EFFECT OF *Mikania micrantha* ON THE DEMOGRAPHY, HABITAT USE, AND NUTRITION OF GREATER ONE-HORNED RHINOCEROS IN CHITWAN NATIONAL PARK, NEPAL

THESIS
SUBMITTED TO THE
FOREST RESEARCH INSTITUTE UNIVERSITY
DEHRADUN, UTTARAKHAND
For
THE AWARD OF THE DEGREE OF
DOCTOR OF PHILOSOPHY IN FORESTRY
(WILDLIFE SCIENCES)

By
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WILDLIFE INSTITUTE OF INDIA
DEHRA DUN, UTTARAKHAND
2012

DECLARATION

I hereby declare that the dissertation **"Effect of *Mikania micrantha* on the demography, habitat use, and nutrition of greater one-horned rhinoceros in Chitwan National Park, Nepal"** is original research conducted by me under the supervision of Dr. Yadvendradev V. Jhala of the Wildlife Institute of India. The thesis has been submitted to the Forest Research Institute University for the award of the degree of Doctor of Philosophy in Forestry (Wildlife Science), and has not formed the basis for the award of any other degree. It embodies my own work and observations, and in that respect the investigation appears to advance knowledge on the subject.

Date: 21.12.2012

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Place: Dehra Dun

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Yadvendradev V. Jhala, PhD
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CERTIFICATE

Date: 21.12.2012

This is to certify that the thesis entitled **"Effect of *Mikania micrantha* on the demography, habitat use, and nutrition of greater one-horned rhinoceros in Chitwan National Park, Nepal"** submitted for the award of the doctor of Philosophy in Forestry (Wildlife Science), to the Forest Research Institute University, Dehra Dun, embodies original research work carried out by Mr. Naresh Subedi under our guidance and supervision. No part of this thesis has been submitted for any other degree and it fulfills all the requirements laid down in the ordinance of Forest research Institute University, Dehra Dun for this purpose.

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Executive Summary

1. Megaherbivores are regarded as the engineer and driver of ecosystem processes. They also serve the role of umbrella and flagship species for ecosystem conservation. Megaherbivores have also been a source of fascination for humans and our relationships with them vary from inspiration to fear and loathing. The world has witnessed a sharp decline of many megaherbivores populations and their ranges contraction in the last 100 years. Certain *k*-selected traits inherent to megaherbivores *i.e.* large body size, long gestation and interbirth interval, single calf, and large home ranges in combination with habitat loss and environmental stochastic events make them more vulnerable to extinction events. Due to these reasons megaherbivores, especially the rhinos, have received global attention since the recent past and many populations have been recovered in spite of ever looming threat of poaching for their horns. At present, we have only five species of rhinos in the world; of which three species are confined to Asia and two species in the African continent. The greater one-horned rhinoceros (*Rhinoceros unicornis*) was abundant until 15th century along the floodplain habitats of Ganges, Brahmaputra and Sindh rivers and their tributaries between Myanmar in the east and Pakistan in the west. But due to rampant hunting and habitat fragmentations they are now confined in small isolated protected areas in India and Nepal totaling not more than 2,850 individuals. Nepal has done a commendable endeavor to recover rhinos from the brink of extinction, since there were less than 100 rhinos left as a single population in Chitwan during 1960s. At present, there are 534 rhinos in Nepal in three small subpopulations. However, these rhinos are still threatened by poaching and habitat degradation caused by invasive *Mikania micrantha* (henceforth *Mikania*). The current study investigates how the invasive *Mikania* has affected the nutrition, time activity budget, demography, and habitat use of rhinos in Chitwan National Park of Nepal with the aim of providing timely scientific inputs for conservation management. The study also estimates population abundance, mortality factors, and synthesizes this information by parameterizing a population habitat viability analysis (PHVA) in VORTEX using field data for advising conservation policy and management. This is the first GPS radio-collar based comprehensive study on greater one-horned rhinoceros.

2. This study was carried out in Chitwan National Park (CNP) that covers an area of 932 km^2 of south central Nepal. CNP is one of the World Heritage Sites and is one of the global priority landscapes for tiger conservation. About 70% of the park is dominated by Sal forest and the remaining are tall grasslands and riverine forests. The park is drained by Narayani,

Rapti and Reu rivers. Chitwan has sub-tropical climate with three seasons: monsoon (June – September), cool dry (October – Jnauary) and hot dry (February – May). Temperature ranges from 8^{0}C to 42^{0}C in different seasons. Chitwan gets about 2,400 mm rainfall annually 80% of which occurs during monsoon. Annual fire and grass cutting by local community once in a year are common phenomenon in Chitwan. It is one of the most visited park of Nepal and gets over 100 thousand visitors each year. Fifty percent of the park's income is channeled back to the buffer zone communities for conservation and development so as to bring communities in the mainstream of conservation.

3. With a high price for rhino horn in the illegal market, conserving free-ranging rhino populations has been a global challenge. In 2011, we assessed the abundance and distribution of rhinos in Nepal covering all potential habitats using block count method. A systematic survey effort of 5,497 km was invested using 3,548 elephant hours in 23 days. The accuracy of the block count was assessed by comparing it's population estimate with those obtained by (a) long-term monitoring using photographic identification of individual rhinos, and (b) closed population sighting-mark-resighting (SMR). A total of 534 rhinos were found during the census consisting of 503 in Chitwan National Park, 24 in Bardia National Park and 7 in Suklaphanta Wildlife Reserve. Rhino density was 1/km^2 in Chitwan, 0.28/km^2 in Bardia and 0.1/km^2 in Suklaphanta within rhino habitats. Chitwan had 66% adults, 12% subadults and 22% calves with female to male ratio 1.24. Population estimates were comparable among the three methods. A country wide block count for rhinos every three years and continuous ID-based monitoring in a SMR framework within selected sensitive subpopulations are recommended so as to keep the pulse of the rhino population in Nepal. The SMR design developed from ID-based monitoring herein will provide the much needed statistical rigor to population estimates of rhinos in Nepal and elsewhere.

4. Seasonal nutritional ecology of rhinos was studied by continuously (24 h sessions) following 8 radio-collared focal rhinos from the elephant back for 304 h in monsoon, 228 h in cool dry season and 192 h in hot dry season. Total dry matter intake from different plants was computed from time spent foraging, average bite weight and bite rate data. Total fecal output was also recorded during the continuous monitoring. Seasonal chemical analysis for crude protein (CP), organic matter (OM), neutral detergent fiber (NDF), acid detergent fiber (ADF), total ash (TA), calcium (Ca), cellulose (Ce) and hemicelluloses (Hc) was carried out for rhino food plants and rhino dung. From this data total seasonal nutrient intake and output, dry matter digestibility (DMD) and nutrient digestibility were computed. A total of 11,199 bites were recorded in the hot-dry season, 10,740 in the cool dry season and 10,151 bites in the

monsoon season from different habitats. Average bite rate per minute was 13.37 ±1.03 in the monsoon, 11.98 ± 0.52 during the cool dry season and 11.50 ± 0.33 during the hot dry season. The average dry weight of the bite was 3.32 ± 0.22 g in the monsoon, 3.93 ± 0.29 g in the cool dry season and 3.02 ± 0.25 g in the hot dry season. Annually, rhinos foraged 71% of the time in grasslands and 29% in the riverine forests. Rhinos spent 38.19 ± 1.79% of the total time for feeding in the monsoon, 40.40 ± 1.19% of time in the hot dry season, and 40.21 ± 2.78% of time during the cool dry season. Fifty eight species of plants were found to be utilized by rhinos at different scales but 14 species of plants contributed 85% dry matter to the annual diet. During hot dry season rhinos consumed 33 species of plants of which eight species contributed over 90% of the diet. *Saccharum spontaneum* (34%), *Imperata cylindrica* (27%), *Eragrostris tenella* (9%), *Cersium wallichii* (5.5%), *Narenga porphyrocoma* (5%), *Cynodon dactylon* (2%), *Phragmites karka* (3%), and *Mikania micrantha* (3%) were the main food plants of the hot dry season. Total dry matter intake (DMI) during the dry season was 21.77 ± 5.87 kg/day and time spent feeding was 9.71 ± 0.28 h/day. Rhinos consumed 39 species of plants during the cool dry season. However, ten species namely *Saccharum spontaneum* (22%), *Imperata cylindrica* (14%), *Saccharum bengalensis* (6%), *Eragrostis tenella* (9%), *Callicarpa macrophylla* (11%), *Phragmites karka* (7%), *Mikania micrantha* (5%), *Coffea bengalensis* (3%), *Litsea monopetala* (4%) and *Lantana camara* (2%) contributed over 80% of the diet. Total DMI during cool dry season was 24.59 ± 6.24 kg/day and time spent feeding was 9.65 ± 0.66 h/day. Forty three species of plants were eaten during the monsoon season. However, 9 species contributed 80% of the monsoon diet. *Saccharum spontaneum* (25%), *Eragrostri tenella* (23%), *Saccharum bengalensis* (4%), *Imperata cylindrica* (8%), *Brachiaria* species (8%), *Trewia nudiflora* fruits (4%), *Phragmites karka* (4%), *Cynodon dactylon* (3%) and *Hemarthria compressa* (3%) were the main food plants. Total DMI was 24.66 ± 4.88 kg/day and time spent feeding was 9.1 ± 0.48 h. Annual average defecation rate and total fecal output were 2.51 ± 0.15 times and 7.03 ± 0.9 Kg/day respectively.

Seasonal chemical analysis of food plants revealed that CP in the diet varied from 4 to 17%, NDF 30 to 85%, ADF 22 to 70% and calcium 0.13 to 4.8%. Average dry matter digestibility (DMD) was 69% in the cool dry season, 72% in the hot dry season and 74% in the monsoon season. Organic matter digestibility ranged between 70% and 75%, and CP digestibility between 65% and 69% across the different seasons. Similarly, NDF and ADF had higher digestion coefficient and both were consistent across all seasons. True protein digestibility (TPD) was 79% in the monsoon, 80% in the cool dry season and 81% in the hot dry season.

The digestibility of different nutrient constituents was found to be quite consistent across seasons. Based on time spent foraging, DMI, DMD and nutrient digestibility it is concluded that seasonal fluctuations in climate have minimal effects on the quality of food resources of rhinos and seasonal effects on the nutritional ecology of rhinos were minimal.

5. Understanding seasonal time budget and activity patterns of endangered species is crucial to develop conservation management plan and strategy. Time budget and activity of rhinos were studied by continuously monitoring 8 radio-collared adult rhinos from the elephant back for 11 days in cool dry season, 13 days in hot dry season and 17 days in monsoon season. Annually, rhinos spent 33.21 ± 2.29% time grazing, 6.4 ± 0.19% time browsing, 39.61 ± 1.93% time feeding, 8.41 ± 1.56% time walking, 14.97 ± 2.39% time wallowing, 30.31 ± 3.05% time resting, 4.93 ± 1.42% time standing and 1.77 ± 0.54% time in other activities. Time spent grazing was 29.20 ± 2.35% in cool dry season, 38.54 ± 1.37% in hot dry season and 31.88 ± 3.13% in monsoon. Grazing did not differ significantly across seasons ($F_{2, 25} = 3.74$, $p = 0.063$). Rhinos spent 11.02 ± 0.68% of time in cool dry, 1.87 ± 0.35% time in hot dry and 6.31 ± 1.70% time during monsoon for the browsing. Time spent browsing varied significantly across seasons ($F_{2, 25} = 18.83$, $p = <0.0001$). Rhinos spent 40.21 ± 2.79% of time in cool dry season, 40.41 ± 1.20% of time in hot dry season and 38.19 ± 1.79% of time during monsoon for feeding. Feeding activity did not differ across seasons ($F_{2, 25} = 0.34$, $p = 0.7187$). Time spent resting was 40.44 ± 1.84% for cool dry season, 25.26 ± 4.80% for hot dry season and 25.23 ± 2.51% for monsoon. The time spent resting was significant across seasons ($F_{2, 25} = 2, 25$, $p = 0.0287$). Time spent wallowing was 2.65 ± 0.97% during cool dry season, 20.62 ± 3.62% in hot dry season and 21.64 ± 2.58% in monsoon. Time spent wallowing was statistically significant across seasons ($F_{2, 25} = 27.68$, $p = <0.0001$). Rhinos exhibited bimodal pattern of grazing in all seasons which was most probably to avoid the heat stress of the day time. Browsing did not have any diel pattern. Rhinos were found resting mostly in the late morning to afternoon in all seasons and were more active during night time. Similarly, wallowing was highest during afternoon time than other period of a day. Walking, vigilance and other activities did not have any patterns. As predicted, 7% increment in the feeding time budget was found compared to previous studies which may be attributed to lost opportunity of raiding farm crops after the installation of power fence on the park border and habitat degradation by *Mikania* invasion.

6. Understanding the impact of *Mikania* on rhinos requires quantitative assessment of habitat use and preference. Data from 8 GPS radio-collared adult rhinos were analyzed to deduce

home range, habitat use and daily movement patterns. A total of 8,491 GPS locations were used for home range analysis. Asymptotes of home range area vs location fixes showed sample adequacy for rhinos (>90 locations). Non-parametric home range estimators: (a) Minimum Convex Polygon (95% and 80% MCPs) and (b) Fixed Kernel contour (95% and 85%) with the reference bandwidth as a fixed proportion of 0.60 in Home Range Tools extension of ArcGIS were used to quantify annual and seasonal core areas and range use by rhinos. Habitat map was prepared by using the satellite images (RapidEye, Germany) with ground verifications using ArcGIS. Habitat preference was investigated at three levels by using compositional analysis: a) Selection of home range within study area, b) Selection of core area within home range, and c) Selection of foraging paths within home range. Average annual 95% Kernel home range was 20.54 ± 6.06 km^2 for male and 10.58 ± 1.34 km^2 for female. The female home range during cool dry season was 10.06 ± 1.48 km^2, 9.08 ± 1.25 km^2 in hot dry season and 9.81 ± 1.19 km^2 in the monsoon. The male home range was 16.52 ± 4.02 km^2 for cool dry season, 17.760 ± 4.94 km^2 for hot dry season and 18.63 ± 4.53 km^2 for monsoon. There was a significant difference between male and female home ranges ($F_{1, 20}$ = 21.21, p < 0.001). There was 47% overlap of home ranges between two males and minimum of three female's home ranges overlapped with the home range of a male. Home range overlap among females was over 60%. This fact suggests that the greater one-horned rhinos were not territorial. In average, male and female rhinos travelled 6.45 ± 0.73 km and 4.06 ± 0.24 km in a day. Distance moved by males in a day was significantly higher than females ($F_{1, 120}$ = 28.34, p < 0.0001). There was a greater movement in night than in day for both sexes ($F_{1, 120}$ = 6.53, p = 0.019). But the movement did not differ with seasons for both sexes ($F_{2, 81}$ = 1.39, p =0.256).

The order of annual habitat preference ($\chi^2_{(6\ df)}$ = 18.63, p <0.001) at study area level was riverine forest > short grassland > tall grassland > wooded grassland > river and river bed > Sal forest > built-up area. Habitat preference order for cool dry season ($\chi^2_{(6\ df)}$ = 16.543, p <0.001) was riverine forest > short grassland > tall grassland > wooded grassland > river and riverbed > built–up area > Sal forest. The preference order for hot dry season ($\chi^2_{(5\ df)}$ = 24.29, p <0.001) was tall grassland > short grassland > riverine forest > wooded grassland > river and riverbed > built-up area > Sal forest. During monsoon the preference ($\chi^2_{(5\ df)}$ = 15.154, p <0.05) order was tall grassland > riverine forest > short grassland > river and riverbed > wooded grassland > built-up area > Sal forest. This variation in the seasonal habitat preference was correlated with the distribution and availability of food plant resources and wallows.

There was three to six folds increment in home range sizes of Chitwan rhinos compared to previous studies which may be attributed to habitat degradation due to invasive *Mikania micrantha* and plant succession, and a significant low rhino population density than past.

7. Demographic parameters of rhinos were deduced by intensively monitoring 53 adults (> 7 year), 23 juveniles and subadults (1 - 7 year) and 12 young calves (< 1year) using telemetry and individual rhino ID profiles in the Sauraha subpopulation of Chitwan. Record of births and deaths among intensively monitored subpopulation was used to compute survival and mortality in the program MARK under known fate model. Similarly, long-term data on mortality (1998 - 2012) and population estimates (1966 - 2011) available from the published literature and research station at Chitwan were used to infer the causes of mortality and trends in population growth. Annual survival rate for young calf was 0.69 ± 0.14, while it was 0.98 ± 0.01 for juvenile and subadults and 0.977 ± 0.01 for adults. Span survival for subadults and adults was 0.91 ± 0.03 and 0.52 ± 0.03 respectively. Mean age of first calving was 08.06 ± 0.31 year (n = 8). Average interbirth interval was 44.2 ± 3.64 months (n = 11) and was higher (49.66 ± 2.14 months) when calf of previous litter survived to independence. There was no seasonality for the birth (N = 44, $\chi^2 = 2$, df =2, p = 0.367) and birth was found distributed across all months. Between 1966 and 2000 the Chitwan population increased at an annual realized rate (r) of 0.05 (p = 0.06, $R^2 = 0.94$). Subsequent five years registered a decline (r = -0.076) due to poaching; thereafter the population has again increased with similar r. A total of 365 rhino mortalities were registered between 1998 and 2012 in Chitwan. Of these, 48% were male, 35% female and 17% unsexed. Poaching was the main causes of rhino mortality in Chitwan (47%) and other causes were old age (22%), natural calamities (7%), tiger predation (5%), trampling by adult rhinos (4%), disease (2%) and unidentified (6%) causes. High mortality of calves (<1 year) was recorded in intensively monitored subpopulation which may be attributed to increased tiger number and increased male proportion in the population compared to past. The density of rhinos in the heavily *Mikania* invaded habitats was found decreased compared to past. *Mikania* invasion in the rhino habitat has negative effect on the demographic parameters of rhinos and the first effect was manifested as decreased local population density in highly invaded sites. Therefore, long-term monitoring of demographic parameters would provide an opportunity to understand further the effects of invasive species on rhino demography.

8. Invasive species are the second greatest agent of species endangerment and extinction after habitat destruction in the modern world. Invasive species have also posed serious impacts on

ecosystem functioning and ecosystem services provisioning. *Mikania micrantha* is a multi-branched scrambling highly invasive perennial vine belonging to family Asteraceae and is native to Central and South America. This weed has been accidently introduced in CNP since 2000 and posing threats to rhinos and native biodiversity. However, there have been very limited studies across globe on impacts of invasive plant species on native fauna. Therefore, to understand how the rhinos have been affected by the invasive *Mikania* in Chitwan 8 adult rhinos were radio-collared and intensively monitored. Fine *Mikania* distribution map was prepared on ArcGIS by using intensive ground survey data (N = 2,696 plots in 63 km^2 area). Daily tracks of rhinos during peak foraging hours were buffered (15 m both side) and overlaid on the *Mikania* habitat map. Compositional analysis was performed to see how the rhinos were preferring *Mikania* invaded and non invaded habitats during foraging peaks. Data generated from clipped quadrates (N = 50) within the vegetation grazing exclosures (n = 10) were used to estimate species richness and biomass production at different level of *Mikania* invasions. The results showed that 21% of the study area was free of *Mikania* invasion, 49% of the habitat had mild level of invasion (<20%), 23% had intermediate level of invasion (20 - 40%) and 7% of the habitat had severe invasion (>40%) of *Mikania*. There was a negative effect of *Mikania* especially on grasses, herbs, shrubs and small trees. Simple linear regression equation depicted that with the increment in the percentage cover of *Mikania*, the biomass (Native biomass (gm) = 6819 (±290.3) - 74.22 (±7.4) * % of *Mikania;* $R^2 = 0.68$, $p < 0.0001$) and percentage cover of native forage plants (% Native cover = 79.80 (±1.7) - 0.87 (±0.1) * % *Mikania* cover; $R^2 = 0.89$, $p < 0.0001$) of rhinos decreased significantly. Species richness reduced significantly as *Mikania* cover increased ($F_{4, 22} = 10.10$, $p < 0.0001$) and the effect was very severe after 80% coverage of *Mikania*.

Habitat preference during foraging peaks was decisively for lower percentage cover *Mikania* across all seasons: i) Annual preference ($\chi^2_{(6\ df)} = 115.27$, $P < 0.0001$) was 10 - 20% > 20 - 30% > 1 - 10% > 0% > 40 - 50% > above 50%. ii) The cool dry season preference ($\chi^2_{(6\ df)} = 64.55$, $P < 0.0001$) was 10 - 20% > 20 - 30% > 30 - 40% > 1 - 10% > 0% > above 50% > 40 – 50%. iii) The hot dry season preference ($\chi^2_{(6\ df)} = 67.39$, $P < 0.0001$) was 10 - 20% > 1 - 10% > 20 -30% > 0% > 30 - 40% > above 50%. iv) The order of preference for the monsoon season was same ($\chi^2_{(6\ df)} = 75.56$, $P < 0.0001$) as of hot dry season. This preference to lower invaded habitat was correlated with the availability of rhino food plants. *Mikania* invasion was detrimental to rhino forage availability by reducing native forage diversity and biomass. *Mikania* was likely to affect all ungulate populations and have cascading effects affecting all higher trophic levels.

9. Population habitat viability analysis (PHVA) was carried out to identify and prioritize threats faced by Chitwan rhinos and to evaluate the likelihood that it will persist for next 100 years. Life history parameters were obtained either from current study or published literature. Based on the ground information 12 different scenarios were built in VORTEX 9.99. These scenarios consisted of i) reduction in carrying capacity for rhinos due to *Mikania* invasion, ii) increased in poaching as observed during periods of political unrest, and iii) effect of severe floods along with various combinations of the above. Each scenario was run 1,000 times to evaluate extinction probability. Sensitivity of the models to critical life history parameters like calf mortality, female or male biased mortality and age of first reproduction were determined by running simulations at different values of these parameters. Loss of carrying capacity even up to 50% by *Mikania* was by itself not likely to cause extinctions. But when combined with poaching it had a synergistic effect, and under reduced carrying capacity even moderate poaching pressure of 8 - 12 rhinos per year caused extinctions. Catastrophe in the form of floods every 25 years had insignificant effect on rhino populations but in combination with *Mikania* and poaching reduced persistence probabilities. The model clearly depicted poaching above 10 rhinos per year was a significant cause of concern and in combination with *Mikania* had disastrous impact on rhinos of Chitwan.

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CHAPTER 1

Introduction

Megaherbivores are always fascinating!

Introduction

Evolution of rhinos

'The Superfamily Rhinocerotidae is the largest and most ecologically diverse group of the perissodactyls, which includes the amynodonts (hippo-like or tapir-like aquatic forms), the hyracodonts (the dog-sized cursorial forms, and gigantic forms which browsed tree tops), and the true rhinoceroses of the family rhinocerotidae. All three groups diverged in the later eocene from a form like *Hyrachyus,* and spread over the northern hemisphere. Both the amynodonts and hyracodonts were reduced to a few surviving genera by the early Oligocene but the rhinocerotidae began to diversify. Most early rhinos were hornless, but the first horned rhinos had paired horns on the tip of their noses, a feature that evolved independently in two different groups, the Diceratheriinae and Menoceratinae. By the late Oligocene, rhinos began to diverge into the major subfamilies and tribes that dominated the northern hemisphere and Africa during the Miocene: the hippo-like grazing single horned Teleoceratinae, the prehensile-leaped browsing hornless Aceratheriinae, and the Rhinocerotinae, which includes all the five living species. These first two groups were almost completely wiped out by the extinctions at the end of Micocene, leaving North America without rhinos, and certain rhinocerotines surviving in Eurasia and Africa. During the Plio-Pleistocene in Eurasia, the dominant rhinos were several species of large derived D*icerorhinus*, and wide ranging wooly rhino. Iranotheres and giant frontal-horned elasmotheres were also present, but all of these groups were extinct by the end of Pleistocene. Today, only two genera of dicerotine rhinos survive in Africa, and three species of rhinos survive in Asia. Greater one-horned rhino (*Rhinoceros unicornis*), Javan rhino (*Rhinoceros sondaicus*) and Sumatran rhino (*Dicerorhinus sumatrensis*) are three Asian rhino species and Black rhino (*Diceros bicornis*) and White rhino (*Ceratotherium simum*) are two African rhino species. All five of these species are heavily poached and are on the brink of extinction, a sad remnant of one of the most diverse and successful groups of mammals in the entire Cenozoic' (Prothereo *et al.* 1989).

Status and distribution

During fifteenth century, the greater one-horned rhinoceros (hereafter referred to as rhino) were abundant throughout the floodplains of the Ganges, Brahmaputra and Sindh rivers and their large tributaries between Myanmar in the east and Pakistan in the west (Blanford 1891, Laurie 1978, Dinerstein 2003) (Figure 1.1). Rhinos are now restricted to small isolated protected areas in India and Nepal totalling not more than 2,850 (Talukdar 2010). In India, the majority are in Assam (Kaziranga, Pobitora, and Manas National Parks and Orang Wildlife Sanctuary), but also in West Bengal (Jaldapara and Gorumara Wildlife Sanctuaries) and a few in Uttar Pradesh (Dudwa National Park and Katerniaghat Wildlife Sanctuary). In Nepal, rhinos occur mainly in Chitwan National Park but have also been reintroduced to Bardia National Park and Suklaphanta Wildlife Reserve (Jnawali 1995, Dinerstein 2003, DNPWC 2009).

