NORGES LANDBRUKSHOGSKOLE
Agricultural University of Norway
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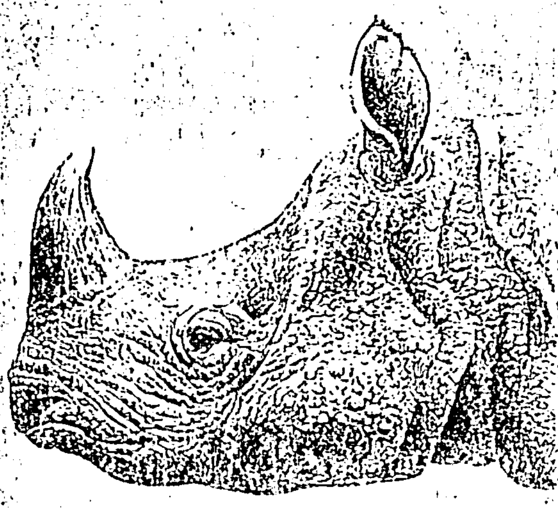
POPULATION ECOLOGY OF GREATER ONE-HORNED RHINOCEROS (*RHINOCEROS UNICORNIS*) WITH PARTICULAR EMPHASIS ON HABITAT PREFERENCE, FOOD ECOLOGY AND RANGING BEHAVIOR OF A REINTRODUCED POPULATION IN ROYAL BARDIA NATIONAL PARK IN LOWLAND NEPAL

by

Shant R. Jnawali



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ABSTRACT

The objectives of this thesis were to examine habitats, diet, ranging pattern, habitat preferences and demography of a founder population of greater one-horned rhinoceros (*Rhinoceros unicornis*) released in Royal Bardia National Park in 1986, and to compare these ecologies of the founder with that of the donor population in Royal Chitwan National Park.

A microhistological technique of fecal analysis was assessed as a method to determine the diet of rhinoceros and was later employed to study the seasonal diets of both populations. Floristic composition of habitats and availability of food plants were determined by quadrat sampling along the transect lines in Bardia and in Chitwan. In Bardia, ten rhinoceros were radio-collared in 1990-1993 to examine the ranging behavior and seasonal preferences of habitats. Data on demography of the translocated population were obtained from the radio-marked animals and supplemented by observations derived from foot tracking by park staff before the main field study was initiated. Spacing behavior of the donor population in Chitwan was available from radio-tracking of five animals during 1985-1987, and information on demography of the donor population was available from Laurie (1978) and Dinerstein and Price (1991).

The microhistological technique provided satisfactory results for determining the diet of rhinoceros. More than 90% of the plant species were identified. Volumetric contribution of plant species that were moderately and less preferred in the diet was sensitive to sample sizes, and samples from ≥ 8 animals and reading of ≥ 20 slide transects/animal were required to estimate >90% of the volume contributed by these species. Pooling samples, and recording frequency of fragment interception rather than measuring the size of each fragment, was less time consuming and had little effect on level of precision.

Floristic richness was higher in Chitwan than in Bardia (283 and 179 species, respectively), especically in the Tall Grassland habitat (131 and 79 species, respectively). Among important food plants, *Saccharum spontaneum* (grass) and *Mallotus phillippinensis* (browse) were more abundant in Bardia, whereas *Saccharum bengalensis* and *Narenga porphyrocoma* (grass species) and *Trewia nudiflora*, *Litsea monopetala*, *Coffea bengalensis* and *Murraya paniculata* (browse) were more abundant in Chitwan. The diet of both populations was dominated by grass species (> 60%), mainly *Saccharum spontaneum*. Animals in Bardia exploited more browse than in Chitwan during winter and hot seasons, probably due to lower productivity of *Saccharum*, attributed to lack of ample substrate moisture during these seasons. Contrary to Bardia, Chitwan animals exploited more browse species during the monsoon, mainly due to better access to *Trewia nudiflora* fruits. Although some species were selectively eaten in each season, the general pattern of food plant consumption was related to the abundance of food plant species in the habitats, confirming that the greater one-horned rhinoceros is a generalist feeder like other species in this family of megaherbivores.

The average annual home range sizes of the Bardia population were 25.1±9.3 km^2 for females (N = 8) and 41.8±4.4 km^2 for males (N = 2), whereas in Chitwan female (N = 4) and male (N = 1) home range sizes were only 2.9±0.9 km^2 and 3.0 km, respectively. Larger range size among males was explained by their seasonal ranges being further apart than those of females, that males probably roam wider in search of females, and that males have higher metabolic needs than females.

Seasonal home range sizes varied between 13.3 km^2 and 21.2 km^2, which was also > 8 times larger than in the donor population. There were no significant differences between seasons for any of four different social groups, except females with calves < 1 yr had smaller ranges during two of the three seasons. Due to large differences in seasonal range sizes between dominant (28.0-30.4 km^2) and subdominant (9.2-13.5 km^2) males, there was no statistical difference between mean seasonal range size of males and females.

The pronounced differences in ranging behavior between the dense donor population (8-10 animals/km^2) and the dispersed founder population (ca 0.3 animals/km^2) were attributed to low density combined with a highly skewed breeding sex ratio, and to a fragmented distribution and small patches of seasonally preferred habitats in Bardia. Khair-Sissoo was the most preferred habitat during winter, Riverine forest during both hot and winter seasons, and Tall Grassland during the hot and particularly during the monsoon season.

After translocation, the founder population bred at the same high rate as recorded in the donor population in Chitwan: mean calving interval was 4.3 years (N = 4), age of first potential breeding among females was 5 years (N = 1), and a young male bred successfully at 10 years of age. Furthermore, most translocated females conceived soon after they had been released. A total of 11 calves were born during the 8 year period. However, total number of animals increased only from 13 to 15, mainly due to direct and indirect affects of poaching. Number of animals lost to natural causes (maximum 3) was minimal. The high breeding rate and low natural mortality rates of calves and adults indicate that habitat quality in Bardia is quite adequate. If poaching is brought under control, the population is expected to increase at maximal rate in the coming years. However, an increase in the rhinoceros population in the Karnali floodplain of Bardia is likely to escalate the conflicts with local people, as animals have already caused substantial damage to agriculture outside the park.

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List of contents

List of papers

This thesis consists of the following papers and an extended synopsis.

I. Jnawali, S.R. 1995. Assessment of microhistological techniques for determining diet of greater one-horned rhinoceros (*Rhinoceros unicornis*). *Journal of Mammalogy*. In Press

II. Jnawali, S.R. 1994. Habitat and food of greater one-horned rhinoceros (*Rhinoceros unicornis*): Comparing floristic composition of habitats and diet selection between a donor and a translocated population in lowland Nepal. Manuscript.

III. Jnawali, S.R. 1994. Ranging behavior and habitat preference by a translocated population of greater one-horned rhinoceros (*Rhinoceros unicornis*) in lowland Nepal. Manuscript.

IV. Jnawali, S.R., and Wegge, P. 1994. Performance of a translocated population of greater one-horned rhinoceros in Nepal. Manuscript submitted to *Oryx*.

SYNOPSIS

Introduction

The greater one-horned rhinoceros' (*Rhinoceros unicornis*, henceforth termed rhinoceros) is listed as one of the world's most endangered species of megaherbivores (IUCN 1990). It once inhabited most of the Indus, Bramhaputra and Gangetic floodplains and nearby foothills of south Asia (Laurie 1978). Due to illegal hunting and habitat clearance, rhinoceros are now restricted to small isolated populations in protected areas on the Indian sub-continent, mainly in Nepal and India. At present only two populations contain >300 individuals, Royal Chitwan National Park in Nepal, and Kaziranga National Park in India (Khan and Foose 1994). Kaziranga holds the largest population with an estimated present population of about 1200 animals (Vigne and Martin 1994).

In Nepal, Chitwan valley harbored about 1000 rhinoceros until 1950 (Gurung 1989). Indiscriminate poaching and destruction of prime habitats between mid 1950s and 1960s drastically reduced this population to about 100 animals (Caughley 1969, Pelinck and Upreti 1972). However, with the creation of a national park in 1973 and adequate protection the population in Chitwan has now revived to about 400 individuals (Dinerstein and Price 1991, Khan and Foose 1994). Density in prime habitats is estimated at 8-10 animals/km^2 (Dinerstein and Price 1991).

To establish new viable breeding populations and to protect this species from natural calamaties and disease (Mishra and Dinerstein 1987) several rhinoceros have been translocated from Chitwan to Dudhwa National Park in India (Sale and Singh 1987, Sinha and

Sawarkar 1993) and to Royal Bardia National Park in Nepal (Bauer 1988, Mishra and Dinerstein 1987, Jnawali and Wegge 1993).

This thesis examines food ecology, habitat preferences, ranging behavior and demography of the population of rhinoceros in Bardia 4-6 years after translocation. These ecological attributes of the founder population are compared with those of the donor population based on similar data collected in Chitwan.

Objectives of separate papers of the thesis are as follows:

Paper I

(i) to assess the microhistological technique of fecal analysis for determining the diet of rhinoceros.

(ii) to determine the sample size (number of slide transects and number of animals) required to identify the range of food plants and to estimate the relative volumetric contribution of the food plants in the diet.

Paper II

(i) to compare seasonal diets of the translocated Bardia sub-population with the Chitwan donor population,

(ii) to assess the diversity and availability of food plants in the two rhinoceros habitats,

(iii) to assess the habitat quality in Bardia in terms of food by comparing with Chitwan where the population is performing well and where, presumably, food quality is adequate.

Paper III

(i) to examine seasonal home ranges and habitat preferences of the translocated population

(ii) to compare ranging behavior of the low-density translocated population with that of the very dense donor population in Chitwan

Paper IV

(i) to examine dispersal and performance (recruitment and mortality) of the translocated Bardia sub-population of rhinoceros during the 8 year period since it was released.

Study Area

The study was carried out in the south-western corner of Royal Bardia National Park (28°30'N 81°15'E) and the north-eastern section of Royal Chitwan National Park (84°20'E, 27°30'N) in lowland Nepal (Fig. 1). Both parks lie between 100 and 200m a.s.l. The climate is sub-tropical monsoonal type with three distinct seasons: winter (November-February), hot (March-June) and monsoon (July to October) seasons. Bardia receives the monsoon rains somewhat later and therefore remains comparatively drier during the hot season than Chitwan.

The vegetation in both areas is sub-tropical type ranging from a mosaic of early successional floodplain communities to a mature climax Sal *Shorea robusta* forest on the upper drie r lands. Among habitat types common to both areas, Sal forest, Tall Grassland and Bushy Pasture are similar floristically. Riverine forests in the two areas differ in species composition with *Trewia nudiflora* dominating in Chitwan and *Mallotus phillippinensis* in Bardia. Detailed descriptions of habitat types of both areas are available elsewhere: Bardia - Dinerstein (1979) and Jnawali and Wegge (1993); Chitwan - Laurie (1978), Mishra (1982) and Dinerstein and Price (1991).

The higher fauna is similar in both areas, except nilgai *Boselephus tragocamalus* and swamp deer *Cervus duvauceli* are confined only to Bardia, and gaur *Bos gaurus* only to Chitwan. Apart from greater one-horned rhinoceros and transient wild elephants *Elephas maximus*, important fauna common to both areas include tiger *Panthera tigris*, leopard *Panthera pardus*, sloth bear *Melursus ursinus*, wild boar *Sus scrofa*, and several species of deer (*Axis spp. Cervus unicolor, Muntiacus muntjack*).

General Methodology

Assessment of the microhistological analysis of fecal samples for determinig diet (Paper I)

Two sets of fresh dung samples (N = 10 from known animals and N = 20 from unknown animals) were collected in Chitwan during the monsoon 1993 during a 3 day period. The 20 samples from unknown animals were pooled into subsets of 5, 10, 15 and 20 to examine intraspecific variation. Five microscopic slides were prepared from each of the ten known samples and from each of the pooled samples from unknown animals. Various parts of >100 plant species were used to prepare reference slides. Identification of each plant species in the fecal sample was based on epidermal characteristics as described by Storr (1961) and Spark and Melechek (1968). The line intercept method (Seber and Pemberton 1979) was employed to estimate the proportion of different plant species.

Comparing habitat and diet of the donor and the translocated population (Paper II)

Quadrat sampling (N = 280 in Bardia and N = 191 in Chitwan) along transect lines was employed to describe floristic composition and availability of food plants in both areas. The minimum number of quadrats needed to describe floristic composition of each habitat type was determined by constructing species area curves. In each 10x10m quadrat, the percent cover of each plant species assumed to be available for rhinoceros (< 3m height) was estimated and later used to calculate prominence values (Dinerstein 1979). Simpson's Index of Diversity (Simpson 1949, cited in Krebs 1989) and Sørensen's Index of Similarity (Sørensen 1948) were used to compare diversity and similarity of plant species in the two areas.

Microhistological analyses of fecal samples were used to determine seasonal food habits of both populations. In Bardia, fresh fecal samples (N = 354) were collected between January 1990 and June 1991. Individual samples in each month were dried, ground and pooled. Food habit data from Chitwan (N = 480), collected during 1985-1986 and analyzed by the same procedure (Gyawali 1986, same as present author), were used to compare with the Bardia animals.

Ranging and habitat use of the translocated Bardia population (Paper III)

Ranging behavior and habitat preference by the translocated Bardia population were examined by recording the movement patterns of ten animals captured and radio-marked during 1990-1993. All animals were immobilized using the same drugs and techniques described by Dinerstein et al. (1990). A total of 1641 locations were obtained over a three year period. Spacing behavior of the Bardia animals was compared with that of the donor population (Chitwan) based on tracking data (N = 652) obtained in Chitwan during 1985-1987 from five radio-marked animals.

Performance of translocated Bardia Population (Paper IV)

Data on initial dispersal of the translocated animals in Bardia were obtained mainly by park staff who tracked rhinos on foot until this study was initiated in 1990. Data on demography were collected from 10 radio-instrumented animals intensively monitored during the 3 year (March 1990- March 1993) field study, supplemented by data collected by park staff before the study was initiated.

Results and Discussion

Microhistological analysis (Paper I)

Microhistological analysis was found to be a reliable method for estimating the composition of the diet, as has also been reported for other large herbivores (Johnson and Pearson 1981, Migongo-Bake and Hansen 1987, Larter and Gates 1991, Alipayo et al. 1992). However, sample size (slide transects and number of animals) was found to be critical to estimate the range of plant species and their volumetric contribution in the diet. An average number of 15 transects/animal were required to estimate at least 90% of the plant species present. Number of transects and number of animals needed to estimate volume contribution varied with the relative proportion of individual species in the diet. For moderately and less preferred species, readings of a minimum of 20 transects/animal from at least 8 different animals were needed to estimate 90% of their volume contribution. Recording the *frequency* distribution of intercepted fragments provided similar results for estimating volume contribution as measuring the size of individual plant fragments, and this method was far less time consuming. Pooling samples from different animals also reduced the time required for analyzing individual samples with little loss of precision.

Habitats and food (Paper II)

In general, species richness was higher in Chitwan than in Bardia (283 and 179 species, respectively). Compared to another study in Chitwan (Laurie 1978), total number of species recorded in the present study was lower, probably due to smaller study area and exclusion of plant species > 3 m and those growing in agricultural fields. Conversely, in Bardia the number of species recorded in this study was higher than in a previous study by Dinerstein (1979). This discrepancy was explained by a much larger sampling area in the present study.

Among all habitat types, Tall Grassland in Chitwan was the most diverse (131 species), whereas this habitat type was least diverse in Bardia, consisting of only 79 species. Mild grazing and availability of adequate substrate moisture were explained as the two major factors contributing to such a high diversity in this habitat in Chitwan. Availability of food plants varied between the two areas. Among the staple food plants, *Saccharum spontaneum* (grass) and *Mallotus phillippinensis, Calamus tenuis* and *Dalbergia sissoo* (browse) were more abundant in Bardia, whereas *Saccharum bengalensis* and *Narenga porphyrocoma* (grass) and *Trewia nudiflora* and *Litsea monopetala* (browse) were more abundant in Chitwan. Two important browse species, *Murraya paniculata* and *Coffea bengalensis*, were not recorded in the study area in Bardia.

