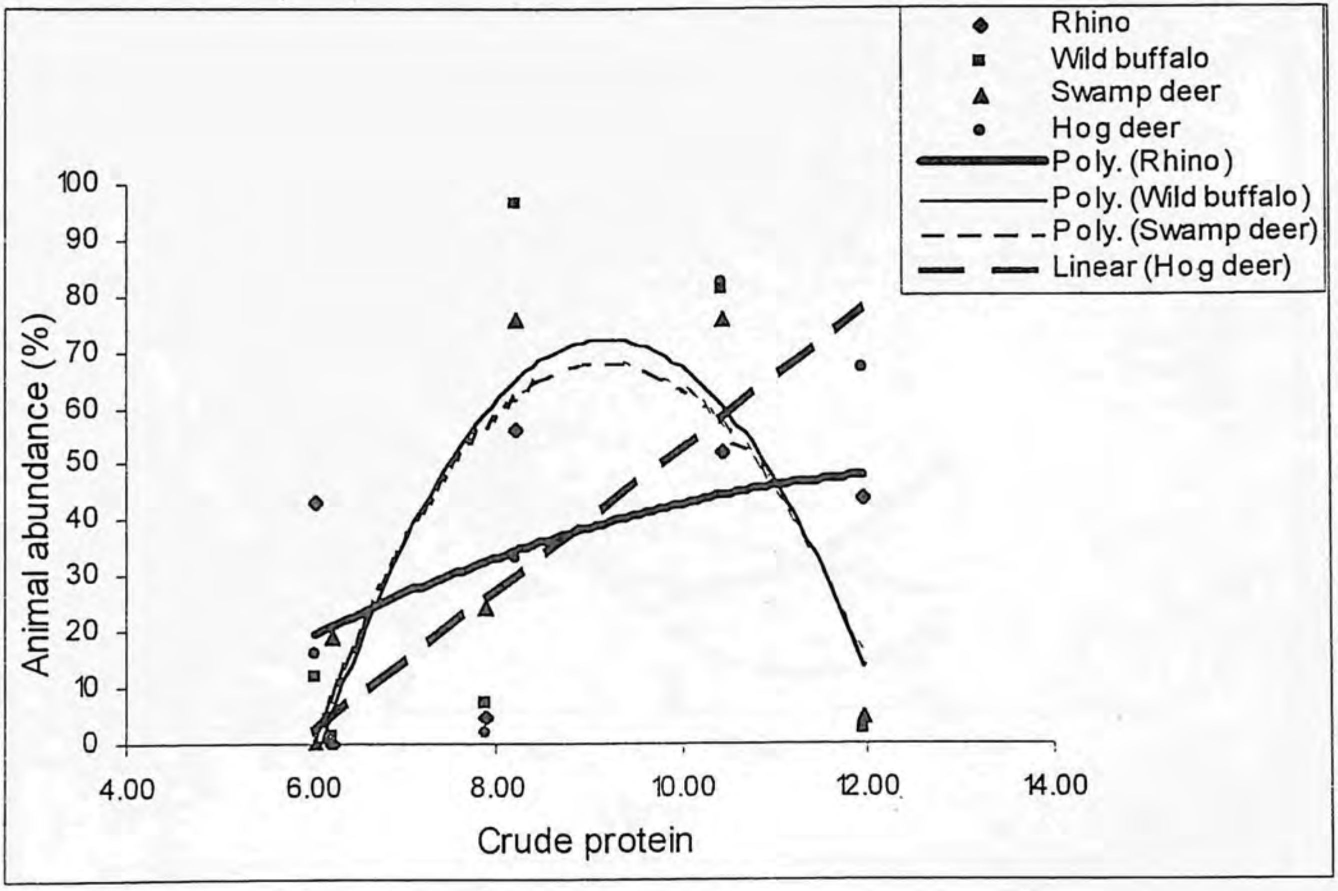


Fig 4.15 Response of rhino, wild buffalo, swamp deer and hog deer to lignin levels in the forage in Kaziranga National Park.