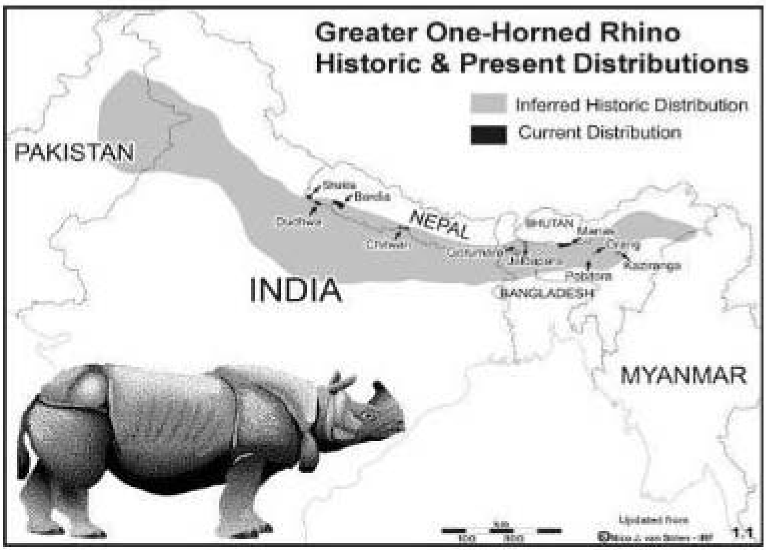

Figure 1.1. Historic and present distributions of greater one-horned rhinoceros (as at 31 December 2005)

The rhino population in Nepal suffered a catastrophic decline during the 1960's to less than 100. This was due to loss of habitat and poaching that resulted from conversion of Terai grasslands and forests to agriculture subsequent to a malaria eradication and resettlement programme launched by the Government of Nepal (Laurie 1978, Dinerstein 2003). Thousands of hectares of land were cleared to resettle hill dwellers in the Terai. During 1960s over 70% of the forests were cleared alone in Chitwan valley (Dinerstein 2003, Caughley 1969). After the establishment of Chitwan National Park (CNP) in 1973, and strict law enforcement, the population gradually recovered to 612 in 2000, which was considered a conservation success (Dinertsein 2003). But again during the decade long armed conflict (1996 -2005) rhino conservation in Nepal was compromised due to intense poaching. The population crashed to about 400 across Nepal (DNPWC 2005). However, the population has been reported to have been gradually increasing since 2006.

Origin of the study

Mikania micrantha (hereafter *Mikania*), known as mile a minute, was first reported from the district of Ilam in 1963 by a Japanese team and scientifically reported later in 1966 in Nepal (Tiwari *et al.* 2005). The weed is suspected to have been introduced accidentally in Nepal via the tea gardens of Assam (North east India) with the tea saplings (Siwakoti 2007). At present, the weed has seriously invaded Koshi Tappu Wildlife Reserve, Chitwan National Park and has spread up to Dang district in the Terai belt of Nepal. Until 2004, there were no reports on the problem of *Mikania* in Nepal. The first national stakeholder workshop on *Mikania* weed invasion in Nepal was organized in November 2004 and various institutions were made aware of the problem of invasive weeds in Nepal (Poudel *et al.* 2005). After that a very superficial national inventory of invasive alien plant species (IAPS) was done by IUCN Nepal (Tiwari *et al.* 2005). Siwakoti (2007) has briefly reported the challenges and community based control practices done in Koshi Tappu wildlife Reserve of Nepal. In Chitwan, *Mikania* was first reported in 1998 in the western corner near the 'Tiger Tops' area (S. R. Jnawali, pers. Comm.). Within a short time period, *Mikania* invaded grasslands and riverine forests and considerable damage to native plants was observed (Sapkota 2007). A preliminary survey on distribution of *Mikania* in Chitwan National Park was done during the rhino count operation in 2008. About 15% of the prime rhino habitats were found to have been severely invaded; overall it was present in 44% of the rhino habitats (DNPWC 2009). Since *Mikania* was killing most of the rhino's food plant species (Sapkota 2007) it was suspected that the weed must have some impact on the rhino population performance and on other aspects of rhino ecology. The Department of National Parks and Wildlife Conservation together with rhino biologists advocated for an immediate study on the level of impact posed by *Mikania* on native plants and wildlife species including rhinos and explore possible control methods (DNPWC 2009) which opened the door for this study. Intensive studies on aspects of rhino ecology were conducted in Chitwan during the 1980s and 1990s (Laurie 1978 and 1982, Dinerstein and Price 1991, Dinerstein and Wemmer 1988, Dinerstein 1989 and 1992, Jnawali 1989 and 1995). However, it is important to understand how the ecology of an endangered species changes with respect to environmental change. Also, a detailed understanding of rhino nutritional ecology was lacking in the previous studies. This paved the way for the current study design wherein efforts have been made to explore the effects of *Mikania* on nutritional ecology, habitat use and demography of rhinos in Chitwan National Park and ultimately produce scientific inputs for the conservation and management of this species in the wild.

Previous studies on greater one-horned rhinoceros

Rhinos are a charismatic species and therefore have got considerable national and international attention in term of scientific study and conservation investment. As a result, it has been studied well in the wild as well as in the captivity. Some of the important studies are reviewed in this section.

In situ studies

Various hunters, naturalists and tea-garden managers have written about the Indian rhino in the wild (Laurie 1978). Some recent hunts were described by Smythies (1942) in Nepal. 'Maners-Smith (1909) described the distribution and abundance of the rhino in Nepal and Bihar. Bengt Berg (1932), a Swedish photographer visited Jaldapara sanctuary in West Bengal and collected some interesting information on movement patterns and feeding habits of rhino' (Cited in Laurie 1978). E.P. Gee (1953a, 1953b, 1959 and 1963) made observations on the rhino of Assam and Nepal, and summarized their distribution, ecology and behaviour (Cited in Laurie 1978).

However, the first prolonged detailed scientific study on ecology and behaviour of the greater one-horned rhinoceros in the wild was conducted by Laurie (1978) in Chitwan National Park between 1972 and 1976. The study methodology was based on direct observations made from towers ('*machan*'), on foot and from elephant back. He estimated a population size of 270 - 310 individuals, based on photographic identification of individuals, with population densities in the favoured flood plain habitats of up to 5.85 rhinos per km^2. There were 32.3% adult females, 19.9% adult males, 21.2% sub-adults and 26.6% calves. Similarly, 183 species of plants representing 57 families were found to be consumed by rhino; 50 species of grasses contributed over 80% of the rhino diet. Ten different vocalizations were identified. Poaching, habitat encroachment, livestock grazing, floods and invasive species invasion on habitat were identified as major threats to the rhinos. Details of the findings are available in Laurie (1978, 1982) and Laurie *et al.* (1983).

The Smithsonian Institution, USA, funded the Nepal Terai Ecology Project based at Chitwan and carried out various ecological researches on rhinos and tall grasslands under which Eric Dinerstein was the principal researcher between 1984 and 1988.

Dinerstein and Wemmer (1988) studied the interaction between rhino and *Trewia nudiflora*. The study revealed a poor germination of uningested fruits compared to ingested fruits and rapid growth of *Trewia* in the rhino dung piles and demonstrated a direct correlation of rhino and seed dispersal and recruitment of *Trewia* in the riverine forests. Further to this study, Dinerstein (1989) experimented whether the feeding behaviour of large ungulates (rhino, Indian bison, spotted deer, sambar, hog deer and barking deer) supports the foliage-as-fruit hypothesis or not. The foliage-as-fruit hypothesis argues that some plants may promote herbivory by large ungulates at the time of seed as a way of achieving seed dispersal. Dinerstein (1989) concludes that there are no obvious examples supporting the foliage-as-fruit hypothesis. Rather annual floods and fires create sufficient micro-sites for the propagation of annual plants and under such disturbance regimes megafauna-mediated dispersal as described by the foliage-as-fruit hypothesis is not apparent. The mega-herbivores are responsible, to some extent, in structuring their habitats. Rhinos also do extensive damage to certain plant species while grazing and browsing. Dinerstein (1992) found that the browsing and trampling by rhinos inhibit vertical growth of *Litsea monopetala*, a preferred browse species, and hence rhinos can have access to new sprouts throughout the year.

For the ecological study and reintroduction to other parks more than 40 rhinos were tranquilized in Chitwan during 1984 to 1991. This exercise gave a good opportunity for scientists to develop a protocol in immobilizing rhinos in the wild. The capture, chemical immobilization, and radio-collar life for greater one horned rhinos is available on Dinerstein *et al.* (1990). Since the Chitwan rhinos had recovered from a small population during 1960s, genetic bottleneck and inbreeding depressions could be expected. To understand genetic status Dinerstein and McCracken (1990) carried out a genetic analysis of Chitwan rhinos (9.9% of the total population) and found a very high heterozygosity. Similarly, genetic variations between the subpopulations of Assam and Nepal are available in Zschokke *et al.*

(2011). The microsatellite analysis demonstrated a strong genetic differentiation between the Assam and Nepal populations and the occurrence of bottleneck in the Assam population before the reported bottleneck in 1908. Similarly, the Nepal population was a recent colonization. The extent of genetic divergence between the two populations suggests the need for separate conservation programs.

Dinerstein (1991) explains the sexual dimorphism that can be observed in wild rhinos. The study found that adult males and females differed significantly only in a few mensuarl characteristics. The males had well developed neck folds and longer incisors than females. There was less sexual dimorphism in the wild compared to captivity.

After Laurie's study, detailed studies on demography and habitat use by Chitwan rhinos was conducted between 1984 and 1988 by Dinerstein and Price (1991). They found the observed rate of population increase to be (r) 4.8% and the total estimated population to be 358 – 376. The mean annual mortality within the calf, subadult and adult categories was estimated to be 2.8, 2.2 and 2.9% respectively. The maximum density of rhinos was 13.3/km^2 in the *Saccharum spontaneum* dominated grasslands and riverine forests which were the most preferred habitats. Annual monsoon floods were found to be the agents for maintaining prime grazing habitats and high population densities.

Eric Dinerstein has probably made the greatest contribution to our current understanding of rhino ecology. After two decades long scientific involvement in rhino conservation in Asia, particularly in Nepal, Dinerstein (2003) published a comprehensive book: *The Return of the Unicornis* in which the author has discussed the natural history, ecology, behaviour, habitat use in the context of changing landscapes, case studies of some habitat restorations and rhino recovery in Nepal. He also focused on how the involvement of local communities in conservation mainstream can help the recovery, large landscape restoration, and build a local stewardship for conservation of endangered mega fauna.

With the increasing number of rhino population in Chitwan valley compounded with human population increment and with habitat conversion outside the national park the level of human rhino conflict increased considerably. Highest economic loss (27.6%) was for rice and it was more intense within 500m periphery of the park. Similarly there was a considerably high level of human harassments (Jnawali 1989).

Jnawali (1995) assessed the microhistological techniques for determining the diet of rhinos. The technique was found effective as over 90% of the plant species could be identified. The study has also compared the seasonal habitat use, ranging behaviour and food habits of donor and translocated rhinos in Chitwan and Bardia. Similarly, performance of translocated rhinos in Bardia National Park has also been discussed. Details of the findings are available in Jnawali and Wegge (1993) and Jnawali (1995).

Steinhem *et al.* (2005) studied dry season diet and habitat use by rhinos and elephants in Babai valley of Bardia National Park. They found 37.5% diet overlap of both species and argued that during the critical period of the year *i.e.* dry season, competition would increase with the increasing number of both sympatric herbivores. The tall grass floodplain habitat and its important forage grass *Saccharum spontaneum* may then become the critical resources. Ultimately rhinos will be weak competitors as elephants are adapted on Sal forest and other habitats too. Pradhan *et al.* (2008) studied comparative feeding ecology of low density but increasing sympatric populations of rhinos and elephant at Karnali floodplain of Bardia National Park and found similar results as explained by Steinhem *et al.* (2005) but having more diet overlap during monsoon season.

Rothley *et al.* (2004) carried out population model analysis for Chitwan rhinos based on the available secondary data. They found very strong negative impact of poaching whereas the population was below the carrying capacity and therefore urged for strong antipoaching efforts for the persistence of Chitwan rhinos. Poudyal *et al.* (2009) carried out ecological and economic analysis of poaching of rhinos in Nepal. They suggested that only the strict law enforcement will not be sustainable model for rhino conservation and therefore urged for the antipoaching policies supplemented with the policies that provide greater economic incentives to the local communities for the successful rhino conservation in the long run.

Kandel and Jhala (2008) studied the demographic structure, activity patterns, habitat use and food habits of rhino during dry season at Chitwan in which adult and calf ratio was found more skewed towards adults compared to previous studies.

A rhino population count has been carried out at 3 to 5 years intervals in Nepal since 1994. The population status, structure and distribution for different years are available in Yonjon (1994), DNPWC (2000, 2005, 2009 and 2011b) for Nepal. However, the validation of the count method has yet to be done.

Studies in ex *situ* condition

Few studies have been carried out in captivity about the nutritional ecology of rhinos. However, there are no studies on nutritional ecology in the wild.

Clauss *et al.* (2005a) studied the digestive physiology and feed digestibilities in captive rhinos. Dry matter intake ranged between 0.8 and 1.3% of the body weight on roughage and concentrates diet while it was 0.5 – 1.2% of body weight on the roughage only. Digestibility coefficients ranged from 35 – 58% on roughage and concentrates diet while on the roughage only dry matter digestibility was 57 - 61%. Rhinos were found having highest ingesta retention time among the monogastric ungulates. Digestibilties were found comparable with the horse in spite of enormous differences in body weight and retention time.

Benign uterus tumours and chronic foot lesions in rhinos in captivity are often related with obesity. Clauss *et al.* (2005b) suggests for control of zoo rations by ration calculation that includes mineral level to ensure the animals are receiving adequate mineral nutrition.

Zschokke *et al.* (2011) studied inbreeding, outbreeding, infant growth and size dimorphism in captive rhinos. Inbreeding did not have effects on gestation period and birth mass but the growth rate and mortality was low compared to outbred rhinos. Outbred individuals (offspring of Kaziranga and Chitwan populations) had the highest infant mortality. They argued that the two populations were genetically partially incompatible. Sexual dimorphism was significant in height and weight and suggested that the sexual dimorphism in adults is the result of a longer growth period in males rather than a difference in growth rate between sexes.

Study Area

Location

The study was carried out in the Chitwan National Park (84^0 20' E and 27^0 30' N) which is located at south-central lowland of Nepal (Figure 1.2). The park was established in 1973, as a first national park of the country that covers an area of 932 km^2 of Chitwan, Nawalparasi, Makawanpur and Parsa districts. To enhance the conservation of the core area an additional 750 km^2 area including settlements around the park was declared as a buffer zone in 1996. The park is contiguous with Barandabhar forest corridor (ca.170 km^2) that connects Chitwan valley with the lesser Himalaya Mahabharat mountains in the north, Parsa Wildlife Reserve (499 km^2) in the east and Balmiki Tiger Reserve (800 km^2) of India in the south and thus forms a greater landscape of over 2,500 km^2. The landscape has been identified as one of the promising tiger conservation landscapes in the Indian sub-continent (Wikramanayake *et al.* 1998). The park has been designated as UNESCO's World Heritage Site in 1984 because of its outstanding biological significance. The park encompasses a wide diversity of habitats and species within the elevation of 110 to 850 msl. The Narayani River and Daunne hill marks the western boundary of the park, Rapti River marks the northern boundary and Someshor hills, Reu River and forest roads mark the southern boundary.

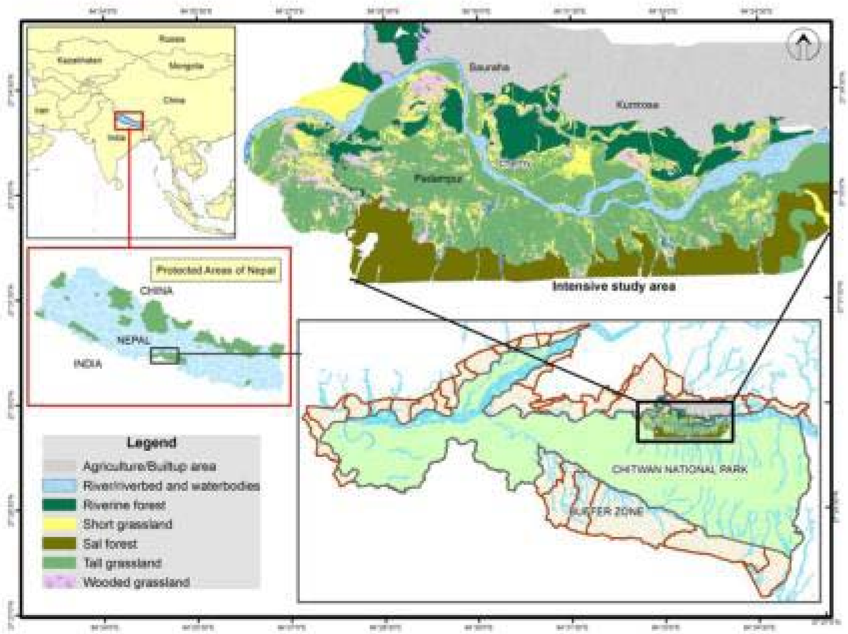

Figure 1.2. Map shows the general location of Nepal and Chitwan National Park. The intensive study area within Chitwan National Park is shown in the inset.

Geology and soils

The Chitwan valley is bordered by the Lesser Himalayan Mahabharat Mountain range in the north and the lower Himalayan foothills- the Churia (Siwalik) - in the south and is dissected by the Narayani, Rapti and Reu river systems. The Mahabharat Range consists of severely eroded pre-Siwalik quartzites, phyllites and sand stones (Berry *et al.* 1974, cited in Laurie 1978). The Siwaliks are characterized by sandstones, conglomerates, quratzites, shales and micaceous sandstones (Stocklin and Bhattarai 1982). Soils are largely alluvial deposits left by shifting river courses. The Narayani and Rapti rivers have markedly influenced the soils of the valley, almost eliminating the original basin deposits. Most dun valley soils reflect the lacustrine and fan-delta characteristics of the watershed draining into the basin during the late Tertiary period. Drainage is variable with the water table ranging seasonally from 0-2 m. Old soils on fans, aprons and ancient river terraces are well drained sandy loam to loam. The water table seasonally ranges from 1-15 m. Hill soils are sandy loam to loamy rubble, with very stony surfaces less than 50 cm from bedrock. Surface drainage is very rapid, internal drainage is poor, and erosion is severe.

Hydrology

The CNP is drained by Narayani, Rapti and Rieu Rivers and their tributaries. The Rapti River originates from the Mahabharat range near Chisapani Garhi at an altitude of 2,120 m and flows southward and then westward from Hetauda for roughly 120 km to its confluence with the Reu and Narayani River (Maskey 1989). Narayani River, the third largest river of Nepal, flows south west about 30 km through a relatively low gradient. The snow-fed Kali Gandaki and Trisuli Rivers are the two major tributaries of Narayani River. The river is called Narayani once Kali and Trisuli meet at Deughat. The river has a maximum width of two kilometres and consists of many channels and islands. It swells to a maximum level during monsoon period carrying a high sediment load. During the dry season (December - March) the river recedes to the main channel at some points leaving some channels with little water. The river constitutes sand banks, rocks, and stands of *Saccharum spontaneum*, *Phragmites karka* and other grasses. The Narayani River eventually joins Ganges River near Hajiipur in India after travelling 25 Km along the base of Someshwar hills in Nepal (Maskey 1989). There are number of tributaries draining to Rapti and Reu inside the park. The average flow ranges from 1000 to 1700 cum/s but the maximum flow ranges from 10,000 to 700,000 cum/s during the monsoon season from June to September.

Climate

The Chitwan valley has a sub-tropical climate with three distinct seasons: a) monsoon (June – September); b) cool dry (October – January); c) hot dry (February – May) (Laurie 1978, 1982). January is the coldest month of the year with mean minimum temperature ca. 8^0 C. April and May are the hottest month and mean temperature reaches above 36^0 C (Figure 1.4). Between 1980 and 2009, mean annual rainfall was 2036 ± 64 mm and 80% of which occurred during monsoon (Figure 1.3). Winter months are relatively dry but a little rain occurs due to westerly wind. Humidity is 98% during the monsoon and cool dry season and low during the dry season. Pre monsoon rains are common during month of May with thunderstorms.

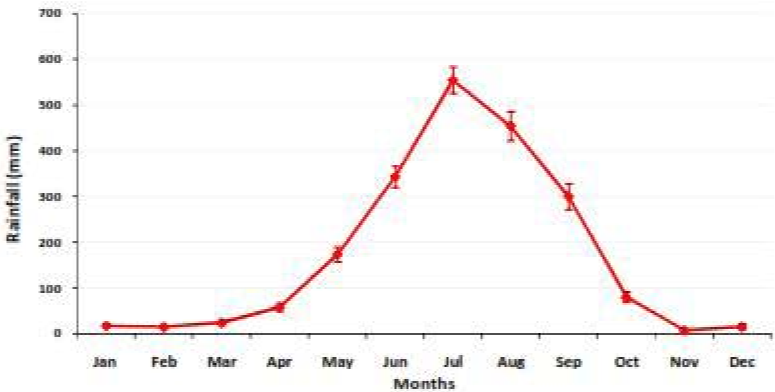

Figure 1.3. Average monthly rainfall in Chitwan between 1980 and 2009. Bars are standard errors. (Data source: Department of Metrology and Hydrology, GovN).

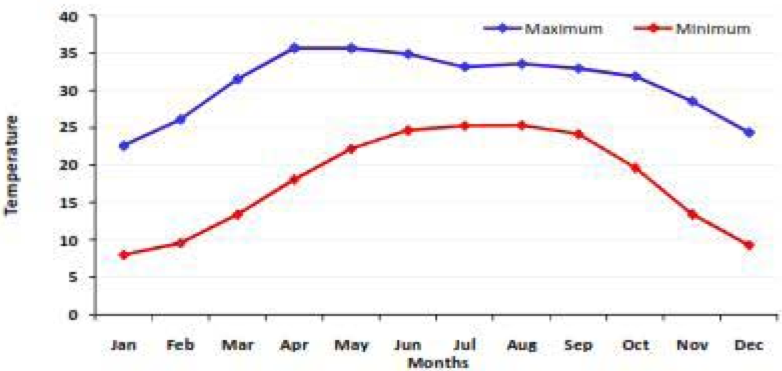

Figure 1.4. Monthly average minimum and maximum temperature (degree Celsius) between 1980 and 2009 in Chitwan. (Data source: Department of Metrology and Hydrology, GovN).

Vegetation

The general vegetation characteristics of the Chitwan National Park have been described by Bolton (1975), Laurie (1978), Mishra (1982) and Thapa (2011). Vegetation of CNP is subtropical type, with mosaics of early successional flood plain communities in alluvial floodplain to climax Sal forest in relatively dry flat lands. About 70 percent of vegetation is dominated by Sal (*Shorea robusta*) forest, a moist deciduous vegetation type of the Terai region (Stainton, 1972; Dobremez, 1976). About 15% of the park is covered by grasslands and remaining by mixed riverine forest (Dinerstein 2003).

The Sal forest is so called climax vegetation of the Terai (Stainton, 1972; Dobremez, 1976). Associated species of Sal forest are *Terminalia tomentosa, T. bellerica, Lagerstroemia parviflorta, Dillenia pentagyna, Buchanania latifolia* and *Semecarpus anacardium.* On the ridge of the Churia hills *Pinus roxburghii* is associated with Sal. Riverine forest is composed of *Dalbergia sissoo, Acacia catechu, Trewia nudiflora, Bombax ceiba, Butea monosperma, Careya arborea, Ehretia laevis* and *Ficus* spp. Lehmkuhl (1994) has classified riverine grassland into eight different associations with ten phases. The floodplain tall grasslands are characterized by *Saccharum spontanum, S. bengalensis, Narenga porphyrocoma, Themeda villosa, Arundo donax,* and *Phragmites karka.* Short grasslands are dominated by *Imperata cylindrica, Cynodon dactylon* and *Chrysopogon aciculatum.*

Fauna

Chitwan harbours 68 species of mammals, 544 species of birds, 56 species of reptiles and amphibians, and 126 species of fish (CNP 2012). Major mammalian species of Chitwan are tiger (*Panthera tigris*), leopard (*Panthera pardus*), sloth bear (*Ursus ursinus*), gaur (*Bos gaurus*), greater one-horned rhinoceros (*Rhinoceros unicornis*), Asian elephant (*Elephas maximus*), dolphin (*Platanista gangetica*). Ungulate prey species includes chital (*Axis axis*), hog deer (*Axis porcinus*), sambar (*Rusa unicolor*), muntjac (*Muntiacus muntjak*) and wild pig (*Sus scrofa*). Globally threatened bird species include greater adjutant (*Leptoptilos dubius*), lesser djutant (*Leptoptilos javanicus*), Pallas's fish-eagle (*Haliaeetus leucoryphus*), greater spotted eagle (*Aquila clanga*) imperial eagle (*Aquila heliacal*), sarus crane (*Grus antigone*), Bengal florican (*Houbaropsisbengalensis*), Indian skimmer (*Rynchops albicollis*), white-throated bushchat (*Saxicola insignis*), Jerdon's babbler (*Chrysomma altirostre*), slender-billed babbler (*Turdoides longirostris*) and bristled grass-warbler (*Chaetornis striatus*). Important reptile species found in good numbers in the park are gharial (*Gavialis gangeticus*), marsh mugger crocodile (*Crocodylus palustris*), golden monitor lizard (*Varanus flavescens*) and Asian rock python (*Python molurus*).

Disturbance factors of ecosystem

Biotic and abiotic factors such as floods, fires, erosion, and human disturbances contribute to maintain a mosaic of grasslands, riverine forests and Sal forests in various stages of succession.

Flood

The riverine forests and grasslands along the floodplains remain water logged during the monsoon season. The rivers and streams carry large loads of sediments during flood and hence frequently change the course. Monsoon floods and river dynamism are important natural forces responsible to maintain the grasslands and riverine forest communities (Dinerstein and Price 1991).

Fire

Annual burning in Chitwan valley is an ancient human practice (Laurie 1978, Lehmkuhl 1989). The grassland and surface litter of Sal forest are burnt between January and April (Mishra 1982). Most fires are lit either by villagers or park staff (Laurie 1978) to remove outer dry layers of tall elephant grass and to get new grasses. Local people use canes of elephant grass for construction of walls and partitions in traditional houses. Early fires during January-February have little effect on shrub and grassland, but the late fires during March-April penetrate most part of the forests. Heavy fires reduce species diversity of grasses, shrubs and trees; however, the annual burning seems to maintain the grasslands from woody encroachments except *Bombax ceiba*, the only fire resistant tree (Troth 1976).

Grass cutting

Since 1978, local villagers have been permitted to enter the park each year to collect thatch grasses (Mishra 1982) and the grass cutting program (GCP) of the CNP is regarded as being very successful in gaining local people's acceptance of park. The GCP opens the park for short period (previously 14 days but now less than a week), where villagers may collect four essential products that are not available to them elsewhere, namely thatch grass (mainly *Saccharum spontaneum* and *Imperata cylindrica*) for roof, reeds (mainly tall grass species such as *Saccharum spontaneum, Narenga Porphyrocoma, Themeda* spp., *Arundo* spp., *Typha elephantine* and *Phragmites karka*), rope bark (*Helicteres isora*) and rope grass (*Eulaliopsis* *binata*). Straeds and Treue (2006) estimated that the almost 50,000 tones of biomass were removed from the Park during ten days access of grass cutting in 1999; the total gross economic value of the GCP in 1999 was more than $1 million. Illegal fuel wood was the single most important product extracted from CNP and accounted for half of the total quantity and economic value of all resources collected (Straeds and Helles 2000).