The annual diet of rhinoceros was dominated by grass species (> 60%) in both study areas, but the proportion of plant groups varied markedly with seasons. The highest proportion of grass species was recorded during the monsoon (92%) in Bardia and during the hot season in Chitwan (86%), and the lowest during the winter season in both areas (42-57%). Browse constituted the highest proportion during the winter and hot seasons in Bardia and during the winter and monsoon in Chitwan. Higher proportion of grasses during the hot season in Chitwan was explained by the availability of high quality *Saccharum spontaneum* which keeps sprouting immediately after grazing and grass cutting (Dinerstein and Price 1991) and burning (Laurie 1978) due to high substrate moisture. In Bardia, low substrate moisture retards grass species from sprouting until the first rains in latter part of the hot season. As a result, animals here exploited more of browse species during the dry seasons than they did in Chitwan. Higher proportion of browse species in Chitwan during the monsoon was due to better access to preferred *Trewia nudiflora* fruits. Although rhinoceros fed selectively on some species in each season, animals in both areas exploited food plants in proportion to their availability, thus confirming that greater one-horned rhinoceros is a generalist feeder like the black *Diceros bicornis* (Mukinya 1977) and the white *Ceratotherium simum cottoni* (Gyseghem 1984) rhinoceros.

Ranging behavior and habitat preference (Paper III)

Five years after translocation, the annual home ranges for males and females in Bardia were estimated at 41.8±4.4 km^2 and 25.1±9.3 km^2, respectively, whereas in Chitwan they were only 3.3 km^2 for one male and 2.9±0.9 km^2 for females. In Bardia, the larger annual home range of males, as has also been recorded among black rhinoceros (Kiwia 1989), was due to seasonal ranges being spaced further apart than those of females and more extensive movements presumably in search for mates. Since adult males weigh 15-20% more than females (Owen-Smith 1988), and in general males have higher metabolic needs than females (McNab 1963), they may also require more space than females. When acquiring dominant breeding status, male home range size was also larger than that of subdominant status. Within social groups, there were no differences in seasonal range sizes in different seasons, except females with small calves (< 1 year old) had smaller home ranges than other social groups during the hot and monsoon seasons.

In Bardia, habitat preferences varied with the seasons, with Riverine forest generally being preferred during the two dry seasons, Khair-Sissoo forest during winter and Tall Grassland during the monsoon. During the dry seasons, good quality grass is less available in the Tall Grassland habitat in Bardia compared with Chitwan. As a result, animals switched to browse species basically confined to Khair-Sissoo and Riverine forests (Paper II). These habitat types are fragmented into smaller patches throughout the north-south elongated floodplain, resulting in increased movement during the dry seasons. Besides, longer distance to agriculture during winter also increased animals' range size in Bardia. During the monsoon, animals were mainly confined to the Tall Grassland habitat, like in Chitwan (Laurie 1978, Dinerstein and Price 1991). However, due to smaller relative size and a more fragmented distribution of this habitat type in Bardia, seasonal range size was larger than in Chitwan. In contrat to Bardia, the Chitwan habitats consisted of a large block of riverine forest surrounded by a continuous large tract of Tall Grassland which is productive throughout the year due to adequate soil moisture (Lehmkuhl 1989, Dinerstein and Price 1991).

Annual and seasonal home ranges were all > 8 times larger in Bardia. At the same time, animal density was > 25 times larger in Chitwan (0.3 animals/km^2 and 8-10 animals/km^2, respectively). The difference in space use was probably not due to non-settled behavior among the translocated animals, as seasonal ranges did not change from one year to the next. A highly skewed breeding sex ratio (1 male/8 females) and a widely scattered distribution may have triggered longer movements in search for conspecifics among the

Bardia animals. However, the difference in ranging behavior was most likely due to the different spatial distribution of preferred habitats. In Bardia, seasonally preferred habitats were fragmented into small patches and cultivated fields were located further away from the natural core areas than in Chitwan.

Performance of the translocated Bardia population (Paper IV)

Following extensive and erratic dispersal after being released, five years later the Bardia population had settled in large home ranges of ca 28 km^2 (Paper IV). Since the release in 1986 until 1994, nearly all breeding age females had calved. Two females were pregnant before translocation and calved within expected time intervals in the new environment. Four females calved twice with mean calving interval of 4.3 years, similar to the calving interval reported among the donor population in Chitwan. One or two breeding age founder females did not conceive during the eight year period, probably due to their very scattered distribution combined with a highly skewed breeding sex ratio of 1 male and 8 females.

Among three nonpregnant adult founders, one calved in September 1988 and one in the early monsoon 1989, indicating that they conceived during one of their first estrous cycles. A female calf born in Bardia conceived at an age of 5 years, indicating that animals reached sexual maturity as early in Bardia as in the donor population. One female, which occupied the extreme southern part of the study area near the Indian border, mated successfully with the then only available young subdominant male of maximum 10 years of age, which was a younger breeding age than reported in Chitwan (Dinerstein and Price 1991).

During eight years, six animals died and a total of 11 calves were born, 10 from the founder females and one by a female calf born in Bardia in 1987. However, since release in 1986 to end of 1994, number of animals only increased from 13 to 15. The causes of death in Bardia were mainly direct or indirect effects of poaching. In the absence of poaching and other irregular deaths, net recruitment of the translocated population would have been close to the maximum potential of the species.

Considering the good breeding performance and high natural survival rate of calves and adult animals, the habitat in Bardia appears to be of adequate quality to sustain a small viable population of rhinoceros. Recent habitat and food studies also support this (Paper II). However, problems of conflict with local people have already emerged as animals frequently move outside the park boundary and raid agricultural crops. With protection from poaching, the population is expected to increase at maximal rate which will escalate the problem of human conflicts in the future.

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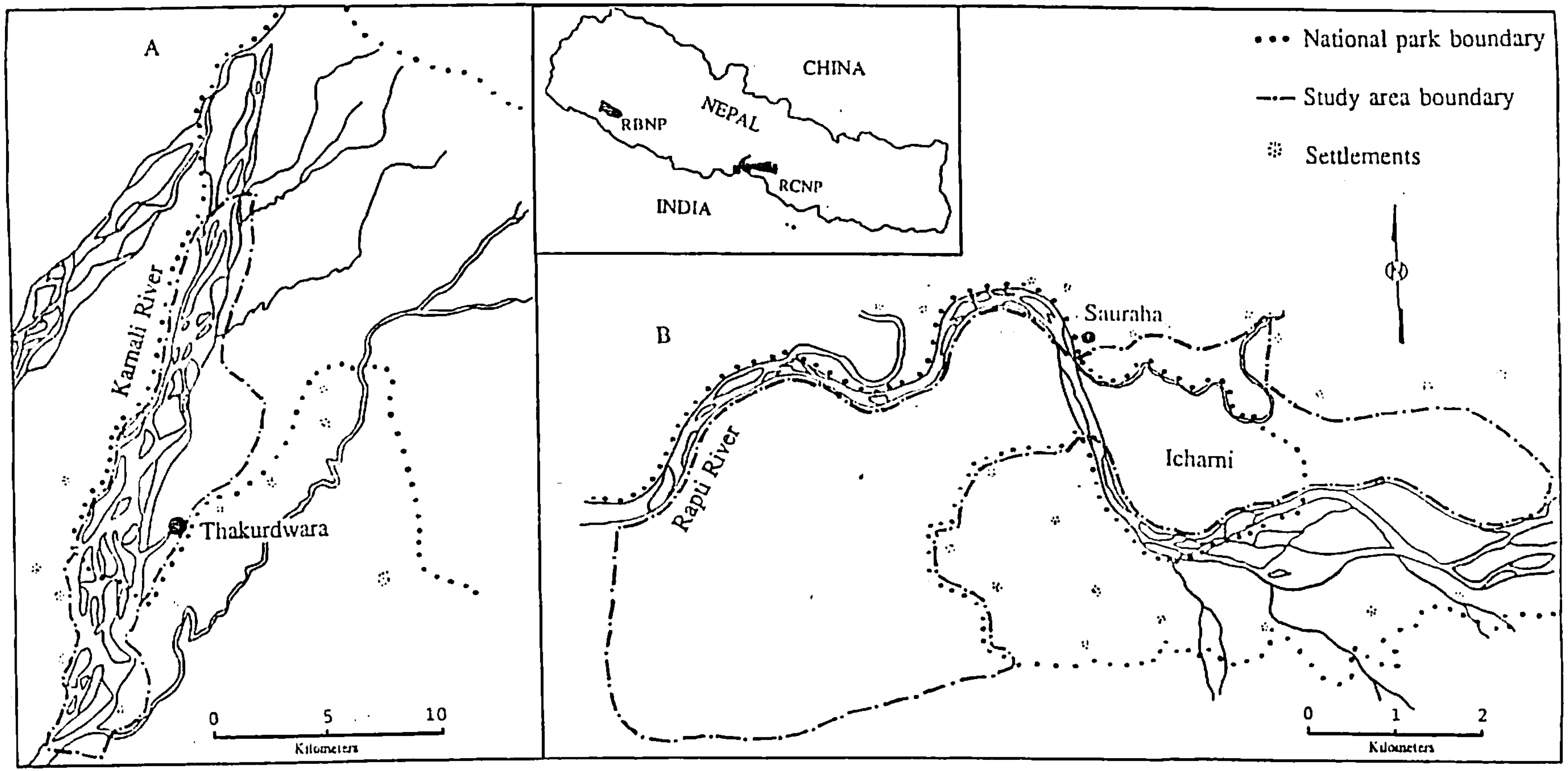

Figure 1. Map of study areas in (a) Royal Bardia and (b) Royal Chitwan national parks.

PAPER I

ASSESSMENT OF MICROHISTOLOGICAL TECHNIQUES FOR DETERMINING DIET OF GREATER ONE-HORNED RHINOCEROS (*RHINOCEROS UNICORNIS*)

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KEY WORDS: *Rhinoceros unicornis*, microhistological technique, line intercept, diet, Nepal.

ABSTRACT

I collected fresh fecal samples of greater one-horned rhinoceros *Rhinoceros unicornis* from Nepal's Royal Chitwan National Park to assess the microhistological technique for determining diet. The microfecal analysis based on the line intercept method provides satisfactory estimation of the range of plant species and their volumetric contribution in the diet. Over 90% of the plant species were identified. Volumetric contribution of plants that are moderately and less preferred is sensitive to size of sample and number of slide transects. To estimate 90% of the volume contributed by these species, samples from more than eight different animals and the readings of a minimum of 20 transects/animal are required. Slide preparation and reading of individual samples of the line-intercept method is laborious. Estimating the volumetric contribution of species by the frequency distribution of fragments encountered is less laborious and give similar results as measuring size of each fragment. Also, pooling samples from different animals reduces the time required for analyzing individual samples with little loss of precision.

INTRODUCTION

Methods for studying diet of free-ranging wild herbivores are direct field observation, feeding trials, clipping and browsing studies and microhistological techniques. Among these, microhistological techniques for examining esophageal (McInnis et al. 1983, Elliot and Barrett, 1985, Kirby and Parman 1986), rumen (Bergerud and Russell 1964, Mitchell and Smoliak 1971, Branan et al. 1985, Lewis 1994), and fecal samples (Stewart 1967, Kessler et al. 1981, Migongo-Bake and Hansen 1987, Alipayo et al. 1992) are most favored.

Limitations associated with esophageal fistula include contamination by rumen contents, incomplete recoveries of fistulated animals, high cost and low precision in sampling for individual species (Holechek et al. 1982). Collection of esophageal and rumen samples also requires sacrificing several animals, which is not feasible when studying rare and endangered species.

In recent years fecal analysis has been found to be a reliable method for estimating the composition of diet of grazing herbivores (Todd and Hansen 1973, Johnson and Pearson 1981, Larter and Gates 1991, Alipayo et al. 1992). However, differential digestion may seriously affect precision of the microhistological analysis among ruminants (Slater and Jones 1971, Anthony and Smith 1974, Fitzgerald and Waddington 1979, Smith and Shandruk 1979, McInnis et al. 1983, Holechek and Valdez 1985, Vavra et al. 1978), but this has been questioned by Alipayo et al. (1992). Such limitations do not apply to the same extent to monogastric species like rhinoceros.

The microhistological technique is based on enumerating identifiable fragments in a certain number of microscopic fields (Sparks and Malechek 1968) or on the line-intercept method (Seber and Pemberton 1979). A main drawback of the technique is that it is time consuming.

The present study is based on analysis of fecal samples from a free-ranging population of wild greater one-horned rhinoceros (*Rhinoceros unicornis*, henceforth termed rhino) in Royal Chitwan National Park (RCNP), Nepal. The main purpose of the study was to determine the sample size (number of slide transects and number of animals) required to identify the range of food plants and to estimate the relative volumetric contribution of the food plants in the diet of rhinos.

METHODS

Types of fecal sample

I collected two sets of fecal samples from RCNP within an area of approximately 2 km^2 of riverine forest and adjacent floodplain grasslands along the Rapti river near Sauraha. The first set was collected from 10 known animals and the second from 20 unknown animals. Samples were collected over a 3 day period during the monsoon in September 1993. The set of 20 unknowns were pooled into groups of five, ten, fifteen and twenty. The purpose was to assess intraspecific variation and to determine sample size needed for adequate representation of food plants and their relative proportion in the diet.

Preparation of fecal sample

Each fresh dung pile, defecated at one time, was thoroughly mixed. Approximately 400 g (wet weight) was extracted, air dried, ground to pass through a 1 mm screen and sieved through a 210 mu micron Endcott sieve to ensure homogenous size of the fragments and to remove dust and fine unidentifiable particles.

About one tablespoonful of ground dung was transferred into test tubes to which warm 5% sodium hydroxide (NaOH) solution was addeded. The test tubes were heated in a boiling water bath for 4-6 minutes and allowed to cool. The supernatant dark fluid in the test tubes was decanted, replaced with fresh NaOH, and repeated 2-3 times until a clear solution was produced. The material was then washed with warm fresh water and absolute alcohol to eliminate the NaOH. Finally, the sample was dehydrated through a series of alcohol and xylene (75, 50, 25 percent) mixtures (Anthony and Smith, 1974).

A small amount (equal in all slides) of dehydrated material was uniformly mounted in canada balsam under a 24 X 50 mm cover slip. Five slides were prepared for each dung sample. The slides were air dried for 5-7 days before analysis.

Zyznar and Urness (1969) used NaOH to clean deer feces and reported low percentage of discernable fragments. Their procedure of treating fecal pellets with NaOH might have influenced the identifiable characteristics of the fragments. They either soaked the fecal pellets over night or boiled them for 15 minutes in 10% NaOH and later stirred vigorously to reduce the material into a pulpy mass. Direct boiling in NaOH and vigorous stirring results in disintegration of fragments. Anthony (1972) also found boiling time to be critical for microfecal analysis.

Procedure for reading slides

Identification of each plant species was based on epidermal characteristics as described by Spark and Malechek (1968) and Storr (1961). The line-intercept method (Seber and Pemberton, 1979) was employed to estimate the proportion of different plant species. Five horizontal transect-lines were randomly located on each slide by moving the slides with a rotating attachment on the microscope. The length of all fragments intercepted by the line was measured to the nearest 0.04 mm with a calibrated ocular micrometer. Each transect was examined under 200X magnification or 500X magnification.

Reference slides used in this study was available from an ongoing vegetation study (Jnawali, in prep.). Above ground parts (leaves, twigs, fruits and flowers) of over 100 different plant species collected from the study area were shredded coarsely using an ordinary electric blender. A teaspoonful of the coarse material was transferred separately into test tubes, marked and mixed with 10% NaOH to clean the epidermal tissues. Dehydrating and mounting procedures were the same as for the fecal material.

RESULTS AND DISCUSSION

General

A total of 28 species of plants (15 grasses, 7 browse and 6 others, including sedges, herbs, ferns and horsetails) were identified from the 10 known but different animals. Mean composition of each species is given in Table 1. Grass species composed about 65%, browse species 20%, and others less than 5%. Unidentifiable fragments averaged 6% of the total volume.

From direct feeding observations Laurie (1978) recorded over 100 species of plant eaten by rhinos in RCNP. However, his results were based on the entire year of a larger area, a wide variety of agricultural crops and associated species, and aquatic plants. Rice, the only available crop during the time of sample collection, was in a very early stage of growth. Similarly, access to aquatic species was restricted because of high flooding during the monsoon 1993, and aquatic plants are eaten mostly during other times of the year (Laurie 1982).

In ruminants investigators report difficulties in identifying species of forbs because they are more thoroughly digested and, as a result, are under-estimated (Storr 1961, Free et al. 1970, Pulliam and Nelson 1979, Vavra and Holechek 1980). Due to low assimilation, fragments of forbs in the present sample were identifiable, and their percent composition was low, all < 1%.

Westby et al. (1976) reported that woody remnants possess less discernable characters than grass species in fecal material. Holechek and Valdez (1985) also reported that fecal analysis underestimates species of shrubs high in stemmy material. Here grass-species constituted about 65% of total volume. Among browse species, the highest contribution was calculated for *Trewia nudiflora* (13.4%), consisting only of fruity parts with discernable features. The influence of woody remnants would have been expected when stems of browse species dominate the diet, particularly in shortage of palatable species of grass during the dry season. However, during the monsoon rhinos eat only the fruity parts of *Trewia nudiflora* (Dinerstein and Wemmer 1988).