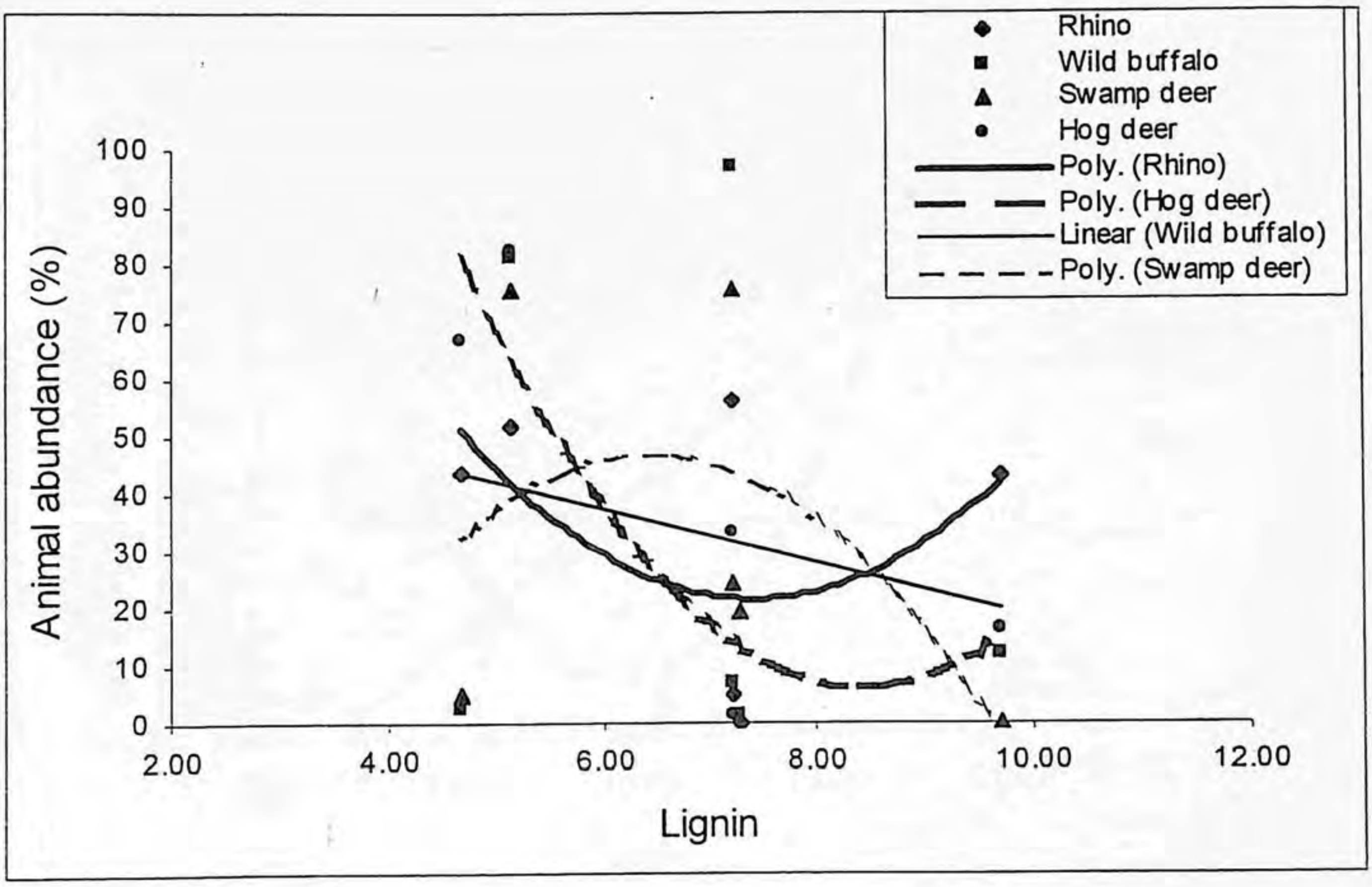


Fig 4.16 Response of rhino, wild buffalo, swamp deer and hog deer to ash content in the forage in Kaziranga National Park.

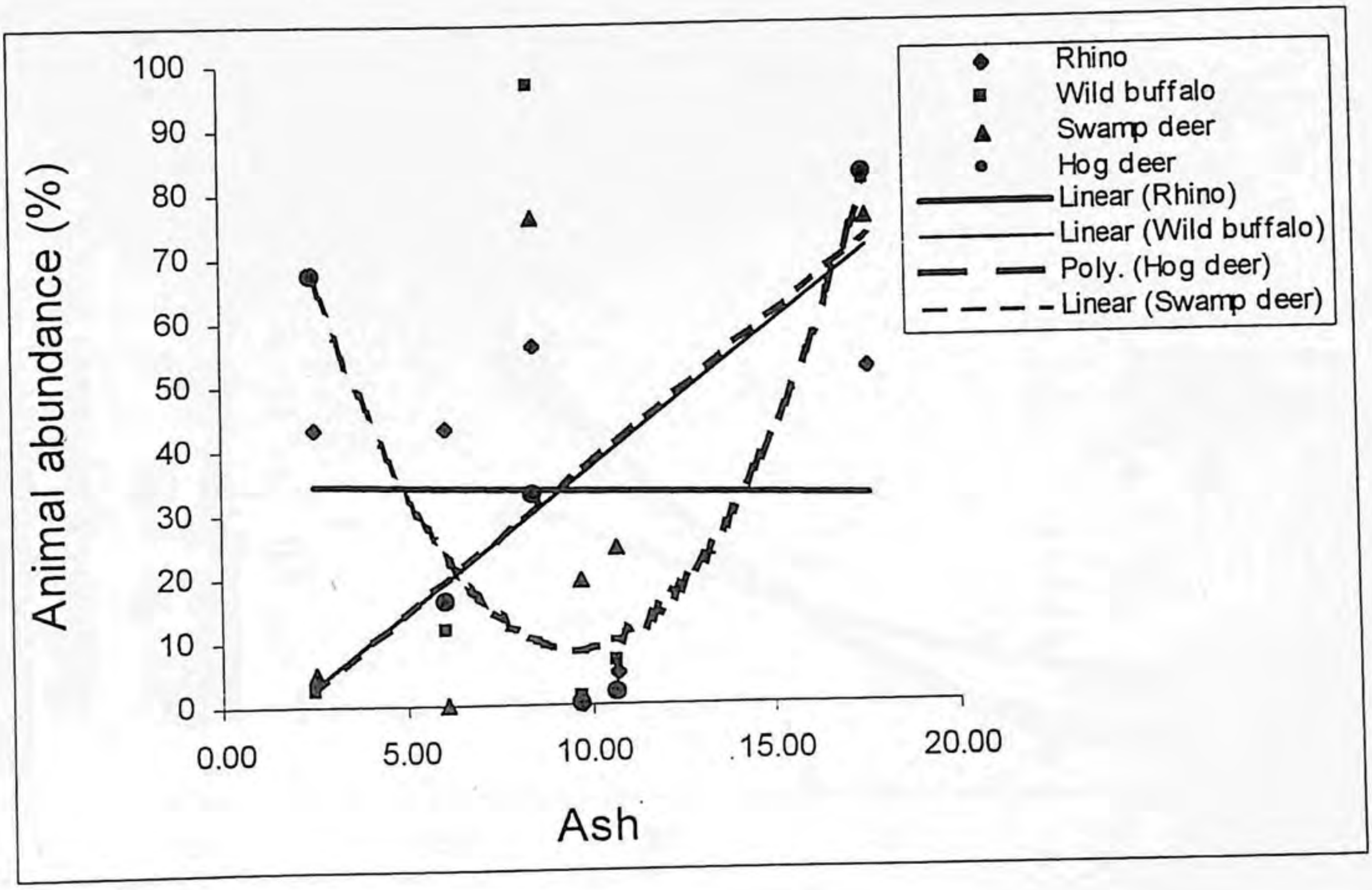


Fig 4.17 Response of rhino, wild buffalo, swamp deer and hog deer to NDF in the forage in Kaziranga National Park.