Tourism

Chitwan National Park is the third biggest tourist destination of the country; it receives more than 150 thousands visitors annually of which ca. 40% are foreigners (CNP 2012). There are more than 130 hotels and resorts in the buffer zone of Chitwan of which the majority are at Sauraha. Visitors are allowed to enter the park for jungle walk, jeep safari, elephant safari and canoeing. Some patches of the buffer zone, like Baghmara and Chitrasen community forests, including some core areas of the park, are over utilized for the tourism purposes. Some visible impacts on wildlife and vegetation have also been observed (Aryal 2005). Sauraha gets more than 70% of the visitors of the park.

Other human disturbances

There are over 1,100 regular army staff and about 300 park staff working inside the Chitwan National Park for the security and management. Similarly, there are 7 concessionaire hotels with over 700 regular staff inside the park. In addition, there are more than 120 captive elephants belonging to the park and concessionaire hotels. The captive elephants use the park for grazing and forage collection. Illegal collection of non timber forest products and grasses by the local people is common (Nepal and Weber 1993, Stræde and Helles 2000, Dinerstein 2003). Fishing activity is common in all rivers along the park border by local communities including Botes and Mushar whose livelihood is attached to the rivers. Sand mining in some river banks has posed threats to gharial crocodiles and other aquatic fauna.

Buffer zone management

The National Parks and Wildlife Conservation Act 1973 (Fourth amendment in 1993), Buffer Zone Management Regulations 1996 and Buffer Zone Management Guidelines 1999 provide a policy and legal framework for the buffer zone program. An additional area of 750 km^2 around the Chitwan NP was declared as buffer zone in 1996 with the aim of creating a protective layer for the park and to meet the resource needs of local communities (Sharma 1998). Cultivated agricultural land (46%) is the dominant land use category in the BZ followed by forest (43%), shrub land, grassland and others (DNPWC, 2000). More than 300,000 people of various ethnic communities reside in the buffer zone of which Tharus are the majority with farming as the main occupation.

The buffer zone of Chitwan spreads over 34 Village Development Committees (VDCs) and 2 Municipalities of 4 Districts (Chitwan, Nawalparasi, Parsa, Makwanpur). The main strength of the program is community based organizations. The buffer zone management committee (BZMC) is an apex body under which there are 21 buffer zone user committees (BZUC), 1 sub- committee and 1,779 user groups. The buffer zone management committee is responsible to make a buffer zone management plan and wisely use 50% of the parks' revenue that is ploughed back into the community by the government for conservation and development in the buffer zone. The committee should allocate 30% of their budget for conservation, 30% for community development, 20% for income generation and skill development, 10% for conservation education and 10% for general administration. The long-term objective of the buffer zone program is to bring the local communities into a main stream of conservation and establish a local stewardship through partnership programs. However, increasing tourism, forest encroachment, increasing demand for timber and firewood, weak law enforcement, unplanned local and national development projects in Chitwan valley are some of the challenges of buffer zone management.

Objectives

The objectives of the study were:

1. To study the seasonal nutritional ecology of rhinos and the role of invasive alien plant species in rhino food plant availability
2. To study the effect of *M. micrantha* infestation on habitat preferences of rhino
3. To estimate the population size, distribution, ranging patterns and demographic parameters of rhinos in Chitwan
4. To evaluate and prioritize between the relative impact of poaching and habitat loss due to invasive species on long term persistence of the Chitwan rhino population

Research hypotheses

I tested the hypothesis that the invasive species *M. micrantha* reduces the carrying capacity of Chitwan for rhinos. Predictions were:

a. Time spent foraging by rhino increases due to *M. micrantha* infestation.
b. Food plant availability decreases in the *M. micrantha* infested habitats.
c. Rhinos prefer habitats that have low degree of *M. micrantha* infestation for foraging.
d. Demographic parameters of the rhino would be compromised in the long run.

CHAPTER 2

Population status, structure and distribution of greater one-horned rhinoceros in Nepal, with special reference to the population of Chitwan National Park

Photo: Participants of rhino count 2011 in Chitwan National Park, Nepal.

Introduction

Mega-herbivores are globally threatened as a result of habitat conversion, fragmentation and poaching due to illegal demand of their body parts. Their populations are mostly confined in small isolated protected areas (Owen-Smith 1988, Sukumar 1989). The populations of the greater one-horned rhinoceros (*Rhinoceros unicornis,* Linnaeus 1758) (henceforth rhino) in Asia have been seriously compromised by this fate. During the fifteenth century, rhinos were abundant throughout the floodplains of the Ganges, Brahmaputra and Sindh Rivers and their large tributaries between Indo–Burmese border in the east and Pakistan in the west (Blanford 1891, Laurie 1978, Dinerstein 2003). At present, some 2,850 rhinos survive in isolated pockets of protected areas within India and Nepal (Talukdar 2010).

Rhinos suffered a catastrophic decline in Nepal during the 1960's to less than 100 individuals and all were confined to Chitwan valley. The decline was attributed to loss of habitat and poaching that resulted from conversion of Terai grasslands and forests to agriculture subsequent to a malaria eradication and resettlement programme launched by the Government of Nepal (Laurie 1978). During the 1960s over 70% of the forests were cleared in Chitwan valley alone (Dinerstein 2003, Caughley 1969, Laurie 1978). After the establishment of Chitwan National Park in 1973 and strict law enforcement the population gradually recovered to about 612 in 2000 (DNPWC 2000, Dinerstein 2003). During this period active rhino population management and reintroductions across Nepal established other populations in (a) Bardia Karnali floodplain ca. 32, (b) Bardia Babai valley ca. 35, and (c) Suklaphnata Wildlife Reserve of ca. 5 individuals. But subsequently during a decade-long armed conflict (1996 - 2005) rhino conservation in Nepal was compromised due to intense poaching, resulting in total elimination of Babai population, reducing Bardia Karnali population to 22, Suklaphanta population to 4 and Chitwan population to 372. The total population in Nepal was about 400 in 2005 (DNPWC 2005).

Being a highly K-selected species, rhinos are extremely vulnerable to extinction due to deterministic factors such as poaching (Poudyal *et al.* 2009). Therefore, to evaluate the effectiveness of conservation activities, regular monitoring of population status is essential for adaptive management.

White (*Ceratotherium simum*) and black (*Diceros bicornis*) rhinos in various parts of Africa have been monitored and population estimation done using individual identification based on body scars, horn shapes and sizes, and other identifying distinct body features (Kiwia 1989, Conway and Goodman 1989, Walpole *et al.* 2001, Patton *et al.* 2007), radio tagging (Galli and Flamand 1996), spoor (Alibhai *et al.* 2008) and camera traps (Stein *et al.* 2010). Aerial counts with fixed winged and helicopters using multiple observers (Ngene *et al.* 2011, Brockett 2002) as well as water hole counts with photographs (Cilliers 1989) have also been used to monitor and estimate population sizes. The precision and accuracy of different methods were tested against known population size for black rhinos in and Etosha National Park (Cilliers 1989) and Kruger National Park (Ferreira *et al.* 2011), and aerial surveys were found to consistently underestimate the actual population. The direct applicability of these methods to the greater one-horned rhinoceros in Terai habitats is questionable (Laurie 1978, Dinerstein and Price 1991). The methods used in Nepal are a combination of several used in Africa with local modifications. In low rhino density areas such as those found in Bardia National Park, Suklaphanta Wildlife Reserve and parts of Chitwan National Park, individually identified (ID-based) rhinos are intensively monitored by regular patrols that are needed for their protection (Amin *et al.* 2006). In high density areas of Chitwan National Park parallel strip counts from elephants are conducted for obtaining total counts similar to aerial block counts done in Africa (*e.g.* Brockett 2002). The tall grass and closed canopy forests of the Terai make the aerial surveys impractical while elephants can easily negotiate this habitat and provide vantage points to detect and count rhinos (Laurie 1978, Dinerstein and Price 1991). On the other hand, captive elephants are readily available in Nepal and regularly used for patrolling.

Herein, we report the status of rhinos in Nepal in 2011 using a total block count method across all rhino habitats. The block count method does not explicitly account for imperfect detections. Imperfect detection may be a minor problem for large bodied animals like the rhinos which are surveyed with a large, planned, and well designed effort as done in Nepal. However, we test this assumption within an intensive study area where we compare rhino population estimate obtained by block counts with estimates obtained by (a) intensive long-term monitoring based on individual identity (ID-based) and (b) closed population sighting-mark-resighting (SMR) that explicitly accounts for imperfect detections.

Study sites

The study covered the current distribution of rhinos within all potential rhino habitats in Chitwan National Park (27°30'N, 84°20'E); Bardia National Park (28°30'N, 81°15'E) including the narrow strip of ca. 13 km long Khata forest corridor along the Geruwa River which connects Bardia with Katarniaghat Wildlife Sanctuary in India; and Suklaphanta Wildlife Reserve ((28°45'N, 80°06'E) (Figure 2.1).

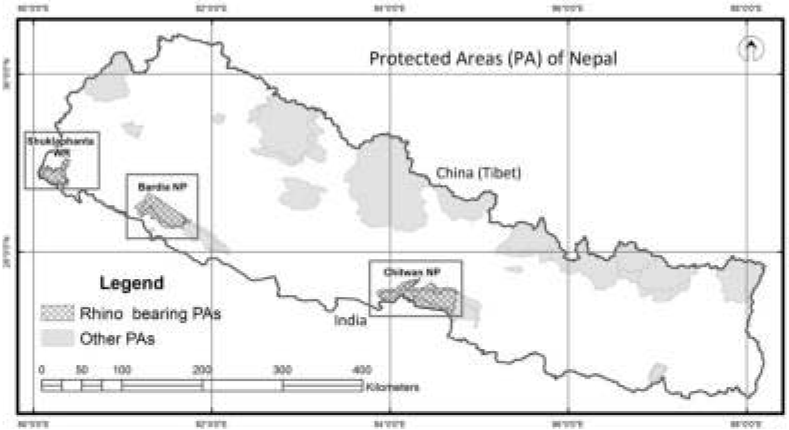

Figure 2.1. Protected areas that were surveyed for estimating the population of greater one-horned rhinoceros (*Rhinoceros unicornis*) in Nepal. These sites are the only known areas where rhinos occur in Nepal.

Chitwan National Park (Henceforth Chitwan) covers an area of 932 km^2 and is located in south central Nepal. The climate is subtropical monsoonal type with three distinct seasons: monsoon (June – October), cool-dry (October – February) and hot-dry (February – June). Average yearly temperature ranges from a minimum 9^{o}C in January to maximum temperature of 36^{o}C in May. Chitwan gets average 2,400 mm of rainfall per year, 90% of which falls in the monsoon season (Dinerstein, 2003). Chitwan harbors 68 species of mammals, 544 species of birds, 56 species of reptiles and amphibians and 126 species of fish (CNP 2012). Tiger (*Panthera tigris*), gaur (*Bos gaurus*), greater one-horned rhinoceros, Asian elephant (*Elephas maximus*), leopard (*Panthera pardus*), sloth bear (*Melursus ursinus*), sambar (*Rusa unicolor*) and chital (*Axis axis*) are major mammals. General vegetation types of Chitwan are described in Bolton (1975), Laurie (1978) and Mishra (1982).

Bardia National Park (henceforth Bardia) is the largest park in the south western lowland Nepal and covers an area of 968 km^2. The flora, fauna and climate is similar to Chitwan but it receives less rainfall. Eighty three rhinos were reintroduced in Bardia (13 in Karnali floodplain and 70 in Babai valley) from Chitwan between 1986 and 2003 to create a second rhino population in Nepal (DNPWC 2009, Dinerstein 2003). The details and establishment of the reintroduced rhinos is available in Jnawali and Wegge (1993), Jnawali (1995) and Dinerstein (2003).

Suklaphanta Wildlife Reserve (henceforth Suklaphanta) is located in far western lowland Terai and covers an area of 305 km^2. Suklaphanta is drier than Chitwan and Bardia with 1,300 to 2,300 mm of rainfall annually. It has 24 species of mammals, 350 species of birds and 14 species of fishes (DNPWC 2009). The rhino population was supplemented in 2003 with the translocation of 4 animals from Chitwan to add to one resident rhino which was first sighted and reported in 1995, possibly migrated from Dudhwa National Park, India (DNPWC 2009). More than 70% of the reserve is covered by Sal (*Shorea robusta*) forest; the remaining is mainly extensive grasslands and patches of riverine forests.

Methods

Block count method

We conducted the rhino census in April 2011 when visibility conditions were most suitable following the annual burning of the tall grasslands and leaf shedding of deciduous trees (Dinerstein and Price 1991). The survey covered all potential rhino habitats in Chitwan (503 km^2) including Barandabhar forest corridor and 86 km^2 in Bardia including Karnali floodplain and Khata forest corridor which is contiguous with Katerniaghat Wildlife Sanctuary of India. In Suklaphanta the census was not done as the small population of 7 rhinos was individually known through a regular ID-based monitoring program.

We used a block count method wherein simultaneous elephant-back parallel strip transects were used to survey the blocks (DNPWC 2009). We divided all potential rhino habitats into 11 to 75 km^2 size blocks based on physical features that likely curtailed short-term movements of rhinos using a topographic map (scale 1:25,000) and reconnaissance surveys (Figure 3 and 4). A block bounded by streams, ridges and Sal forest (Laurie 1978, Dinerstein and Price 1991) was considered a sampling unit and was surveyed in a single day. Block surveys were conducted from east to west in Chitwan and south to north in Bardia.

We used 40 elephants in Chitwan and 15 elephants in Bardia to survey each block systematically. The total census comprised 19 days in Chitwan, and 5 days in Bardia with a search effort of 3,548 elephant hours. A total of 5,497 km of systematic survey effort was conducted, consisting of 4,854 km in Chitwan and 643 km in Bardia. Each elephant had a trained observer and elephant *Mahut* on the back. Elephants were lined up and moved parallel along transects at a spacing of 50 m in dense forests and 100 – 200 m in open grasslands moving at an average speed of 1-2 km per hour. Each elephant team was equipped with a camera, datasheets, hand held GPS (Garmin ETrexH, Taiwan) loaded with each day's transect track and a wireless radio handset (Kenwood ProTalk TK 3200U8P, China) for navigation and coordination.

To prevent animals from being double counted during the block count, rhinos sighted along transects were recorded only after they had been pushed behind the line of elephants. All rhino sightings were communicated by wireless radio sets and observers from adjacent transects confirmed the rhino sightings. We minimized double counts by the above-mentioned coordination and by recording the GPS coordinates, time of sighting, habitat type, group size, movement direction of the rhino, and its age and sex along with any distinguishing features and photographs when possible. The age of the rhinos were categorized as calf, subadult and adult (Laurie 1978). Fifty five observers participated in the survey and all of them were previously trained in rhino survey techniques and tested for consistency in ageing and sexing. If stage and sex was not 100% confirmed it was recorded as unsexed and unaged. The entire team of observers, *Mahuts* and coordinators was debriefed each evening and potential double counts corrected and data compiled for the surveyed block to arrive at conservative estimates.

Validating block counts

Block count method assumes a detection probability equal to one resulting in a total count of rhinos. Due to large body size of the rhino, its nature of moving when approached and the intensive survey effort invested by us, this assumption was likely close to the truth. However, we checked the validity of the assumption by comparing the population estimate obtained by (a) long-term ID-based monitoring of individual rhinos in Sauraha study area of 214 km^2 within Chitwan (block 1-5, fig 2) and the Karnali floodplain population of Bardia (86 km^2) and (b) closed population sighting-mark-resighting (SMR) population estimation conducted just prior to the block count within Sauraha study area of 214 km^2 in Chitwan.

Most rhinos are identified individually from well recognized features such as horn shapes, folds and body marks (Laurie 1982, Dinerstein and Price 1991). We have been monitoring rhinos by individual identification on a weekly basis in the study areas for the past three years. *Mahuts* and senior wildlife technicians from National Trust for Nature Conservation (NTNC) routinely search and record individual rhinos whose profile protocol includes full body photographs highlighting distinguishing characteristics, sex, age and information about locations and associated rhinos (Conway 1989, Walpole *et al.* 2001, Amin *et al.* 2006). Few rhinos, mainly subadults, do not have any recognizable features. However, these constitute only 2 - 5% of all sightings and such individuals were distinguished from others by their location and range use, as well as from associated identified rhinos. This intensive and extensive monitoring allowed to know the total population using our study areas with reasonable certainty (Walpole *et al.* 2001).

Two weeks prior to the total count exercise, we conducted a sighting-mark-resighting based population estimation using information on individually identified rhinos in Sauraha subpopulation of Chitwan. We divided the area into 1 X 1 km grids which were intensively searched by 13 elephants, each with two observers. The entire area was covered within a period of 4 days, which constituted an occasion. We invested equal search effort within each grid. Three complete coverage searches (occasions) were completed within 12 days (726 elephant hours) so as to ensure population closure. On sighting of a rhino, the observers either identified it based on a photo catalogue that they carried and/or they took photographs, which were then later used to identify the animal. The data over the three occasions were then organized in a 'X' capture matrix and analyzed in program CAPTURE (Otis *et al.* 1978) to arrive at a population estimate. Population closure was formally tested using program close test (Stanley and Burnham 1999, Otis *et al.* 1978).

The population estimate obtained by total block counts and from intensive monitoring based on photo profiles of individually identified rhinos was then compared with the population estimate obtained by SMR analysis by generating a 95% confidence interval (CI) on SMR estimate and checking if point estimates of block count and intensive ID-based estimate were within the CI or not.

Results

Abundance and distribution

The 2011 survey recorded a total of 503 rhinos in Chitwan, 24 rhinos in Bardia, and 7 rhinos in Suklaphanta, giving a total rhino population of 534 animals for Nepal (Table 2.1).

Table 2.1. Population status and structure of rhinos (*Rhinoceros unicornis*) in Nepal in April 2011.

Protected area	Age-group	Female	Male	Unidentified	Total
Chitwan National Park	Adult	157	126	49	332
	Subadult	14	9	37	60
	Calf	12	10	89	111
	Total	183	145	175	503
Bardia National Park	Adult	7	4	4	15
	Subadult	1	0	3	4
	Calf	1	1	3	5
	Total	9	5	10	24
Suklaphanta Wildlife Reserve	Adult	2	2	0	4
	Subadult	0	0	2	2
	Calf	0	0	1	1
	Total	2	2	3	7
Total for Nepal		194	152	188	534

In Chitwan, 48 animals (9.54%) were recorded outside the park in community forests and Barandabhar forest corridor (Figure 2.2). Altogether in Chitwan, 44% of the rhinos were found in tall grasslands, 37% in riverine forest, 7% in wetland, 7% in short grasslands and 5% in Sal forest. The highest concentration of rhinos was in block 8 and 9 (Sukhibar to Temple tiger) (Table 2.2). This area of 48 km^2 holds 46.5% of Chitwan rhinos. The density and encounter rate in Sukibhar area was 5.6 individuals/km^2 and 0.32/km respectively. While in the far eastern corner i.e. block 1 and 2, the density and encounter rate was lowest at 0.02/km^2 and <0.01/km respectively.

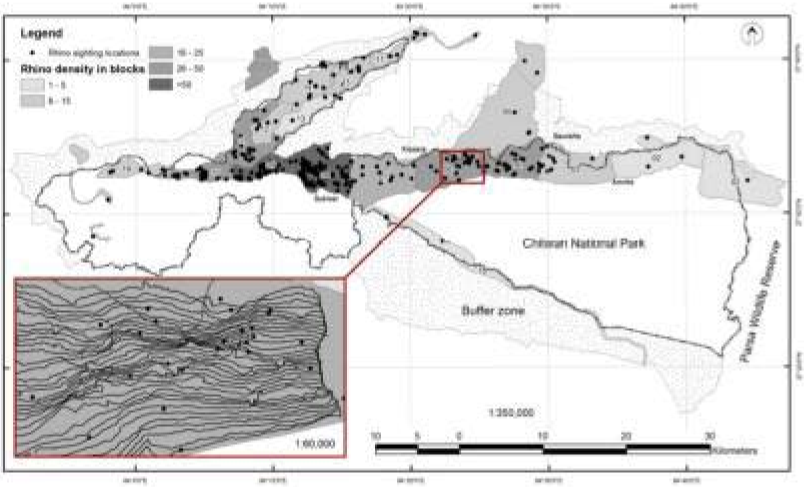

Figure 2.2. Rhino (*Rhinoceros unicornis*) distribution and density (rhinos/km^2) gradient in Chitwan in 2011 as determined by elephant-back block counts. The inset figure shows track plots of elephant-back survey lines within part of block 6 of Chitwan National Park, Nepal.

Table 2.2. Block size, rhino (*Rhinoceros unicornis*) number, density and encounter rate in different count blocks of Chitwan National Park in April 2011.

Block number	Name of the block	Number of rhino	Block size (km²)	Searched efforts (km)	Density/ km²	Encounter rate/km
1	Sunachuri, Harda	1	46.3	318	0.02	<0.01
2	Harda, Amrite, Kuchkuche	4	34.9	310.8	0.11	0.01
3	Amrite, Marchauli, Icharny	19	33.5	392.4	0.57	0.05
4	Barandabhar corridor	7	24.9	517.5	0.28	0.01
5	Marchauli, Dumaria	46	74.7	235.2	0.62	0.2
6	Dumaria, Kasara	34	31.6	265.6	1.07	0.13
7	Kasara, Kamaltal	17	38.7	273	0.44	0.06
8	Sukibhar, Rapti-Reu junction	164	29.3	510.7	5.6	0.32
9	Reu-Khoraimuhan,	70	17.9	197.7	3.9	0.35
10	Khoria, Temple tiger	43	12	195	3.58	0.22
11	Gharial island, Lamichur, Kawasoti	26	38.5	238.1	0.67	0.11
12	Gharial island, Bhorsaghat	10	11.7	183.5	0.86	0.05
13	Bhagedi, Seri, Tamsapur	3	15.1	246.2	0.2	0.01
14	Main island of Bandarjhula	13	20	222.2	0.65	0.06
15	Bhorsaghat, Kujauli	12	10.5	132.7	1.12	0.09
16	Mardighol, Gajapur	8	4.9	126.1	1.63	0.06
17	Kujauli, Sikrauli	11	11.6	258	0.95	0.04
18	Madi, Thori	4	27.7	119.5	0.14	0.03
19	Seri, Tribeni	11	19.2	75	0.57	0.15
	Grand total	503	503	4,817		

Twenty four rhinos were found in Bardia and all of them were confined to the Karnali floodplain. Out of which two were outside the Park within Khata forest corridor (Figure 2.3). Sixty five percent rhinos were recorded in mixed riverine forest and 35% in the floodplain tall grasslands in Bardia. No rhinos or their signs were found in the Babai valley.

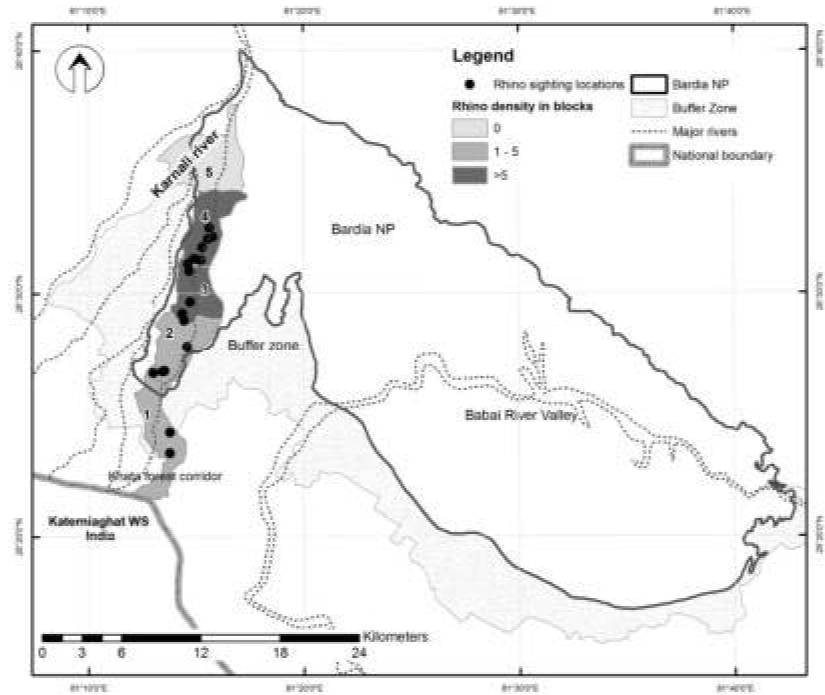

Figure 2.3. Rhino (*Rhinoceros unicornis*) distribution and density (rhinos/km^2) in 2011 as determined by elephant-back block counts in Bardia National Park, Nepal.

In Suklaphanta, seven rhinos were found distributed along the Chaudhar and Mahakali river floodplains (Figure 2.4). Out of which four were in mixed riverine forest and three were in tall grasslands.

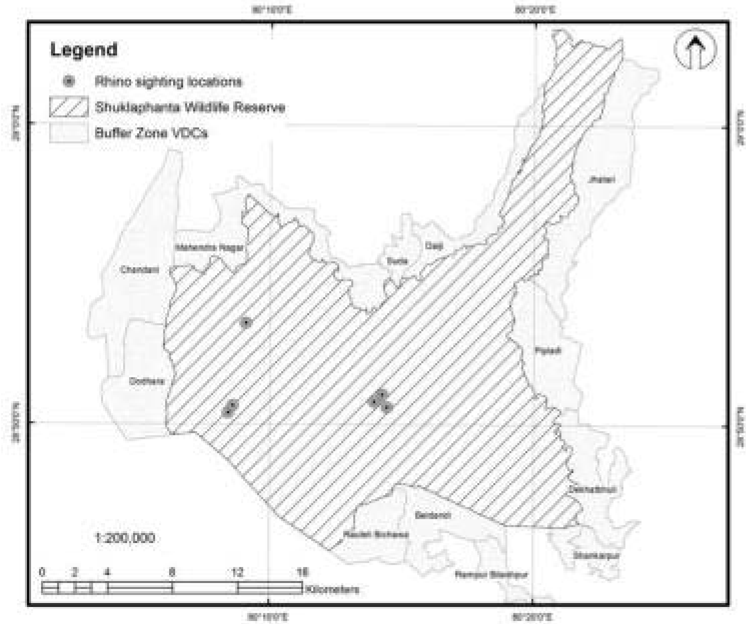

Figure 2.4. Rhino (*Rhinoceros unicornis*) distribution in Suklaphanta Wildlife Reserve, Nepal.