Coefficients of variation (CV) were calculated for all plant species detected. Variation was low for all three key species, *Trewia nudiflora* (17.9%), *Saccharum spontaneum* (24.6%), and *Narenga porphyrocoma* (30%); while variation was noticeably higher among moderately and less preferred species (Table 1). The CV decreased significantly ($R^2 = 38.6$, $p < 0.001$) with increasing relative proportion of plant species in the diet.

Analysis of individual dung samples

Among 10 different animals, three were randomly selected to determine the number of transects needed to record the range of plant species in the diet. An average number of 15 transects were required to record at least 90% of the plant species present (Fig. 1). Hence, with five transects on each slide, a minimum of four slides were needed for this level of precision.

A sample from one randomly selected animal was chosen to see how the volume estimates of three grass species varied with number of transects examined (Fig. 2). For the key species, *Saccharum spontaneum*, approximately 13 transects were needed to estimate a volume within 90% of the mean of 25 transects. For moderately preferred (*Imperata cylindrica*) and less preferred (*Vetiveria zizanoides*) species more than 20 transects were required for a similar level of precision (Fig. 2).

Data from the same animal were used to compare volume composition based on frequency distribution of fragment interception and estimates based on actual measurements of individual fragments (Table 2). The results showed very close agreement for all species, and the correlation was highly significant ($r^2 = 0.99$, $P < 0.001$).

Variation between individual animals

A pooled sample of fifteen randomly collected samples obtained more than 90% of the total number of species collected from 20 unknown animals. In the case of known animals a pooled sample of ten produced the same range of species in the diet.

So far, the number of fecal samples required in order to establish the food habits of a megaherbivore like rhino has not been documented. Anthony and Smith (1974) suggested that a minimum of 15 fecal samples are required for studying deer diets within a particular period. But they did not mention whether the same number of fecal samples from the same or different animals provided similar results.

The discrepancy in the results between known and unknown animals in the present study may have occurred because some fecal samples collected from unknown animals could have been duplicated by the same animal. Rhinos use common latrines and defecate on the same spot several times in a twenty-four hour cycle (Laurie, 1978). In the present study all fecal samples of unknown animals were collected in early morning from latrines located within an area of approximately 2 km^2, and at each latrine 2 or more dung piles that had been defecated during the preceding night were collected. This might have led to some duplication of fecal samples from the same animal. Thus, it is suggested that if fecal samples are collected from unknown animals a pooled sample from at least twenty different latrines is required in order to represent the total range of food plants. Two grasses and one browse species were selected to see how the variation in volume estimates varied with number of individuals sampled. The results showed that key food species were less sensitive to the sample size than were moderately and less preferred species (Fig. 3). For key species (*Saccharum spontaneum*, *Narenga porphyrocoma* and *Trewia nudiflora*) samples from 4-5 different animals gave results within 10% of the volume estimate of ten animals, while at least 8 and 9 samples were required for the same level of precision for moderately preferred (*Phragmites karka*, *Saccharum bengalensis* and *Callicarpa macrophylla*) and less (*Typha elephantina*, *Chrysopogon aciculatus* and *Mallotus phillippinensis*) preferred species, respectively.

The diet volume composition from pooled samples of 5 and 10 animals, and the mean of five different animals were compared with the mean diet composition of ten different animals (Table 1). The two pooled samples both fell within 95% confidence limits of the mean of 10 different animals. The range of variation in five random combination of five different animals was also low for key species and higher for medium and less common species (Table 1). Among key species the range was 9.8%-19.9%, 19.3%-36.4%, and 24.9%-37.1% for *Trewia nudiflora*, *Saccharum spontaneum* and *Narenga porphyrocoma*, respectively.

Volume estimates were also compared to see how accuracy is influenced by pooling samples. Highest variation was recorded among the less preferred species (Fig. 4). Precision for moderately and less preferred species increased slightly by pooling the samples from 5 to 10, however, none of these increments were statistically significant. Besides, the mean of 5 different animals also did not provide better estimates than the pooled sample of 5 random animals.

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Table 1. Comparison of the relative proportion of the diet composition between ten individual samples and pooled samples.

	Mean composition of 10 different animals		Range of variation (%) of 5 random combinations of 5 diff. animals	Mean of 5 different animals		Pooled of 10 animals	Pooled of 5 animals
	%	CV		%	CV	%	%
Grass species							
Saccharum spontaneum	22.7	24.6	19.3 - 36.4	26.5	19.3	21.2	24.5
Narenga porphyrocoma	20.0	30.0	24.9 - 37.1	19.6	30.1	23.2	19.5
Saccharum bengalensis	4.5	106.7	91.7 - 113.9	1.7	223.6	6.3	6.6
Phragmites karka	3.6	116.7	85.1 - 97.5	0.8	137.5	3.1	4.3
Imperata cylindrica	3.5	102.9	98.5 - 113.1	3.9	113.1	3.4	4.8
Themeda sp.	3.3	115.2	101.9 - 224.0	1.0	224.0	3.8	2.2
Saccharum arundinaceum	2.3	52.2	40.8 - 71.7	2.3	71.7	1.2	3.2
Cyanodon dactylon	2.2	159.1	96.0 - 146.5	3.1	146.5	3.5	2.1
Vetiveria zizanoides	1.5	100.0	64.4 - 107.2	1.5	107.2	0.7	0.8
Seteria sp.	1.1	118.2	94.0 - 224.2	1.2	110.5	0.9	0.8
Desmostachia bipinnata	1.0	160.0	112.1 - 164.2	1.3	134.4	1.3	0.0
Chrysopogon aciculatus	0.9	188.9	146.2 - 222.2	1.6	146.2	0.3	0.0
Typha elephantina	0.7	171.4	13.3 - 223.5	1.3	113.3	0.6	1.0
Cymbopogon sp.	0.4	220.0	223.1 - 225.0	0.3	225.0	1.0	0.0
Panicum sp.	0.5	220.0	223.8 - 224.2	0.4	223.8	1.1	0.0
Browse species							
Trewia nudiflora	13.4	17.9	9.8 - 19.9	14.4	19.9	11.7	15.3
Callicarpa macrophylla	4.2	52.4	39.9 - 81.4	3.3	63.7	3.4	3.4
Ehretia laevis	1.8	150.0	119.9 - 158.8	1.7	158.8	2.0	0.0
Colebrookia oppositifolia	1.6	162.5	100.0 - 146.2	3.1	100.0	0.3	0.9
Murraya paniculata	0.7	142.9	114.5 - 213.8	0.4	176.2	0.2	0.5
Bahunia sp.	0.4	225.0	158.8 - 224.1	0.8	158.8	0.2	0.0
Mallotus pillippinensis	0.4	225.0	223.5 - 224.1	0.5	224.1	0.6	0.0
Others							
Cyperus sp.	1.6	112.5	88.1 - 162.5	2.3	88.0	1.1	1.2
Circium wallachii	0.8	187.5	152.3 - 225.0	0.4	225.0	1.6	0.3
Urena lobata	0.7	185.7	146.5 - 222.5	0.4	222.5	0.1	0.9
Pteris sp.	0.6	100.0	73.8 - 104.4	0.5	95.8	1.0	1.3
Truimfetta sp.	0.3	233.3	171.7 - 224.0	0.1	225.0	0.2	0.0
Artemisia vulgaris	0.2	400.0	0.0 - 222.9	0.5	222.9	0.1	0.0
Unidentified	5.6	21.6	18.1 - 27.5	5.4	25.9	5.9	6.4

...l samples and pooled

...led ...0 ...nals	Pooled of 5 animals
	%
	24.5
	19.5
	6.6
	4.3
	4.8
	2.2
	3.2
	2.1
	0.8
	0.8
	0.0
	0.0
	1.0
	0.0
	0.0
	15.3
	3.4
	0.0
	0.9
	0.5
	0.0
	0.0
	1.2
	0.3
	0.9
	1.3
	0.0
	0.0
	6.4

Table 2. Diet composition based on actual measurements of fragments and on the freque distribution of number of intercepted fragments from microfecal analysis of one rando selected animal.

Plant species	Volumetric Measurements Volume (%)	SE	Frequency distribution No. of fragments	f(%)	S
S. spontaneum	22.3	1.4	177	21.6	2.
N. porphyrocoma	20.2	1.5	165	20.1	1.
T. nudiflora	15.7	1.8	121	14.7	1.
S. bengalensis	9.6	1.1	87	10.6	1.
I. cylindrica	6.1	1.1	57	6.2	0.
P. karka	4.8	0.9	36	4.4	2.
Themeda sp.	4.4	1.7	27	3.2	2.
C. macrophylla	3.7	0.7	30	3.7	1.
S. aurandineceum	2.5	1.3	23	2.8	1.
V. zizanoides	2.1	1.5	17	2.1	2.
Cyperus sp.	1.0	0.7	23	2.8	1.
Pteris sp.	1.1	0.8	14	1.7	1.
Unidentified	6.5	0.6	50	6.1	1.
Sum	100		827	100	

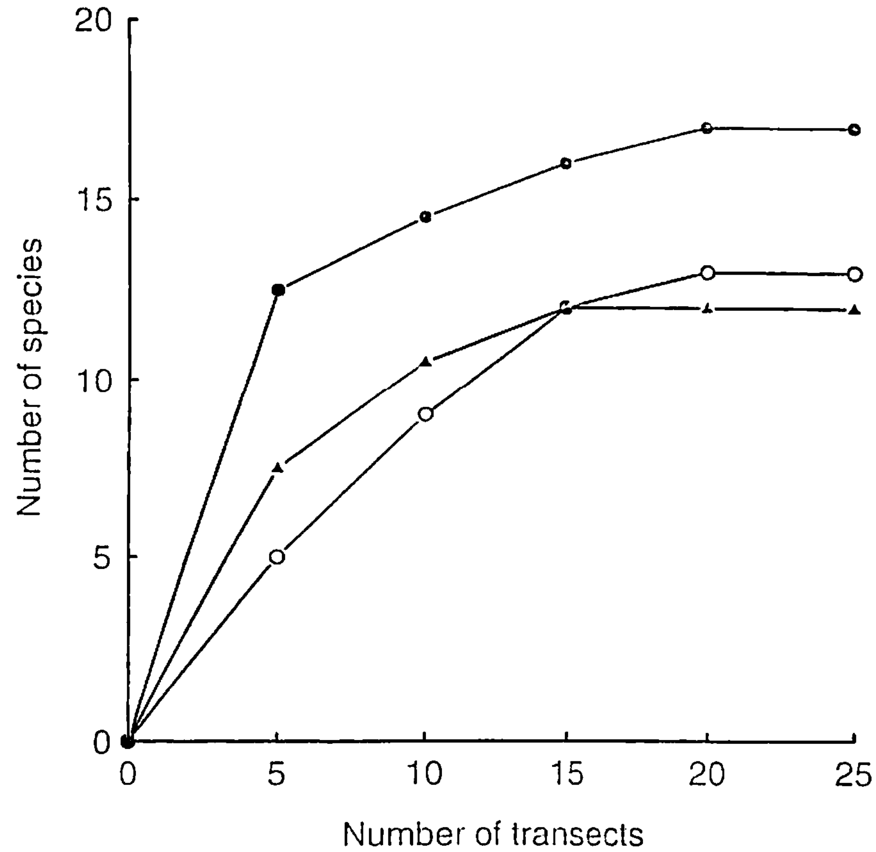

Fig. 1. Relationship between number of species recorded and number of transects examined based on fecal samples from three different animals.

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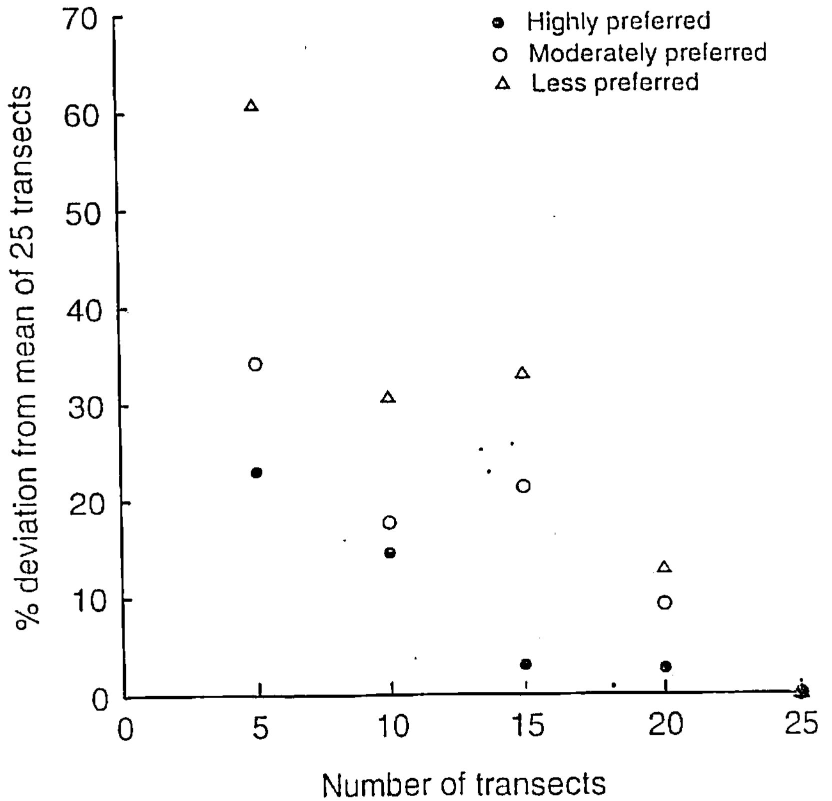

Fig. 2. Relationship between volume estimates of three grass species and number of transects examined.

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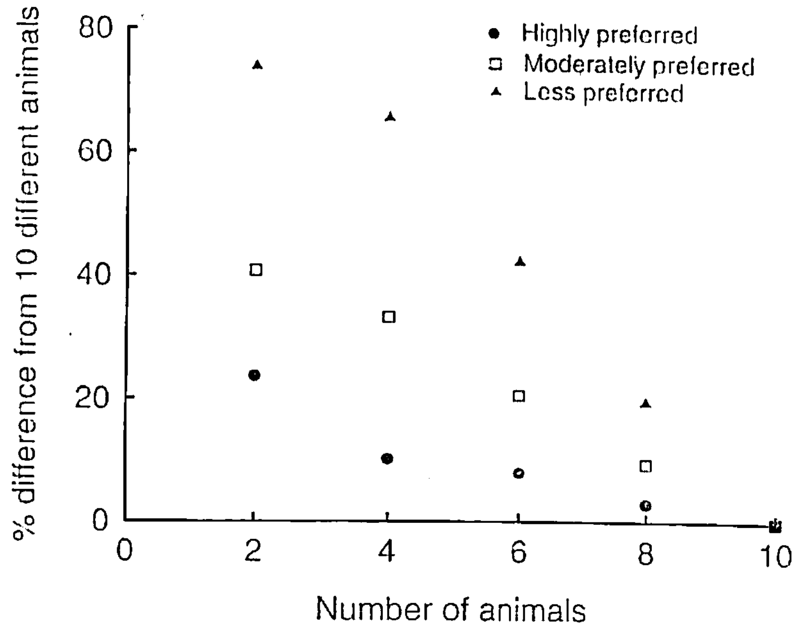

Fig. 3. Relationship between number of different animals sampled and volume estimates of different categories of food plants in the diet.

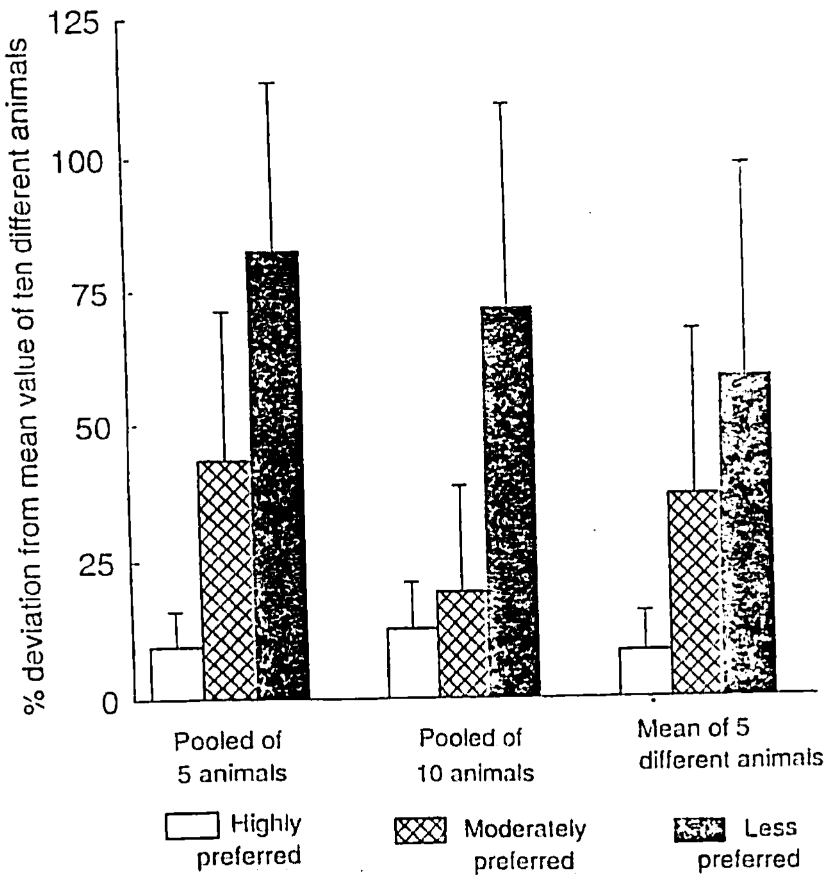

Fig. 4. Relationship between percent deviation in volume estimates of pooled samples from mean value of ten known different animals. Vertical

Fig. 4. Relationship between percent deviation in volume estimates of pooled samples from mean value of ten known different animals. Vertical lines ... S.D.