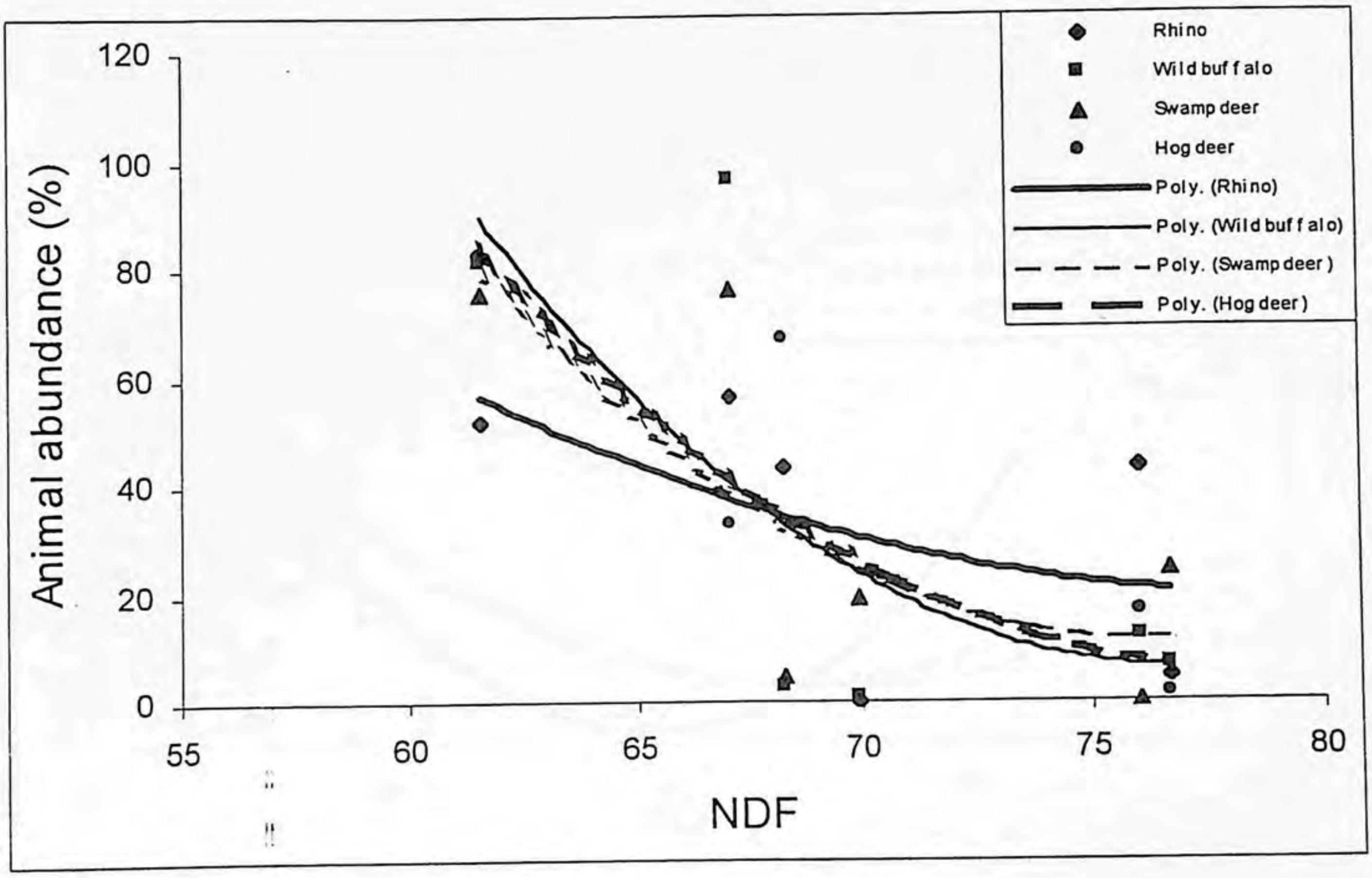
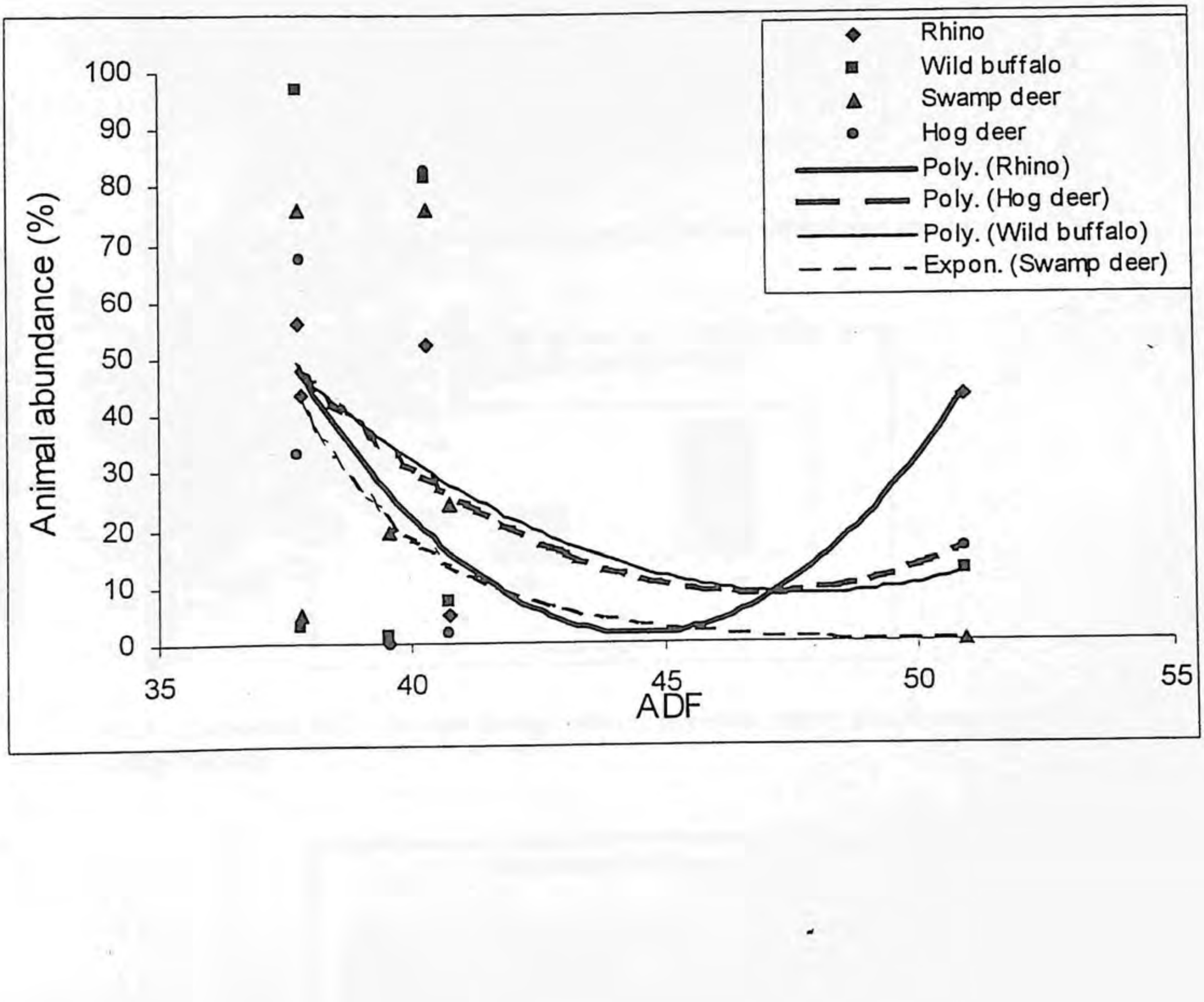
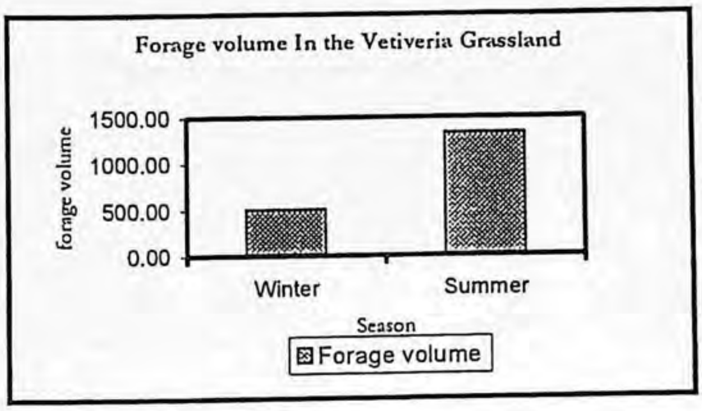