Comparison of three different abundance estimation methods

The total rhino population estimated by the block count method in the Sauraha study area of Chitwan was 77 (block 1-5, table 1.2) and the population was 24 rhinos in the Karnali floodplain of Bardia (Table 1.1).

Based on the long-term ID-based monitoring of rhinos in the Sauraha study area (block 1-5) we made a profile of 67 individually identified rhinos and 5 subadults with photos but not having clear features for identification. These subadult rhinos were considered to be unique individuals based on temporal and spatial separation during sightings, as well as simultaneous sighting of two to three individuals in the same group. Also, there were 3 individually identifiable adult rhinos that occasionally used the study area. Based on this long-term information, between 72 and 75 animals were known to occupy the Sauraha study area at any one time. The intensive ID-based monitoring gave a population estimate of 23 known rhinos in the Karnali Floodplain of Bardia.

During the SMR exercise in Sauraha study area of Chitwan we obtained 168 rhino sightings of 66 unique ID individuals and 5 non-ID individuals. The population closure tests revealed that the assumptions of a closed population was not violated ($\chi^2 = 0.85$, $p = 0.35$, Stanley and Burnham (1999), closure test; $p = 0.99$, $z = 2.88$, Otis *et al.* (1978) closure test). The best model selected by CAPTURE was model Mh that incorporated individual heterogeneity in capture probabilities ($p = 0.81$). The population in intensive study area was estimated at 66 with a 95% confidence interval of 66 to 81 rhinos. Since the population of non-identifiable rhinos in the study area was known to be 5, the 95% confidence interval on the total population estimate was adjusted to be between 71 and 86 rhinos. The intensive ID-based monitoring and closed SMR population estimates were statistically similar but marginally lower than block count estimate.

Population structure

Out of the 503 rhinos recorded, 66% were adults, 12% subadults and 22% calves in Chitwan (Table 1.1). Thirty five percent of the adult animals could not be sexed. Among those that were sexed the adult female to male ratio was 1.24 (N = 283) for the Chitwan and 1.75 (N = 17) for Bardia. In Chitwan 60% of the adult females had calves and 55% had calves in Bardia. Bardia population had 62% adults, 21% subadults and 17% calves. Likewise Suklaphanta with as low as 7 individuals 3 were male and 4 were females. Out of seven 2 were subadults, 1 calf and 4 adults.

Discussion

Population structure and distribution

The female to male sex ratio for rhinos was 1.58 in 1988 (Dinerstein and Price 1991), while the ratio was found 1.24 in 2011. It indicates a slight increment of male proportions in the population compared to previous studies. In 1975, there were 52.2% adults, 21.2% sub-adults and 26.6% calves (Laurie 1982), and the population structure was similar in 1988 and 1994 (Dinerstein and Price 1991, Yonjon 1994). The maximum proportion of adults was recorded (68.75%) in 2005 and it was 66% during present study. The maximum proportion of adults in chitwan rhino population during 2005 was likely due to high poaching of breeding females in 2002 and 2003. The gradual increment of the male proportion in Chitwan may also be attributed to male biased births in rhinos (Lang *et al.* 1977) and removal of more females for reintroductions and captive breeding. A total of 103 individuals were removed from Chitwan for conservation breeding and reintroduction after 1984 of which over 70% were females (NTNC unpublished data). However, the population structure of different years (1975 to 2011) was not statistically different ($\chi^2 = 16.3$, df = 12, p = 0.18).

Out of 503 rhinos recorded in Chitwan, 9.54% were located outside the park and were residing in Barandabhar forest corridor and community forests in the buffer zone. Dispersal of rhinos outside the park is a challenge for security but is also an opportunity for partnership with local communities in rhino conservation. Some of the community forests earn good amount of money from nature based tourism (Bookbinder *et al.* 1998). Because of strong community engagement in rhino conservation in the buffer zone and the corridor, poaching has been sharply reduced in these areas. However, the security of these rhinos and the human-rhino conflict is a constant challenge for park management.

Temporal and spatial distribution of rhinos was found to be changing in Chitwan. Long-term data clearly show a continuous decline of Sauraha subpopulation after 1988. From as many as 252 rhinos in Sauraha (east of Kasara) during 1988 (Dinerstein and Price 1991), the population has steadily declined to 128 in 2011 (49%). However, the rhino population west of Kasara in Chitwan is gradually increasing. The reasons for the decline in Sauraha could be: (i) Removal of 65 rhinos from the Sauraha subpopulation between 1984 and 2003 for reintroductions and captive breeding (DNPWC 2009 and NTNC unpublished data), (ii) Out of the total poached rhinos (N = 171, 1998 - 2010), 48% of the animals killed were from this small area in Chitwan. About 60% of the poachers arrested from Chitwan valley were from villages close (ca. 20 km north) to Sauraha (NTNC unpublished data). Therefore, we suspect even higher pressure from poaching in this area than actually recoded especially during the period of armed conflict. (iii) Annual monsoon floods are responsible for maintaining prime grazing habitat and high population densities in Chitwan (Laurie 1978, Dinerstein and Price 1991). This phenomenon has been obscured after the establishment of a 9 km long dyke along the northern bank of Rapti River between Kumrose and Lothar during 1990s. This has resulted in a channelized river flow in place of a meandering, silt depositing flow. Due to this the productivity of the floodplain grasslands and distribution of oxbow lakes in the Sauraha block (east of Amrite) has been impacted, possibly lowering the carrying capacity for rhinos.

The declining trend of Sauraha subpopulation can be turned around by applying the principles of biological management. The fastest option to increase the population would be by translocation of some individuals from the western subpopulation of Chitwan to Sauraha. This should be done after a careful study to narrow down the causes of decline and ensure that these factors are controlled through active habitat management and antipoaching activities. On the other hand, the population at Suklaphanta is too small and therefore demands immediate actions by further supplementation of some individuals. For Bardia, studies on habitat availability, population performance and security threats are needed to provide scientific inputs for decision making regarding further supplementation of rhinos. In Babai valley of Bardia 70 rhinos were released between 1991 and 2003 and all of these were poached during armed conflict (DNPWC 2009). Some of the Bardia rhinos have dispersed to India towards Katerniaghat Wildlife Sanctuary (DNPWC 2009, Jnawali 1995) through the Khata forest corridor which still serves as a functional corridor for movement of rhinos, elephants and tigers between Nepal and India connecting the large transboundary Terai Arc Landscape (Jhala *et al.* 2011). Some 4 to 6 individuals were reported in Katerniaghat Wildlife Sanctuary at the time of count (Ramesh Thapa, pers. comm.).

There has been no recorded rhino poaching in 2011 across Nepal. Current integrated antipoaching strategy *i.e.* intensive strategic patrolling, rhino monitoring in the core areas, activation of effective intelligence network and arrest of criminals through Wildlife Crime Control Bureau (WCCB) by coordination among all security agencies, seems to be effective for the time being. More than 150 poachers were arrested across Nepal and imprisoned between 2010 and 2011 (DNPWC 2011a). However, poaching can escalate at any time and is correlated with periods of political instability like between 2001 and 2005. Currently, Nepal is in a period of political transition and therefore the poaching threat is prominent. On the other hand, habitat degradation due to recent infestation by *Mikania micrantha*, which has seriously invaded more than 15% of the prime rhino habitat, as well as succession of tall grasslands to woodlands have the potential to reduce carrying capacity and also to retard population growth (DNPWC 2009). Yet, proportion of 60% breeding age females having calves as recorded in Chitwan, is a good indicator of a healthy growing population especially for highly k-selected species like the rhino.

Comparison of different methods of population estimation

Tall grasslands and dense riverine forests of Terai makes aerial count and transect count used for estimating rhinos in Africa inefficient in Nepal (Laurie 1978). Identification and photo registration of each individual is one of the most reliable methods for carrying out rhino population estimation (Laurie 1978, Kiwia 1989, Conway and Goodman 1989, Dinerstein and

Price 1991, Walpole *et al.* 2001). We compared the results of block count with those obtained from intensive ID-based monitoring and with statistically robust SMR methods. Though the block count estimate was marginally higher than ID-based estimates but it was within the 95% confidence interval of the SMR estimate. We believe that the small but consistently higher estimate of block count in comparison to long-term ID-based estimate was due to movement of rhinos from the counted block to neighbouring blocks. This was likely as rhinos were disturbed by elephant movement and census activity within the block being counted. In the future, by delineating blocks with less porous boundaries, such movements outside the counted block could be minimized lending greater accuracy of block counts. Based on our data we conclude that the three methods provide comparable estimates of rhino population size for all practical purposes.

Intensive ID-based monitoring method needs relatively long time (over a year) for the preparation of profile of individual rhinos when the population is larger (>300). But it can be effectively done for small populations (<100) within a couple of months. The total block count method which demands higher resources is quick but needs greater precautions and planning to avoid double or under counts. As most of the guard posts have captive elephants for patrolling and wildlife monitoring within rhino bearing protected areas of Nepal, intensive ID-based rhino monitoring is feasible and is important to deter the poaching.

We propose a monitoring system wherein countrywide status is obtained by combination of all three methods used herein. Since rhinos are vulnerable to poaching a three years time gap between subsequent monitoring may be too long for adaptive management. Therefore, we propose that certain important and representative populations are intensively monitored annually using the SMR design that relies on the ID-based system. The SMR design provides the much needed statistical rigour for estimating rhino populations in Nepal, and can be readily adapted to estimate black and white rhinos in various parts of Africa as well where ID-based profiles are available.

CHAPTER 3

Seasonality in the nutritional ecology of greater one-horned rhinoceros in Chitwan National Park, Nepal

Photo: Counting bites from elephant back while rhinos are feeding.

Introduction

The greater one-horned rhinoceros (*Rhinoceros unicronis*), henceforth rhino, was once widely distributed across the floodplains of Ganges, Brahmaputra and Indus rivers from Pakistan in the west to Myanmar in the east. However, their distribution is now limited on isolated protected areas of India and Nepal (Laurie 1978, Dinerstein and Price 1991, Jnawali 1995). There are now 534 rhinos in Nepal (DNPWC 2011) and about 2,300 rhinos in india (Talukdar 2010). Because of its population recovery especially in Kaziranga it has been down-listed from endangered to vulnerable on IUCN's conservation priority (IUCN 2008). But due to the ever looming poaching threat because of high illegal demand and price for the horn the rhino is retained as a schedule-I species in Nepal under the National Parks and Wildlife Conservation Act 1973 and is of national and international importance.

Previous research on free-ranging rhinos include ecology and behaviour (Laurie 1978 and 1982), demography and habitat use (Dinterstein and Price 1991), genetic variation (Dinerstein and MCcracken 1990, Zschokke *et al.* 2011), rhino and plant interactions (Dinerstein and Wemmer 1988, Dinerstein 1989, Dinerstein 1992), capture, chemical immobilization and radio collaring (Dinerstein *et al.* 1990), human-rhino conflict (Jnawali 1989), dry season diets (Steinheim *et al.* 2005), feeding ecology and ranging behavior of donor and newly re-established population (Jnawali 1995), ecological and economic analysis of poaching (Poudyal *et al.* 2009), demographic structure, activity patterns, habitat use and food habits (Kandel and Jhala 2008) and feeding ecology of Asian elephant (*Elephas maximus*) and rhino (Pradhan *et al.* 2008). Dinerstein (2003) summarizes most of the publications and field experiences and provides in-depth historical and ecological information on rhino along with its successful recovery through public engagement in Nepal.

Wildlife nutritional ecology has received greater attention in the recent years as it provides an understanding of specific biochemical and biophysical interactions critical to the survival and productivity of individuals and populations (Robbins 1993). Only few research on digestive physiology and feed digestibility (Clauss *et al.* 2005a), energy, mineral nutrition and water intake (Clauss *et al.* 2005b) in the captive greater one-horned rhinoceros are available. More scientific publications are available on African white (*Ceratotherium simum*) and black (*Diceros bicornis*) rhinoceros. For example: mineral status of free ranging and captive rhinoceros (Dierenfeld *et al.* 2005), mineral absorption (Clauss *et al.* 2007a), digestive performance (Clauss *et al.* 2006) of captive black rhinoceros as well as dietary tannin supplementation on this performance (Clauss *et al.* 2007b), dry season food and nutrient intake by wild white rhino (Shrader *et al.* 2006). Similarly, chemical content analysis of browse species of black rhino (Ghebremeskel *et al.* 1991, Joubert and Eloff 1971, Loutit *et al.* 1987, Hall- Martin *et al.* 1982; Dierenfeld *et al.* 1995) and diet comparison of free ranging and captive black rhino (Helary *et al.* 2009) are also available. In contrast to the African species, studies on the seasonal nutritional ecology of free-ranging greater one-horned rhinoceros are lacking. Moreover, understanding the nutritional context of habitat degradation due to invasive plant species like *Mikania micrantha, Lantana camara* and *Chromolaena odorata* on rhinos and other herbivores is of immense importance for conservation management of these species. It is possible that these invasive plants impact population performance of rhinos. Rhinos are bulk feeders and have the capacity to tolerate low quality foods compared to small ungulates (Owen-Smith 1988). However, white rhinos are reported not to compensate for seasonal declines in food quality by adjusting food intake or diet breadth; rather they mobilize body fat to meet their nutritional needs during the dry season (Shrader *et al.* 2006). To understand the seasonal nutritional ecology of rhinos we conducted a two years study (2010 – 2012) on 8 focal animals by continuously monitoring them with the aid of radio-telemetry from the elephant back in different seasons. The following questions were specifically evaluated:

i) What habitats do the rhinos use in different seasons?

ii) What do the rhinos eat from these habitats in different seasons and how do the nutrient contents differ across seasons?

iii) How much do the free-ranging rhinos eat in a day? Like African rhinos, do the greater one-horned rhinoceros exhibit seasonality in their nutritional ecology and to what extent?

Study Area

The study was carried out in eastern sector of Chitwan National Park (27°30'N, 84°20'E). The park covers an area of 932 km^2 of south central Nepal. The climate is subtropical monsoonal type with three distinct seasons: monsoon (mid June –mid October), cool-dry (mid October – mid February) and hot-dry (Mid February – mid June). Average yearly temperature ranges from a minimum 9^0 C in January to maximum temperature of 36^0 C in May. Chitwan gets average 2400 mm of rainfall per year, 90% of which falls in the monsoon season (Dinerstein 2003). Chitwan harbors 68 species of mammals, 544 species of birds, 56 species of reptiles and amphibians and 126 species of fish (CNP 2012). General vegetation types of

Chitwan are described in Bolton (1975), Laurie (1978) and Mishra (1982). The vegetation is subtropical, ranging from early successional floodplain communities along the Rapti, Reu and Narayani rivers to mature climax Sal (*Shorea robusta)* forest on the upper and drier areas. Sal forest covers 70% of the park, 15% by tall grasslands and remaining by riverine and other forest types (Dinerstein 2003).

The intensive study area (Figure 3.1) consists of a mosaic of habitats dominated by mixed riverine forests, tall grasslands, riverbeds, wetlands and short grasslands. The tall grasslands are characterized by *Saccharum spontaneum, Saccharum bengalensis, Phragmites karka* and *Narenga prophyrocoma* while the short grasslands are dominated by *Imperata cylindrica, Cynodon dactylon* and *Saccharum spontaneum*. *Trewia nudiflora* and *Bombax ceiba* are the dominant species of mixed riverine forest while *Litsea monopetala, Ehretia laevis, Myrsine chisia, Murraya koenigii* and *Ficus racemosa* forms the mid layer of the canopy. The ground layer is formed by *Callicarpa macrophylla, Colebrookia oppositifolia, Coffea bengalensis, Pogostemon bengalensis, Clerodendron viscosum* and short grasses. The area is mostly used for tourism and local communities are also allowed for grass cutting in the fringe of the park. Annual fire is a phenomenon of the south Asian tall grasslands (Lehmkuhl 1989) and about 45% of the study area gets burnt annually between January and April. The intensive study area also encompasses an area of 18 km^2 of recently evacuated Padmapur village (now is mostly tall grassland) from where 1,928 households consisting of 11,037 people were relocated between 1995 and 2004 (Dhakal *et al.* 2011).

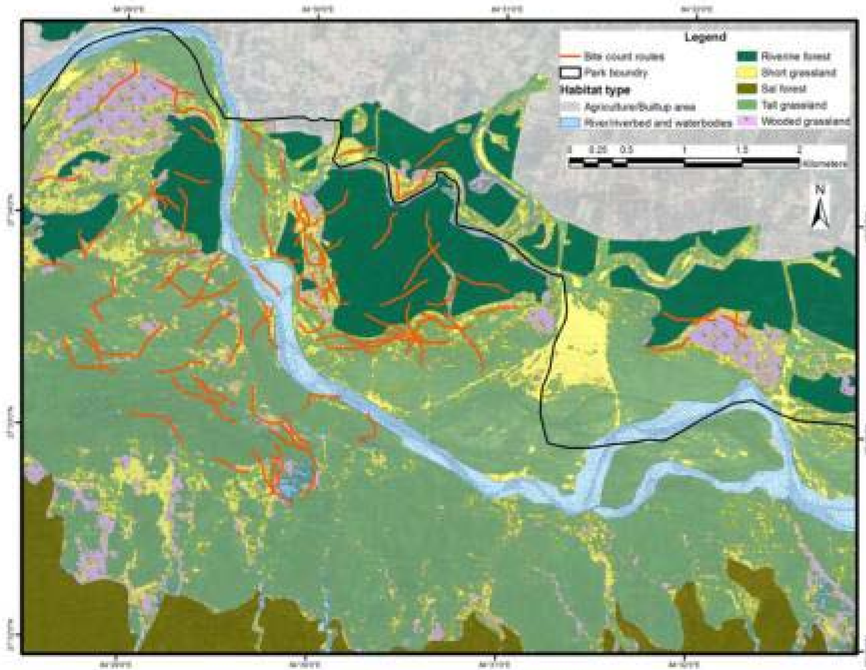

Figure 3.1. Map of intensive study area showing different habitat types and bite count tracks of rhinos.

Methods

Bite rate and bite weight

I sampled eight adult radio-collared rhinos (2 males, 6 females) as focal animals (Altmann 1974) to obtain seasonal feeding data. These rhinos were habituated with captive elephants (Laurie 1978, Dinerstein and Price 1991) and could be approached up to 5 m distance when required without disturbing their normal behavior. The focal animals were observed in the morning, mid day, evening and night while they were feeding in different habitats. Most of the time two observers observed from the elephant back. One observer recorded number of bites, time duration and species eaten on the dicta-phone recorder while the other assisted on confirming the species, and logging the GPS tracks of rhino. Binocular (8x50) was used if needed to confirm the grass species eaten. The bite count events lasted from 2 to 60 minutes based on the duration of the feeding bout.

Once the bite count was over the observers got off from the elephant and followed the rhino's tracks; and then mimicked the rhino's bites by hand simulation. Ten bites of each food species were kept in a separate poly bag and fresh weight of bites was recorded through standard digital weighing machine. The bites were brought to the field camp and oven dried at 50^{0} C in paper bags to constant weights. The dried samples were kept in air tight box with silica gel for chemical analysis. Chemical analysis was done by the end of each season to avoid quality deterioration of the dried plant samples. Only the species contributing more than 5% of the total bites were taken for chemical analysis.

I trained and tested all field assistants (n = 4) for 3 days prior to the real data collection for consistency in recording bites, behavioral sates and events and identifying plant species eaten by rhinos.

Computing seasonal dry matter intake (DMI)

Each rhino was followed from elephant back for 1 to 3 sessions (days) continuously for 24 hours in each season in a relay system where elephants and observers were changed after 6 hours to avoid observer/elephant fatigue. Continuous monitoring was mostly done during full moon and night vision equipment was used to observe and record various activities. During continuous monitoring, data on time spent foraging in each habitat, number of bites on each species eaten, number of defecations and their weight, number of urination, and behavioral activities of the rhinos were recorded (see chapter 4 for details on behavior).

Bite counts ranging between 30 and 1,500 were recorded from eight radio-collared rhinos (Wallmo and Neff 1970, Altamann 1974) in each season in each habitat. The seasonal aggregate of the total number of bites recorded for each food item in each habitat was multiplied by the proportional foraging activity of radio-collared rhinos in that habitat type. This provided a measure of the proportional contribution of different food item bites to the rhino diet from each habitat type (Hobbs *et al.* 1981, Jhala 1997). Bite rate, *i.e.* the average number of bites taken from a particular food plant species, was estimated from the data collected during observations and recording of bite counts. These observation bouts lasted from 2 to 60 minutes, during which time all food items consumed were recorded.

The proportion of bites of a food item were multiplied by the bite rate (average number of bites per minute for that food item) to obtain the proportion of time spent by the rhino for feeding of the food item. Total time spent foraging on a food item was obtained by multiplying the proportion time by total hours spent foraging in that habitat type by a rhino.

By multiplying the total time spent by a rhino on a food item by the bite rate I obtained an estimate of the total number of bites of a particular food item that a rhino takes in a day. Total numbers of bites of a food item were converted to dry matter intake of that food item by multiplying with dry weight per bite for that season.

Summing all the dry matter ingested across all food items eaten provided me with an estimate of total dry matter intake by a rhino during the 24 hour cycle (1 day).

Estimation of total fecal output (TFO) and defecation rate

I followed radio-collared rhinos from elephant back continuously for 24 hours sessions ($n = 21$) in different seasons to record the number of defecations and urinations. Average defecation rate for each season was then obtained.

Total fecal output (TFO) was estimated by weighing the fresh dung of focal animal during the continuous monitoring period. Once the focal animal defecated the fresh dung weight was weighed and part of the defecation (1-2 kg) excluding external dusty layer was collected in a poly bag. The dung samples were then dried at 40 to 50^{0} C to constant weight, and kept for chemical analysis in air tight box. Similarly, to find out the relation between fresh and dry weight of the dung I oven dried 7 samples (weight ranging from 50 gm to 1500 gm) of fresh dung at 90^{0} C to constant weight in each season. A simple linear regression equation was then derived to convert all fresh dung weights into dry weights for each season.

Chemical analysis of food plants and dung samples

By the end of a season all the dried bite samples of food plants and dung were ground and sieved through a 0.5 mm mesh. Sixty grams of ground forage powder was taken for chemical analysis. Chemical analysis was done at Animal Nutrition Laboratory of Nepal Agricultural Research Council (NARC), Kathmandu. Seventy samples from 14 species of major food species (5 replicates of each species) for the monsoon season, 50 samples from 10 species of food plants for cool dry season, and 65 samples from 13 species of food plants for the hot dry season were analyzed for crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), total ash (TA), Organic matter (OM), cellulose (Ce), hemicelluloses (HC) and calcium (Ca). Similarly, five dung samples were analyzed for the above mentioned constituents for each season.

Rhino food plant samples were analyzed for crude protein (N x 6.25) by Kjeldahl (Pierce and Haenisch, 1947) method. Fiber (ADF and NDF) fractions were determined sequentially using the procedures of Van Soest (1982) and Van Soest *et al.* (1991).

Total nutrient intake

Once the total DMI of each species and the percentage of its nutrient content (DM) was computed, the amount of the total nutrient content ingested by the rhinos was calculated. Similarly, the total amount of nutrient contents excreted in the feces was also calculated as follows:

CP (gm) ingested from food species A = (DMI of species A x % CP of species A)/100

Crude protein (gm) excreted = (TFO x % CP in feces)/100

In this way, total nutrients taken by the rhinos and total nutrient excreted in fecal matter for total ash (TA), organic matter (OM), crude protein (CP), neutral detergent fibre (NDF), acid detergent fiber (ADF), hemicelluloses (HC), cellulose (Ce) and calcium (Ca) were calculated. Based on this information digestibility of all nutrients was computed.

Estimation of dry matter digestibility (DMD), crude protein digestibility (CPD) and true protein digestibility (TPD)

Dry matter digestibility (DMD) and nutrient digestibility can be estimated if DMI and TFO are available with reasonable accuracy (Church 1976, Robbins 1993, Van Soest 1982, Jhala 1997). In my case, I obtained estimates of DMI and TFO from the radio-collared rhinos by continuous monitoring and calculated DMD as follows:

DMD = (DMI – TFO)/DMI

Crude protein digestibility (CPD) is estimated as:

CPD = {(CP in forage x DMI) – (CP in feces x TFO)}/CP in forage x DMI

Similarly, true protein digestibility (TPD) was calculated as follows (Schwartz and Hobbs 1985, Jhala 1997):

TPD = [CP intake – {CP in feces – (MFN x 6.25)}]/CP intake

Where, MFN is the metabolic fecal nitrogen. MFN was estimated by regressing seasonal nitrogen (N) content of diet against seasonal N content in feces. The Y intercept *i.e.* N in dung when N content in diet (intake) is zero gives an estimate of metabolic fecal nitrogen (Jhala 1997).

Results

Seasonal food habits and dry matter intake

The focal rhinos were continuously followed from the elephant back for 304 h in monsoon, 228 h in cool dry season and 192 h in hot dry season covering daylight and night. A total of 11,199 bites were recorded in the hot-dry season, 10,740 in the cool dry season and 10,151 bites in the monsoon season from different habitats (Table 3.1). Average bite rate per minute was 13.37 ±1.03 in the monsoon, 11.98 ± 0.52 during the cool dry season and 11.50 ± 0.33 during the hot dry season. The average dry weight of the bite was 3.32 ± 0.22 g in the monsoon, 3.93 ± 0.29 g in the cool dry season and 3.02 ± 0.25 g in the hot dry season.

Table 3.1. Number of bites recorded from different habitats in different seasons and seasonal average bite rate and bite weight of greater one-horned rhinoceros in Chtwan National Park, Nepal. Values in parentheses are standard errors.

Habitat type and bite details	Monsoon	Cold dry	Hot dry
Riverine forest	3841	6110	1000
Tall grassland	4467	4340	9401
Short grassland	1843	290	798
Total bites recorded	10151	10740	11199
Average bite rate/minute	13.37 (1.03)	11.98 (0.52)	11.50 (0.33)
Average dry bite weight (g)	3.32 (0.22)	3.93 (0.29)	3.02 (0.25)

Annually, rhinos foraged 71% of the time in grasslands and 29% in the riverine forests (Table 3.2). Riverine forests were extensively used during monsoon compared to other season. Rhinos spent 38.19 ± 1.79% (mean ± SE) of the total time for feeding in the monsoon, 40.40 ± 1.19% of time in the hot dry season, and 40.21 ± 2.78% of time during the cool dry season (Figure 2). Fifty eight species of plants were found utilized at different scales (Appendix -1).