PAPER II

HABITAT AND FOOD OF GREATER ONE-HORNED RHINOCEROS (*RHINOCEROS UNICORNIS*): COMPARING FLORISTIC COMPOSITION OF HABITATS AND DIET SELECTION BETWEEN A DONOR AND A TRANSLOCATED POPULATION IN LOWLAND NEPAL

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KEY WORDS: Greater one-horned rhinoceros, *Rhinoceros unicornis*, habitat, diet, Nepal.

ABSTRACT

Habitat and diet of a translocated (in Royal Bardia National Park) and a donor (in Royal Chitwan National Park) population of greater one-horned rhinoceros (*Rhinoceros unicornis*) are compared. Quadrat sampling (N = 471) along transect lines was employed to describe floristic composition and availability of food plants. Seasonal diets were determined from microhistological analyses of fecal samples (N = 834). Species richness was higher in Chitwan than in Bardia (283 and 179 plant species, respectively), especially in the Tall Grassland community (131 and 79 species, respectively). Among important food plants, *Saccharum spontaneum*, *Erianthus ravennae*, and *Arundo donax* (grasses) and *Mallotus*

phillippinensis, *Calamus tenuis*, and *Dalbergia sissoo* (browse) were more abundant in Bardia, whereas *Cyanodon dactylon*, *Saccharum bengalensis*, *Narenga porphyrocoma* (grasses) and *Trewia nudiflora*, *Litsea monopetala*, *Coffea bengalensis* and *Murraya paniculata* (browse) were more abundant in Chitwan, and the latter two not being present in the Bardia habitats. In spite of lower species diversity in Bardia, the annual diet was more diverse there (57 versus 44 food plants, respectively). In both areas, the annual diet was dominated by grasses (> 60 %), particularly *Saccharum spontaneum*. In Bardia, browse was more important than grasses than in Chitwan during winter and hot seasons, probably because the staple food plant - *Saccharum spontaneum* - was less available and nutritious in Bardia due to a drier floodplain during the dry season. Conversely, during the monsoon, Chitwan animals exploited a larger proportion of browse than in Bardia because of better access to preferred *Trewia nudiflora* fruits. Among available food plants, highest selection was recorded for *Arundo donax* and *Phragmites karka* (grasses) and *Mallotus phillippinensis*, *Cqlamus tenuis* and *Dalbergia sissoo* (browse) in Bardia; in Chitwan *Saccharum spontaneum* and *S. bengalensis* were the most selectively consumed grasses and *Coffea bengalensis* and *Murraya paniculata* the most preferred browse species. Although certain species were selectively eaten in each season, animals in both areas exploited food plants in proportion to their availability, confirming that the greater one-horned rhinoceros is a generalist feeder like other species in this family of megaherbivores.

INTRODUCTION

The family Rhinocerotidae contains five monogastric, herbivorous species. The large body enables them to consume large quantities of food, hence they are commonly referred to as bulk feeders (Owen-Smith 1988). Due to slower metabolic rate, large animals require less energy and protein per unit weight and survive better on lower quality food compared to smaller ungulates (Janis 1976, Jarman 1974). Because of lower energy requirement, rhinoceros fulfill the needs of essential elements like amino acids, vitamins and minerals by favoring a high floristic diversity in the diet (Laurie 1978). However, selection of food plants and foraging pattern vary markedly among the species. The greater one-horned rhinoceros, *Rhinoceros unicornis*, is reported to be a mixed feeder, switching from a graminoid dominated diet during the wet season to increased proportion of woody browse in the dry season (Laurie 1982). Three others, *Diceros bicornis* (Goddard 1968 and 1970), *Dicerorhinus sumatransis* and *Rhinoceros sondaicus* (Owen-Smith 1988) are mainly browsers and forage upon leaves and small branches of diverse woody vegetation. The northern *(Ceratotheruim simum cottoni)* (Gyseghem 1984) and the southern (*Ceratotheruim simum simum*) (Owen-Smith 1988) species of square-lipped white rhinos, on the other hand, are strictly grazers and exploit grasses throughout the year.

The greater one-horned rhinoceros (hereafter termed rhinoceros) is adapted to floodplain and riverine vegetation where water and some green growth remain available all year round. A mosaic of various forest and tall grassland communities on the alluvial floodplain are the critical habitats for this species (Dinerstein and Price 1991). The species is now restricted to small, isolated populations on the Gangetic plains of the Indian sub-continent. At present, Kaziranga national Park, India, holds the largest population of

> 1100 individuals (Bhattacharya 1993, Vigne and Martin 1994). In Nepal, until recently, rhinoceros was confined only to the Royal Chitwan National Park in the mid-southern lowland. During mid 1960s, the population declined drastically to about 100 individuals mainly due to illegal hunting and habitat alteration (Caughley 1969). After the declaration of a national park in 1973 the population has now increased to about 375-400 individuals (Khan and Foose 1994). To safeguard this species against natural calamities and to establish a new viable breeding population, a small sub-population based on individuals translocated from Chitwan was established in the Royal Bardia National Park, about 500 km west from Chitwan (Jnawali and Wegge 1993). The purpose of this paper is to (i) compare the seasonal diets of the translocated Bardia sub-population with the donor population (ii) assess the diversity and availability of food plants in the two rhinoceros habitats, and (iii) assess the habitat quality in Bardia in terms of food by comparing with Chitwan where the population is performing well and where, presumably, food quality is adequate.

STUDY AREA

This study was conducted in two national parks, Royal Bardia (RBNP) in the western and Royal Chitwan (RCNP) in the middle part of Nepal's southern lowland (Fig. 1). In Bardia, the study area consists of a narrow strip of about 70 km^2 in the south-western corner of the park (81°20'E, 28°35'N). About 6 km^2 extends southward from the park boundary to the Indian border along the Geruwa river. In Chitwan, a study area of about 20 km^2 was selected on the northern floodplain of RCNP (84° 20' E 27° 30' N) along the Rapti river, near Sauraha. Both areas lie at about 100 m a.s.l.

The climate in both areas is subtropical, monsoonal type. More than 80% of the precipitation occurs during the monsoon. In Bardia, the monsoon starts somewhat later and the area remains drier than in Chitwan. Average maximum temperatures in both areas may reach up to 40°C during May and early June and gradually drop to about 5° C during December and January.

The vegetation in both study sites exhibits subtropical types ranging from early successional stages on the silty river beds with colonizing *Saccharum spontaneum* to a mature climax type of Sal *Shorea robusta* dominated forest on the upper, drier lands. In Bardia, the vegetation includes four main forest types: (i) Sal (ii) Riverine (iii) Khair-Sissoo and (iv) Mixed Hardwood forests, and three types of grasslands: (i) Tall Grassland (ii) Phanta (revegetated previously cultivated dry fields) and (iii) Wooded Grassland with scattered tree species, also assumed to have an anthropogenic origin. Dinerstein (1979a) has provided a detailed description of these types.

A description of the vegetation types in Chitwan where this study was conducted is available elsewhere (Laurie 1982, Lehmkuhl 1989). Lehmkuhl (1989) classified the vegetation into three forest types: (i) Sal (ii) Mixed Riverine, and (iii) Trewia-Bombax Riverine forest, and several sub-types of Tall Grasslands. For comparative purposes only three distinct vegetation types: (i) Sal forest, (ii) Riverine forest, and (iii) Tall Grassland, were classified in the present study. In Chitwan, formerly cultivated paddy fields now dominated by tall grass species (Lehmkuhl 1989) are combined with Tall Grassland community along river beds. Bushy Pastures outside the National Park boundary were mapped and added as an additional vegetation type to encompass peripheral areas frequently used by rhinoceros in both areas. Bushy Pastures in both areas are similar to the scrub vegetation type described by Laurie (1978).

The fauna in both parks is similar except some species are confined only to either of the areas. Important fauna common to both Parks include *Rhinoceros unicornis, Elephas maximus, Melursus ursinus, Panthera tigris, P. pardus*, four species of deer - *Axis axis, A. porcinus, Muntiacus muntjack*, and *Cervus unicolor*. Uncommon mammalian species include *Bos gaurus* in RCNP, and *Boselaphus tragocamelus* and *Cervus duvauceli* in RBNP. Bolton (1976) and Gurung (1983) have provided a detailed description of fauna of Bardia and Chitwan, respectively.

Of the two study sites, Chitwan harbors a centuries-old population of rhinoceros. More than 60% of the total present population occupies the area where the present study was conducted, estimated at a density of about 8-10/km^2 (Dinerstein and Price 1991). The Bardia population originates from 13 animals that were translocated from Chitwan and released during the dry season of 1986. A description of this population is given by Jnawali and Wegge (1993). From a biological point of view both populations were performing well with a mean annual rate of increment of 6.4 % in Bardia and 2.7% in Chitwan (Dinerstein and Jnawali 1993). Animal density in Bardia during the time of this study was approximately 0.3/km^2, or roughly 2% of that of Chitwan.

METHODS

Vegetation analysis

Vegetation analyses in both areas were carried out between late July and August when all plant species had already emerged. In both areas, quadrat sampling along transect lines was employed to determine the floristic composition in various habitat types. In Bardia, a total of 20 transect lines spaced 1 km apart were laid out in an east-west direction to pass through the different vegetation types. 10m X 10m quadrats were laid out along the transect lines at a intervals of 150 meters. Altogether 280 quadrats were sampled of which 59 fell in Riverine, 51 in Sal and 60 in Khair-Sissoo forests, 51 in Tall Grassland, 17 in Wooded Grassland, 26 in Bushy Pastures, 7 in Phanta and 9 in Mixed Hardwood forest.

A similar procedure was employed in Chitwan with some modification due to the location of vegetation types. The transects were laid in a north-south direction starting from the bank of the Rapti river. The interval between transects was reduced to 500 m to obtain enough samples in Riverine forest because this vegetation type extends in a narrow strip along the Rapti and Dhungre rivers. Out of 191 quadrats sampled in Chitwan, 63 were in Riverine forest, 41 in Sal forest, 69 in Tall Grassland and 18 in Bushy Pastures.

The minimum number of quadrats needed to describe the floristic features was determined by constructing species area curves for all vegetation types. The number of quadrats needed to include 90% of the total number of species (the asymptote) was used when comparing floristic diversity in the two study areas. In each quadrat, the percent cover of each species assumed to be available for rhinoceros (< 3 m height) was estimated and recorded in classes as follows: high = > 50%, medium = 26 - 50%, low = 11 - 25%, rare = 1 - 10% and trace < 1%. These data were later used to calculate prominence values (PV) for each species (Dinerstein 1979a):

$$PV_x = M_x (\sqrt{f_x})$$

PV_x = Prominence value for species *x*

M_x = Mean percent cover of *x* species

f_x = Frequency of occurrence of *x* species

Simpson's Index of Diversity (Simpson 1949, as described by Krebs 1989) was applied for measuring floral diversity:

$$1 - D = 1 - \Sigma(p_i)^2$$

D = Simpson's index of diversity

pi = Proportion of individuals of species *i* in the community

Sorensen's index of similarity (IS_s) (Sorensen 1948) was employed to compare similarity of plant species in the two study areas:

$$IS_s = \frac{c}{1/2\ (A + B)} \times 100$$

c = Number of species common to both areas

A = Total number of species in habitat *A*

B = Total number of species in habitat *B*

Diet analysis

A microhistological analysis of fecal samples (Jnawali, in press) was conducted to determine the food habits of rhinoceros in each area. In Bardia, fresh fecal samples (N = 354) were collected during 18 months, from January 1990 to June 1991. Individual samples collected in each month were dried, ground and pooled. Monthly sample sizes in Bardia ranged from a minimum of 20-25 during the monsoon, to > 50 during the dry season. Food habit data from Chitwan collected during 1985 - 1986 and analyzed by the same procedure (Gyawali 1986, same as present author) were used to compare with Bardia animals. In addition, results from 30 samples collected from the same area during the monsoon 1993 were combined with the previous ones.

Analysis followed the method described by Jnawali (in ms). Five microscopic slides were prepared from each pooled fecal sample of every month. Identification of plant fragments was based on the morphological features observed by microscopic examination. Volumetric estimation of each food plant species was calculated for every month and later combined for seasons. Seasons referred to here are the same as described by Jnawali and Wegge (1993) -Winter: November - February, Hot: March - June and Monsoon: July - October.

Reference slides from various above ground parts (leaves, twigs, fruits, flowers etc.) of more than 200 plant species collected from both study sites were prepared prior to examining the fecal samples. The histological features of each plant part were also sketched to match with the fecal plant fragments.

Relative Importance Values (RIV) of each plant species observed in the fecal sample were calculated as follows:

$$RIV_x = D_x \ (\sqrt{f_x})$$

RIV_x = Relative importance value for species x

D_x = Mean percent of species x in fecal sample

f_x = Frequency of species x in fecal sample

Two indices were computed to detect selection of plants eaten:

(i) Diet selection value (DSV)

$$DSV_x = RIV_x / PV_x \ X \ 100$$

DSV_x = Diet selection value for species x

RIV_x = Relative importance value of species x in the diet

PV_x = Prominence value of species x in the habitat

(ii) Ivlev's electivity index (IEI) (Ivlev 1961)

$$IEI_i = \frac{r_i - n_i}{r_i + n_i}$$

IEI_i = Ivlev's electivity index for species *i*

r_i = Percentage of species *i* in the diet

n_i = Percentage of species *i* in the habitat

RESULTS AND DISCUSSION

Habitat

Species richness and diversity

Among the four vegetation types common to both areas, species richness was higher in Sal forest, Riverine forest and Tall Grassland community in Chitwan (Table 1 and Fig. 2). Only in Bushy Pasture was species richness higher in Bardia.

The Tall Grassland community in Chitwan was the most (SDI > 0.986) diverse habitat type. In contrast, this community was the least diverse habitat in Bardia. Here, Riverine forest was the most diverse (SID = 0.925) type. When combining all vegetation types, Chitwan was more diverse than Bardia with indices of 0.968 and 0.918, respectively. The diversity indices of other habitat types available only in Bardia were all < 0.8.

Various factors may have contributed to higher diversity, especially in the Tall Grassland community, in Chitwan. Mild grazing is reported to have a positive effect by maintaining the grass proportion and keeping the herbaceous layer more diverse (Singh 1976). Grazing may also reduce competitive exclusion of less abundant species (Whittaker 1977). In Chitwan, the grasslands are seasonally grazed by domestic stock from the surrounding villages (Sharma 1991). A number of non-floodplain species were also recorded where grazing was more pronounced, particularly in the grasslands around Icharni forest. Besides, rhinoceros' role in seed dispersal may also have increased the diversity in the Tall Grassland in Chitwan. Rhino latrines on Tall Grassland yielded a large number of non-floodplain species, including a most common riverine forest tree, *Trewia nudiflora* (Dinerstein and Wemmer 1988) and *Cassia tora* (Joshi 1986), a common forb species in Bushy Pastures. In Bardia, domestic stock grazing was terminated when the area was made a wildlife reserve in 1976. Only a small population of rhinos and hog deer share the floodplain, and their role in Tall Grassland dynamics is expected to have been minimal. Probably equally or more important: in Chitwan the water table is higher than in Bardia. In Chitwan, in Tall Grassland soil moisture remains 20%-30% throughout the year (Lehmkuhl, 1989). Furthermore, some water logged areas create suitable substrate for other species adopted to such marshy environments. The high moisture content also allow some of the palatable riverine flora to become interspersed in the Tall Grassland. Lastly, inclusion of old tall grass floodplain terraces may also have increased the diversity of Tall Grassland in Chitwan. In Bardia, the floodplain consists of young alluvial sandy soils established on a thick layer of boulders underneath. During the dry season the soil moisture in such sandy soil drops below 5% (Lehmkuhl 1989). As a result, apart from the monsoon season, the floodplain in Bardia remains dry, creating unsuitable substrate for herbaceous plants and seedlings of woody plant species.

