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DEMOGRAPHIC STRUCTURE, ACTIVITY PATTERNS, HABITAT USE AND FOOD HABITS OF *RHINOCEROS UNICORNIS* IN CHITWAN NATIONAL PARK, NEPAL

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We studied the time activity budgets, habitat preference, food habits and population structure of the Greater One-horned Rhinoceros *Rhinoceros unicornis* in Chitwan National Park, Nepal by monitoring eight different free ranging rhinos from elephant back for 94.5 hrs (7-24 hours per rhino) and by an intensive survey of rhino habitats from elephant back and a four-wheel drive vehicle in early 2003. We classified 92 rhino sightings into seven age and gender groups. There was a calf for every 2.54 adult female rhino. We found that the adult sex ratio was equal, the proportion of adult rhinos had increased and the calf:cow ratio had decreased compared with earlier studies. We found that rhinos spent most of their time resting (42.9% ±7 SE) and foraging (32.7% ±6.1 SE). There was a foraging peak in the morning and afternoon, and rhinos rested or wallowed during the noon hours. Rhinos were observed to use grasslands, riverine mixed forests and ecotones (grasslands interspersed with mixed forests) and were not observed to use Sal forests and agricultural fields. They preferred to forage in grasslands (50.7% ± 9.9 SE) and ecotones (18.5% ±7.7 SE), preferring riverine mixed forests for resting (73.2% ±16 SE). Food habits of rhinos were estimated from 11,101 bite counts from seven rhinos (155 to 2,785 bites from each rhino) from different habitats. Bite counts were corrected for proportional use of a habitat for foraging and for dry weight per bite, to compute the dry biomass contribution of a food plant to the rhino's diet. Rhinos were observed to feed on 42 different plant species. However, only seven species contributed 85% of the dry biomass consumed by rhinos: these were *Saccharum spontaneum* (33%), *Phragmites karka* (16.7%), *Imperata cylindrica* (16.2%), *Saccharum bengalense* (6%), *Callicarpa macrophylla* (5.1%), *Neranga porphyrocoma* (5%) and *Hemarthrea compressa* (4.8%).

Key words: Indian Rhinoceros, diet composition, population structure, ranging patterns

INTRODUCTION

The Greater One-horned Rhinoceros *Rhinoceros unicornis* henceforth rhinos, once ranged throughout the Gangetic Floodplain (Gee 1959, 1963), but at present, its range has been drastically reduced (Stracey 1957; Rookmaaker 1984; Dinerstein 2003). In recent times, the Greater One-horned Rhinoceros has received much scientific and conservation attention with successful introductions and reintroductions (Laurie 1978, 1982; Jnawali 1995; Dinerstein 2003; Sinha *et al.* 2005). The two largest populations of rhinos are located in Kaziranga National Park (>1,500 rhinos, Vasu 2003) and in Chitwan National Park (>500 rhinos, DNPWC 2000). These two populations hold promise for the long-term viability of the rhino and as a potential source for reintroductions of rhino to parts of their historic range (Dinerstein and McCracken 1990; Sinha and Sawarkar 1993; Dinerstein 2003). Due to ever increasing threats to the habitats in these areas from anthropogenic pressures it is imperative that some form of scientific monitoring be implemented for the species. Herein, we present the findings of a short intensive study on habitat use, activity patterns, food habits and the population structure of the Greater One-horned Rhinoceros in Chitwan National Park, Nepal.

STUDY AREA

The present study was carried out in the Chitwan National Park of Nepal between November 2002 and May 2003. The park is located in the *terai* region bordering India, in the southern portion of the Chitwan Valley between 27° 19′ N 83°55′ E and 27°33′ N 84°58′ E (Fig. 1). The Park covers a pristine area of the Siwalik Hills and river valleys that harbours an unique ecosystem of world significance and is designated as a World Heritage Site. The hillsides (762 m above sea level) are forested with deciduous and semi-deciduous trees, mainly Sal *Shorea robusta*, and the low-lying areas (altitude varies from 107 m to 183 m above sea level) along the rivers in the Park are a mosaic of riverine forest types and grasslands (Laurie 1982). There are substantial areas of floodplain habitat with grassy meadows where grassland communities flourish (Lehmkuhl 1993).

The maximum and minimum temperatures are 38 °C in May and 11 °C in January respectively. The climate is monsoonal, and the average yearly rainfall is more than 2,330 mm; nearly 2,000 mm of precipitation occurs during the monsoon between June and September. Though the study site is north of the tropics, its climate is tropical to