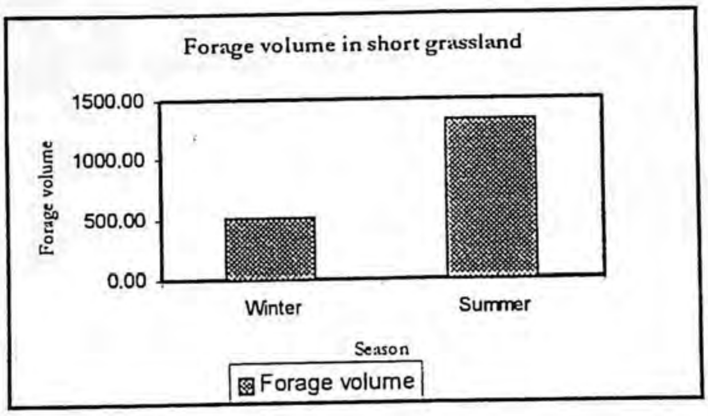
Fig 4.18 Response of rhino, wild buffalo, swamp deer and hog deer to ADF in the forage in Kaziranga National Park.



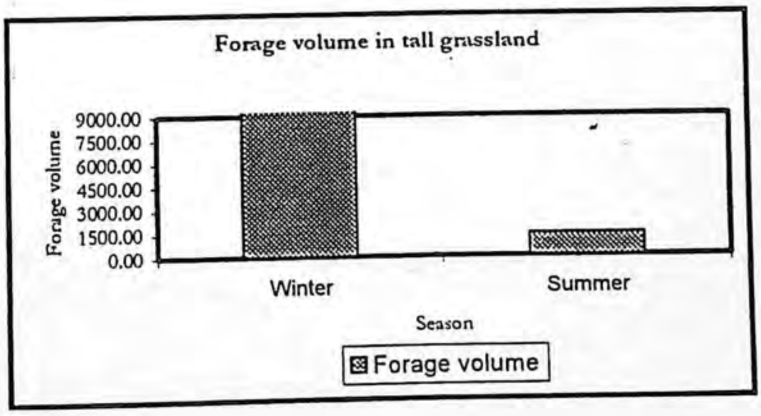
4.19 Seasonal variation and forage volume between winter and summer in the *Vetiveria* grassland



4.20 Seasonal variation and forage volume between winter and summer in the short grassland



4.21 Seasonal variation and forage volume between winter and summer in the tall grassland



4.22 Relationship between crude protein, ash content, lignin, ADF and NDF with mean abundance of rhino, wild buffalo, swamp deer and hog deer in Kaziranga National Park

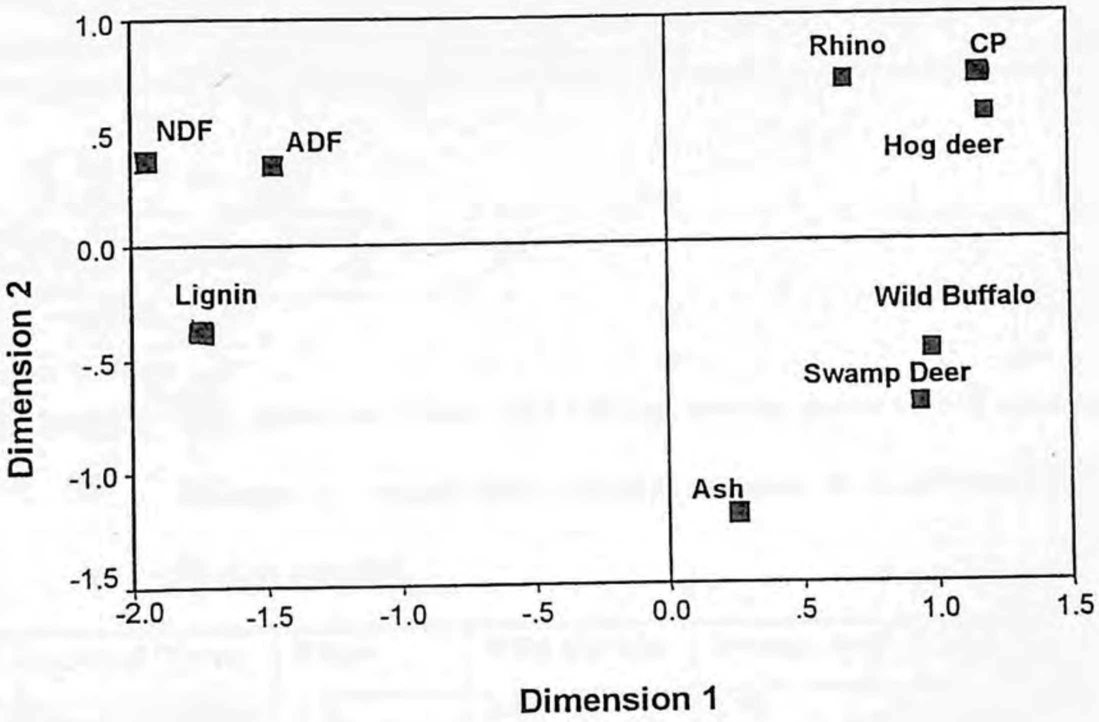


Table 4.1 : Distribution of rhino, wild buffalo, swamp deer and hog deer across different grassland types during winter in Kaziranga National Park in winter

Grassland Types	Rhino	Wild buffalo	Swamp deer	Hog deer
Vetiveria grassland	6 %	3%	25 %	0 %
Short grassland	65 %	85%	75 %	85 %
Tall grassland	29 %	12 %	0 %	15 %

Table 4.2 : Distribution of rhino, wild buffalo, swamp deer and hog deer across different grassland types during summer in Kaziranga National Park in summer

Grassland Types	Rhino	Wild buffalo	Swamp deer	Hog deer
Vetiveria grassland	0 %	0 %	3 %	0 %
Short grassland	58 %	100 %	97 %	30 %
Tall grassland	42 %	0 %	0%	70 %

Table 4.3 : **G test values showing difference in habitat use patterns by rhino, wild buffalo, swamp deer and hog deer across different grassland types during winter and during summer in Kaziranga National Park**

Season	**G (adj)**	**df**	**P value**	**G (crit)**
Winter	80.78	6	0.00	12.59
Summer	382.59	6	0.00	12.59

Table 4.4 : **G test values showing difference in habitat use patterns by individual ungulate species across different grassland types between winter and summer in Kaziranga National Park**