Altogether 179 species in Bardia and 283 species in Chitwan were recorded in the present study (Table 1). The highest number (131 species) were recorded in Tall Grassland in Chitwan. In Bardia, highest number of species was observed in Riverine forest with 93 species, compared to 117 species in this type in Chitwan. Among the common habitat types, Bushy Pastures contained the lowest number of species in both areas.

Among the four common vegetation types, Sal forest had highest (IS_s = 67.1%) similarity in species composition (Table 1). Lowest similarity (IS_s < 50%) was observed in Riverine forest, probably because two kinds of Riverine sub-types were combined in Chitwan. When combining all vegetation types, about 70% of the species were similar.

In Bardia, the total number of species was higher than recorded by Dinerstein (1979a). In his study, Dinerstein (1979a) sampled a smaller section of the present study area. The present study was conducted in a much larger area of the floodplain, including areas outside the park boundary to the south. In addition, exclusion of Bushy Pastures and Phanta also reduced the total range of plant species in his study. In Chitwan, the total number of species recorded by Laurie (1978) was higher than in the present study. His list of plant species was derived from samples collected in a much more larger area both inside and around the park, and also included agricultural crops, vegetation growing in cultivated fields and aquatics. Besides, inclusion of species > 3 m also contributed to a higher species number in his study.

Availability of food plants

Availability of plant species recorded to be eaten by rhinoceros in the two study areas is shown in Tables 2 and 3. *Saccharum spontaneum* was the most abundant species in Tall Grassland of both study areas (PV = 630.3 and 243.0 in Bardia and Chitwan, respectively). *Saccharum bengalensis* was more abundant (PV = 87.5) in Bardia's Tall Grass land than in Chitwan (PV = 78.8). *Narenga porphyrocoma* was abundant (PV = 141.1) in Tall Grassland in Chitwan but occurred only in a small proportion (PV = 1.6) in Bardia. *Themeda sp.* was common in Sal forest (PV = 125.7), Riverine forest (PV = 20.3) and Tall Grassland (PV = 62.0) in Chitwan. In Bardia, this species was only sparsely distributed in Wooded Grassland

(PV = 1.5) and Mixed Hardwood forest (PV = 0.6). *Cynodon dactylon* was abundant in Bushy Pastures of both study areas with prominence values of 77.3 and 217.0 in Bardia and Chitwan, respectively.

Of important browse species, *Coffea bengalensis* and *Murraya paniculata* with PV of 27.2 and 22.8, respectively, occurred only in Riverine forest in Chitwan (Table 2). *Callicarpa macrophylla* was abundant in Wooded Grassland in Bardia (PV = 264.1), and in Bushy pasture (PV = 152.4) in Chitwan. *Litsea monopetala* was more abundant (PV = 61.9) in Riverine forests in Chitwan than in any other vegetation types of both study areas. *Mallotus phillippinensis* was most abundant in Riverine and Mixed Hardwood forests in Bardia with PVs of 30.4 and 12.2, respectively, and less common in Chitwan. In contrast, *Trewia nudiflora* was abundant in Riverine forest (PV = 40.7) in Chitwan, but quite scarce in Bardia.

Among the species listed above, rhinoceros eat only the mature fruits of *Trewia nudiflora* fallen on the ground during the monsoon. Similarly, only seed bearing pods of *Cassia tora* and *Cassia occidentalis* and flowers of *Bombax ceiba* were recorded to be eaten. Hence, their PVs do not reflect their availability as food for the animals; instead they indicate the relative abundances of these species in the two study areas.

Highest proportion of wild food plants occurred in Tall Grassland and Riverine forest (Fig. 3). Animals in Chitwan foraged on a larger proportion of these species in both habitats compared to Bardia (Tall Grassland: 91.5% and 71.9% and Riverine forest: 77.2% and 71.9%, respectively). Also in Sal forest did Chitwan animals exploit a larger proportion of food plants than in Bardia (45.6% vs 33.3%, respectively).

Food habits

Annual and seasonal diet

The diet of rhinoceros consisted of a diverse species of food plants, but > 70% of the volume in the diet was contributed by less than ten species in both areas (Table 4). In Bardia, eight species (five grasses: *Saccharum spontaneum*, *Arundo donax*, *Cyanodon dactylon*, *Saccharum bengalensis* and *Erianthus ravennae*, and four browse species: *Mallotus phillippinensis*, *Dalbergia sissoo*, *Callicarpa macrophylla*, *Calamus tenuis*) composed about 75% of the diet. Similarly, in Chitwan seven species (four grasses: *Saccharum spontaneum*, *Saccharum bengalensis*, *Cyanodon dactylon* and *Narenga porphyrocoma*, and three browse species: *Coffea bengalensis*, *Murraya paniculata* and *Litsea monopetala*) contributed > 85% of the toal volume in the annual diet.

Grass species dominated in both study areas. Their proportion was higher in Chitwan (73.4%) than in Bardia (63.3%). Browse species made up about 20%, and agricultural crops > 6% of the diet in both areas. Other food plants, mainly forbs and herbs, ferns, horsetails, sedges, and equisetum constituted up to 8%, with a higher proportion in Bardia than in Chitwan.

The proportion of plant groups varied remarkably between seasons, but the pattern was not identical in the two areas (Fig. 4). Grass species constituted ca 92% of the total diet during the monsoon in Bardia and ca 86% during the hot season in Chitwan. It constituted the lowest proportion during the winter in both areas, ca 42% in Bardia and ca 57% in Chitwan, respectively. Highest proportion of browse species was recorded during winter (31%) and hot (30%) season in Bardia, and during winter (25%) and monsoon (23%) in Chitwan. Agricultural crops were most important during winter (> 13%) and lowest during the monsoon (< 5%) in both areas. 'Others' were eaten mainly during winter and constituted a larger proportion in all three seasons in Bardia.

Compared to the present study Laurie (1978) and Jnawali (1989) reported higher proportion of agricultural crops during the monsoon. This discrepancy was probably due to large interspecific variation and small samples. Also, during this period rhinoceros prefer to remain in the floodplain feeding upon sprouting nutritional grasses rather than struggling with the farm guards. Leafy stage of rice and to lesser extent maize are the main crops available during monsoon. Rice raiding becomes prevalent when it has matured in early winter. Other crops such as wheat, mustard and lentils also become available and are eaten during winter and early part of the hot season (Jnawali 1989).

The proportion of browse was higher in Bardia (Fig. 5). Highest ratio of browse to grass was recorded during the winter season in both areas. In Bardia, the ratio declined from winter through the hot season to the monsoon, whereas in Chitwan the ratio declined from winter to hot and then increased slightly during the monsoon. The ratios differed significantly between areas in all three seasons (winter and monsoon: paired $t = 2.02$ and 1.99, respectively, $0.1 > p > 0.05$, hot: paired $t = 3.27$, $p < 0.025$).

The higher proportion of grasses in Chitwan during the winter and hot seasons was probably related to the nature of the grasslands. In Chitwan, the water table is high and substrate moisture is available for plant growth all year round. The most dominant grass species in the floodplain, *Saccharum spontaneum*, keeps sprouting soon after grass cutting and grazing (Dinerstein and Price 1991), and burning (Laurie 1978) in winter, and a new flush becomes available already early in the hot season. Hence, in Chitwan this species is exploited, although to a lesser extent, also during the dry seasons. In Bardia, the low substrate moisture retards grass species from sprouting until the first rain in the latter part of the hot season. In Bardia, scarcity of nutritious grasses is compensated for by exploiting young leaves of browse species.

Laurie (1978) also recorded highest (22%) proportion of browse species in the diet during the winter. In his study in Chitwan, lowest (2%) proportion of browse was recorded during the monsoon. This contradicts with the present study from Chitwan, but follows the same pattern as observed in Bardia. The increased proportion of browse forage during the monsoon in Chitwan is probably due to *Trewia nudiflora* fruits becoming accessible during this season, as rhinos consume about 5 kg of *Trewia* fruits in a 24 hour cycle during this season (Dinerstein and Wemmer 1988). Due to its scarcity, *Trewia* only contributed < 1% to the diet in Bardia.

Diet selection

Rhinos foraged upon 29.6% of the total number of different wild plant species available in Bardia and about 13.1 % in Chitwan (Fig. 6). The proportion of plant species eaten in each season varied slightly, with animals in Bardia consistently eating a larger proportion of available plants than in Chitwan. In Bardia, the highest proportion (24.0%) of the plant species were exploited during the winter season, whereas in Chitwan the highest proportion occurred during the monsoon (11.0%). The higher proportion of food plants extracted in Bardia was a result of higher diet diversity combined with lower species diversity in the habitats (Table 1 and 4)

Number of different food plants recorded in Bardia was higher in all three seasons (Table 5). Rhinoceros utilized the highest number of species during winter with 47 and 33 species in Bardia and Chitwan, respectively. In both areas, more than 70% of the diet consisted of the same species, but with notable seasonal variation. The highest proportion (66.7%) of similar species was observed during the monsoon and the lowest (49.2%) during the hot season.

Total number of different food plants in the diet of both populations (n = 64) was less than recorded by Laurie (1978) from direct field observations in Chitwan. However, his study area was much larger area, including the entire floodplains of Rapti, Reu and Narayani rivers, and was conducted over a longer time period of about four years. The high number of species in his study was also due to a variety of soft-tissue plants, including aquatics, which were not recorded in the fecal material from either of the two study areas. Similarly, a number of kitchen garden plants known to be eaten by Chitwan animals (Laurie 1978, Jnawali 1989) did not occur in the present diet analysis. Such species are either digested thoroughly or by chance did not occur in our sample. However, Laurie (1978) also recorded other species of monocots and dicots eaten by rhinoceros that did not occur in the present study. Owen-Smith (1988) estimated about 1% of forb species in the annual diet of white rhinos and reported that most of them were ingested accidentally along with the other preferred species. Laurie probably also incorporated some plant species that were ingested accidently. Furthermore, the microfecal analysis does not incorporate all species, as represented by ca 6% of unidentified material (Jnawali, in press).

A more diverse diet in winter may be attributed to scarcity of good quality food. Laurie (1978) concluded that rhinos exploit higher variety of food plants to fulfill their nutritional requirement during the dry season when most of their preferred food plants in the Tall Grassland have reached maturity and are less nutritional. The high similarity of food plants during the monsoon recorded in this study supports this: during this season rhinos mainly exploit high quality grass species common to both areas.

Seasonal variation of species in diet

Saccharum spontaneum was by far the most important food plant during all seasons in both study areas (Table 4). In Bardia this species was most important during the monsoon (RIV = 45.4), whereas in Chitwan highest RIV (43.1) was recorded during the hot season. *S. spontaneum* was least important during winter in both areas. RIV of *Saccharum bengalensis* was higher during the hot (RIV = 13.8) and winter (RIV = 14.9) seasons in Chitwan and during monsoon in Bardia (RIV = 8.7). *Narenga porphyrocoma* contributed little to the Bardia diet but was consistently recorded in Chitwan with highest RIVs (8.4) during the hot and monsoon seasons. *Arundo donax* was recorded consistently in all three seasons in Bardia diet but did not occur in the diet in Chitwan. Similarly, *Erianthus ravennae* was recorded only in Bardia with a highest RIV (ca 5) during the monsoon.

Among important browse species, *Mallotus phillippinensis* had highest RIVs during winter in both study areas, 7.9 and 2.6 in Bardia and Chitwan, respectively (Table 4). *Dalbergia sissoo* and *Calamus tenuis* were eaten only in Bardia with highest RIVs during the hot season. *Trewia nudiflora* was important during the monsoon in Chitwan (RIV = 11.2). In Bardia, this species was recorded sparsely only during the monsoon. *Coffea bengalensis, Murrya paniculata* and *Litsea monopetala* were recorded only in Chitwan with highest RIVs of 6.5, 5.8 and 5.0, respectively, during the winter season. Among common browse species in Chitwan, *Coffea bengalensis* and *Murraya paniculata* were most important. Their RIVs were significantly higher than that of *Callicarpa macrophylla* in all three seasons ($p = < 0.05$, all one tailed paired t-test). *Calamus tenuis*, a climbing palm, was recorded only in the diet in Bardia with relatively high RIVs during the hot and winter seasons.

Arundo donax, Erianthus ravennae, Calamus tenuis, and *Dalbergia sissoo* were reported to be eaten by animals in Chitwan (Laurie 1978), but were not recorded in the diet of Chitwan rhino in the present study. *Coffea bengalensis* and *Murraya paniculata*, two important browse species in Chitwan, were not available in Bardia. *Litsea monopetala*, another important browse species in Chitwan was only sparsely distributed in Bardia and did not occur in the diet. The high consistency of *Arundo donax* in the Bardia diet in all three seasons was probably related to its availability. This species grows on edges of riverlets where substrate moisture is adequate throughout the year, which enables it to sprout even during dry periods. The lower relative proportion of *Saccharum spontaneum* in Chitwan during the monsoon may have been due to availability of *Trewia nudiflora* fruits, but the overall decrease of browse species during the monsoon in both areas was due to availability of high quality grasses.

Oloo et al. (1994) also reported a seasonal variation in preference for various food plants among black rhinoceros *Diceros bicornis*: animals tended to feed less on each plant in the dry season than in the wet season, most likely due to decreased palatibility during the dry season. However, among black rhinoceros the diversity of food plants in the diet was higher (15%) during the wet season (Oloo 1994), contrary to what was found in the present study.

Species Selection

The diet selection values (DSV) varied between different food plants (Fig. 7). In general, highest species selection occurred in Bardia. Among grasses particularly high selection values were found for *Arundo donax* (DSV = 115.9) and *Phragmites karka* (DSV = 70.4) in Bardia. Selection for *Saccharum spontaneum* and *S. bengalensis* was slightly lower in Bardia than in Chitwan. Among browse species, highest DSV was estimated for *Mallotus phillippinensis* (DSV = 88.5), *Calamus tenuis* (DSV = 87.2) and *Dalbergia sissoo* (DSV = 83.8), also all in Bardia. In Chitwan, the highest selection for browse species was calculated for *Murraya paniculata* (DSV = 61.0) and *Coffea bengalensis* (DSV = 58.5). DSV for *Callicarpa macrophylla* was low in both areas (DSV < 6.6).

Ivlev's electivity index (IEI) gave similar results (Fig. 8): highest preference values were calculated for *Arundo donax* (IEI = 0.8) and *Phragmites karka* (IEI = 0.6) in Bardia and *Saccharum spontaneum* (IEI = 0.5) and *Saccharum bengalensis* (IEI = 0.4) in Chitwan. Among browse species, highest preference was estimated for *Dalbergia sissoo* (IEI = 0.7) and *Mallotus phillippinensis* (IEI = 0.6) in Bardia and *Murraya paniculata* (0.57) and *Coffea bengalensis* (IEI = 0.5) in Chitwan. *Callicarpa macrophylla* was avoided by both populations with IEI values of -0.3 and -0.4 in Bardia and Chitwan diet, respectively.

An important grass *Saccharum spontaneum* and one browse *Mallotus phillippinensis* (in Bardia) and *Coffea bengalensis* (in Chitwan) species were selected from each study area to compare seasonal variation in species diet selection (Fig. 9). The DSV of *Saccharum spontaneum* increased from winter to the monsoon in both areas with consistantly higher values in Chitwan. Seasonal variation in DSV of browse species was opposite with a slight increase in Chitwan during the monsoon.

Higher selection for grasses during the hot and monsoon seasons confirms the pattern reported earlier: grasses are most important during these seasons, and grasses are exploited more vigorously in Chitwan. A higher DSV of browse species in Chitwan during the monsoon was probable due to the species (*Coffea bengalensis*) used in the analysis.

Saccharum spontaneum is the most important single food plant for rhinos in both areas. Higher selection for browse species during the dry season in Bardia indicates that grass quality is poorer there than in Chitwan. The fact that Bardia animals eat proportionally less of *Saccharum spontaneum* and do not select it to the same extent as in Chitwan support this. In Bardia, animals switch to browse species, mainly *Mallotus phillippinensis, Dalbergia* *sissoo*, *Callicarpa macrophylla* and *Calamus tenuis*, which appear to be adequate substitutes for poor quality *Saccharum spontaneum*. However, for the increasing Bardia population *Mallotus phillippinensis* may become limiting for rhinos due to competetion with other ungulates. *Mallotus* is highly preferred by nilgai *Bosclaphus tragocamelus* (Khatri 1993) and a very dense population of axis deer *Axis axis* (Dinerstein 1979b, Moe and Wegge 1995). This may ultimately force rhinos to become more dependant on agricultural crops, thus accelerating conflicts with the villagers. In Bardia, a switch from grass to browse during dry seasons is not probably due to higher quality of browse species. If this was the case, Chitwan animals would have been expected to eat proportionally more of those browse species (eg. *Mallotus phillippinensis* and *Callicarpa macrophylla)* common in both areas.