However, 14 species of plants contributed 85% of annual diet in terms of dry biomass consumption.

Table 3.2. Percentage feeding activity of rhinos by season in different habitats as determined from 724 h of continuous monitoring from elephant back in Chitwan National Park, Nepal.

Season	Riverine forest	Tall Grassland	Short grassland
Monsoon	41.80	43.36	14.84
Cold dry	28.52	49.66	21.82
Hot dry	17.77	58.07	24.16
Annual average	29.36	50.36	20.28

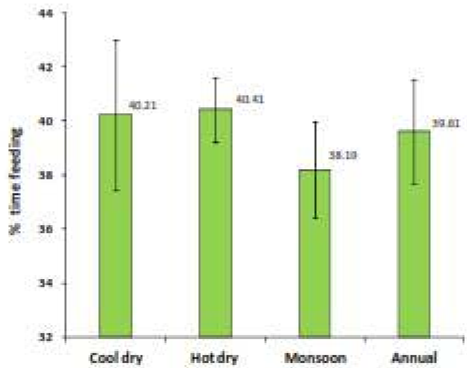

Figure 3.2. Seasonal and annual percentage time spent feeding by rhinos. Bars are standard errors.

Hot dry season diet

During hot dry season rhinos consumed 33 species of plants of which eight species contributed over 90% of the diet (DM basis). *Saccharum spontaneum* (34%), *Imperata cylindrica* (27%), *Eragrostris tenella* (9%), *Cersium wallichii* (5.5%), *Narenga porphyrocoma* (5%), *Cynodon dactylon* (2%), *Phragmites karka* (3%), and *Mikania micrantha* (3%) were the main food plants of the hot dry season (Table 3.2). Browse species contributed about 5% of the diet. Water plants that are sparsely available were avidly consumed. Total dry matter intake (DMI) during the dry season was 21.77 ± 5.87 kg/day (Figure 3.3, table 3.3). Daily (24 h) time spent feeding was 9.71 ± 0.28 h.

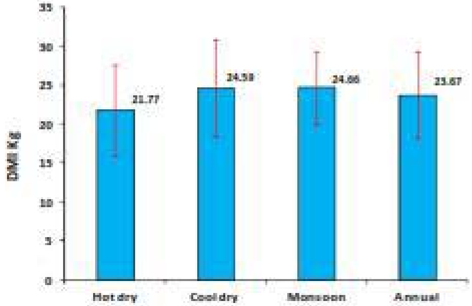

Figure 3.3. Annual and seasonal dry matter intake (DMI) by rhinos (male and female combined) in Chitwan National Park. Error bars are standard errors.

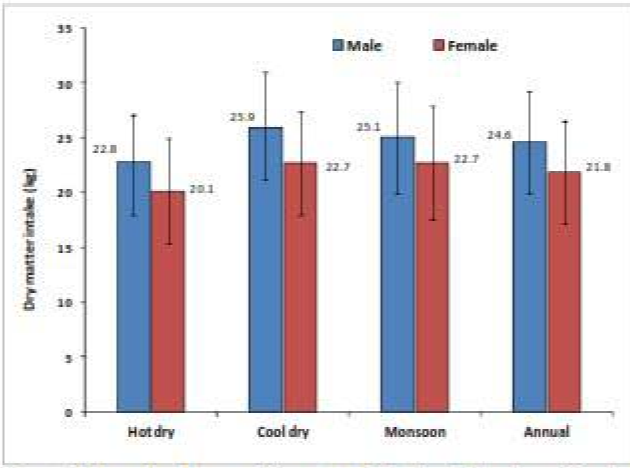

Figure 3.4. Annual and seasonal dry matter intake by adult male and female rhinos in Chitwan National Park. Error bars are standard errors.

The male rhinos were found to take slightly higher dry matter intake (DMI) in all seasons compared to females ((Figure 3.4), but the difference was not significant (Kruskal Wallis one-way ANOVA, $\chi^2 = 2.24$, df $=1$, $p = 0.152$).

Table 3.3. Diet composition and dry matter intake (DMI) of greater one-horned rhinoceros in Chitwan National Park as estimated by bite counts, time spent foraging in different habitats, bite rates and bite weights during the **hot dry season** 2010 - 2011. In the table tb is total number of bites in the particular habitat and tsf is time spent feeding in that habitat.

Food plants	Bite rate (X)	DW/ bite (Y)	Tall grassland (tb = 9401; tsf = 5.16 h)					Short grassland (tb = 798; tsf = 2.01 h)					Riverine forest (tb = 1000; tsf = 2.54 h)					Total DMI (gm)	% in diet
			A	B	C	D	E	A	B	C	D	E	A	B	C	D	E		
Eragrostris tenella	12.16	2.64	6.32	0.52	0.32	236.48	623.28	16.92	1.39	0.34	246.90	650.73	14.4	1.18	0.36	265.69	700.24	1974.25	9.08
Saccharum bengalensis	11.76	2.20	8.51	0.72	0.45	318.50	701.13	0.75	0.06	0.02	10.97	24.16	3.4	0.29	0.09	62.73	138.09	863.38	3.97
Saccharum spontaneum	12.18	3.06	40.78	3.35	2.09	*1526.39*	4673.66	29.07	2.39	0.58	424.30	1299.16	24.6	2.02	0.62	453.88	1389.73	7362.56	33.88
Imperata cylindrica	12.18	5.65	11.53	0.95	0.59	431.56	2440.23	22.56	1.85	0.45	329.20	1861.42	16.5	1.35	0.42	304.43	1721.38	6023.03	27.72
Callicarpa macrophyla	12.54	3.54	2.33	0.19	0.12	87.19	308.55	0.00	0.00	0.00	0.00	0.00	2.1	0.17	0.05	38.75	137.12	445.66	2.05
Mikania micrantha	11.52	2.82	2.58	0.22	0.14	96.74	272.57	7.52	0.65	0.16	109.73	309.16	2.2	0.19	0.06	40.59	114.36	696.09	3.20
Cynodon dactylon	12.00	1.42	6.30	0.52	0.33	235.69	334.10	4.39	0.37	0.09	64.01	90.74	0.00	0.00	0.00	0.00	0.00	424.84	1.95
Cersium wallichii	12.00	1.80	7.56	0.63	0.39	283.06	510.57	0.00	0.00	0.00	0.00	0.00	21	1.75	0.54	387.46	698.87	1209.43	5.57
Narenga porkyorocoma	12.20	1.97	9.22	0.76	0.47	345.17	681.49	0.00	0.00	0.00	0.00	0.00	9.1	0.75	0.23	167.90	331.49	1012.98	4.66
Phragmites karka	11.65	3.34	3.51	0.30	0.19	131.38	438.92	4.51	0.39	0.09	65.84	219.96	0.00	0.00	0.00	0.00	0.00	658.88	3.03
Hemarthria compressa	12.62	2.59	0.15	0.01	0.01	5.57	14.45	5.39	0.43	0.10	78.66	203.99	0.00	0.00	0.00	0.00	0.00	218.44	1.01
Other species	12.07	2.82	1.20	0.10	0.06	44.99	126.94	8.90	0.74	0.18	129.85	366.40	6.70	0.55	0.17	123.62	348.82	842.17	3.88
Total			100	8.27	5.16	3742.73	11125.9	100	8.26	2.01	1459.47	5025.72	100	8.26	2.54	1845.04	5580.10	21731.7	100

Bite rate per minute (X)

Dry weight (gm) per bite (Y)

% bites on a species (**A**) = (total number of bites on a species/total number of bites on the habitat)*100

Proportional amount of time spent in feeding (minute) on a species while obtaining 100 bites from the particular habitat (**B**) = % bites /bite rate i.e B = A/X

Total time spent (h) on a particular species in that habitat (C) = B* total time spent feeding in the habitat/Total time for 100 bites i.e. **C**= B*∑C/∑B

Number of bites on a species in a day (D) = Time foraging in a species (C)*bite rate*60; *i.e.* **D** = C * X * 60

Dry matter intake (DMI) in gm per day from a species (E) = Number of bites on a species in a season (D) * Dry bite weight (Y) i.e. **E** = D * Y

Cool dry season diet

The rhinos were observed to consume 39 species of plants during the cool dry season. However, ten species namely *Saccharum spontaneum* (22%), *Imperata cylindrica* (14%), *Saccharum bengalensis* (6%), *Eragrostis tenella* (9%), *Callicarpa macrophylla* (11%), *Phragmites karka* (7%), *Mikania micrantha* (5%), *Coffea bengalensis* (3%), *Litsea monopetala* (4%) and *Lantana camara* (2%) contributed over 80% of the diet (Table 3.3). Browsing in the cool dry season increased compared to other seasons and 25% of the diet was contributed by browse species. Water plants were eaten avidly. Total dry matter intake (DMI) during cool dry season was 24.59 ± 6.24 kg/day (Fig 3.3, table 3.4). Daily time spent feeding was 9.65 ± 0.66 h.

Monsoon season diet

Forty three species of plants were eaten during the monsoon season. However, 9 species contributed 80% of the monsoon diet (DM basis). *Saccharum spontaneum* (25%), *Eragrostri tenella* (23%), *Saccharum bengalensis* (4%), *Imperata cylindrica* (8%), *Brachiaria* species (8%), *Trewia nudiflora* fruits (4%), *Phragmites karka* (4%), *Cynodon dactylon* (3%) and *Hemarthria compressa* (3%) were the main food plants (Table 3.5). During the monsoon rhinos feed on a variety of annual herbs and water plants. Total dry matter intake (DMI) was 24.66 ± 4.88 kg/day (Figure 3.3). Daily time spent feeding was 9.1 ± 0.48 h.

Table 3.4. Diet composition and dry matter intake (DMI) of greater one-horned rhinoceros in Chitwan NP Nepal as estimated by bite counts, time spent foraging in different habitats, bite rates and bite weights during the **cool dry season** 2010 -2011. In the table tb is total number of bites in the particular habitat and tsf is time spent feeding in that habitat.

Food plants	Bite rate X	DW/bite Y	Tall grassland (tb = 4340, tsf = 5 h)					Riverine forest (tb = 6110, tsf = 2.71 h)					Short grassland (tb = 290, tsf = 1.93 h)					Total DMI (gm)	% in diet
			A	B	C	D	E	A	B	C	D	E	A	B	C	D	E		
Imperata cylindrica	10.74	3.65	5.60	0.52	0.28	181.40	662.09	3.94	0.37	0.11	69.07	252.10	57.24	5.33	1.10	709.70	2590.39	3504.58	14.25
Callicarpa macrophylla	10.43	5.32	6.36	0.61	0.33	206.03	1096.08	10.77	1.03	0.30	188.58	1003.23	11.38	1.09	0.23	141.08	750.57	2849.87	11.59
Mikania micrantha	10.76	1.40	11.06	1.03	0.56	358.31	501.64	11.65	1.08	0.32	204.05	285.67	26.55	2.47	0.51	329.20	460.87	1248.19	5.08
Lantana camara	10.79	2.61	3.76	0.35	0.19	121.68	317.58	5.48	0.51	0.15	96.01	250.58	4.83	0.45	0.09	59.85	156.22	724.38	2.95
Saccharum spontaneum	10.52	5.20	24.95	2.37	1.28	808.44	4203.90	11.49	1.09	0.32	201.19	1046.17						5250.07	21.35
Saccharum bengalensis	10.48	3.05	15.07	1.44	0.78	488.20	1489.01	1.82	0.17	0.05	31.81	97.03						1586.04	6.45
Eragrostris tenella	10.60	5.92	9.98	0.94	0.51	323.23	1913.51	4.17	0.39	0.11	73.08	432.64						2346.15	9.54
Phragmites karaka	10.85	5.85	6.54	0.60	0.33	212.00	1240.21	3.47	0.32	0.09	60.76	355.43						1595.64	6.49
Coffea bengalensis	10.31	5.30	0.21	0.02	0.01	6.72	35.61	8.31	0.81	0.24	145.59	771.62						807.23	3.28
Litsea monopetala	10.88	4.05	2.60	0.24	0.13	84.35	341.63	7.77	0.71	0.21	136.13	551.33						892.96	3.63
Cynodon dactylon	11.05	3.57	1.66	0.15	0.08	53.75	191.88	9.07	0.82	0.24	158.77	566.81						758.69	3.09
Dryopteris cochleata	10.76	3.32	1.01	0.09	0.05	32.85	109.05	3.90	0.36	0.11	68.21	226.45						335.50	1.36
Narenga porphyrocoma	10.91	5.19	2.58	0.24	0.13	83.61	433.92	0.38	0.03	0.01	6.59	34.21						468.13	1.90
Brachiaria spp	10.79	4.80	1.08	0.10	0.05	35.08	168.41	2.19	0.20	0.06	38.40	184.34						352.74	1.43
Solanum Spp	16.25	2.50	4.40	0.27	0.15	142.58	356.45	0.00	0.00	0.00	0.00	0.00						356.45	1.45
Water plants	11.10	3.84	0.00	0.00	0.00	0.00	0.00	3.85	0.35	0.10	67.35	258.58						258.58	1.05
Other species	11.08	4.10	3.13	0.28	0.15	101.40	415.56	11.73	1.06	0.31	205.40	841.75						1257.31	5.11
Total			100	9.26	5.00	3239.62	13476.5	100	9.32	2.72	1750.99	7157.94	100	9.34	1.93	1239.83	3958.05	24592.5	100

Bite rate per minute (X)

Dry weight (gm) per bite (Y)

% bites (A) = (total number of bites on a species/total number of bites on the habitat)*100

Proportional amount of time spent in feeding (minute) on a species while obtaining 100 bites from the particular habitat (B) = % bites /bite rate *i.e.* B = A/X

Total time spent (h) on a particular species in that habitat (C) = B* total time spent feeding in the habitat/Total time for 100 bites *i.e.* C= B*∑C/∑B

Number of bites on a species in a day (D) = Time foraging in a species (C)*bite rate*60 *i.e.* D = C * X * 60

Dry matter intake (DMI) in gm per day from a species (E) = Number of bites on a species in a season (D) * Dry bite weight (Y) *i.e.* E = D * Y

Table 3.5. Diet composition and dry matter intake (DMI) of greater one-horned rhinoceros in Chitwan National Park as estimated by bite counts, time spent foraging in different habitats, bite rates and bite weights during the **monsoon season** 2010 -2011. In the table tb is total number of bites in the particular habitat and tsf is time spent feeding in that habitat.

Species	Bite rate (X)	DW/ bite (Y)	Tall grassland (tb = 4467, tsf = 4.34 h)					Riverine forest (tb = 3841, tsf = 3.79 h)					Short grassland (tb = 1843, tsf = 1.02 h)					Total DMI (gm)	% in diet
			A	B	C	D	E	A	B	C	D	E	A	B	C	D	E		
Eragrostris tenella	13.99	2.39	36.00	2.57	1.41	1185.04	2832.26	31.84	2.28	1.24	1037.10	2478.66	23.82	1.70	0.25	205.88	492.06	5802.98	23.53
Saccharum bengalensis	14.06	3.19	4.57	0.32	0.18	150.34	480.33	4.56	0.32	0.18	148.40	474.13	1.03	0.07	0.01	8.91	28.47	982.93	3.98
Saccharum spontaneum	14.01	4.99	22.81	1.63	0.89	750.97	3747.34	8.90	0.64	0.35	290.01	1447.17	16.01	1.14	0.16	138.35	690.37	5884.88	23.86
Phragmites karka	14.48	7.01	0.11	0.01	0.00	3.68	25.84	2.00	0.14	0.08	65.30	457.85	6.29	0.43	0.06	54.40	381.46	865.14	3.51
Imperata cylindrica	13.96	2.54	10.32	0.74	0.41	339.74	862.27	7.81	0.56	0.30	254.40	645.66	24.63	1.76	0.25	212.92	540.39	2048.31	8.30
Brachiaria spp	15.56	2.65	6.76	0.43	0.24	222.56	589.13	15.02	0.97	0.52	489.29	1295.16	3.80	0.24	0.04	32.83	86.90	1971.19	7.99
Mikania micrantha	14.02	1.21	2.04	0.15	0.08	67.06	81.13	4.79	0.34	0.19	156.03	188.75	1.14	0.08	0.01	9.85	11.91	281.79	1.14
Cynodon dactylon	14.00	5.28	0.92	0.07	0.04	30.22	159.55	1.51	0.11	0.06	49.18	259.71	7.54	0.54	0.08	65.19	344.23	763.49	3.10
Water plants	3.06	4.06	3.31	1.08	0.59	109.07	442.33	0.00	0.00	0.00	0.00	0.00	0.16	0.05	0.01	1.41	5.71	448.04	1.82
Flemeniga spp	17.79	5.72	1.21	0.07	0.04	39.80	227.59	0.57	0.03	0.02	18.66	106.69	0.00	0.00	0.00	0.00	-	334.29	1.36
Callicarpa macrophylla	17.02	4.28	0.94	0.06	0.03	30.95	132.61	1.04	0.06	0.03	33.92	145.32	0.00	0.00	0.00	0.00	-	277.93	1.13
Hemarthria compressa	14.02	3.75	2.48	0.18	0.10	81.80	306.49	0.00	0.00	0.00	0.00	0.00	12.70	0.91	0.13	109.74	411.17	717.66	2.91
Litsea monopetala	15.77	4.88	0.45	0.03	0.02	14.74	71.85	2.19	0.14	0.08	71.23	347.25	0.00	0.00	0.00	0.00	-	419.11	1.70
Trewia nudiflora	13.96	4.45	0.00	0.00	0.00	0.00	0.00	7.52	0.54	0.29	245.07	1091.43	0.00	0.00	0.00	0.00	-	1091.43	4.42
Other species	13.98	4.03	8.08	0.58	0.32	266.00	1071.51	12.24	0.88	0.48	398.67	1605.97	2.88	0.21	0.03	24.89	100.28	2777.75	11.26
Total			100	7.91	4.34	3292.0	11030.2	100	7.00	3.80	3257.26	10543.7	100	7.15	1.03	864.37	3092.93	24666.9	100

Bite rate per minute (X)

Dry weight (gm) per bite (Y)

% bites (A) = (total number of bites on a species/total number of bites on the habitat)*100

Proportional amount of time spent in feeding (minute) on a species while obtaining 100 bites from the particular habitat (B) = % bites /bite rate *i.e.*B = A/X

Total time spent (h) on a particular species in that habitat (C) = B* total time spent feeding in the habitat/Total time for 100 bites *i.e.* C= B*∑C/∑B

Number of bites on a species in a day (D) = Time foraging in a species (C)*bite rate*60 *i.e.* D = C * X * 60

Dry matter intake (DMI) in gm per day from a species (E) = Number of bites on a species in a season (D) * Dry bite weight (Y) *i.e.* E = D * Y

Total fecal output (TFO)

The average daily defecation rate was 2.25 ± 0.25 times in the hot dry season, 2.61 ± 0.42 times in the cool dry season and 2.65 ± 0.27 times in the monsoon season. The regression equations for converting fresh dung weight to dry weight (Y) were: Y = 0.183 (±0.002)*fresh weight – 0.6 (±1.55) ($R^2 = 0.99$, $p < 0.001$) for the hot dry season, Y = 0.1925 (±0.003)*fresh weight – 1.1 (±0.58) (($R^2 = 0.99$, $p < 0.001$) for the cool dry season and Y = 0.1647 (±0.012)*fresh weight + 5.53 (±0.91) ($R^2 = 0.98$, $p < 0.001$) for the monsoon season. Average daily fecal output in term of dry weight were 5.98 ± 0.66 kg for the hot dry season, 8.22 ± 1.32 Kg for the cool dry season and 7.33 ± 0.72 kg for the monsoon (Figure 3.5). Average annual TFO was 7.03 ± 0.9 Kg per day (in 24 h). The average daily dung output was found consistent across the seasons (One-Way ANOVA, $F_{2,36} = 0.65$, $p = 0.526$).

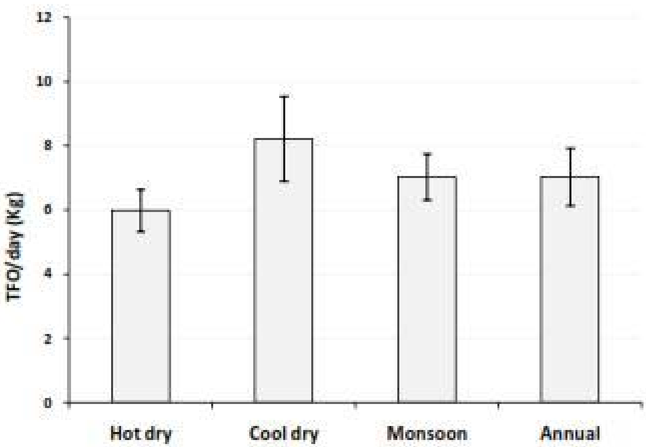

Figure 3.5. Annual and seasonal daily total fecal output (DW) of adult greater one horned rhinoceros. Error bars are SE.

Average annual fresh weight of fecal matter (per defecation) for adult male was 17.7 ± 1.2 kg while for the female it was 15.6 ± 1.1 kg and the difference was not significant (Kruskal Wallis One-way ANOVA, $\chi^2 = 2.4$, df =1, p =0.121).

Chemical analysis of food plants

Seasonal food plants of rhinos were analyzed for total organic matter (OM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), total ash (TA), hemicelluloses (HC), cellulose (Ce), and calcium (Ca) (See Tables 3.6, 3.7, and 3.8). The CP content in the rhino's food plants varied from 4% to 17% on a dry matter basis. CP in cool dry season was highest in browse species like *Mikania micrantha*, *Litsea monopetala* and *Callicarpa macrophylla*, while NDF and ADF values were then low (Table 3.7). The grass species had low CP and high NDF and ADF in that season compared to the other seasons.

Browse species like *Litsea monopetala, Callicarpa macrophylla, Mikania micrantha* and *Coffea bengalensis* had higher CP but low NDF and ADF in all seasons. The grass species had higher CP during the growing season (late dry to early monsoon) but were low in CP during the cool dry season. In general, the major food plant species like *Saccharum* species, *Narenga prophyrocoma, Phragmites Karka, Cynodon dactylon, Eragrostris tenella,* and *Imperata cylindrica* did not show marked seasonal variation in the nutrient contents. However, to supplement their dietary needs rhinos strategically switched into different species (eg. browses) that have high CP and low ADF, NDF according to the seasons. Seasonal variations in the nutrient content of the major food plants are presented on figures 3.6 and 3.7.

CP and NDF in the fecal material were found to be higher in the dry season compared to the cool dry and the monsoon season (Table 3.9). There was no marked seasonal change in the other nutrient contents in the fecal material.

Table 3.6. Chemical analysis of the **hot dry season** food plants of rhinos in Chitwan. The values are in percentage mean and parenthesis values refer to the standard error. The values of other species were derived from the mean of all species for further calculation purposes.

SN	Food plants	N	TA	OM	CP	NDF	ADF	HC	Ce	Ca
1	*Cersium wallichii*	4	21.94 (0.31)	78.06 (0.310	6.47 (0.38)	33.97 (0.59)	23.26 (0.97)	10.71 (0.81)	16.07 (1.79)	4.83 (0.59)
2	*Narenga porphyrocoma*	3	9.14 (0.22)	90.85 (0.22)	10.07 (0.42)	81.04 (3.13)	40.27 (2.18)	40.76 (2.50)	35.21 (1.820	0.95 (0.15)
3	*Imperata cylindrica*	5	6.66 (0.75)	93.33 (0.75)	6.18 (0.24)	85.97 (0.82)	60.52 (3.88)	25.44 (3.95)	47.17 (3.25)	0.97 (0.13)
4	*Saccharum spontaneum*	4	10.72 (0.82)	89.27 (0.81)	7.85 (0.36)	87.56 (1.30)	46.54 (3.96)	41.02 (4.96)	37.64 (3.37)	0.74 (0.18)
5	*Coffea bengalensis*	3	9.45 (0.72)	90.54 (0.72)	10.76 (0.30)	44.05 (5.69)	37.23 (5.50)	6.81 (2.79)	18.75 (8.52)	1.73 (0.16)
6	*Saccharum bengalensis*	5	11.54 (1.51)	88.45 (1.51)	10.04 (0.30)	82.69 (0.71)	50.28 (2.19)	32.40 (2.70)	20.35 (1.260	0.47 (0.06)
7	*Phragmites karka*	5	12.23 (1.25)	87.76 (1.25)	13.10 (0.87)	68.88 (1.15)	35.71 (1.31)	33.17 (1.67)	31.65 (10.5)	0.33 (0.07)
8	*Litsea monopetala*	5	7.90 (0.13)	92.01 (0.13)	13.13 (0.55)	48.44 (0.96)	35.65 (2.60)	12.78 (2.03)	16.26 (1.39)	0.56 (0.05)
9	*Callicarpa macrophylla*	5	9.71 (0.38)	90.28 (0.38)	10.07 (0.37)	42.47 (1.48)	30.25 (1.61)	12.21 (0.23)	23.15 (1.50)	1.04 (0.11)
10	*Mikania micrantha*	5	14.04 (0.16)	85.95 (0.16)	8.96 (0.12)	31.3 (0.34)	24.39 (0.50)	6.90 (0.68)	10.85 (0.74)	1.65 (0.04)
11	*Brachiaria* spp	5	15.40 (0.65)	84.59 (0.65)	8.7 (0.26)	62.19 (1.25)	33.60 (1.25)	28.58 (0.56)	27.69 (1.84)	0.62 (0.12)
12	*Cynodon dactylon*	5	12.06 (0.37)	87.93 (0.37)	7.74 (0.71)	72.25 (0.90)	38.85 (4.84)	33.40 (4.38)	30.66 (4.89)	0.81 (0.10)
13	*Eragrostris tenella*	4	13.10 (0.40)	86.89 (0.45)	9.49 (1.12)	73.36 (0.64)	56.18 (4.07)	17.18 (3.52)	48.85 (3.72)	0.91 (0.09)
14	Other spp		11.84 (0.59)	88.15 (0.59)	9.43 (0.46)	62.63 (1.46)	39.44 (2.68)	23.18 (2.37)	28.02 (2.70)	1.20 (0.14)

N, number of samples; TA, total ash; OM, organic matter; CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; HC, hemicellulose; Ce, cellulose; Ca, calcium.

Table 3.7. Chemical analysis of the **cool dry season** food plants of rhinos in Chitwan. The values are in percentage mean and parenthesis values refer to the standard error. The values of other species were derived from the mean of all species for further calculation purposes.