Season	**G (adj)**	**df**	**P value**	**G (crit)**
Rhino	6.72	2	0.03	5.99
Wild Buffalo	14.98	2	0.00	5.99
Swamp deer	20.121	1	0.00	3.84
Hog deer	54.42	2	0.00	5.99

Table 4.5 : **Variation in the utilization of the different grassland types for feeding by all ungulate species during winter and summer in Kaziranga National Park as shown by the G test values**

Season	G (adj)	df	P value	G (crit)
Winter	37.71	6	0.00	12.59
Summer	45.41	6	0.00	12.59

Table 4.6 : **Comparison of seasonal variation in the utilization of the different grassland types for feeding by each individual species in Kaziranga National Park by using the G test values**

SEASON	G (ADJ)	DF	P VALUE	G (CRIT)
Rhino	48.96*	2	0.00	5.99
Wild Buffalo	1.22	2	0.54	5.99
Swamp deer	0.15	2	0.92	5.99
Hog deer	7.84 *	2	0.01	5.99

5. DISCUSSION

5.1 Expected and observed patterns of habitat use by Rhinoceros and sympatric species

That the rhino and three other sympatric ungulates in the study area share the mosaic of short and tall grasslands without any apparent competition is evident. The outer fringes of KNP especially the *Vetiveria* dominated grasslands are regularly grazed by 10-15 camp elephants and approximately 600 domestic livestock. Such a high abundance of ungulates in a relatively small area is possible only as a result of spatio-temporal variation in their habitat use. It was expected that large bodied ungulates would follow similar patterns of habitat use as opposed to the medium sized swamp deer and the smallest ungulate in KNP, the hog deer. Ungulates with a larger body size were expected to show greater flexibility of habitat use patterns.

Significant seasonal variation in the degree of use of different habitats was recorded during the course of fieldwork. The most striking feature observed was a marked difference in the flexibility of habitat use patterns for individual species. It was observed that rhinos and hog deer showed a similar preference habitat for feeding within the short grassland during winter but showed a significant utilization of the burnt tall grasslands in the summer. There was a relatively less seasonal variation in the habitat occupancy patterns exhibited by wild buffalo and swamp deer. Both species selected the short grasslands for feeding during winter and summer. Hog deer showed the most pronounced variation in habitat use patterns over the two seasons. Hog deer concentrated within the short grassland for feeding during winter and selected the burnt tall grasslands in early summer for feeding to exploit the highly nutritious forage that sprouts during the post fire period.

The *Vetiveria* dominated grassland was utilized to some extent by swamp deer with marginal use by rhinos and wild buffaloes for feeding during the winter. During summer no species apart from the swamp deer was seen to use these grasslands. There was a marked decline in the use of this grassland type by the swamp deer during summer as compared to winter. It was not utilized by any other species for feeding during the summer season. Hog deer did not utilize the *Vetiveria* grassland for feeding during winter or summer. The *Vetiveria* grasslands were not used by ungulate species in proportion to its nutrient content during the summer. This was possibly an artifact of the high levels of disturbance caused by livestock grazing and human presence within the grasslands as well as the ecological needs of the species.

The pattern of habitat selection for feeding was seen to be remarkably similar for rhinos and hog deer on one hand and for wild buffaloes and swamp deer on the other hand. There is in practice some degree of segregation based on spatial partitioning on the basis of body size and diet selection.

5.2 Seasonal variation in forage quality

Patterns of use of different habitats are related to varying amounts of nutrients affecting the forage quality during winter and summer. Forage phenology, quality and volume showed a marked seasonal variation across the different grassland types. They in turn were found to be positively correlated with the seasonal distribution patterns of ungulates and in the patterns of habitat utilization for feeding.

The *Vetiveria* grasslands were found to have greater forage volume in winter but the overall level of nutrition did not vary between summer and winter. The short grasslands on the other hand had higher levels of crude protein and had higher associated values of ash. This was also observed to be the preferred grazing grounds for all the herbivores during winters. The forage in tall grasslands were of low quality during winter due to high cell wall content, high lignin and low crude protein and were found to be used only by the rhino which is a more generalist species and could tolerate forage of lower quality. In the summer there was a significant increase in the levels of crude protein accompanied by a sharp decrease in the levels of lignin and ash content. The rhino and hog deer also utilized the tall grasslands during this stage. Wild buffaloes and swamp deer did not utilize the tall grasslands despite higher levels of crude protein being found in the tall grasslands as compared to the short grasslands.

The key to the variation in the seasonal patterns of habitat use and the formation of the observed associations lay in the nutritive quality of the forage in the different grassland types and the nutritional demands of each species.

5.3 Inter relationship between habitat selection, body size, forage volume and forage quality

Quality of forage is a function of the proportion between the cell constituents and the cell wall. Cell contents are composed primarily of sugars, proteins and storage carbohydrates. This fraction can be digested directly by the vertebrate enzymes or fermented rapidly by microbes. The cell wall fraction is composed of the structural components and cannot be degraded by vertebrate digestion but can be hydrolyzed slowly by bacterial and fungal enzymes (Robbins1983, Hudson and White 1985). Therefore the use of cell wall as a nutrient source is also dependent on microbial symbiosis.

Lignin has an important effect on the digestibility of the forage (Van Soest, 1967). A high degree of lignin and cell wall in the forage renders it unfavourable for ruminants. Ruminants such as the hog deer are incapable of digesting such coarse forage due to the constraints placed on them due to their gut physiology.

The digestion rate of the forage (proportional to its cell wall content) and the extent of its potential digestibility (proportional to its lignification) usually affect quality of forage. Forage quality is generally considered as inversely related to the amount of cell wall and lignification. Therefore, herbivores are sensitive to differences between functional categories of plant material which is reflected in the overall forage quality when making feeding decisions and hence a choice of a certain type of habitat for feeding.

In general, smaller ungulates such as the hog deer that is a concentrate feeder, require a better quality diet than do larger ungulates such as the rhino because of the formers higher metabolic rate. On the other hand, larger ungulates require larger absolute quantities of food. Over the course of evolution, smaller ungulates have mouth structure adapted to select discrete high quality food items whereas large ungulates have mouths adapted for rapid ingestion of large quantities of undifferentiated items, possibly of low quality.

Maximum herbivore concentration occurred in short grass areas which have been created and maintained by the combined grazing pressure of a wide range of ungulates and through the defoliation regime such as periodic burning of grasslands by man (Bell 1971). All species prefer the short and more nutritive grasses having.

higher levels of crude protein and lower amounts of lignin. Young tissues and leaves have a thin cell wall and higher protein as compared to older tissues and stems of grasses and small dicotyledons where cell walls are thickened and lignified and the protein content is lower and less accessible. This formed the preferred food of all ungulates as observed in the present study. Herbivores have to extract sufficient protein to satisfy their maintenance requirement (Robbins, 1983). Rhinos and wild buffalo have a higher intake per day and are more sensitive than small animals to reduction of the density (weight/area) of the herb layer. Smaller animals such as hog deer and swamp deer have more time in which to make its daily requirements and can afford to be more selective. However small mammals have a higher metabolic rate that affects their protein requirement as well as their energy requirements. Therefore hog deer and swamp deer which can afford to be more selective must direct their selectivity towards the easily digestible, high protein, low cell wall component of the vegetation. They are more sensitive to decline in quality of the food supply such as growth of tall grasses in the wet season.