The general pattern of food plant selection was related to species abundance in the natural habitats. Mean RIVs and PVs (adjusted according to relative size of habitats) were positively correlated in both areas ($r^2 = 0.861$, $p < .001$, and $r^2 = 0.732$, $p < .001$, in Bardia and Chitwan, respectively). Because the significant correlations may be the result of exceptionally high RIV and PV of *Saccharum spontaneum*, this species was removed from the analysis. Excluding *S. spontaneum* did not change the significance of the correlations in either area.

To detect if species selection occurred in any of the three seasons, seasonal correlations were correlated on the basis of combined data sets from Bardia and Chitwan, with and without *Saccharum spontaneum*. All correlations were significant ($p < 0.05$) with lowest value for the winter season without *S. spontaneum* ($r^2 = 0.313$, $p < 0.5$, $df = 60$) (Fig. 10). The results confirm that, in general, rhinos are generalist feeders. Like reported by Mukinya (1977) and Gyseghem (1984) for black *Diceros bicornis* and northern white *Ceratotherium simum cottoni* rhinoceros, respectively, the greater one-horned rhinoceros also exploited proportionally more those food plants which were most abundant in their natural habitats.

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Table 1. Floristic composition, diversity and similarity in different habitat types of the two study areas.

Vegetation type	Study areas	Total number of species	Simpson's index of diversity	Total number of common species	Sorensen's Index (%)
Sal forest	Bardia	73	0.781		
	Chitwan	97	0.883	57	67.1
Riverine forest	Bardia	93	0.925		
	Chitwan	117	0.941	52	49.5
Tall Grassland	Bardia	79	0.671		
	Chitwan	131	0.986	58	55.2
Bushy Pastures	Bardia	63	0.863		
	Chitwan	55	0.823	34	57.6
Khair-Sissoo	Bardia	76	-	-	
Wooded Grassland	Bardia	49	-	-	
Phanta	Bardia	35	-	-	
Mixed Hardwood forest	Bardia	53	-	-	
All	Bardia	179	0.918		
	Chitwan	283	0.968	159	68.8

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Sorensen's index (%)
67.1
49.5
55.2
57.6
68.8

Table 2. Prominence values of plant species recorded to be eaten by rhinos in Royal Bardia (RB) and Royal Chitwan (RC) National Parks

Species	SF		RF		TG		BP		All habitats	
	RB	RC	RB	RC	RB	RC	RB	RC	RB	RC
Grasses										
Cyanodon dactylon	0.4	0.5	15.1	35.4	3.1	71.9	77.3	217.0	95.9	324.8
Saccharum spontaneum	0.0	0.1	6.3	21.2	630.3	243.0	1.7	6.3	638.3	270.6
Apluda mutica	0.0	0.0	0.0	0.0	10.0	4.0	32.3	3.0	42.3	7.0
Arundo donax	0.0	0.0	0.0	0.7	23.2	2.2	0.0	0.0	23.2	2.9
Desmostachia bipinnata	168.0	7.2	23.7	3.3	0.2	0.0	47.1	0.0	239.0	10.5
Imperata cylindrica	122.0	28.9	48.1	28.6	37.5	71.9	3.0	128.5	210.6	257.9
Cymbopogon sp.	0.0	0.0	0.2	0.0	8.1	2.7	0.0	0.0	8.3	2.7
Saccharum bengalensis	0.0	0.2	0.1	21.9	87.5	78.8	0.6	0.01	88.2	100.9
Narenga porphyrocoma	15.1	43.6	0.1	22.9	1.6	141.1	0.0	0.01	16.8	207.6
Themeda sp.	0.0	125.7	0.0	20.3	0.0	62.0	0.0	0.0	0.0	208.0
Chrysopogon aciculatus	0.0	0.0	0.2	0.0	0.0	13.6	29.8	204.2	30.0	217.8
Erianthus ravennae	0.8	7.2	0.1	0.0	19.0	11.9	1.2	0.0	21.1	19.1
Vetiveria zizanoides	14.7	0.6	15.1	11.3	6.5	0.1	1.3	0.0	37.6	12.0
Setaria pallide-fusca	0.0	0.0	0.0	0.0	1.2	6.6	0.0	0.0	1.2	6.6
Oplismanus compositus	0.0	0.3	0.2	0.6	0.0	1.0	0.0	0.0	0.2	1.9
Panicum sp	0.0	5.4	0.0	5.2	30.0	40.2	0.0	0.0	30.0	50.8
Brachiaria sp.	0.1	0.0	0.0	0.0	30.6	13.0	0.0	0.0	30.7	13.0
Phragmites karka	0.0	0.5	1.1	2.7	9.7	6.5	0.0	0.0	10.8	9.7
Typha elephantina	0.0	0.0	0.0	0.0	0.3	3.9	0.0	0.1	0.3	4.0
Saccharum arundinaceum	0.0	0.0	0.0	1.1	2.6	15.7	0.0	0.0	2.6	16.8
Browse										
Mallotus phullippinensis	4.2	0.5	30.4	9.4	0.1	1.3	0.1	0.0	34.8	11.2
Ehretia laevis	0.0	0.5	14.5	33.9	0.2	4.4	0.1	4.4	14.8	43.2
Bridelia stipularia	0.0	3.4	2.3	2.4	0.0	0.0	0.0	0.0	2.3	5.8
Ficus glomarata	0.0	0.0	0.5	2.7	0.0	0.1	0.1	0.3	0.6	3.1
Bombax ceiba	0.0	1.4	1.1	3.0	0.1	11.2	1.4	17.2	2.6	32.8
Syzigium cumini	2.8	1.5	11.5	5.2	0.6	0.01	0.0	0.0	14.9	6.7
Bauhinia sp.	0.0	0.1	0.1	7.3	0.0	1.0	0.1	0.0	0.2	8.4
Dalbergia sissoo	0.0	0.0	0.3	0.8	9.5	0.5	0.1	0.0	9.9	1.3
Trewia nudiflora	0.0	0.0	1.5	40.7	0.1	7.4	0.7	2.5	2.3	50.6
Grewia sp	2.6	14.9	0.1	3.8	0.0	4.0	0.0	0.0	2.7	22.7
Callicarpa macrophylla	2.4	0.0	85.5	63.4	13.0	34.2	3.6	152.4	104.5	250.0
Colebrookia oppositifolia	0.1	0.0	27.4	150.2	0.2	4.0	9.4	131.5	37.1	285.7
Zizyphus mauritiana	0.0	0.0	4.3	2.2	0.1	0.6	169.4	13.0	173.8	15.8
Coffea bengalensis	0.0	0.0	0.0	27.2	0.0	0.0	0.0	0.0	0.0	27.2
Murraya paniculata	0.0	0.0	0.0	22.8	0.0	0.0	0.0	0.0	0.0	22.8
Litsea monopetala	2.1	12.8	0.3	61.9	0.0	1.9	0.0	16.2	2.4	92.8
Calamus tenuis	0.1	0.0	26.2	0.0	0.0	0.0	0.0	0.0	26.3	0.0
Acacia concinna	0.0	0.5	10.3	66.7	0.6	0.9	4.2	0.0	15.1	68.1
Others										
Pogostemon bengalensis	0.0	1.3	14.3	50.8	7.0	16.0	6.1	47.7	27.4	115.8
Cirsium wallichii	0.0	0.0	0.2	9.0	3.7	8.9	0.0	0.0	3.9	17.9
Solanum sp.	0.0	0.0	0.0	0.6	0.5	2.1	0.7	10.2	1.2	12.9
Cassia tora	0.0	0.0	1.1	14.8	0.1	9.4	28.0	262.8	29.2	287.0
Cassia occidentalis	0.0	0.0	0.0	0.0	0.0	0.4	0.4	5.7	0.4	6.1
Pteris sp	1.1	0.1	15.9	1.3	2.3	1.7	1.1	3.7	20.4	6.8
Urena lobata	1.7	0.0	1.3	6.6	0.2	3.8	0.0	0.0	3.2	10.4
Cyperus sp.	0.1	0.3	2.2	0.9	2.0	0.4	5.7	16.3	10.0	17.9
Artemisia vulgaris	1.0	0.0	0.9	3.8	0.6	23.6	0.1	62.8	2.6	90.2
Triumfetta sp.	0.0	0.0	1.7	2.7	0.0	1.2	0.6	0.4	2.3	4.3
Sida acuta	0.0	0.0	0.2	0.1	0.0	0.4	0.0	9.8	0.2	10.3
Sida rhombifolia	0.1	0.0	0.0	0.0	0.6	0.8	1.6	17.7	2.3	18.5
Piper nepalens	0.0	0.1	0.1	7.3	1.2	0.4	0.0	0.0	1.3	7.8
Amaranthus spinosus	0.0	0.0	0.0	0.0	0.7	0.2	0.0	0.0	0.7	0.2
Equisetum sp	0.0	0.0	0.3	0.0	1.4	11.3	0.3	0.0	2.0	11.3
Ageratum conyzoides	0.0	0.1	0.1	12.7	0.1	8.2	0.4	43.3	0.6	64.2
Lippia nodiflora	0.0	0.0	0.0	0.0	0.8	3.5	0.1	3.7	0.8	7.2
[illegible] compesit	0.0	0.0	0.2	0.7	0.0	1.4	0.0	0.0	0.2	2.1
Acanthacea sp	0.0	0.0	0.0	0.9	0.0	3.2	0.0	0.0	0.0	4.1

SF = Sal forest, RF = Riverine forest, TG = Tall Grassland, BP = Bushy Pasture

Table 3 Prominence values of plant species recorded to be eaten by rhinos in four vegetation types available only in Bardia.

Species	KS	WG	PH	MHF	All 4 types
Grasses					
Cyanodon dactylon	42.9	13.3	12.4	0.0	68.6
Saccharum spontaneum	42.9	125.0	241.1	137.2	546.2
Desmostachia bipinnata	42.4	72.6	6.4	45.7	167.1
Imperata cylindrica	62.7	316.5	388.9	124.1	892.2
Cymbopogon sp.	10.4	28.0	8.6	0.0	47.0
Saccharum bengalensis	0.9	0.0	0.0	0.0	0.9
Narenga porphyrocoma	0.0	5.0	37.3	8.2	95.5
Themeda sp.	0.0	1.5	0.0	0.6	2.1
Chrysopogon aciculatus	0.8	0.0	0.0	0.0	0.8
Erianthus ravennae	11.0	1.5	0.0	30.6	43.1
Vetiveria zizanoides	5.6	36.7	17.6	45.9	105.8
Prhagmites karka	2.1	0.0	3.1	0.0	5.2
Oplismenus compositus	0.0	0.1	0.0	0.0	0.1
Brachiaria sp.	1.9	6.0	0.0	1.2	9.1
Browse					
Mallotus phillippinensis	0.2	6.3	0.0	12.2	18.7
Ehretia laevis	6.7	20.0	0.0	16.4	43.1
Bombax ceiba	0.3	0.3	0.3	0.9	1.8
Syzigium cumini	1.4	10.1	2.7	13.4	27.6
Bauhinia sp.	0.0	1.6	0.0	0.0	1.6
Dalbergia sissoo	5.2	0.4	2.8	0.0	8.4
Trewia nudiflora	1.5	0.0	0.0	0.0	1.5
Grewia sp.	0.0	0.3	0.0	0.0	0.3
Callicarpa macropylla	96.7	264.1	2.7	4.6	368.1
Colebrookia oppositifolia	45.9	25.9	0.0	95.4	167.2
Ziziphus mauritiana	37.3	0.0	0.0	0.0	37.3
Calamus tenuis	0.1	0.0	0.0	0.0	0.1
Acacia concinna	5.8	0.0	0.0	0.0	5.8
Others					
Pogostemon bengalensis	127.3	0.4	0.4	30.5	158.6
Cirsium wallichii	0.1	0.0	0.2	0.0	0.3
Solanum sp.	0.1	0.0	0.0	0.0	0.1
Cassia tora	25.0	2.1	0.1	0.0	27.2
Cassia occidentalis	1.9	0.0	0.0	0.0	1.9
Pteris sp.	3.6	0.3	0.0	6.4	10.3
Urena lobata	0.1	0.0	0.0	0.0	0.1
Cyperus sp.	3.3	0.9	9.8	1.9	15.9
Artemisia vulgaris	1.0	0.0	0.7	0.0	1.7
Truimfetta spp.	0.2	0.3	0.0	0.0	0.5
Sidda acuta	0.1	0.0	0.0	0.0	0.1
Sidda rhombifolia	0.1	0.0	0.0	0.0	0.1
Piper nepalens	0.0	0.0	0.1	0.0	0.1
Equisetum sp.	0.0	0.0	0.0	1.3	1.3

KS = Khair-Sisso forest WG = Wooded Grassland, PH = Phanta, MHF = Mixed Hardwood forest available only in

All 4 types
68.6
546.2
167.1
892.2
47.0
0.9
95.5
2.1
0.8
43.1
105.8
5.2
0.1
9.1
18.7
43.1
1.8
27.6
1.6
8.4
1.5
0.3
368.1
167.2
37.3
0.1
5.8
158.6
0.3
0.1
27.2
1.9
10.3
0.1
15.9
1.7
0.5
0.1
0.1
0.1
1.3

Table 4. Relative importance values of main wild food plants in the diet of rhinoceros in Royal Bardia (RB) and Royal Chitwan (RC) National Parks.

Species	Relative Importance Value							
	Winter		Hot		Monsoon		All year	
	RB	RC	RB	RC	RB	RC	RB	RC
Grasses								
Saccharum spontaneum	18.9	25.7	21.2	43.1	45.4	41.9	28.5	36.9
Saccharum bengalensis	0.8	14.9	3.2	13.8	8.7	8.2	4.2	12.3
Narenga porphyrocoma	-	1.6	0.7	8.4	2.3	8.4	1.0	6.1
Erianthus ravennae	2.1	-	3.8	-	4.7	-	3.5	-
Cyanodon dactylon	4.4	4.3	4.7	7.6	3.1	8.2	4.1	6.7
Imperata cylindrica	-	0.4	4.4	2.3	1.2	2.6	1.9	1.8
Themeda sp.	-	3.1	-	2.2	-	2.8	-	2.7
Cymbopogon sp.	0.7	2.3	2.0	3.2	3.8	0.5	2.2	2.0
Phragmites karka	1.9	0.7	1.5	1.2	2.2	0.8	1.9	0.9
Arundo donax	5.6	-	5.4	-	4.5	-	5.2	-
Browse								
Callicarpa macrophylla	3.9	3.7	4.5	1.0	3.2	2.0	3.9	2.2
Litsea monopetala	-	5.0	-	0.4	-	0.6	-	2.0
Coffea bengalensis	-	6.5	-	2.8	-	3.0	-	4.1
Murraya paniculata	-	5.8	-	2.1	-	4.0	-	3.9
Mallotus phillippinensis	7.9	2.6	5.9	0.3	0.6	0.4	4.8	1.1
Dalbergia sissoo	-	-	7.9	-	0.7	-	2.9	-
Trewia nudiflora	-	0.2	-	-	0.1	11.2	0.03	3.8
Calamus tenuis	4.4	-	5.0	-	0.9	-	3.4	-
Bombax ceiba	1.2	0.2	0.6	0.1	-	-	0.6	0.1
Colebrookia oppositifolia	1.6	0.1	0.8	-	0.1	0.2	0.8	0.1
Ehretia laevis	1.1	-	0.3	-	0.1	0.2	0.5	0.1
Ficus glomarata	1.7	-	0.1	-	0.3	-	0.7	-
Ziziphus mauritiana	1.0	-	0.1	-	-	-	0.4	-
Acacia concinna	1.3	0.1	0.4	-	0.2	-	0.6	0.03
Others								
Truimfetta sp.	0.4	0.4	0.1	-	0.1	0.2	0.2	0.2
Urena lobata	0.9	0.1	1.8	0.1	0.6	0.1	1.1	0.1
Circium wallichii	4.2	0.1	3.1	1.5	1.3	-	2.9	0.5

Table 5. Seasonal similarity of food plants[1] recorded in the diet of two rhinoceros populations.

Seasons	Study area	Number of species	Number of common species	Sorensen's Index (%)
Winter	Bardia	47		
	Chitwan	33	23	57.5
Hot	Bardia	43		
	Chitwan	22	16	49.2
Monsoon	Bardia	43		
	Chitwan	32	25	66.7
All season	Bardia	57		
	Chitwan	44	36	71.3

[1] agricultural crops included.