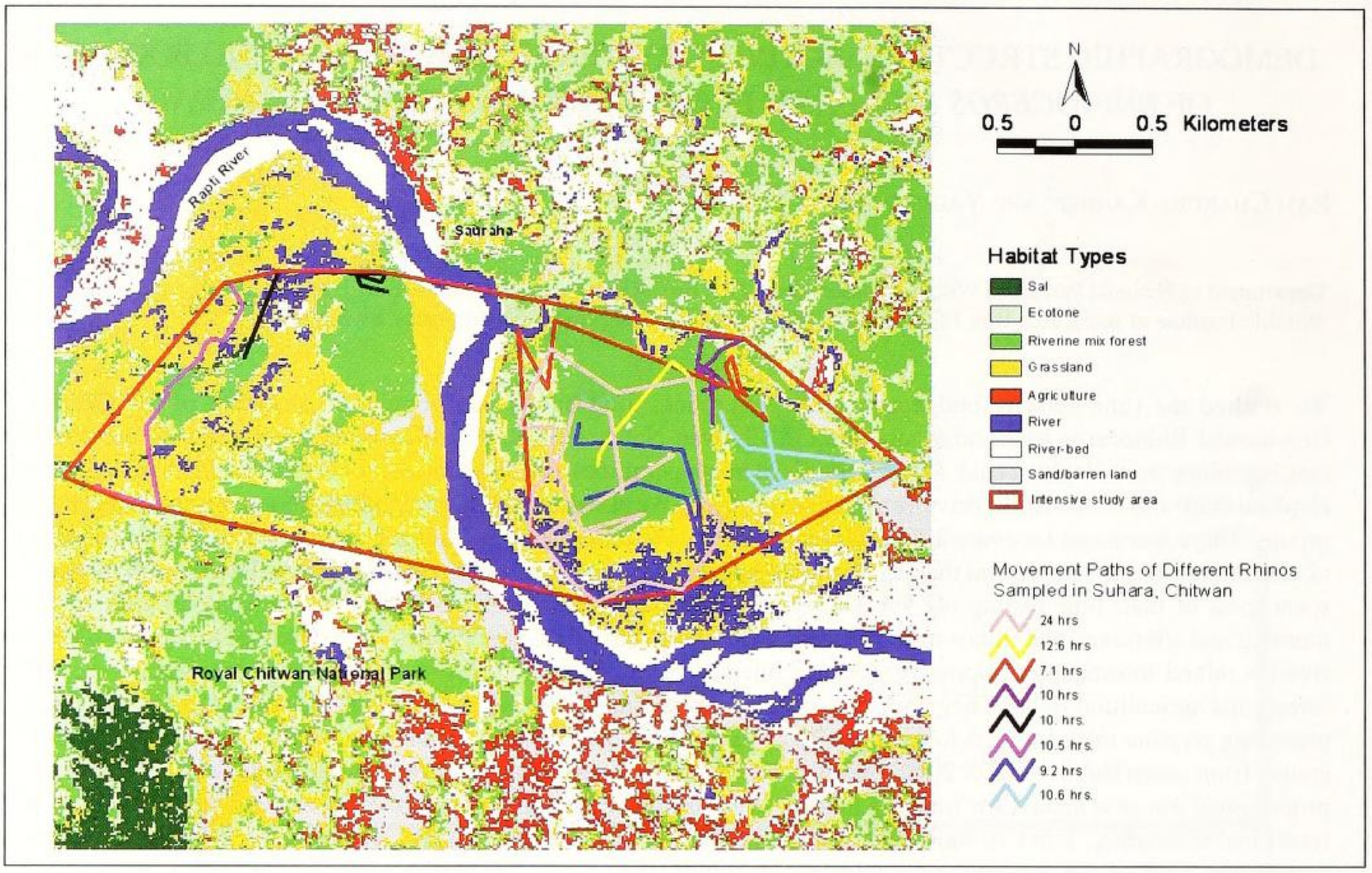

Fig. 1: Habitat types of Sauraha in Chitwan National Park, the minimum convex polygon defining the intensive study area with movement paths of sampled rhinos is shown

subtropical due to the protection of the Great Himalayan Massif running east to west. There are three distinct seasons: winter, spring and summer. The soils in the valley are deep and rich. Surface water is well distributed and available year round.

The Park supports the largest populations of Rhino and Tiger *Panthera tigris* in Nepal. Some other large animals found are Leopard *Panthera pardus*, Gharial *Gavialis gangeticus*, Marsh Crocodile *Crocodylus palustris* and ungulates such as Gaur *Bos gaurus*, Sambar *Cervus unicolor*, Spotted Deer *Axis axis*, Hog Deer *Axis porcinus*, Barking Deer *Muntiacus muntjak* and Wild Pig *Sus scrofa*. Livestock are sympatric with rhinos along the fringes of the National Park and in the buffer zone community forests.

METHODOLOGY

Habitat use, activity, and foraging by rhinos was studied in the Sauraha area comprising the floodplain of the Rapti river with grasslands, riverine forests, mixed forests and ecotonal forests, since this area was easily accessible and had a good rhino density. It was also the study site for earlier studies on rhinos by Laurie (1978), Jnawali (1995) and Dinerstein (2003), thus enabling us to compare our data with those studies. Data from rhino habitats throughout Chitwan were obtained for estimating the demographic structure of the rhino population.