Body size and gut physiology have been considered as a possible mechanism for interspecific differences in diet quality and therefore, habitat use (Bell 1970, Sinclair 1977, Demment 1980, Van Soest 1982). Along a continuum of body sizes, from small (hog deer) to large herbivores (rhino), digestive capacity and total metabolic requirements increase. The fibre composition and silica content of the plant material was found to be the scaling variable for the resource axis constituted by different plant communities within different habitats. Species differ in their adaptation to spatial and temporal differences in forage quality due to constraints imposed on them by their body size, gut physiology and also to avoid competition.

Rhino, being a hindgut-fermentor relied on areas with high crude protein content and low silica content. It was also seen to require high amounts of forage volume. Therefore, during summer it was observed utilizing the short grasslands for feeding apart from acquiring a high crude protein diet from the burnt tall grasslands with their fresh grass forage.

Wild buffalo, a foregut-fermentor is tolerant of a high fibre diet. Apart from that it requires approximately 5-6% crude protein in its diet which is met within the short grassland during both the seasons.

Swamp deer needs approximately 7-8 % of crude protein in its diet on the basis of its body weight. The short grasslands provide it optimum levels of crude protein, which meets its body requirements during both winter and summer. Since its nutritional requirements are satisfied within the short grasslands they possible do not perceive a need to feed within the burnt tall grasslands during the summer even though the burnt tall grasslands have a higher crude protein level.

Hog deer, the smallest of the ungulates in this assemblage was found to require a minimum of 10% crude protein in its diet. Therefore, hog deer selected the flush of fresh green grass with high crude protein for feeding during the summer season when the crude protein content of the forage within the short grassland decreased in comparison.

Competition for food resources is important in structuring communities. Hence body size, structure of the mouth and gut physiology are factors providing a mechanism by which herbivores can differentially use food resources without competing for the same resources. Two large bodied ungulates such as the rhino and wild buffalo coexisting in the same habitat and depending on similar dietary resources for their survival will soon exclude each other from the habitat. This will also be true in the case of small-bodied ungulates such as the hog deer and swamp deer since they have similar body requirements. Thus there will be spatial partitioning of resources by these two feeding guilds, each of which has two ungulates with complementary body sizes, as a means to avoid competition. This was borne out by the observed trends.

In the floodplain grasslands the biomass shifts seasonally into the high quality, low fibre and ash content forage after the burning of the grasslands. There is rapid growth of fresh grass that is highly nutritious having low fibre and high crude protein content within these grassland patches. Since the distribution of high quality forage within the tall grasslands following the event of burning is spatially and temporally dynamic, ungulates are expected to manipulate dietary selection by habitat choice. As a response to the seasonal variability in the forage there seems to be an association of rhino (a mega herbivore) and a hog deer (the smallest ungulate in the spectrum in KNP) that exploit areas with the highest amount of CP and low silica. In addition, being a large bodied herbivore the rhino showed a positive association with areas having greater forage volume. The other feeding guild was formed by wild buffalo and swamp deer which again differ substantially in their body size and hence their body requirements. This guild, again made up of a smaller ungulate and a comparatively larger ungulate, seemed to be tracking constant levels of crude protein in the short grassland even though the ash content may have been higher in these grasslands as compared to other grassland types.

Why don't wild buffaloes and swamp deer utilize the tall grasslands for feeding in the post fire season? Wild buffaloes and swamp deer seem to be more sedentary and exploit only the short grasslands where there was relatively high content of crude protein in forage over winter and summer. Another factor that may have affected these two species was the relative dispersion of high quality forage amidst clumps of low quality stalks and unburnt forage. This could be a limiting factor for species such as the wild buffaloes and the swamp deer that may not be able to exploit such areas as profitably as the hog deer and the rhino. The hog deer is a concentrate feeder and is capable of selecting morsels of patchily distributed high quality forage whereas the rhino is a bulk feeder and is not limited by the factor of patchy distribution of resource. Risk of predation in the case of wild buffalo and swamp deer may also modify the motivational status of the species to move into the tall grassland areas to exploit forage with higher nutrient value.

This is a preliminary study and a longer-term study would be essential before the following hypothesis can be established beyond any measure of doubt.

Another interesting observation that came to the fore was that there was the presence of extremely heavy livestock grazing pressure and human presence within the *Vetiveria* dominated grassland even though the forage quality did not vary substantially over the winter and summer. These were likely factors that may be responsible for the low abundance of wild ungulates sighted within this grassland during the summer. The area was not only nutritionally very poor but also had a very high degree of disturbance during the summer.

However, this is a cause for concern since the *Vetiveria* grassland falls in the second addition area of KNP and is adjoining to the Park boundary. Heavy livestock grazing and disturbance regimes may convert this area into a sub-optimal habitat in the long run. This may be of significance when one considers that KNP is a habitat island amidst a mosaic of human dominated landscape. Each year it experiences a period of resource crunch during the peak summer when the forage quality in the short grassland and *Vetiveria* grasslands is poor. A shift in utilization patterns gives these sub optimal habitats a chance to recover. Over the years an increasing pressure on available resources by growing wildlife populations confined to these habitat islands reduces the allowed time during which the habitat can recuperate. Additional competition from livestock for resources such as food, water and wallowing sites will serve to make the situation critical in the long run. This requires a long-term study to document the effects of livestock pressure on wild stock.

Does burning of the tall grassland help all herbivore communities? Fire as a management tool is a complex issue, particularly in the case of KNP with its multi species assemblage of 4 endangered ungulates dependent on the grasslands. The current burning practices seem to be beneficial for the rhino and hog deer. However, the effect of annual burning on wild buffalo and swamp deer is not clear. Wild buffalo and swamp deer may utilize the burnt tall grassland for feeding if they are unable to meet their crude protein requirements in the short grasslands for some reasons.

Species such as the rhino are generalist feeders (Owen-Smith 1988). They require a high forage volume as well as an optimum crude protein content in their diet in order to sustain their metabolic requirements. Burning of all patches of tall grassland at the same time may in fact be narrowing down their choice of food during the early summer. If this indeed occurs then the practice may in fact be detrimental because it might promote competition for forage within the short grasslands during this period. These are the short-term effects of annual burning. The effects of annual burning in the long run may in fact be detrimental leading to changed grass community.

composition and decrease in species diversity. This is an important aspect that requires a longer-term study.