SN	Food plants	N	TA	OM	CP	NDF	ADF	HC	Ce	Ca
1	*Litsea monopetala*	5	6.5 (0.29)	93.5 (0.28)	12.02 (0.34)	47.06 (1.02)	32.07 (1.72)	14.98 (2.42)	15.83 (1.12)	5.08 (0.37)
2	*Mikania micrantha*	5	12.56 (0.22)	87.44 (0.22)	16.87 (0.42)	46.98 (1.03)	36.15 (1.08)	10.83 (0.54)	17.58 (1.75)	5.00 (0.32)
3	*Lantana camara*	5	10.29 (0.27)	89.70 (0.27)	12.78 (0.28)	48.37 (1.64)	33.74 (0.7)	14.62 (1.23)	19.04 (0.75)	3.58 (0.43)
4	*Coffea bengalensis*	5	9.61 (0.08)	90.39 (0.08)	7.60 (0.12)	47.09 (2.31)	29.24 (0.95)	17.85 (2.66)	19.03 (0.420	6.22 (0.73)
5	*Callicarpa macrophylla*	5	8.22 (0.46)	91.77 (0.46)	11.61 (0.39)	55.65 (0.94)	42.24 (2.32)	13.40 (1.54)	25.39 (1.83)	4.08 (0.29)
6	*Desmodium* spp	5	5.78 (0.06)	94.21 (0.07)	14.91 (1.01)	69.16 (1.93)	61.15 (2.74)	8.00 (1.27)	29.1 (1.510	4.26 (0.35)
7	*Imperata cylindrica*	5	7.99 (0.52)	92.00 (0.52)	6.09 (0.23)	85.48 (1.15)	50.24 (1.56)	35.23 (1.71)	37.49 (2.20)	2.31 (0.23)
8	*Phragmites karka*	5	8.86 (0.21)	91.13 (0.21)	8.12 (0.39)	80.01 (0.93)	50.48 (1.48)	29.53 (1.26)	36.63 (1.84)	2.16 (0.23)
9	*Saccharum begalensis*	5	6.79 (0.54)	93.20 (0.54)	6.69 (0.49)	86.77 (0.69)	60.60 (3.08)	26.16 (3.11)	47.11 (3.06)	2.39 (0.34)
10	*Saccharum spontaneum*	5	6.18 (0.3)	93.82 (0.30)	6.11 (0.28)	82.24 (0.81)	44.85 (0.94)	37.39 (0.58)	38.41 (1.68)	1.86 (0.24)
11	*Eragrostris tenella*	4	13.10 (0.40	86.89 (0.40)	9.49 (1.12)	73.36 (0.64)	56.18 (4.07)	17.18 (3.52)	48.85 (3.72)	0.91 (0.09)
12	Other species		8.72 (0.31)	91.28 (0.310	10.21 (0.46)	65.65 (1.19)	45.18 (1.87)	20.47 (1.81)	30.40 (1.81)	3.44 (0.33)

N, number of samples; TA, total ash; OM, organic matter; CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; HC, hemicellulose; Ce, cellulose; Ca, calcium.

Table 3.8. Chemical analysis of the **monsoon season** food plants of rhinos in Chitwan. The values are in percentage mean and parenthesis values refer to the standard error. The values of other species were derived from the mean of all species for further calculation purposes.

Habit	Food plants	N	TA	OM	CP	NDF	ADF	HC	Ce	Ca
1	*Imperata cylindrica*	5	6.67 (0.19)	93.33 (0.19)	7.22 (0.19)	83.34 (0.94)	69.48 (2.87)	13.86 (3.24)	61.01 (2.06)	0.16 (0.01)
2	*Phragmites karka*	5	9.85 (0.27)	90.15 (0.27)	11.95 (1.01)	80.55 (1.97)	69.64 (1.04)	10.92 (1.22)	57.3 (0.94)	0.17 (0.01)
3	*Mikania micrantha*	5	12.96 (0.34)	87.04 (0.34)	13.41 (0.71)	52.73 (3.76)	43.21 (1.00)	9.52 (3.08)	20.83 (3.29)	0.27 (0.08)
4	*Trewia nudiflora*	5	8.54 (1.12)	91.46 (1.12)	10.83 (0.33)	31.1 (0.52)	26.05 (0.99)	5.05 (0.81)	20.93 (0.89)	0.59 (0.05)
5	*Saccharum bengalensis*	5	6.18 (0.16)	93.82 (0.16)	6.31 (0.33)	85.54 (0.45)	71.87 (3.27)	13.67 (3.50)	53.06 (4.92)	0.48 (0.04)
6	*Cynodon dactylon*	5	11.77 (1.56)	88.23 (1.56)	7.82 (0.71)	77.95 (2.54)	43.5 (3.07)	34.45 (4.45)	37.09 (3.59)	0.16 (0.03)
7	*Eragrostris tenella*	5	13.67 (1.31)	86.33 (1.31)	7.04 (0.30)	76.76 (1.33)	56.22 (3.09)	20.54 (2.57)	48.59 (2.52)	0.87 (0.04)
8	*Hemarthria compressa*	5	8.41 (0.89)	91.59 (0.89)	6.08 (0.46)	81.75 (2.7)	60.57 (3.22)	21.18 (5.19)	50.8 (2.97)	0.70 (0.02)
9	*Narenga prophyrocoma*	5	6.02 (0.4)	93.98 (0.4)	4.41 (1.16)	81.56 (1.18)	66.35 (5.21)	15.21 (4.71)	55.9 (4.51)	0.19 (0.07)
10	*Brachiaria* spp	5	10.53 (0.92)	89.47 (0.92)	2.11 (0.61)	68.03 (5.29)	55.46 (3.56)	12.57 (1.76)	51.61 (2.89)	0.13 (0.02)
11	*Litsea monopetala*	5	5.88 (0.26)	94.12 (0.26)	14.81 (0.94)	62. 59 (1.310	54.8 (1)	7.79 (1.8)	32.57 (1.00)	1.18 (0.09)
12	*Coffea bengalensis*	5	9.27 (0.46)	90.73 (0.46)	10.33 (0.84)	43.12 (1.29)	35.78 (1.40	7.35 (0.48)	23.47 (1.15)	0.67 (0.09)
13	*Saccharum spontaneum*	5	12.1 (2.9)	87.90 (2.9)	6.60 (1.00)	78.24 (1.06)	67.69 (2.63)	10.55 (3.43)	57.24 (1.92)	0.47 (0.08)
14	*Callicarpa macrophylla*	5	7.12 (0.04)	92.88 (0.04)	9.81 (0.67)	61.14 (2.00)	50.25 (1.17)	10.89 (2.22)	31.49 (3.54)	1.41 (0.10)
15	Other species		7.12 (0.77)	90.79 (0.77)	8.48 (0.66)	68.88 (1.88)	55.06 (2.4)	13.82 (2.57)	42. 99 (2.56)	0.53 (0.05)

N, number of samples; TA, total ash; OM, organic matter; CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; HC, hemicellulose; Ce, cellulose; Ca, calcium.

Table 3.9. Seasonal chemical content of the fecal material of rhinos in Chitwan. The values are in percentage mean dry weight and the parentheses refer to the standard errors.

Season	TA	OM	CP	NDF	ADF	HC	Ce	Ca
Monsoon	16.41 (1.27)	83.58 (1.27)	8.97 (0.27)	57.55 (2.31)	51.2 (2.57)	6.35 (4.31)	36.25 (4.49)	2.12 (0.19)
Cool dry	18.11 (0.71)	81.88 (1.01)	8.34 (0.34)	57.51 (2.49)	48.18 (1.36)	9.33 (1.99)	35.35 (2.58)	2.39 (0.12)
Hot dry	18.21 (1.40)	81.79 (1.4)	9.77 (0.37)	63.12 (1.98)	51.11 (2.10)	12.01 (3.02)	36.86 (1.67)	2.77 (0.25)

TA , total ash; OM, organic matter; CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; HC, hemicellulose; Ce, cellulose; Ca, calcium.

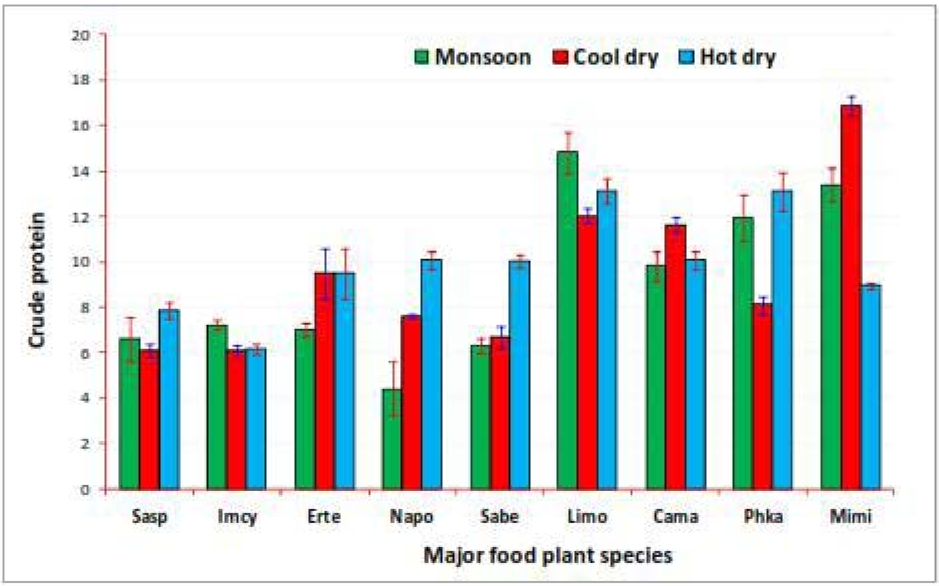

Figure 3.6. Seasonal variation in CP in nine major food plants of rhinos. Sasap, *Saccharum spontaneum;* Imcy, *Imperata cylindrica;* Erte, *Eragrostris tenella;* Napo, *Narenga porphyrocoma;* Sabe, *Saccharum bengalensis;* Limo, *Litsea monopetala;* Cama, *Callicarpa macrophylla;* Phka, *Phragmites karka* and Mimi, *Mikania micrantha.*

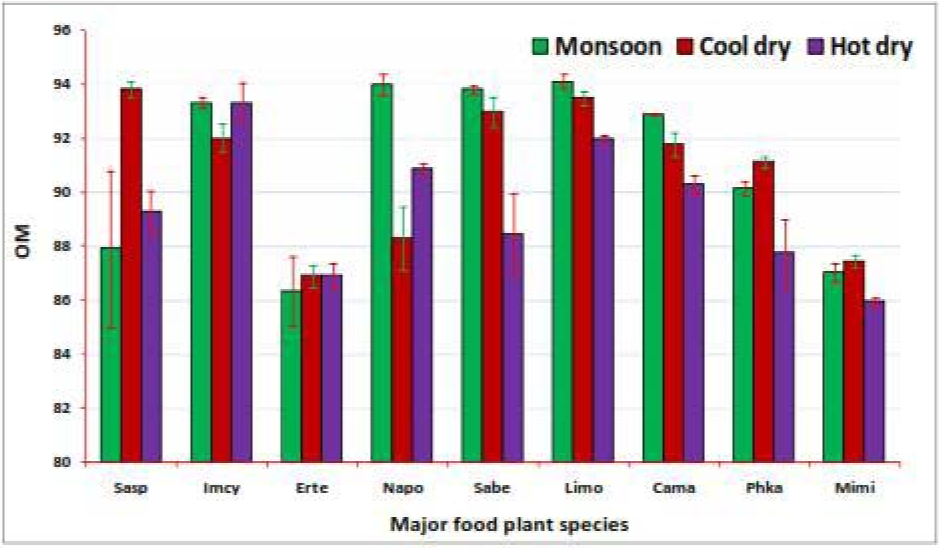

Figure 3.7. Seasonal variation in OM in major food plants of rhinos. Sasap, *Saccharum spontaneum;* Imcy, *Imperata cylindrica;* Erte, *Eragrostris tenella;* Napo, *Narenga porphyrocoma;* Sabe, *Saccharum bengalensis;* Limo, *Litsea monopetala;* Cama, *Callicarpa macrophylla;* Phka, *Phragmites karka* and Mimi, *Mikania micrantha.*

Total nutrient intake and digestibility

Total dry matter intake (DMI) of a species was multiplied by the percentage of its nutrient content to estimate the total nutrient intake from that species by the rhino. A detailed account of the total nutrient intake by the rhinos from different species in the monsoon, the cool dry season and the hot dry season is given in tables 3.10, 3.11 and 3.12 respectively. Total nutrient intake and excretion were highest in the cool dry season.

Table 3.10. Average daily nutrient intake (gm), average daily nutrient output (gm) in fecal and nutrient digestibility of greater one-horned rhinoceros during **monsoon season** in Chitwan National Park.

Food plants	TA	OM	CP	NDF	ADF	HC	Ce	Ca
Imperata cylindrica	136.57	1911.74	147.92	1707.06	1423.20	283.87	1249.69	3.29
Phragmites karka	85.21	779.93	103.34	696.89	602.45	94.44	495.69	1.43
Mikania micrantha	36.51	245.27	37.78	148.57	121.75	26.82	58.70	0.75
Trewia nudiflora	93.19	998.24	118.21	339.43	284.28	55.15	228.43	6.42
Saccharum bengalensis	60.74	922.18	62.05	840.74	706.38	134.37	521.52	4.71
Cynodon dactylon	89.88	673.61	59.67	595.12	332.12	262.99	283.21	1.22
Eragrostris tenella	793.45	5009.53	408.31	4454.13	3262.30	1191.83	2819.45	50.43
Hemarthria compressa	60.34	657.31	43.67	586.66	434.67	151.99	364.57	5.04
Narenga prophyrocoma	2.62	40.91	1.92	35.50	28.88	6.62	24.33	0.08
Brachiaria spp	207.48	1763.71	41.59	1340.99	1093.28	247.72	1017.28	2.52
Litsea monopetala	24.65	394.46	62.06	262.33	229.69	32.64	136.51	4.94
Coffea bengalensis	11.21	109.69	12.49	52.13	43.25	8.88	28.37	0.81
Saccharum spontaneum	711.97	5172.91	388.33	4604.05	3983.44	620.61	3368.46	27.82
Callicarpa macrophylla	19.79	258.13	27.26	169.93	139.66	30.27	87.52	3.92
Other species	312.79	3082.90	287.96	2339.11	1869.71	469.40	1459.89	18.05
Total nutrient intake (gm)	2646.41	22020.49	1802.55	18172.64	14555.04	3617.60	12143.64	131.44
Total nutreint in dung(gm)	1292.96	5873.70	630.52	4044.64	3598.08	446.56	2547.34	149.04
Total Digestibility	0.51	0.73	0.65	0.78	0.75	0.88	0.79	-0.13

TA, total ash; Om, organic matter; CP, crude protein; NDF, neutral detergent fibre; ADF, acid detergent fibre; HC, hemicellulose; Ce, Cellulose; Ca, Calcium.

Table 3.11. Average daily nutrient intake (gm), average daily nutrient output (gm) in fecal and nutrient digestibility of greater one-horned rhinoceros during **Cool dry season** in Chitwan National Park.

Food plants	TA	OM	CP	NDF	ADF	HC	Ce	Ca
Litsea monopetala	58.01	834.94	107.34	420.25	286.40	133.85	141.36	45.41
Mikania micrantha	156.77	1091.41	210.57	586.45	451.26	135.20	219.52	62.44
Lantana camara	74.64	650.28	92.67	350.67	244.64	106.03	138.08	25.98
Coffea bengalensis	77.56	729.66	61.39	380.19	236.03	144.15	153.64	50.21
Callicarpa macrophylla	234.38	2615.49	330.92	1586.12	1204.05	382.08	723.72	116.52
Desmodium spp	10.19	165.96	26.27	121.83	107.73	14.10	51.26	7.51
Imperata cylindrica	280.24	3224.34	213.60	2995.82	1760.87	1234.95	1313.85	81.00
Phragmites karka	141.50	1454.13	129.37	1276.74	805.53	471.20	584.52	34.59
Saccharum begalensis	107.84	1478.19	106.25	1376.21	961.18	415.03	747.18	37.98
Saccharum spontaneum	324.55	4925.52	320.94	4317.97	2354.93	1963.04	2016.86	97.86
Eragrostris tenella	307.40	2038.74	222.78	1721.25	1318.09	403.16	1146.17	21.43
Other species	314.85	3295.89	368.68	2370.67	1631.37	739.30	1097.97	124.40
Total nutrient intake (gm)	2087.94	22504.55	2190.77	17504.17	11362.09	6142.08	8334.11	705.34
Total nutreint in dung(gm)	1489.41	6734.59	686.26	4729.69	3962.16	767.53	2907.22	196.50
Total Digestibility	0.29	0.70	0.69	0.73	0.65	0.88	0.65	0.72

TA, total ash; Om, organic matter; CP, crude protein; NDF, neutral detergent fibre; ADF, acid detergent fibre; HC, hemicellulose; Ce, Cellulose; Ca, Calcium.

Table 3.12. Average daily nutrient intake (gm), average daily nutrient output (gm) in fecal and nutrient digestibility of greater one-horned rhinoceros during **hot dry season** in Chitwan National Park.

Food plants	TA	OM	CP	NDF	ADF	HC	Ce	Ca
Cersium wallichii	265.35	944.08	78.31	410.92	281.37	129.55	193.72	58.48
Narenga porphyrocoma	92.66	920.32	102.06	820.96	407.97	412.99	356.62	9.68
Imperata cylindrica	401.48	5621.55	372.58	5178.13	3645.30	1532.83	2841.45	58.76
Saccharum spontaneum	789.40	6573.16	578.33	6446.94	3426.98	3019.96	2771.52	54.63
Coffea bengalensis	2.40	22.95	2.73	11.17	9.44	1.73	4.75	0.44
Saccharum bengalensis	96.77	741.22	84.15	693.00	421.42	271.58	170.57	3.97
Phragmites karka	80.60	578.27	86.34	453.87	235.30	218.57	208.55	2.19
Litsea monopetala	2.35	27.41	3.91	14.42	10.61	3.81	4.84	0.17
Callicarpa macrophylla	43.31	402.35	44.88	189.29	134.84	54.45	103.20	4.65
Mikania micrantha	97.74	598.35	62.37	217.87	169.83	48.05	75.59	11.53
Brachiaria spp	28.11	154.38	15.88	113.50	61.33	52.17	50.54	1.13
Cynodon dactylon	51.26	373.57	32.90	306.96	165.05	141.91	130.28	3.46
Eragrostris tenella	258.67	1715.58	187.47	1448.41	1109.16	339.26	964.49	18.03
Other spp	100.47	747.95	80.02	531.39	334.67	196.72	237.75	10.23
Total nutrient intake (gm)	2310.58	19421.13	1731.92	16836.83	10413.26	6423.57	8113.88	237.35
Total nutrient in dung(gm)	1089.02	4892.54	584.27	3775.78	3057.29	718.49	2205.15	165.76
Total digestibility	0.53	0.75	0.66	0.78	0.71	0.89	0.73	0.30

TA, total ash; Om, organic matter; CP, crude protein; NDF, neutral detergent fibre; ADF, acid detergent fibre; HC, hemicellulose; Ce, Cellulose; Ca, Calcium.

Average dry matter digestibility (DMD) was 69% in the cool dry season, 72% in the hot dry season and 74% in the monsoon season. Organic matter digestibility ranged between 70% and 75%, and CP digestibility between 65% and 69% across the different seasons. Similarly, NDF and ADF had higher digestion coefficient and both were consistent across all seasons (Table 3.13). By regressing the forage nitrogen with fecal nitrogen I obtained this equation: fecal nitrogen (Y) = 0.1958 (±0.066) * forage nitrogen + 41.61 (± 20.34); ($R^2 = 0.89$, $p = 0.2078$). In the equation the intercept (41.61) represents the metabolic fecal nitrogen (MFN). MFN is the quantum of nitrogen excreted in the feces when intake of nitrogen in the diet is zero. Based on this information, TPD was calculated to 79% for the monsoon, 80% for the cool dry season and 81% for the hot dry season (Table 3.13, Figure 3.8). In a nutshell, the digestibility of different nutrient constituents was found to be quite consistent across seasons.

Table 3.13. Seasonal digestibility coefficients achieved by free ranging greater one-horned rhinoceros for different constituents in Chitwan National Park Nepal.

Season	OM	CP	NDF	ADF	HC	Ce	DMD	TPD
Monsoon	0.73	0.65	0.78	0.75	0.88	0.79	0.74	0.79
Cool-Dry	0.70	0.69	0.73	0.65	0.88	0.65	0.69	0.80
Hot-Dry	0.75	0.66	0.78	0.71	0.89	0.73	0.72	0.81

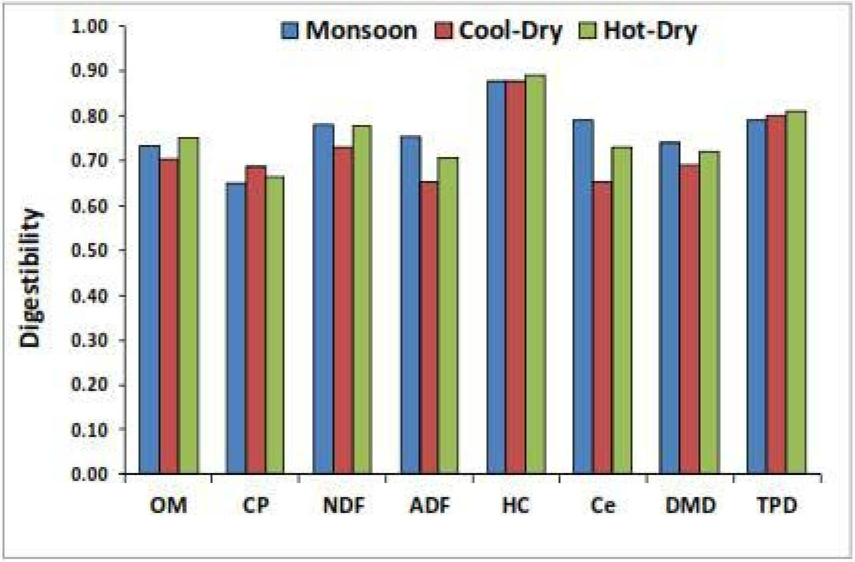

Figure 3.8. Seasonal average digestibility coefficients achieved by greater one horned rhinoceros for different nutritional constituents. OM, organic matter; CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; HC, hemicelluloses; Ce, Cellulose; DMD, dry matter digestibility; TPD, true protein digestibility.

Discussion

Bite rates and amount of food consumed

The food intake of the grazers is influenced by height and bulk density (weight per unit volume) of the grasses (Laca *et al.* 1992), oral morphology and mechanics of food consumption (Shipley *et al.* 1994). Close observation of foraging radio-collared habituated rhinos followed by hand simulation of bites allowed me to accurately quantify bite weight of various food items. Average bite rate (per minute) was 13.37 ± 1.03 for the monsoon, 11.98 ± 0.52 during the cool dry season and 11.50 ± 0.33 during the hot dry season. Average dry weight of the bite was 3.32 g for the monsoon, 3.93 g for the cool dry and 3.02 g for the hot dry season. Mean food intake in the monsoon was 44 g/min, 47 g/min during in cool dry and 35 g/min during the hot dry season. In general, the bite weight and bite rate were inversely related. The bite weight was higher in the cool dry season as the rhinos were mostly browsing and grazing sprouted bunch of grasses, but the bite rate was low. Shrader *et al.* (2006) has also reported decreased bite rate and increased bite weight with the increasing height of the grass in white rhinos. Maximum bite rate was 75/min for white rhino and maximum intake was 100 g/min. Mean food intake of 40 g/min in white rhinos has been reported (Shrader *et al.* 2006). The dry bite weight for cattle has been reported from 0.5 to 1.05 g/bite in different sward height (Soder *et al.* 2009). In general, the average intake per minute (35 - 47 g/min) by the greater one-horned rhinoceros was comparable with white rhinos. Black rhinos are true browsers and the intake rate and bite rate were not available for the comparison.

Habitat use and diet composition

The use of different habitats across seasons is driven by the availability of food plants and water bodies (Laurie 1978, Jnawali 1995, Dinerstein 2003). The rhinos were found to follow the natural nutritional gradient of plant species and foraging on them so as to have optimal nutrient intake and digestibility. For example, when the grass species matured and had low crude protein during the cool dry season rhinos shifted to browse species with higher CP content. Similarly, rhinos heavily utilized new sprouts of the grasses like *Saccharum spontaneum*, *Narenga porphyrocoma*, *Imperata cylindrica* and forbs like *Cersium wallichii* during hot dry season when these plants had good CP, and low fibers.

In a previous study in Chitwan, Jnawali (1995) reported that the browse species contributed 25% diet of the cool dry season, 14% in the hot dry season and 23% in the monsoon season. In an earlier study, Laurie (1982) reported that browse species contributed 22% of the diet in the cool dry season, 8% in the hot dry and 6% in the monsoon season. I found that the browse species contributed 25% of the cool dry season diet, 10% of the hot dry and 15% of the monsoon season diet. All studies were carried out in the same area and were showing the similar pattern except for monsoon. The differences in the contribution of browse species in the diet during monsoon was possibly due to differences in the availability of main browse species like *Trewia nudiflora* and use of different methods for study *i.e.*microhistological analysis (Jnawali 1995), occasional observations (Laurie 1978) and continuous direct observation (present study). Pradhan *et al.* (2008) reported that rhinos in Bardia NP were utilizing maximum browses (up to 46% of the diet) during the cool dry season. Jnawali (1995) also reported higher proportion of browse species in the rhino diet in Bardia. The intake of a higher proportion of browse species in Bardia was probably due to less availability of favored *Saccharum spontaneum* and high availability of browse species (Jnawali 1995, Pradhan *et al.* 2008).