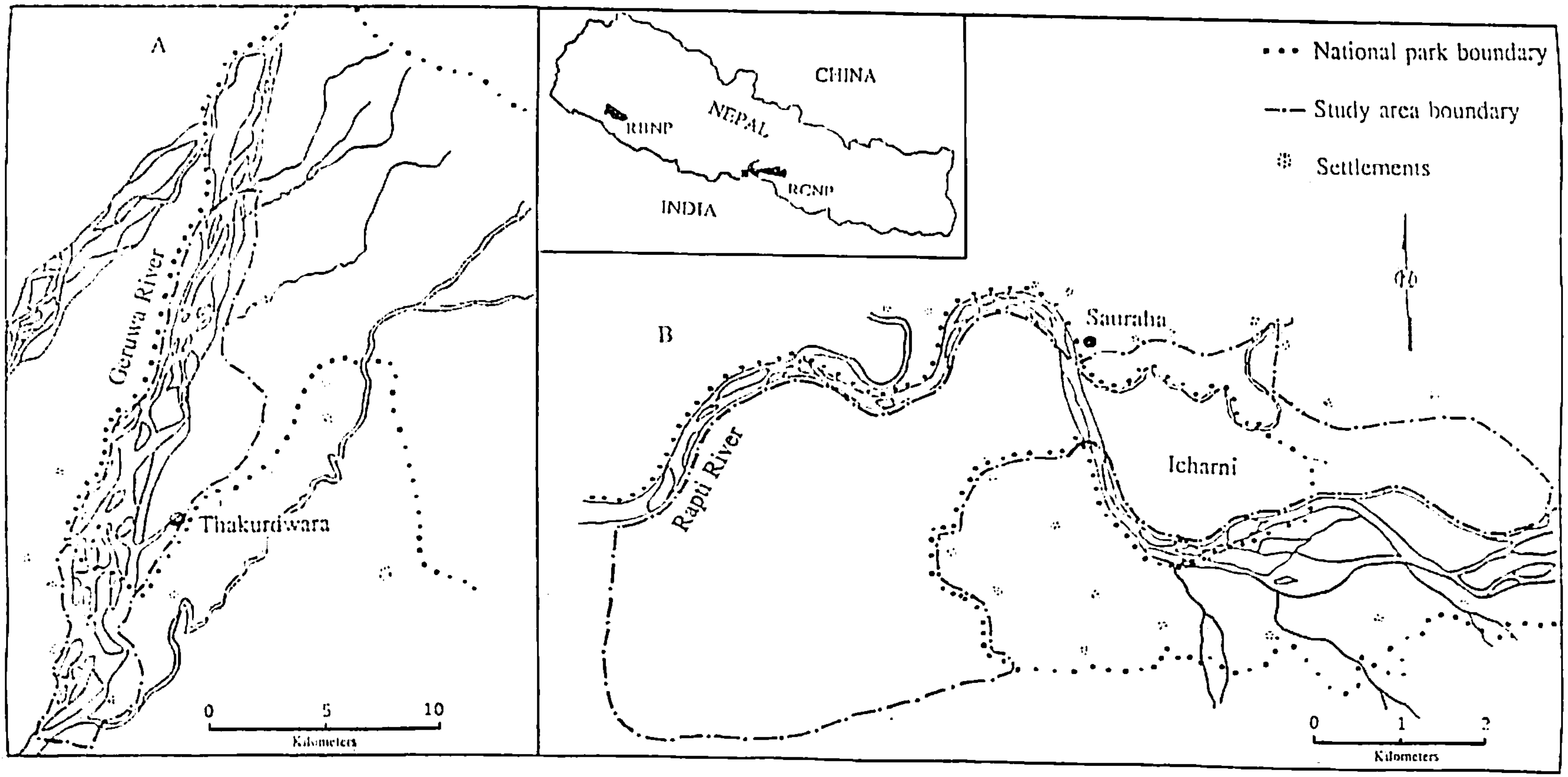

Figure 1. Map of study areas in (a) Royal Bardia and (b) Royal Chitwan national parks.

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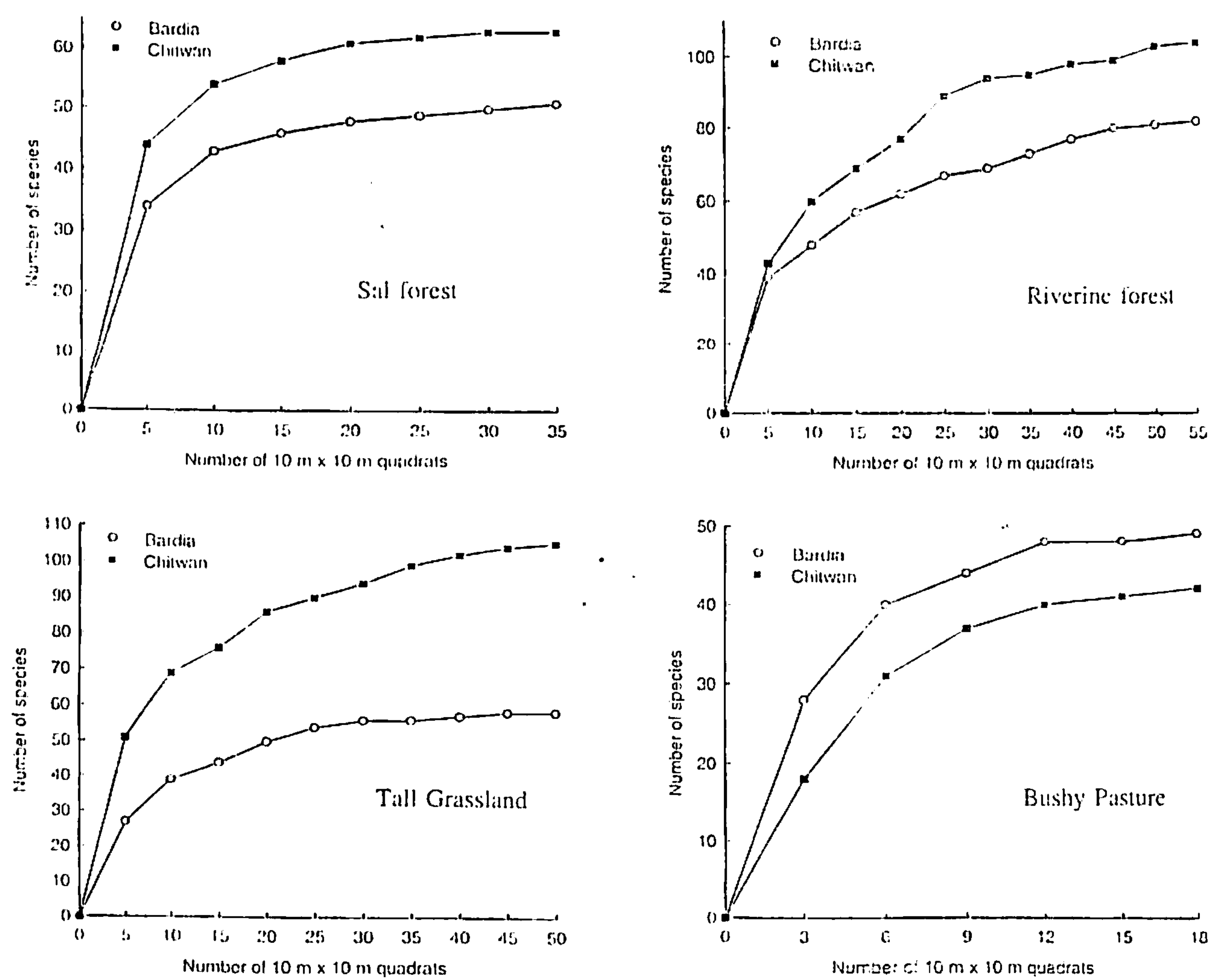
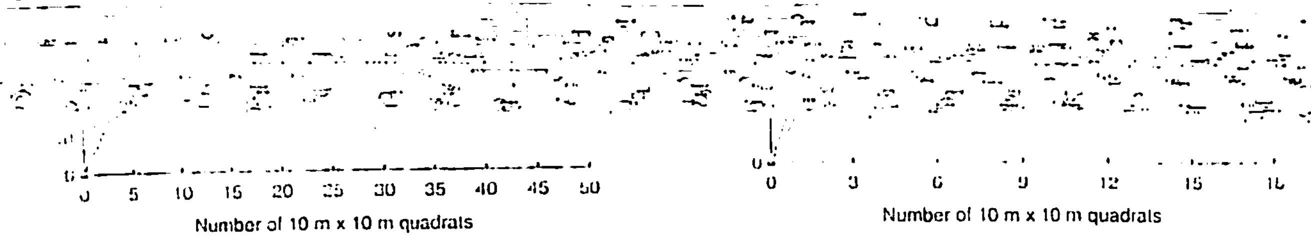


Figure 2. Species area curves for different vegetation types in the two study areas.



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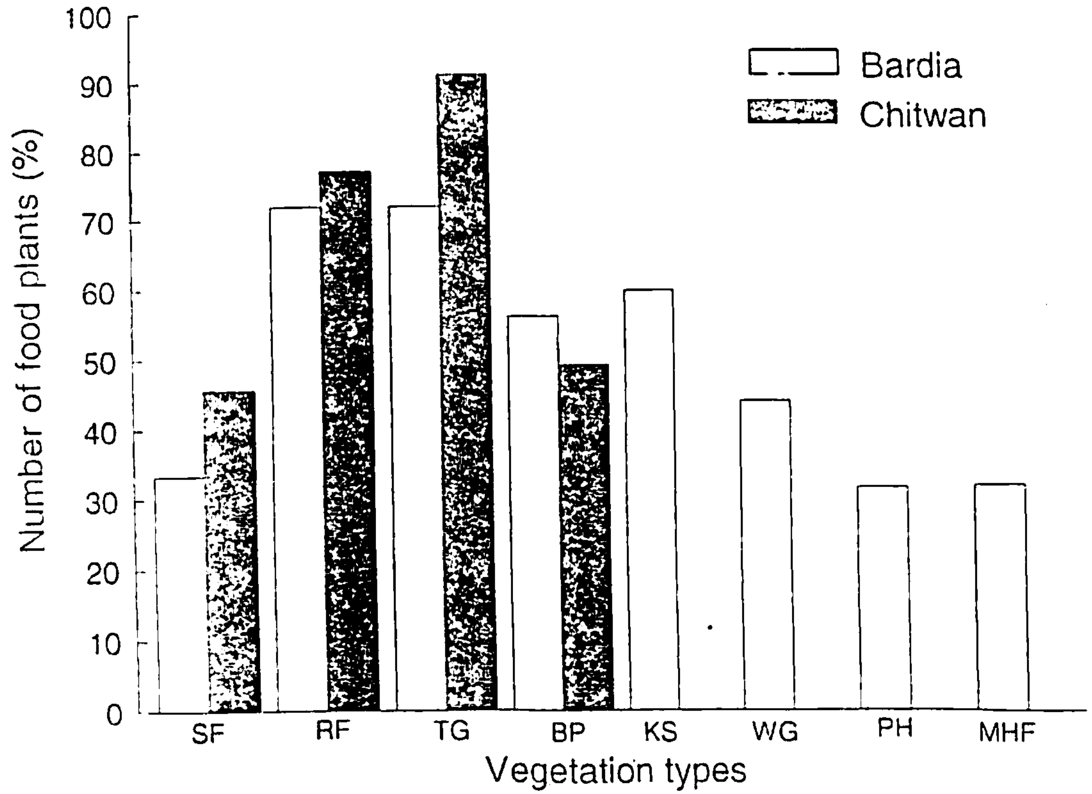

Figure 3. Distribution of food plant species in different habitat types in the study areas.

SL = Sal forest, RF = Riverine forest, TG = Tall Grassland, BP = Bushy Pastures, KS = Khair-Sissoo forest, WG = Wooded Grassland, PH = Phanta, MHF = Mixed Hardwood forest.

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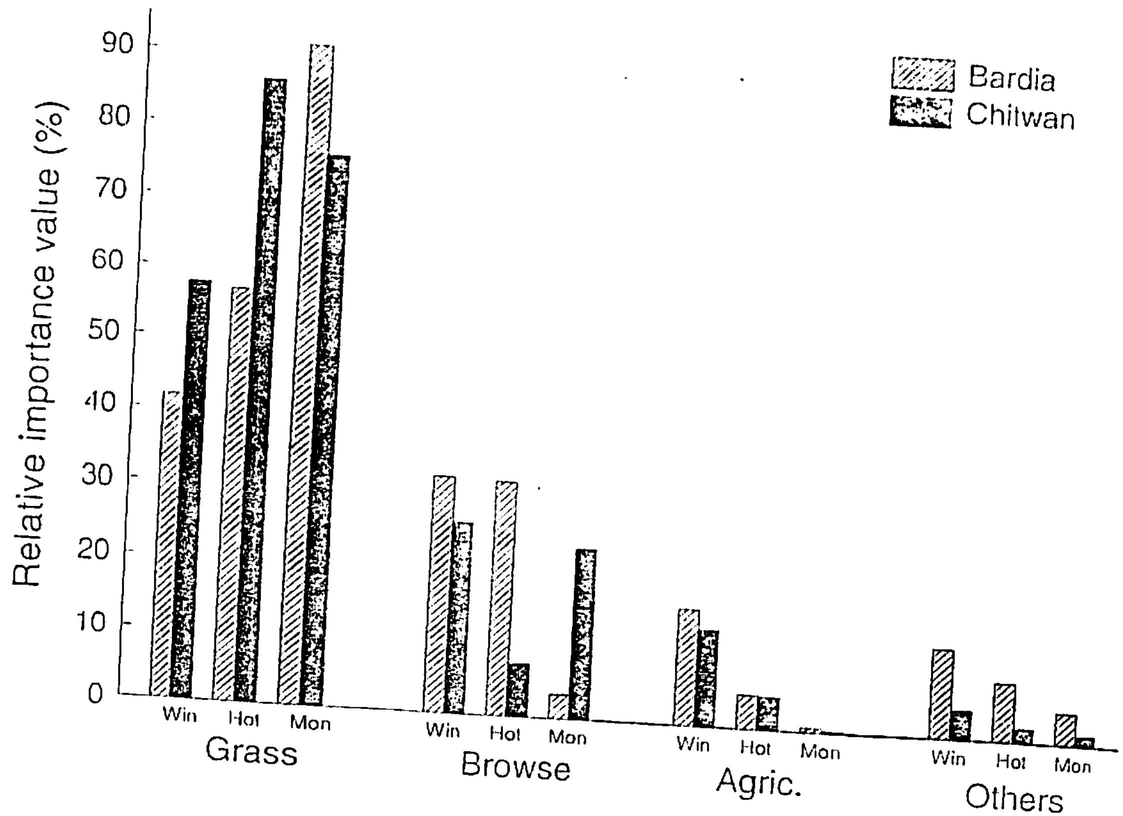
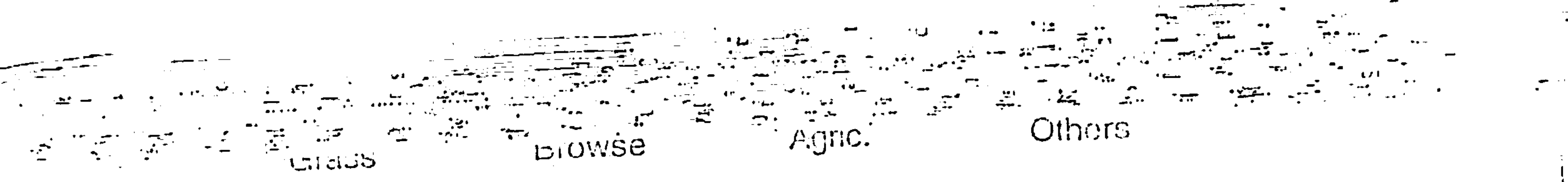


Figure 4. Composition of seasonal diets in the two areas. Win = Winter, Mon = Monsoon, Agric.= Agricultural corps



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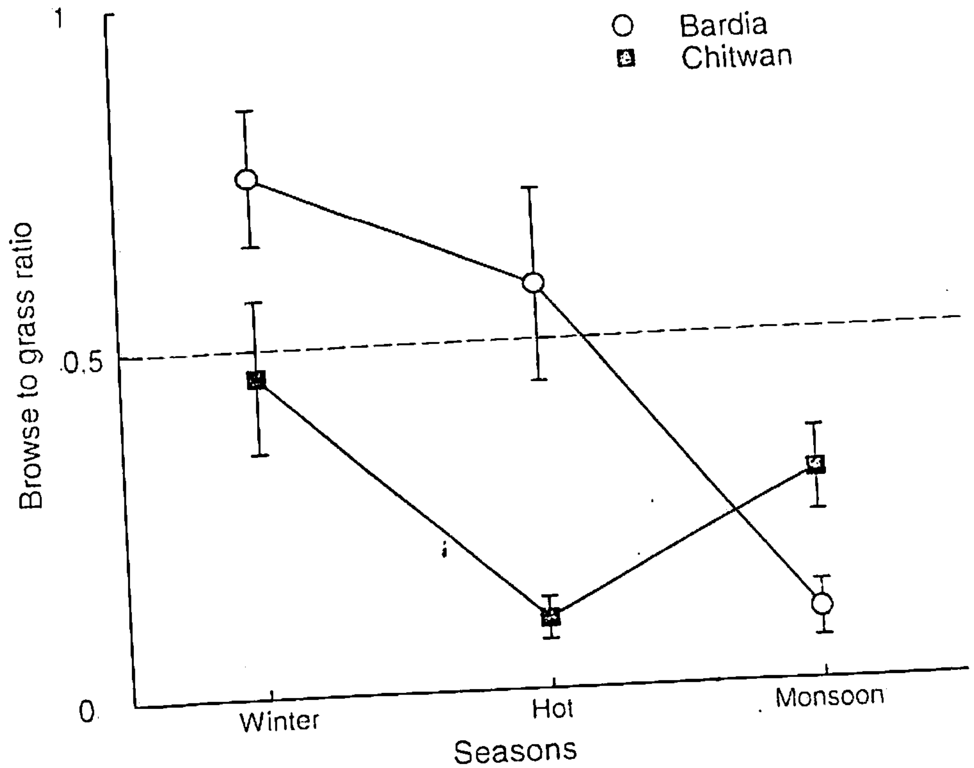

Figure 5. Seasonal variation (mean±s.d.) in browse to grass ratios in the diet of the two rhinoceros populations.