The limitation of the present study was the short time span of the project. The results of the study are preliminary in nature and validate the need for long term studies along similar lines. The logistic difficulties faced while working within the tall wet grassland ecosystem influenced the kind of statistical analysis that could be carried out on the data that was collected.

5.4 Conclusions

1. Seasonal and spatial differences observed in habitat occupancy patterns by rhino and the sympatric ungulates the ungulate within KNP seem to be a way of partitioning resources in order to minimize competition.

2. Differences between habitat use by species and possible explanations for the spatial and temporal partitioning were sought by relating the distribution patterns of ungulates and the nutrient quality of the available forage within the grassland habitats.

3. Forage quality was evaluated by measuring the quantity of crude protein, which is believed to be the most important factor determining habitat use. Apart from the crude protein, lignin, ash content, NDF (cell wall) and ADF (cell soluble components) were also measured. These were correlated with the relative abundances of rhinos, wild buffaloes, swamp deer and hog deer observed feeding within each of these habitats. Crude protein and silica (ash) content emerged as important factors affecting habitat selection by all species.

4. Rhino and hog deer formed a feeding guild exploiting high levels of crude protein and low levels of ash. Wild buffaloes and swamp deer utilized areas that had relatively high levels of crude protein and intermediate levels of silica. Possibly the gregarious nature of the wild buffalo and swamp deer and their sedentary behaviour did not allow them to exploit the tall grasslands even though they had higher levels of crude protein.

5. In the short term, fire appeared to be beneficial for rhino and hog deer, species that require high crude protein levels and low silica content in the forage. Its effect on wild buffalo and swamp deer were not clear. Fire as a management tool needs to be used with caution. Managing the habitat for the four endangered ungulate species is a complex issue. Long-term effects of fire maybe detrimental for the habitat due to factors such as the promotion of fire resistant species dominating the grasslands. Therefore, the effect of fire on the ungulate population in KNP is a subject that needs long term monitoring and research.

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Summary of Principal Components Analysis done on raw data (nutrients) for two seasons-winter and summer

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.522
Bartlett's Test of Sphericity	Approx. Chi-Square	27.024
	df	10
	Sig.	.003

Total Variance Explained

Comp.	Initial Eigen values	% of Variance	Cumulative %	Extraction Sums of Squared Loadings	% of Variance	Cumulative %	Rotation Sums of Squared Loadings	% of Variance	Cumulative %
	Total			Total			Total		
1	2.109	42.178	42.178	2.109	42.178	42.178	2.045	40.905	40.905
2	.995	19.905	62.084	.995	19.905	62.084	1.059	21.179	62.084
3	.884	17.679	79.763						
4	.723	14.461	94.224						
5	.289	5.776	100.000						

Extraction Method: Principal Component Analysis.

Rotated Component Matrix

	Component	
	1	2
ADF	.847	
LIGNIN	.764	
NDF	.659	
CP	-.554	
AIA		.971

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.
a Rotation converged in 3 iterations.

Appendix II

Summary of Principal Components Analysis done on raw data (nutrients, forage volume and animal abundances) for two seasons-winter and summer

Total Variance Explained

Comp.	Extraction Sums of Squared Loadings	% of Variance	Cumulative %	Rotation Sums of Squared Loadings	% of Variance	Cumulative %
	Total			Total		
1	3.551	50.735	50.735	2.631	37.582	37.582
2	1.661	23.722	74.457	2.581	36.875	74.457

Extraction Method: Principal Component Analysis.

Component Score Coefficient Matrix

	Component	
	1	2
CP	-.111	.374
ASH	.400	-.199
FV	-.208	.024
RHINO	-.064	.347
WILD BUFFALO	.284	.059
SDEER	.368	-.028
HDEER	-.049	.376

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization

Appendix III

List of Flora from Intensive Study Area within Kaziranga National Park

Botanical Name	Vernacular Name
Grass species	
Andropogon spp	*
Apluda mutica	*
Arthraxon	Bapatiya ghaa
Arundo donax	Khagori
Axonopos	*
Cenchrus ciliaris	*
Chrysopogon aciculatus	Sapeti ghaa
Cynodon dactylon	Dubori
Digitaria spp.	*
Eleusine indica	*
Eragrotis spp	*
Saccharum ravanae	Ikora
Haemarthria compressa	Lokosa
Imperata cylindrica,	Ulu khair
Paspalum	*
Phragmites karka	Nol
Saccharum narenga	Borta khair
Saccharum spontaneum	Kohua
Setaria glauca	*
Sporobolus	*
Themeda villosa	*
Vetiveria zizanoides	Birinna
Floating and submerged vegetation	
Azolla bipinnata	*
Ceratophyllum demersum	*
Cyperus spp	*
Eichhornia crassipes	Meteka
Enhydra spp	*
Hydrilla verticillata	*
Hygrorhiza aristata	Dol
Ipomea spp	*
Leersia hexandra	*
Nymphaea spp	*
Pistia stratiotes	*
Polygonum spp	*
Scirpus spp	*
Typha	*

Botanical Name	Vernacular Name
Herbs/ Shrubs	
Alpinia alloghus	Tora
Amania	*
Ampylopteris prolifera	Bilomoni
Calamus	Bet
Clerodendron	*
Desmodium bipinnata	Jhadu bon
Diplagium esculentum	Dhekia
Evolvulus alzinoides	*
Lantana indica	*
Mikenia scandens	Jaarmani lota
Mimosa himalayana	Lajuki lota
Polygonum spp	*
Solanum spp	*
Spheranthus	*
Trees	
Albizzia procera.	*
Bombax ceiba	Himolu
Bridelia retusa	*
Bischoffia javanica	*
Careya arborea	*
Cretaeva unilocularis	*
Dioxoxylum binectariferum	*
Lagerstroemia parviflora	Aajar
Leea indica	*
Prerna bengalensis	*
Trewia nudiflora	Bhelu goch
Alstonia scholaris	*
Dillenia indica	Ou tenga
Garcinia tinctoria	*
Glycosmis	*
Ficus spp	*
Litsea nitida	*
Stereospermum personatum	*
Syzigium cumini	Jaam

* Vernacular names not known

Appendix IV

List of mammals recorded for Kaziranga National Park

Common name	*Zoological Name*	**Vernacular name**
Great One Horned Rhinoceros	*Rhinoceros unicornis*	Gaur
Elephant	*Elaphus maximus*	Hathi
Wild buffalo	*Bubalis bubalus*	Moe
Gaur or Indian Bison	*Bos frontalis*	Methun
Swampdeer	*Cervus duvaucelli*	Barahinghiya pohu
Hog deer	*Axis porcinus*	Sagoli pohu
Sambar	*Cervus unicolor*	Sambar
Barking deer	*Muntiacus muntjac*	*
Wild Boar	*Sus scrofa*	Gahori
Tiger	*Panthera tigris*	Baagh
Leopard **	*Panthera pardus*	Naahorphutuki baagh
Jungle cat	*Felis chaus*	Hepa
Sloth Bear	*Melursus ursinus*	Bhalu
Hoolock gibbon	*Hylobates hoolock*	Hoolo bandor
Capped Langur	*Presbytes pileatus*	*
Rhesus macaque	*Macaca mulatta*	Bandor
Indian porcupine	*Hystrix indica*	*
Common mongoose	*Herpestes edwardsi*	*
Indian Hare	*Lepus nigricollis*	*
Gangetic dolphin	*Platanista gangetica*	*
Clawless otter	*Aonyx cinerea*	Oot
Smooth Indian otter	*Lutra perspicillata*	Oot
Common otter	*Lutra lutra*	Oot

* Vernacular name unknown.