Saccharum spontaneum has always been the main food plant of rhinos in all seasons in Chitwan (Jnawali 1995, Dinerstein 2003, Laurie 1978) and my findings also corroborate this. The high contribution of *S. spontaneum* to the rhino diet was probably because of its unique nature of sprouting throughout the year (Lehmkuhl 1989) and its high standing biomass (Jnawali 1995). My study showed some differences in diet composition of rhinos compared to previous studies in Chitwan, which are: i) During the previous studies 5% to 13% of the rhino diet was composed of agricultural crops (Jnawali 1995) but this has dropped almost zero at present. This is because of the installation of a rhino proof power fence on the fringe of the Park in recent years, which prevents rhinos from accessing crop fields for foraging; ii) Invasive species like *Mikania micrantha*, and *Lantana camara* contributed ca. 5% of the annual diet in the present study. This component was absent in the previous studies (Dinerstein 2003, Jnawali 1995, Laurie 1978). *Mikania micrantha* was accidently introduced in Chitwan in late 1990s, while *Lantana camara* has been reported since 1980s. More than 15% of the prime rhino habitat has been invaded by *Mikania micrantha* in recent years and the species has been reported to have negative impacts on the rhino population (Murphy *et al.* 2012) as it kills the rhino's native food plants. iii) Some of the species like *Eragrostris tenella*, *Callicarpa macrophylla*, and *Brachiaria* species were found consumed more than in previous studies. This may be due the increased availability of these species after the evacuation of ca. 18 km^2 Padampur village in early 2000 (Dhakal *et al.* 2011). These plants are early successional species and have high CP and low NDF.

The study shows that rhinos are opportunistic bulk feeders but quite adaptable in diet selection and that they optimize their intake according to the availability of food plants. Rhinos obviously have a broad diet breadth.

Dry matter intake, total fecal output and nutrient digestibility

Often cited ecological advantages of large body size are: i) larger animals have lower relative energy requirements, ii) large gastrointestinal tract from which they achieve higher ingesta retention time, and iii) capacity to use low quality forage (Demment and Van Soest 1985). Most animals regulate total food intake relative to energy expenditures. Correspondingly, all animals must optimize diet selection and intake in order to meet all nutrient requirements within energy, time and bulk constraints (Robbins 1993). For large herbivores, empirical data do not – so far – support the notion that intake is increased in response to declining diet quality (Meyer *et al.* 2010). However, data are in accord with the assumption that most large herbivores have an anticipatory strategy of acquiring body reserves when high-quality forage is available, and reducing food intake (and potentially metabolic losses) when only low-quality forage is available (Meyer *et al.* 2010). Compared to other megaherbivores rhinos are better in selecting the digestible and nutritious foods in their habitat. Their prehensile lip allows them to select less fibrous plant parts, which may allow them for greater digestive efficiency (Clemens and Maloiy 1983). Greater one-horned rhinoceros have the highest ingesta retention time among monogastric ungulates (Clauss *et al.* 2005), and the ingesta particle sizes are also smaller compared to white rhinos, black rhinos, hippos and elephants, which allow them better digestive efficiency (Clauss *et al.* 2009, Steuer *et al.* 2010).

In the floodplain grasslands of Chitwan the soil is very fertile and the ground water table is high throughout the year (Lehmkuhl 1989). Chitwan receives 2,242 mm rainfall annually; 1582 mm in the monsoon, 54 mm in the cool dry season and 606 mm in the hot dry season (DMH 2001 to 2009, unpublished data). Grasses sprout and grow (vegetative phase) during the late hot dry period, flower and mature during the monsoon and senescence during the cool dry season. Thus, nutritionally the cool dry season should be poorest period in the region. However, as a management practice, the grasslands are burnt during cool dry season and early hot dry season. Due to high moisture content of the alluvial floodplain soils and sporadic rainfall the grasses sprout in early hot dry season, providing a flush of new nutrient-rich, highly digestible food sources. This explains why there was little seasonal variation in the nutrient quality of the ingested forage.

The rhinos spent longer time for foraging during the cool and hot dry season compared to monsoon but they obtained nutritious and digestible forages even during the assumed stressful period (January to early March in case of Chitwan). During the monsoon, the animals feed on variety of annuals and forbs together with late growing grasses and browses. Thus, the rhinos in Chitwan were not facing a seasonal scarcity of food resources like rhino in the African continent. Long ingesta retention time, small ingesta particle sizes provides increases digestive efficiency (Clauss *et al.* 2009, Steuer *et al.* 2010) and permits them to survive on lower quality foods (Illius and Gordon 1992). This could explain why DMI, DMD and TPD of the rhinos living in productive alluvial floodplain of Chitwan were high and consistent across seasons.

Clauss *et al.* (2005) reported 13 to 28 kg of DMI, which was almost 0.5% to 1.3% of the body weight with 35% to 61% DMD and 85% to 95% TPD in the zoo rations for greater one-horned rhinoseros. Black rhinos achieved 46% to 72% DMD and over 88% TPD in conventional zoo rations (Clauss *et al.* 2006). Atkinson (1995) reported DMD 28% to 50% for black rhinos held in bomas in Zimbabwe and fed indigenous browse, comparable to the estimated digestibility of approximately 50% reported by Hall-Martin *et al.* (1982) for free ranging black rhinos. Whereas digestibility (organic matter) met by zoo rhinos fed diets of alfalfa hay were as high as 65% (Foose 1982). White rhinos achieved 41% to 57% DMD in different rations in feeding trials (Kiefer *et al.* 2001). DMI in Sumatran rhinos (*Dicerorhinus sumatrensis*) was 2.8 to 4.1% of the BW while the DMD was 82% which was comparatively higher in this species than reported previously. Mean CP level (ca. 10% DM) in diets of Sumatran rhinos was within the ranges reported from free-ranging black rhinos (Dierenfeld *et al.* 2006).

The weight of free ranging rhinos varied from 1600 to 2200 kg in Chitwan based on the weight taken during translocation (S.R. Jnawali, pers. comm.). If I take 1900 kg as an average weight and annual average DMI as 23.67 kg for free ranging rhinos, their daily DMI would be about 1.25% of the body weight, which is within the upper ranges reported for this species in captivity. Obviously, to maintain physiological balances, DMI should be higher among rhinos living in the wild than in captivity. There was no difference between male and female rhinos in dry matter intake in my study in spite of their body weight differences. The reason for this could be because of small sample size (male = 2, female = 6) and all studied females were lactating fully grown adults. The lactating females obviously should take more DMI to meet their metabolic needs. The DMI, DMD and TPD calculated from the field data were comparable with other rhino species and with greater one-horned rhinos in captivity. The DMD was a bit higher compared to captivity. Dierenfeld (2006) has also reported higher DMD in Sumatran rhinos (fed on wild browse) which is in line with my results in greater one-horned rhinos.

Generally, skewed births or seasonality in breeding and calving are observed where there is strong seasonal variation in food quality and/or climate. Chitwan rhinos do not have any seasonality in breeding (Laurie 1978, Dinerstein 2003, Chapter 8 of this study).

From the results and observations of (a) time spent foraging, (b) DMI, (c) DMD, (d) nutrient digestibility, and (e) reproductive/birth rate seasonality I conclude that seasonal fluctuations in climate have minimal effects on quality of food resources for rhinos in the floodplain habitats of Chitwan. The effect of rainfall variation across seasons was manifested in a behavioral shift towards browse consumption when grasses were of low nutrient content. However, DMI, DMD and nutrient intake was maintained more or less constant across seasons.

CHAPTER 4

Seasonal time budget and activity patterns of greater one-horned rhinoceros in Chitwan National Park, Nepal

Photo: Observing activities and feeding by rhinos from elephant back

Introduction

Seasonal and daily time budget and activity patterns are key biological aspects of an animal that give an insight in the evolutionary history and adaptability of the species. Timing activity is important in reducing competition, avoiding predation while maximizing nutrient intake. Activity patterns of animals are influenced by both biotic and abiotic factors. Abiotic environmental factors such as light and temperature may influence optimum daily and seasonal activity patterns (e.g., Nielsen 1983, Patterson *et al.* 1999). Body mass, human disturbance, social behavior, predator avoidance, prey acquisition, and competition also may affect activity in different forms (e.g., Bunnell and Harestad 1990, O'Donoghue *et al.* 1998, Rogowitz 1997). Animals need to balance their nutrient requirement with seasonal availability and quality of forage and minimize the risk of predation and competition. This is done through optimal time and space allocation to various activities differentially across seasons (Owen-Smith 1979, Dulphy *et al.* 1980). Megaherbivores are mostly bulk feeders and are adapted to low quality diet compared to small ungulates because of their large body size. They spend about half of the daily rhythm on feeding (Owen-Smith 1988). The activity pattern and time spent for different activities are substantially affected by the energy demand of the animal and number of constrains that the animal encounters (Bunnel and Gillinghan 1985). As a result, understanding daily and seasonal time budget and activity patterns is important for developing conservation plans for endangered species (Hwang and Garshelis 2007).

Papers describing the daily and seasonal activities and time budgets of *Rhinoceros unicornis* (hereafter rhinos) are few (e.g., Laurie 1978, Dinerstein 2003) and knowledge on how rhinos are performing with respect to changing habitat dynamics is very important for effective conservation management of this endangered species. The study area, where previous studies on rhinos were carried out by Laurie (1978), Jnawali (1995) and Dinerstein (2003), has changed substantially over the years. The observed changes are: 1) *Mikania micrantha*, a highly invasive creeping vine, has seriously invaded over 15% of the prime rhino habitats and 44% of the habitat is under invasion of various levels in the recent decade (Murphy *et al.* 2012). This invasion can potentially kill native food plants of rhinos leading to substantial habitat degradation (DNPWC 2009, Murphy *et al.* 2012). 2) Rhinos used to obtain 5% to 13% of their diet from the agricultural crops (Jnawali 1995). This opportunity of obtaining highly nutritious foods has been lost by the installation of rhino proof power fence on the Park border in the recent decade (NTNC unpublished data). 3) Padampur village, which was inside the core area, has been evacuated in 2004 (Dhakal *et al.* 2011). This has provided an extra 18 km^2 of grassland and wetlands to rhinos within the study area. 4) Vegetation succession is very rapid in the alluvial floodplains of the Chitwan. As a result, short grasslands have been converted to tall grasslands and tall grasslands into forested areas. In this context, my study was very timely to explore how rhinos are responding to these changes. In this chapter, I have explored on seasonal and daily activity patterns and time budget of rhinos and comparison with previous studies have been made with ecological explanations.

Methods

Animal capture

Radio-telemetry has been used to study rhinos in Nepal for over 25 years. This technology has provided significant insight into the life-history strategies of these rhinos (Dinerstein 2003). Between 2010 and 2011, six females and two males were immobilized and fitted with GPS radio-collars. The animals were captured following the methodology developed by Dinerstein *et al.* (1990). We used VECTRONIC Aerospace GmbH GPS collars (Germany) for 6 animals and Afro Trek GPS collars (South Africa) for 2 animals. The collars functioned between 3 months and over 30 months. For detail on capture, anesthesia and collaring see chapter 5.

Activity patterns

The radio-collared rhinos were habituated to captive elephants (Laurie 1978, Dinerstein and Price 1991) and could be approached to within 5 - 10 m distance without disturbing their normal behavior. Each rhino was followed on elephant back continuously for 24 hours in each season for one to three sessions (days) to record behavioral data where elephants and observers were changed after 6 hours to avoid observer/elephant fatigue. Continuous monitoring was mostly done during full moon and night vision equipment was used to observe behavioral activities. During continuous monitoring every activity state and event was recorded. I recorded any behavior lasting more than two minutes as activity state and less than two minute as activity event (Altmann 1974, Lehner 1996). Based on previous studies (Laurie 1982, Dinerstein 2003, Kandel and Jhala 2008) behaviors were assigned following mutually exclusive and exhaustive categories:

Grazing: Feeding on non woody vegetation like grasses, forbs, aquatic plants etc. The grass species may have low height (ca. 5 cm) to maximum height of 7 meters in Chitwan.

Browsing: Rhinos feeding on woody vegetation like tree/shrub twigs, leaves, climbers and their fruits.

Feeding: Feeding refers to both grazing and browsing. It does not include the time spent walking while searching for food plants.

Wallowing: Immersing the body in water often combined with rolling in mud.

Resting: Laying down on the substrate, sleeping, or standing but resting with keeping its head low.

Standing: Standing still and scanning the area around.

Walking: Moving from one place to another purposefully in search of wallow, bedding place, food, or to find mates.

Other activities (Events): Social interactions, lactation (suckling), urination, defecation and drinking water.

Care was taken to avoid any disturbance to the rhinos by the presence of observer and elephant while collecting behavioral data. Dicta-phone recorders were used to record all observations.

Data analysis

Hourly activities were summed and averaged across all rhinos and all monitoring sessions in a single season to understand time activity patterns. Total time invested in different activity states by each rhino across all continuous monitoring sessions was averaged and variability between rhinos was reported as standard errors. Activity data were tested for normality by Kolmogorav-Smirnov test. Subsequently parametric tests were conducted in NCSS (2007) to check for seasonal difference in seasons and individuals. I used two-way ANOVA with seasons and individual rhinos as main effects and season x individual rhinos as the interaction term (Zar

2010). If interaction was found to be non significant, it was omitted from the analysis to gain better statistical power for testing the main effects (Sokal and Rohlf 2012). For data analysis the year was divided into three seasons: cool dry (mid October - mid February), hot dry (mid February – mid June), and monsoon (mid June – mid October). The results of this study were compared with previous studies (Laurie 1978, Dinerstein 2003) to see if time budgets and activity patterns across seasons had changed since their earlier studies.

Results

Seasonal time budget and activity

Eight radio-collared rhinos were observed continuously for 11 days in cool dry season, 13 days in hot dry season and 17 days in monsoon season. Annually, rhinos spent 33.21 ± 2.29% time grazing, 6.4 ± 0.19% time browsing, 39.61 ± 1.93% time feeding, 8.41 ± 1.56% time walking, 14.97 ± 2.39% time wallowing, 30.31 ± 3.05% time resting, 4.93 ± 1.42% time standing and 1.77 ± 0.54% time in other activities (Table 4.1).

Table 4.1. Percentage (Average ± SE) time spent in different activities by rhinos during cool dry (n = 11 days), hot dry (n = 13 days), and monsoon (n= 17 days) seasons.

Activities	cool dry	Hot dry	Monsoon	Annual
Grazing	29.20 ± 2.35	38.54 ± 1.37	31.88 ± 3.13	33.21 ±2.29
Browsing	11.02 ± 0.68	1.87 ± 0.35	6.31 ± 1.70	6.40 ±0.91
Feeding	40.21 ± 2.79	40.41 ± 1.20	38.19 ± 1.79	39.61 ±1.93
Walking	10.26 ± 2.26	6.60 ± 1.23	8.39 ± 1.19	8.41 ±1.56
Wallowing	2.65 ± 0.97	20.62 ± 3.62	21.64 ± 2.58	14.97 ±2.39
Resting	40.44 ± 1.84	25.26 ± 4.80	25.23 ± 2.51	30.31 ±3.05
Standing	5.30 ± 0.79	5.38 ± 2.46	4.11 ± 0.99	4.93 ±1.42
Others	1.14 ± 0.20	1.74 ± 0.63	2.43 ± 0.77	1.76 ±0.54

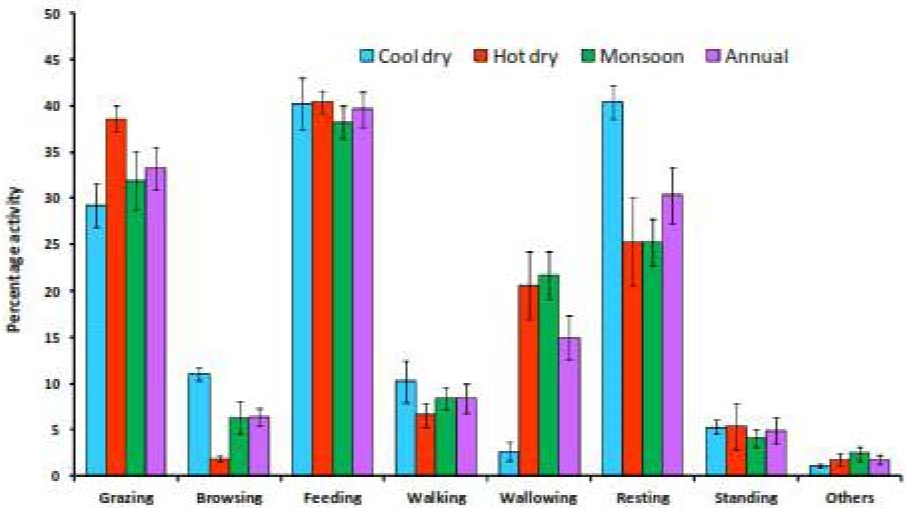

Figure 4.1. Seasonal and annual percentage time spent in different behavioral activities by greater one-horned rhinoceros as determined by 41 days continuous monitoring of radio-collared 8 individuals in Chitwan National Park, Nepal. Error bars are standard errors. Feeding is the combination of grazing and browsing.

Table 4.2. Test result of the normality for different seasonal activity data.

		Grazing	Browsing	Foraging	Walking	Wallowing	Resting	Standing	Others
N		26	26	26	26	26	26	26	26
Normal Parameters (a,b)	Mean	33.560	6.637	40.198	8.400	13.689	31.143	4.888	1.683
	Std. Deviation	7.403	4.613	6.341	5.291	11.085	11.491	4.274	1.475
Most Extreme Differences	Absolute	0.161	0.183	0.099	0.133	0.130	0.160	0.214	0.271
	Positive	0.072	0.183	0.098	0.133	0.116	0.160	0.214	0.271
	Negative	-0.161	-0.171	-0.099	-0.081	-0.130	-0.150	-0.206	-0.175
Kolmogorov-Smirnov Z		0.823	0.934	0.503	0.677	0.662	0.818	1.092	1.383
Asymp. Sig. (2-tailed)		0.507	0.347	0.962	0.750	0.773	0.515	0.184	0.044

a Test distribution is Normal.

b Calculated from data.

The test for normality for different activities failed to reject normality (Table 4.2). I therefore used parametric comparisons to compare activities between different seasons.

Seasonal behavioral activity

Grazing

Time spent grazing was 29.20 ± 2.35% in cool dry season, 38.54 ± 1.37% in hot dry season and 31.88 ± 3.13% in monsoon (Table 4.1, fig 4.2). There was no interaction effect between season and individual rhinos for time investment in grazing (Two way ANOVA, $F_{6, 25} = 1.35$, $p = 0.3546$). Grazing did not differ significantly across seasons (Two way ANOVA, $F_{2, 25} = 3.74$, $p = 0.063$). Similarly, time spent grazing between the individuals was not significant (Two way ANOVA, $F_{3, 25} = 2.14$, $p = 0.1446$).

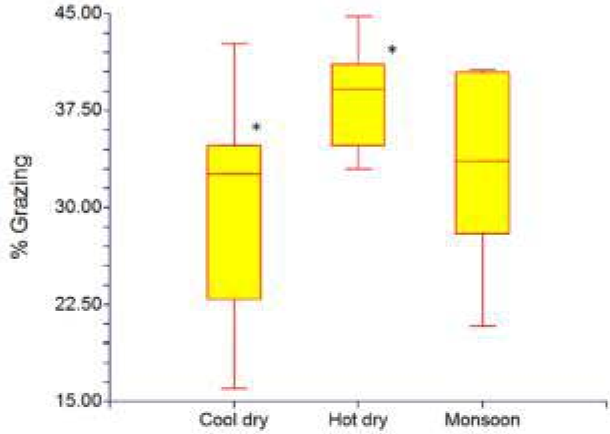

Fig 4.2. Time spent grazing by rhinos in Chitwan depicted by season. * Significant at $p \leq 0.05$ (Tukey-Kramer Multiple-Comparison Test).

Browsing

Rhinos spent 11.02 ± 0.68% of time in cool dry, 1.87 ± 0.35% time in hot dry and 6.31 ± 1.70% time during monsoon for the browsing (Table 4.1, fig 4.3). There was no significant interaction between season and individual rhinos ($F_{6, 25} = 0.53$, $p = 0.7766$). Time spent browsing varied significantly across seasons ($F_{2, 25} = 18.83$, $p = <0.0001$). Browsing was not significant between individual rhinos ($F_{5, 26,} = 0.61$, $p = 0.6207$).

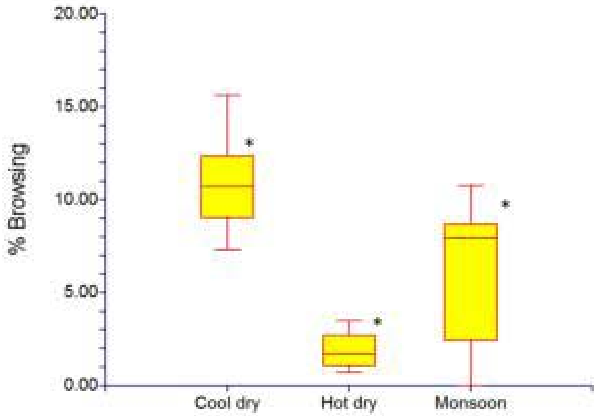

Fig 4.3. Time investment by rhinos on browsing depicted by season. * Significantly different at $p \leq 0.05$ (Tukey-Kramer Multiple-Comparison Test).

Feeding

Rhinos spent 40.21 ± 2.79% of time in cool dry season, 40.41 ± 1.20% of time in hot dry season and 38.19 ± 1.79% of time during monsoon for feeding (Table 4.1, fig 4.4). There was no interaction between season and individual rhinos ($F_{6, 25} = 1.01$, $p = 0.4617$). Feeding activity did not differ across seasons ($F_{2, 25} = 0.34$, $p = 0.7187$) nor did individual rhinos differ in their time investment for feeding ($F_{3, 25} = 1.46$, $p = 0.2705$).

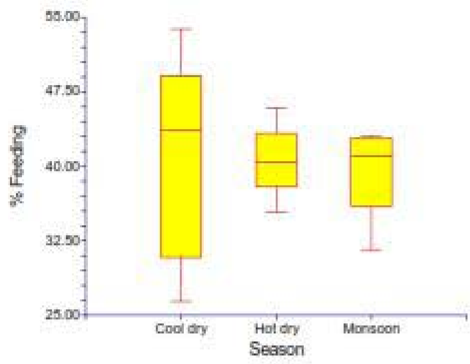

Fig 4.4. Time investment by rhinos on feeding depicted by season. * Significantly different at $p \leq 0.05$ (Tukey-Kramer Multiple-Comparison Test).

Resting

Time spent resting was 40.44 ± 1.84% for cool dry season, 25.26 ± 4.80% for hot dry season and 25.23 ± 2.51% for monsoon (Table 4.1, Fig 4.5). There was no interaction between season and individual rhinos ($F_{6, 25} = 0.20$, $p = 0.9692$). The time spent resting was significant across seasons ($F_{2, 25} = 2, 25$, $p = 0.0287$). Resting was not significant between individual rhinos ($F_{3, 25} = 0.12$, $p = 0.9470$).

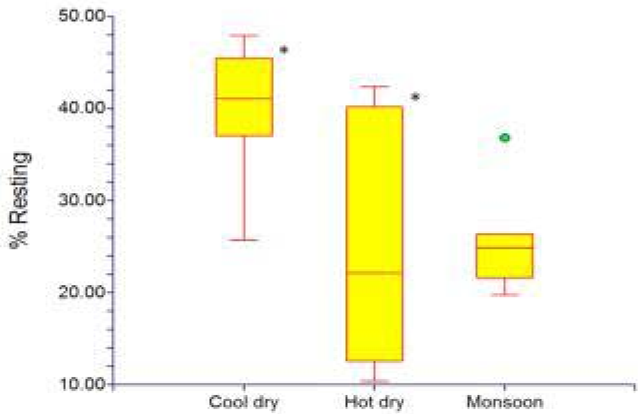

Fig 4.5. Time investment by rhinos on resting depicted by season. * Significantly different at $p \leq 0.05$ (Tukey-Kramer Multiple-Comparison Test).

Wallowing

Time spent wallowing was 2.65 ± 0.97% during cool dry season, 20.62 ± 3.62% in hot dry season and 21.64 ± 2.58% in monsoon (Table 4.1, fig 4.6). There was no interaction between season and individual rhinos ($F_{6, 25} = 2.70$, $p = 0.0631$). Time spent wallowing was statistically significant across seasons ($F_{2, 25} = 27.68$, $p = <0.0001$). However, there was no difference between individuals ($F_{3, 25} = 1.38$, $p = 0.2831$).

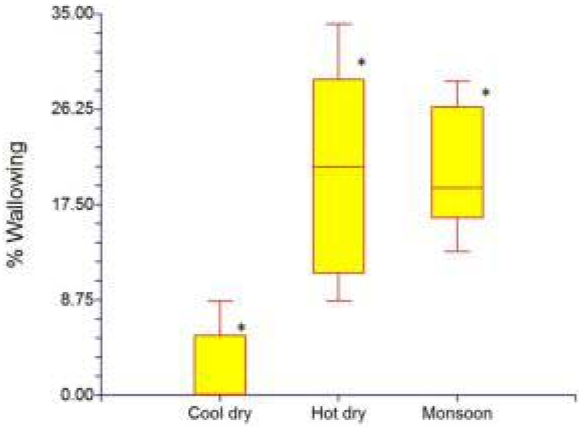

Fig 4.6. Time investment by rhinos on wallowing depicted by season. Cool dry is different with hot and monsoon; Hot dry and monsoon were not different. * Significantly different at $p \leq 0.05$ (Tukey-Kramer Multiple-Comparison Test).

Walking

Time spent walking for cool dry season was 10.26 ± 2.26%, 6.60 ± 1.23% for hot dry season and 8.39 ± 1.19% during monsoon (Table 4.1, fig 4.7). There was no interaction between season and individual rhinos ($F_{6, 25} = 1.70$, $p = 0.1993$). The time spent walking was not significant across seasons ($F_{2, 25} = 0.44$, $p = 0.6506$). Similarly, there was no difference on the time invested walking between individuals ($F_{3, 25} = 0.77$, $p = 0.5335$).

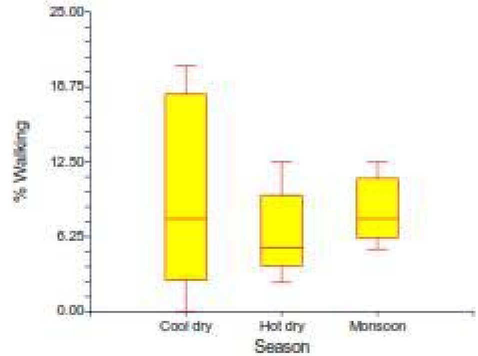

Fig 4.7. Time investment by rhinos on walking depicted by season. * Significantly different at $p \leq 0.05$ (Tukey-Kramer Multiple-Comparison Test).