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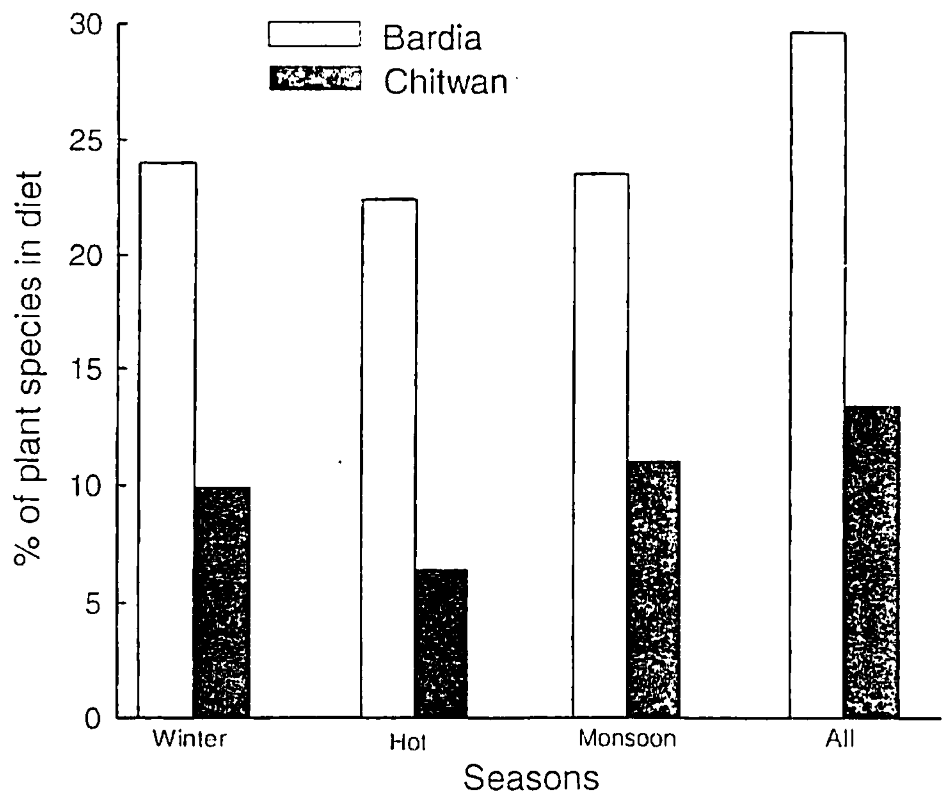

Figure 6. Proportion of plant species in the diet of rhinoceros in the two study areas.

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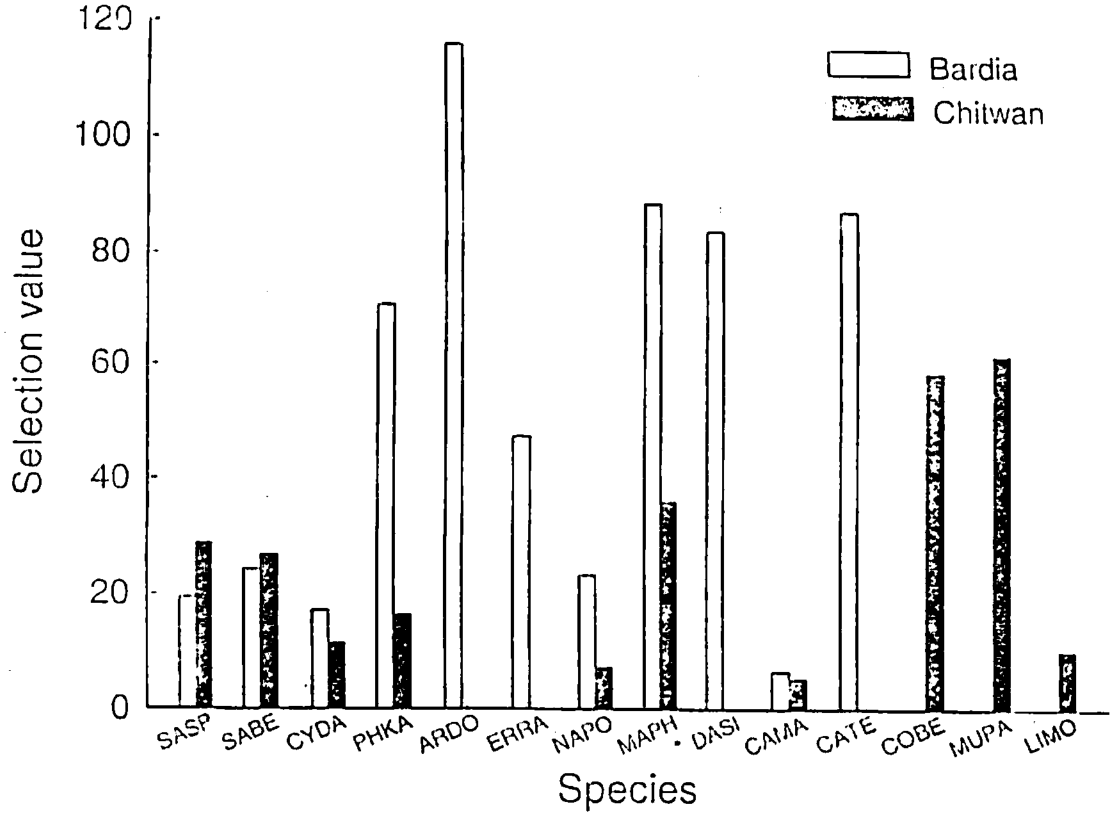

Figure 7. Selection values of important food plants in the two study areas.

SASP = *Saccharum spontaneum*, SABE = *Saccharum bengalensis*, CYDA = *Cyanodon dactylon*, PHKA = *Phragmites karka*, ARDO = *Arundo donax*, ERRA = *Erianthus ravennae*, NAPO = *Narenga porphyrocoma*, MAPH = *Mallotus phillippinensis*, DASI = *Dalbergia sissoo*, CAMA = *Callicarpa macrophylla*, CATE = *Calamus tenuis*,

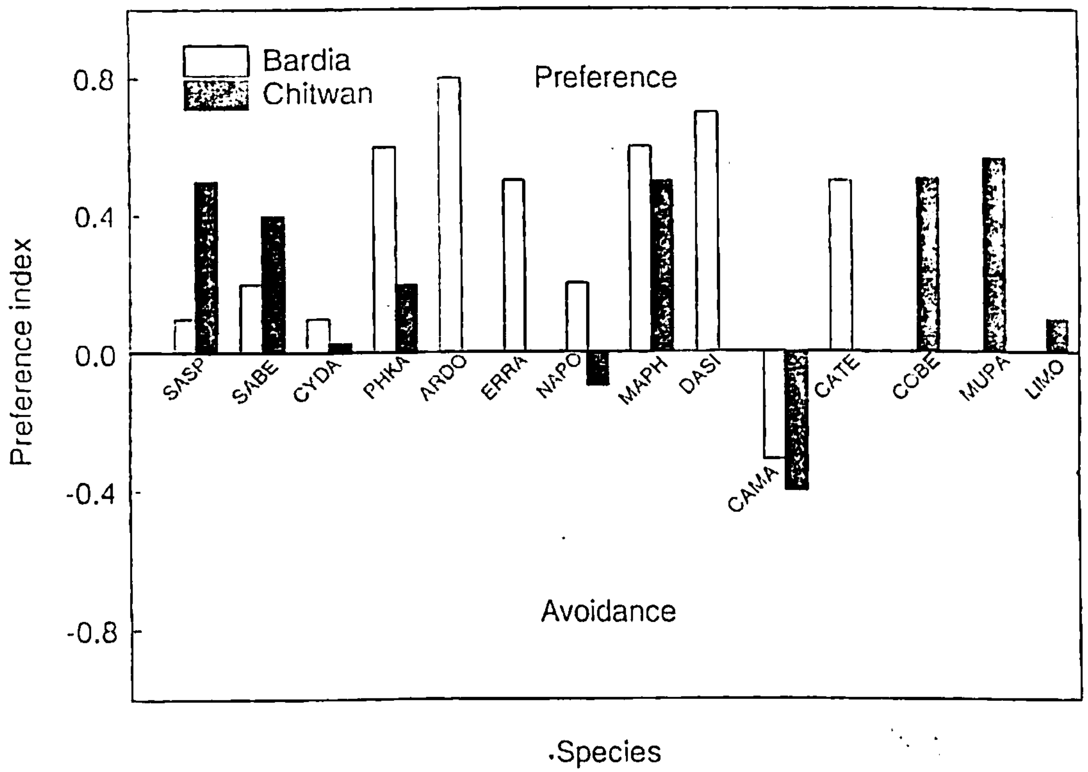

Figure 8. Electivity indices of important food plants in the two study areas.

SASP = *Saccharum spontaneum*, SABE = *Saccharum bengalensis*, CYDA = *Cyanodon dactylon*, PHKA = *Phragmites karka*, ARDO = *Arundo donax*, ERRA = *Erianthus ravennae*, NAPO = *Narenga porphyrocoma*, MAPH = *Mallotus phillippinensis*, DASI = *Dalbergia sissoo*, CAMA = *Callicarpa macrophylla*, CATE = *Calamus tenuis*, COBE = *Coffea bengalensis*, MUPA = *Murraya paniculata*, LIMO = *Litsea monopetala*.

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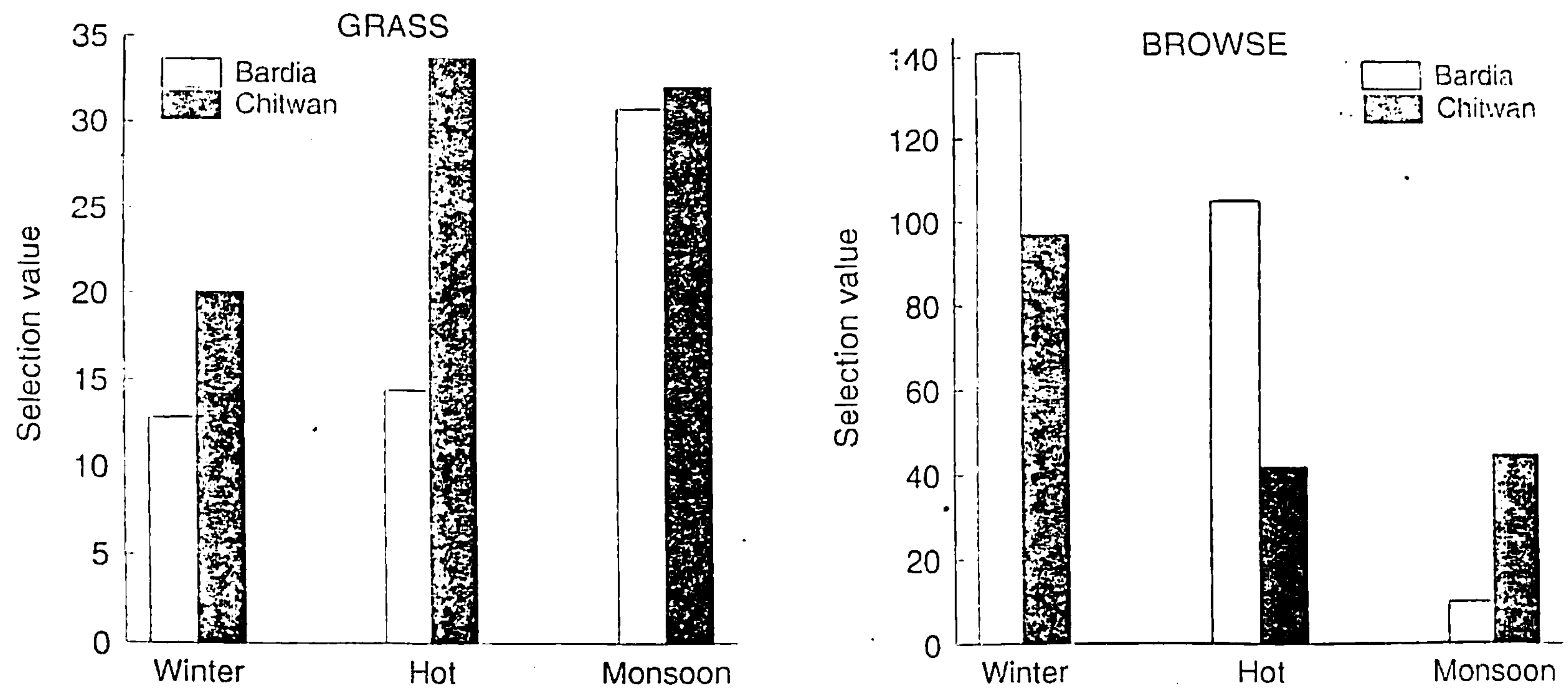

Figure 9. Seasonal variation in selection values of important grass (*Saccharum spontaneum*) and browse species (*Mallotus phillippinensis* in Bardia and *Coffea bengalensis* in Chitwan) in the two study areas.

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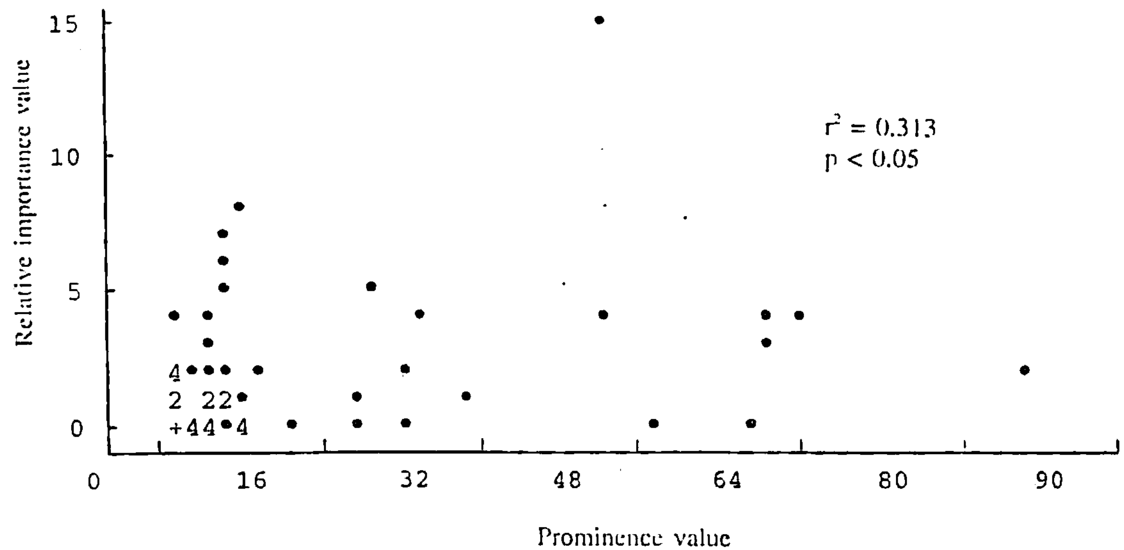

Figure 10. Relationship between relative importance value and prominence value of all food plants known to be eaten by rhinoceros during winter, *Saccharum spontaneum* excluded.