** sighted in the neighbouring tea gardens.

Appendix V

List of birds for Kaziranga National Park

Species	**Zoological Name**
Swamp Francolin	*Francolinus gularis*
Rufous throated partridge	*Arborophila rufogularis*
Khalij Pheasant	*Lophura leucomelanos*
Lesser whistling duck	*Dendrocygna javanica*
Bar headed goose	*Anser indicus*
Ruddy shelduck	*Tadorna tadorna*
Cotton pygmy goose	*Nettapus coromandelianus*
Gadwall	*Anas strepera*
Mallard	*Anas platyrhyncos*
Spot billed duck	*Anas poecilorhynca*
Common teal	*Anas crecca*
Garganey	*Anas querquedula*
Northern pintail	*Anas acuta*
Northern shoveller	*Anas clypeata*
Red crested pochard	*Rhodonessa rufina*
Common pochard	*Aythya ferina*
Rufous woodpecker	*Celeus brachyurus*
Fulvous breasted woodpecker	*Dendrocopos auriceps*
Black rumped flameback	*Dinopium bengalense*
Coppersmith Barbet	*Megalaima haemacephala*
Blue-throated Barbet	*Megalaima asiatica*
Common Hoopoe	*Upupa epops*
Indian roller	*Coracias benghalensis*
Oriental pied Hornbill	*Anthracocros albirostris*
Rufous treepie	*Dendrocitta vagabunda*
Common kingfisher	*Alcedo atthis*

Species	**Zoological Name**
Stork-billed kingfisher	*Halcyon capensis*
White throated kingfisher	*Halcyon smyrensis*
Pied kingfisher	*Ceryle rudis*
Chestnut headed bee-eater	*Merops leschenaulti*
Green bee-eater	*Merops orientalis*
Greater Coucal	*Centropus sinensis*
Lesser Coucal	*Centropus bengalensis*
Alexandrine Parakeets	*Psittacula eupatria*
Rose ringed Parakeets	*Psittacula krameri*
Blossom headed Parakeets	*Psittacula roseata*
Red Breasted Parakeets	*Psittacula alexandri*
House Swift	*Apus affinis*
Barn owl	*Tyto alba*
Spotted owlet	*Athene brama*
Rock pigeon	*Columba livia*
Oriental turtle dove	*Streptopilea orientalis*
Spotted dove	*Streptopilea chinensis*
White breasted waterhen	*Amaurornis phoenicurus*
Ruddy breasted crake	*Porzana fusca*
Purple swamp-hen	*Porphyrio porphyrio*
Common moorhen	*Gallinula chloropus*
Common coot	*Fulica atra*
Common greenshank	*Trings nebularia*
Common sandpiper	*Actitis hypoleucos*
Bronze-winged jacana	*Metopidius indicus*
Little ringed plover	*Charadrius dubius*
Red wattled lapwing	*Vanellus indicus*
Grey headed lapwing	*Vanellus cinereus*
River tern	*Sterna aurantia*
Black kite	*Milvus migrans*

Species	**Zoological Name**
Pallas's Fishing eagle	*Haliaeetus leucoyphus*
Grey headed fishing eagle	*Icthyophaga icthyaetus*
Red headed Vulture	*Sarcogyps calvus*
Common kestrel	*Falco tinnunculus*
Eurasian Marsh Harrier	*Circus aeruginosus*
Pallid Harrier	*C. macrourus*
Pied Harrier	*C. melanoleucos*
Hen Harrier	*C. cyaneus*
Little grebe	*Tachyobaptus ruficollis*
Darter	*Anhinga melanogaster*
Little cormorant	*Phalacrocorax niger*
Little egret	*Egretta garzetta*
Great egret	*Casmerodius albus*
Intermediate egret	*Mesophyox intermedia*
Cattle egret	*Bubulcus ibis*
Indian pond heron	*Ardeola cinerea*
Grey heron	*Ardeola purpurea*
Yellow bittern	*Ixobrychus sinensis*
Black crowned night heron	*Nycticorax nycticorax*
Spotbilled pelican	*Pelicanus phillippensis*
Asian open-bill	*Anastomus oscitans*
Lesser adjutant stork	*Leptoptilos javanicus*
Greater adjutant stork	*Leptoptilos dubius*
Black necked stork	*Ephippiorhyncus asiaticus*
Grey backed Shrike	*Lanius tephronotus*
Long tailed shrike	*Lanius schach*
Asian Koel	*Eudynamys scolopacea*
Large billed crow	*Corvus macrorhyncus*
Black hooded oriole	*Oriolus xanthornus*
Eurasian wryneck	*Jynx torquilla*

Species	**Zoological Name**
Oriental white-eye	*Zosterops palpebrosus*
Common tailorbird	*Orthotomus sutorius*
Scarlet minivet	*Pericrocotus flammeus*
White throated fantail	*Rhipidura albicollis*
Black drongo	*Dicrurus macrocereus*
Spangled drongo	*Dicrurus hottentothis*
Bluethroat	*Luscinia svecica*
Oriental magpie robin	*Copsychus saularis*
Common mynah	*Acridotheres tristis*
Jungle mynah	*Acridotheres fuscus*
White vented mynah	*Acridotheres cinereus*
Bank mynah	*Acridotheres ginginianus*
Plain martin	*Riparia paludicola*
Red vented bulbul	*Pycnotus cafer*
Ashy Prinia	*Prinia socialis*
Dusky warbler	*Phylloscopus fuscatus*
Jungle babbler	*Turdoides striatus*
Jerdons babbler	*Chrsomna altirostra*
Oriental skylark	*Alauda gulgula*
Ruby cheeked sunbird	*Anthreptes singalensis*
House sparrow	*Passer domesticus*
White wagtail	*Motacilla alba*
Yellow wagtail	*Motacilla flava*
Baya weaver	*Ploceus phillipinus*
Black headed munia	*Lonchura malacca*
Bengal Florican	*Houbaropsis bengalensis*
Striated Grassbird	*Megalurus palustris*
Great Tit	*Parus major*