Standing/vigilance

Rhinos spent 5.30 ± 0.79% of time during cool dry season, 5.38 ± 2.46% of time in hot dry season and 4.11 ± 0.99% of time during monsoon in the standing/vigilance (Table 4.1, fig 4.8). There was no interaction between season and individual rhinos ($F_{6, 25} = 0.41$, $p = 0.8579$). The seasonal time spent vigilance was not significantly different ($F_{2, 25} = 0.48$, $p = 0.6296$). There was no seasonal variation in the vigilance time budget between the individuals ($F_{3, 25} = 1.34$, $p = 0.3038$).

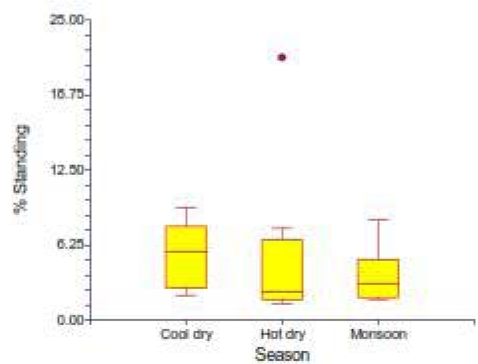

Fig 4.8. Time investment by rhinos on standing/vigilance depicted by season. * Significantly different at $p \leq 0.05$ (Tukey-Kramer Multiple-Comparison Test).

Other activities

Rhinos spent 1.14 ± 0.20% of time in cool dry season, 1.74 ± 0.63% of time in hot dry season and 2.43 ± 0.77% of time during monsoon for other activities (Table 4.1, fig 4.9). There was no interaction between season and individual rhinos ($F_{6, 25}$ = 1.16, p = 0.3834). There was no seasonal difference in the time spent on other activities ($F_{2, 25}$ = 2.08, p = 0.1647). Similarly, there was no individual variation on other activities ($F_{3, 25}$ = 1.22, p = 0.3424).

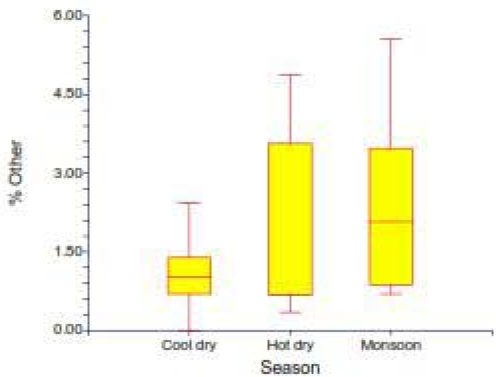

Fig 4.9. Time investment by rhinos on other activities depicted by season. * Significantly different at p ≤ 0.05 (Tukey-Kramer Multiple-Comparison Test).

Diel activity patterns

Grazing

During cool dry season rhinos exhibited four small peaks of grazing: first during midnight, second between 6:00 and 9:00 h, third in the late afternoon between 14:00 and 18:00 h, and forth between 21:00 h and 22:00 h (Fig 4.10). In the hot dry season, the animals followed a bimodal grazing pattern (Fig 4.10); grazing was highest in early morning (between 3:00 h and 7:00 h) and evening (between 17:00 h and 20:00 h). Three peaks were observed during monsoon (Fig 4.10). Highest grazing activity occurred between 3:00 h and 7:00h in the morning, 16:00 h and 18:00 h, and between 21:00 h and 22:00 h in the night. Rhinos spent more time grazing in the daytime during cool dry season than during hot dry and monsoon seasons.

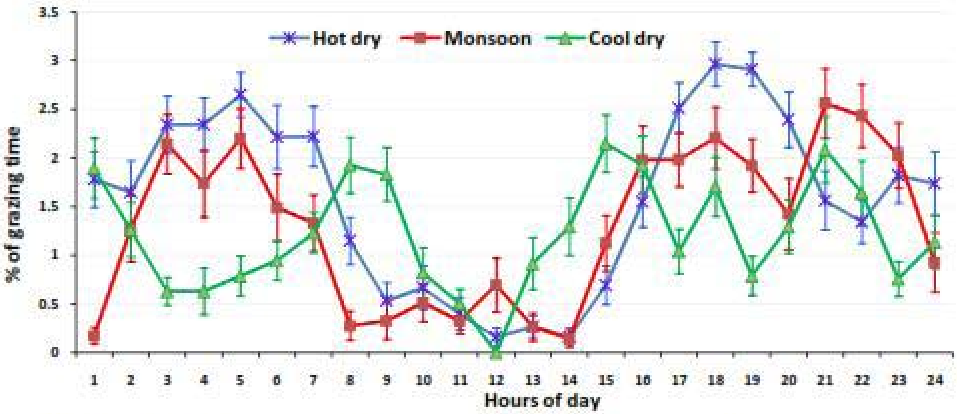

Fig 4.10. Seasonal diel patterns of grazing by greater one-horned rhinoceros (n = 8) in Chitwan National Park. Bars are standard errors.

Browsing

Figure 4.11 shows the seasonal diel browsing pattern. During the cool dry season browsing did not have a pattern but there was a tendency for more browsing in late evening and midnight. Browsing was lowest during hot dry season and was mostly done during the afternoon. In the monsoon browsing was high during late afternoon and midnight but did not show any particular diel pattern.

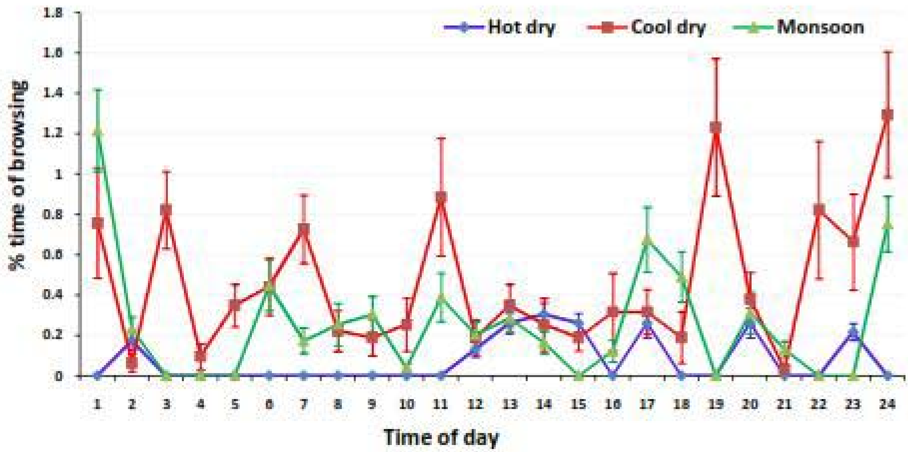

Fig 4.11. Seasonal diel patterns of browsing by greater one-horned rhinoceros (n = 8) in Chitwan National Park. Bars are standard errors.

Feeding

During hot dry and monsoon seasons feeding showed similar bimodal pattern (Fig 4.12). During winter animals showed a bimodal pattern with a short peak in the morning (7:00 – 9:00), followed by a little activity during mid day and then increased activity and a long peak lasting until shortly after mid night (22:00 – 1:00).

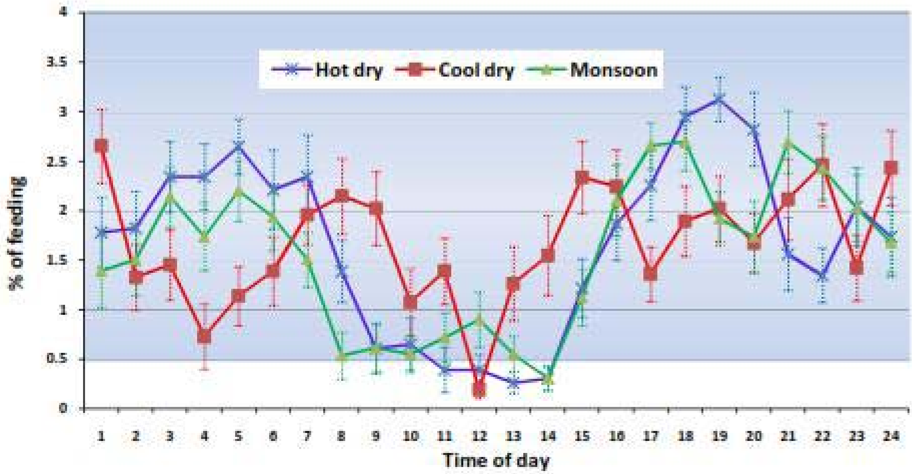

Fig 4.12. Seasonal diel pattern of feeding by greater one-horned rhinoceros (n = 8) in Chitwan National Park. Bars are standard errors.

Resting

Resting peaked during midday (between 9:00 and 14:00 h) with smaller peaks before midnight (between 19:00 h and 23:00 h) and very early morning (between 3:00 and 5:00 h) during the cool dry season (Fig 4.13). Two peaks of resting (8:00 h to 11:00 h, and 21:00 h to 22:00 h) occurred in hot dry season. The rhinos rested mostly during morning until late afternoon in the monsoon.

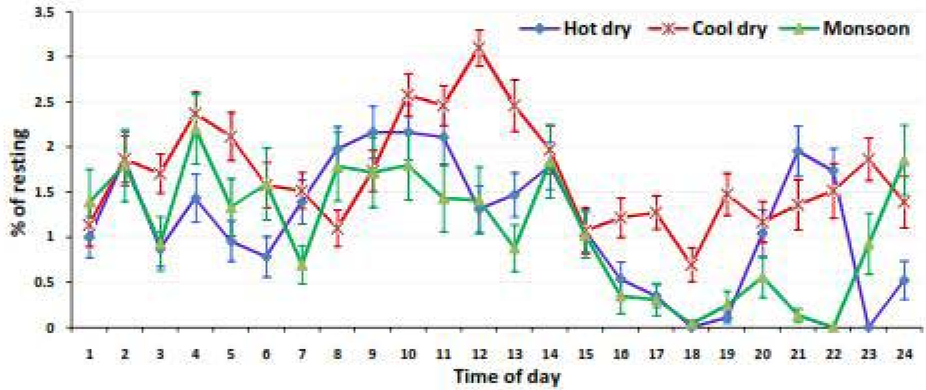

Fig 4.13. Seasonal diel pattern of resting by greater one-horned rhinoceros (n = 8) in Chitwan National Park. Bars are standard errors.

Wallowing

During the hot dry season wallowing was concentrated between 10:00 h and 15:00 h, and had a short peak during midnight (Fig 4.14). In the monsoon, wallowing was frequent from very early morning until late afternoon, with small, short peaks in the evening and at midnight. The low frequency of wallowing occurred mainly during early morning in all seasons. There was very little wallowing during cool dry season compared to other seasons and was mostly observed during 18:00 h.

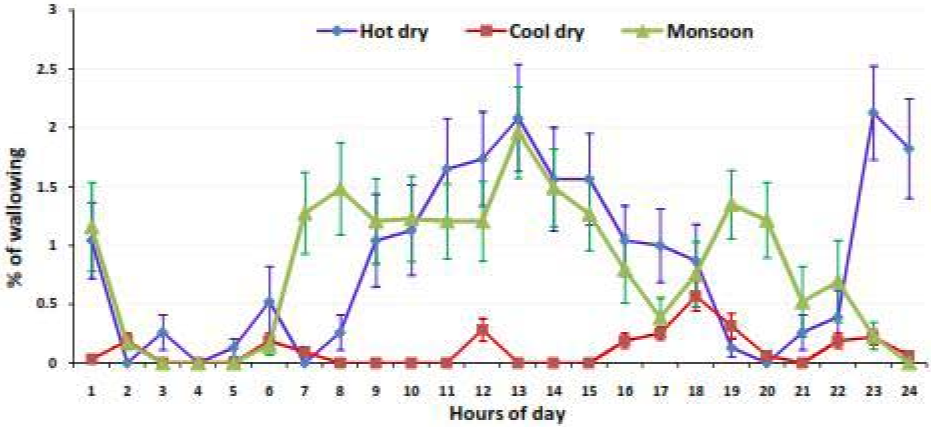

Fig 4.14. Seasonal diel pattern of wallowing by greater one-horned rhinoceros (n = 8) in Chitwan National Park. Bars are standard errors.

Walking

Walking did not show any diel pattern in any of the three seasons (Fig 4.15).

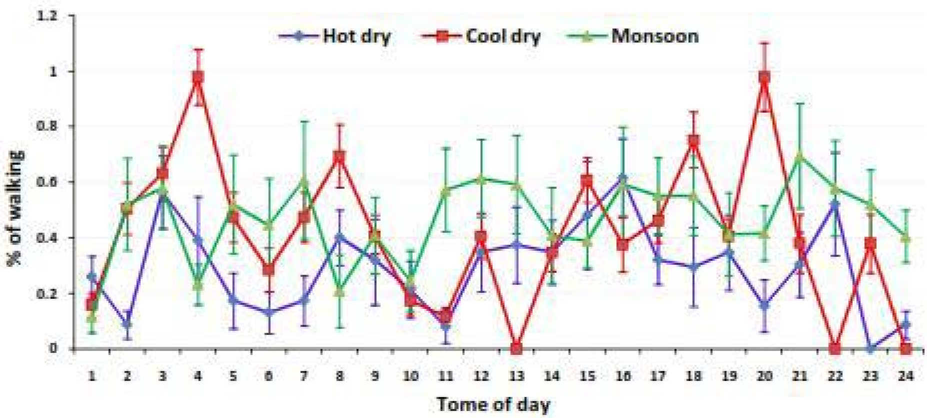

Fig 4.15. Seasonal diel pattern of walking by greater one-horned rhinoceros (n = 8) in Chitwan National Park. Bars are standard errors.

Standing/vigilance

Standing did not exhibit any clear diel patterns during the cool dry or the monsoon seasons, but showed irregular peaks in late night, forenoon and early evening (cool dry) and in the forenoon in the monsoon (Fig 4.16).

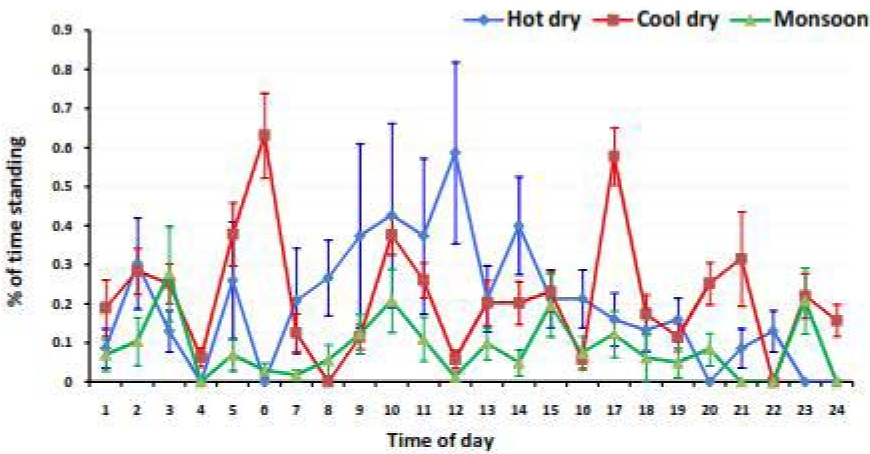

Fig 4.16. Seasonal diel pattern of standing by greater one horned rhinoceros (n = 8) in Chitwan National Park. Bars are standard errors.

Other activities

Time spent on other activities was very small and it showed no diel pattern (Fig 4.17). However, a mall peak between 05:00 h and 07:00 h in the hot dry season and a small peak between 21:00 h and 23:00 h in the monsoon were observed.

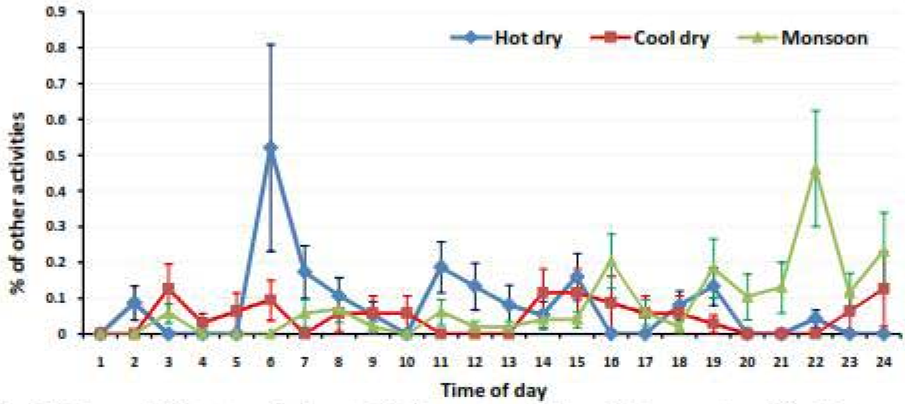

Fig 4.17. Seasonal diel pattern of other activities by greater one-horned rhinoceros (n = 8) in Chitwan National Park. Bars are standard errors.

Discussion

Seasonal activity pattern

During the 24 hour period, herbivores must, in general, spend up to 10 hours foraging in order to meet their metabolic needs (Bunnel and Gillingham 1985). The time spent feeding differs with availability and quality of food resources (See chapter 3 on nutritional ecology). For greater one-horned rhinoceros, grazing activity was highest during the hot dry season and low during the monsoon and cool dry season. Browsing was high in the cool dry season and lowest during the hot dry season. During the cool dry season grasses are over matured and the nutrients are either allocated for seeds and/or translocated to underground parts in perennial species. Thus leaves and shoots have low crude protein and digestible energy contents. This could be the reason to explain why rhinos switched to browse species during the cool dry season. Similarly, during the hot dry season, they grazed most of the time and browsed less as there was ample supply of newly sprouted grasses like *Saccharum spontaneum, Narenga prophyrocoma* and *Imperata cylindrica* after annual burning. The sprouting grasses are low in fiber content and of high nutritive value. This type of shift in browsing and grazing according to food availability in different seasons was also reported by Laurie (1978), Jnawali (1995) and Dinerstein (2003).

The amount of time spent feeding was also influenced by the availability and height/structure of the grasslands. The time spent feeding was low in monsoon due to the high availability and high density of the grasses. The high density good quality forage could be grazed in a shorter duration for meeting the nutrient needs of the rhinos. Similarly, time spent feeding was highest during cool dry season because of low availability of good forage and time needed for selecting the best part from the matured grass sward. In the hot dry season grasses sprouted after burning were low in height and rhinos should separate the new flushes from the unburned swards which was more time consuming compared to monsoon. As the food density and availability decreases foraging effort must either increase or animal rely on body reserves conserving energy by lowering foraging investment (Robbins 1993). Although the animal can alter foraging strategies by selecting other species (*e.g.* browse in case of rhino); becoming less selective (*e.g.* foraging even on *Mikania* by rhinos) or choosing more favorable food patches in the total environment (*e.g.* selecting more wet patches during dry season in case of rhinos); foraging efficiency must ultimately decrease as the animal is forced to expand more time and energy in acquiring the necessary food (Robbins 1993). This availability and selectivity of nutrient rich palatable forage could probably be the main cause leading to seasonal variation in the time spent feeding. Even though forage quality was low in cool dry season compared to other seasons, it was not below critical levels where there would be negative returns by investing more energy/time in foraging. Chitwan has diverse habitat patches that due to edaphic characteristics maintain differential growth phases of grasses. Also with each grass sward there continue to be some growing shoot, especially in species that grow in moist soils. Thus, by investing more search time rhinos are able to locate these micro habitats and select grass/plant parts that have relatively higher nutrient content. The prehensile upper lip and flexible mouth parts of the greater one-horned rhinoceros enable it to be more selective in choosing plant parts compared to the white rhino (*Ceratotherium simum*) a similar sized grazer. Thereby it is advantageous for greater one-horned rhinoceros to increase investment in feeding and obtain the required nutrients in place of accumulating body reserves (fat) and metabolizing this during times of low forage quality as fat production storage and use are energetically more costly (Robbins 1993).

Wallowing is widespread among large mammalian herbivores. For the mega-herbivores living in tropical open habitats, wallowing is a mechanism to adjust to the heat stress (Owen-Smith 1988, Dinerstein 2003). In Chitwan average maximum temperature remains ca. 32 - 36^0 C during April to September (hot dry and monsoon) and ca. 23^0 C during January/February (cool dry season). I clearly observed the following three strategies adopted by greater one-horned rhinoceros to cope with the annual temperature fluctuations: a) Spending more time feeding in late afternoon and night during the hot dry and monsoon seasons and proportionally more feeding during daylight hours in the cool dry season (see fig 5). b) Resting in the riverine forest shade during hot day hours and c) Increasing frequency and time of wallowing with increasing temperature and rains in the late hot dry and monsoon seasons. The rhinos mostly preferred streams and rivers for wallowing during the night time in cool dry season as it was relatively warmer than of stagnant water. Similarly, stagnant pools/wallows were preferred during hot dry and monsoon season as it provides sufficient mud coat to the body for cooling and protection against insect bites. Similar types of observations have been reported by Dinerstein (2003) and Laurie (1978). Similarly, changes in behavioral responses with the changes in atmospheric temperatures have been reported in the white and black rhinos by Owen-Smith (1988).

Daily activity pattern

Rhinos were active both in day and night. During hot dry season and monsoon the rhinos showed a bimodal feeding pattern, while there was tendency towards bimodal pattern with some fluctuations during cool dry season. Wallowing was highest during the day time and early evening during hot dry and monsoon. It is clearly observed that both feeding and wallowing were influenced by the atmospheric temperature. Similarly, during the winter period rhinos used more time for resting especially in the grassland during late morning and afternoon to get the mild sunlight and hence to get relief from the severe cold of the night. Similar type of diel patterns have been reported earlier by Dinerstein (2003) and Laurie (1978) from their studies in the same area ca. 24 and 34 years ago.

The White rhinos spent 44% - 48% of time on feeding and 41% of the time in resting. They showed bimodal feeding patterns. The main active periods were the early part of the morning and late afternoon, extending in to the evening. Black rhinos (*Diceros bicornis*) were active for 47% of the day and 95% of the night. They spent 30% of the daylight hours in feeding (Owen –Smith 1988).

Comparing feeding time budget with previous studies

I compared the seasonal time spent on feeding by rhinos with that reported by Dinerstein (2003) to see if there were differences between two time frames. The estimates of feeding time reported by Dinerstein (2003) for different seasons were lower than 95% confidence interval generated for feeding time invested by rhinos in monsoon and hot dry season during the current study. While the estimates of Dinerstein (2003) though lower than time spent foraging in cool dry season estimated in the current study was not statistically significant (Figure 4.18).

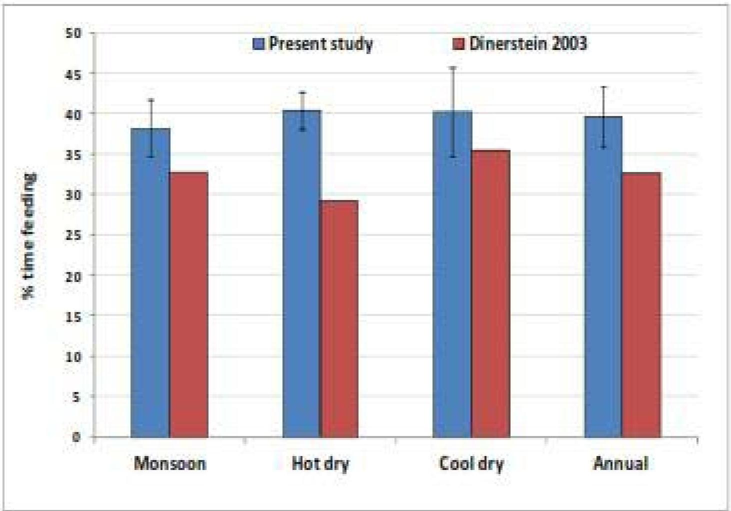

Fig 4.18. Comparison of seasonal and annual percentage time spent feeding by rhinos in present study of 2011 and Dinerstein (2003). The error bars are 95% confidence interval.

Although Laurie (1978) had also reported the time spent feeding based on his occasional short term observations these estimates were not as reliable as of Dinerstein (2003) because Laurie's study was not based on radiotelemetry. Dinerstein (2003) had good data set generated from radio-collared animals like mine. However, my dataset is more extensive and intensive compared to previous studies that represent the present field context and comparing with the result of Dinerstein (2003) makes a good sense. Small variations on the results of similar research could be obtained because of sample size and some variations in the several biotic and abiotic factors in the field research. However, I tried to maintain the same methodology and got adequate sample sizes to compare with the previous studies. In spite of these efforts there was 7% increment in the average annual daily feeding time budget of rhinos compared to previous study of Dintersten (2003) and highest differences was observed during hot dry season (11%) (Figure 4.18).

The evacuation of Padampur village in 2004 (ca. 18 km^2) from the park has added prime grassland habitat for rhinos and may have buffered the lost foraging opportunity on the farm crops after the installation of power fence on the park border. Moreover, the population density of the rhinos in the study area (especially in Icharny island) has decreased from 10.5/km^2 (Dinerstein 2003) to 5.7/km^2 (present study) in the Icherny Island. In the normal situation, the addition of new prime habitat and decrease in the population density should provide ample space and food for the rhinos and the same level of time spent feeding or even less time spent feeding could be expected. *Mikania micrantha* has been reported to affect over 100 species of plants in Chitwan (Sapkota 2007). Over 15% of the prime rhino habitat has been seriously invaded by the *Mikania micrantha* and resulted in the habitat degradation and low availability of forage plants to rhinos and other herbivores (Murphy *et al.* 2012, DNPWC 2009, see chapter 7). This has been further exacerbated by the drying up of some waterholes and wetlands and change in the plant structure due to rapid plant succession. Rhinos are adapted to early successional vegetation and habitats along the alluvial floodplains. I suspect that because of combination of these factors the rhino habitat quality has become degraded compared to past. As a result, the time spent feeding of rhinos may have been increased. The theoretical (Emlen 1966, Schoener 1971) and empirical (Homewood 1978) studies qualifies a habitat resource as poor if animals spend more time feeding. It seems that since rhinos are generalists and have a very wide diet breadth of diet and small changes in habitats could be adjusted easily. I found that rhinos were feeding on *Mikania micrantha* and other invasive plants (see chapter on nutritional ecology) and were found to use larger space for foraging and other activities (see chapter on ranging behavior and habitat use). This shift in time budget to large feeding time in combination with other interferences on population density and home ranges suggests deterioration of rhino habitat that could pose a threat to the population performance of the endangered rhinos. Hence, immediate interventions to check further degradation of habitat and keep the population growth at present rate (r = 5%) is of immense importance for long-term survival of rhinos in Chitwan. Since the changes observed in my intensive study area are also observed in most rhino habitats of Nepal and India the results and recommendations are applicable elsewhere as well.