Population Structure of Rhinoceros

Since rhinos are primarily restricted in their distribution to riverine mixed forest, floodplain grasslands and low elevation forests, and rarely venture far from water (Dinerstein 2003), we intensively surveyed such habitats using a four wheel drive vehicle and on elephant back to obtain rhino sightings. Areas were systematically searched once so as to minimise repeated counts of the same individual rhinos. All rhino sightings (n=92) were classified into age and gender groups. Most adults and many immature animals could be distinguished individually using variations in horn size and shape, skin folds and tubercles, scars, ear nicks and tail cuts (Laurie 1982; Dinerstein 2003). These characteristics along with the geographical location of the animals permitted us to identify and exclude rhinos that were encountered more than once during our survey. In order to avoid the biases on exact aging, animals were divided into seven age categories (Laurie 1982; Dinerstein 1991, 2003). These were young calf (<6 months), old calf (>6 months-2 years), juvenile (2-3 years), subadult (3-5 years), young adult (5-10 years), prime adult (10-15 years) and old adult (>15 years) based on body size, condition of skin folds, and shape and size of the horn. Calves that were shorter than their mother's belly line were classified as young calves; they were observed to have smooth skin and were totally dependent on their mother's milk. Older calves, though dependent on suckling also attempt to sample vegetation and were slightly taller than their mother's belly

·line. The height of juvenile rhinos matched that of their mother's chest. Though still associated with their mothers, they tended to venture and often foraged some distance away. Subadult rhinos were almost adult size; they formed a loose association with their mothers and were often seen by themselves or in small groups of similar age and sex. Subadult rhinos had facial characteristics between those of adult and juvenile rhinos. Their skins folds are not fully formed like those of the adults. Rhinos in the adult categories were differentiated based on their height, horn and body size, skin folds and tubercles, and physical and social maturity. Age categories for adult rhinos were developed with the assistance of local field experts who could recognise animals individually and had known them for several years. Age categories were tested for consistency and replicability between local field experts and the authors on several known rhinos prior to field sampling. Average and typical group sizes were calculated (Jarman 1974).

Behavioural observations and ranging patterns

We located rhinos in the early morning hours in the intensive study area and continuously followed the focal animal on elephant back. Rhinos were followed until light conditions prevented observation; night monitoring was done on one night. Eight free ranging rhinos were continuously monitored for 7 to 24 hours each. Data were recorded as duration for all behaviour states and as frequency for events using all occurrence sampling and focal animal sampling (Altmann 1974; Lehner 1996).

Behavioural states were defined in broad categories as (a) foraging, (b) resting, (c) wallowing, (d) walking, (e) running, and (f) standing. A behavioural state was recorded if it lasted more than one minute. Position coordinates obtained using a hand held GPS unit were recorded for all behavioural states and when a rhino moved over 30 m. The habitat types within 10 m and 50 m radii of the rhino were recorded for each behavioural state.

Food Habits

A record was kept on the duration of feeding bouts in different habitats. The total number of bites of each plant species by focal rhinos in different habitats was recorded (Wallmo and Neff 1970; Field 1972; Hobbs *et al.* 1981; Butts *et al.* 1982; Jhala 1997). This was possible in most cases since rhinos permitted a close approach (5-10 m) on elephant back. Most items eaten could be identified from this distance. In cases where identification of forage species was in doubt, direct observation was followed by on-site inspection and collection of samples that were later identified using published checklists (Thapa 1994) and by local plant taxonomists.

Bite Weight and Proportional Consumption of Forage by Rhino

Twenty simulated rhino bites of all major food plants were hand plucked. The fresh weight and dry weight of these simulated bites were determined by oven drying at 60 °C to constant weight (Neff 1967; Wallmo *et al.* 1973). The total number of bites recorded for each food item in each habitat was multiplied by the proportional grazing activity of wild rhinos in that habitat (Jhala 1997). This provided the proportional contribution of different food item bites to the rhino's diet from each habitat type. The dry biomass contribution of different food items to the rhino's diet was computed following Hobbs *et al.* (1981) and Jhala (1997).

Habitat Availability, Use and Ranging Pattern

Satellite imagery (LANDSAT) of Sauraha for February 2002 was classified into eight relevant habitat types using unsupervised and supervised classification (Schowengerdt 1997). These were (1) riverine mixed forest, (2) grassland, (3) ecotone (between grassland and riverine mixed forest), (4) sal forest, (5) agriculture, (6) river/water body, (7) riverbed and (8) sand/barren land using ERDAS IMAGINE (Pouncey *et al.* 1999). The classified image was then imported to Arcview (Arc view 3.1 GIS 1996) for further analysis (Fig. 1).

Movements of each rhino were plotted on the classified image, and the rate of movement was calculated. The extreme rhino locations were connected to define the intensive study area using the 100% minimum convex polygon (MCP) method (Mohr 1947) using the "Animal movement" extension in Arcview. The polygon defining the intensive study area was plotted on the classified imagery using Arcview and the proportions of available habitats within the MCP were obtained. The proportion of time spent in various activities in different habitats was considered as the use of that habitat for a particular activity (Johnson 1980). The analysis for habitat use and availability was carried out using Compositional Analysis (Aebischer *et al.* 1993) to determine habitat preference.

RESULTS

Age and Sex Composition of the Rhino Population in Chitwan

In 92 rhino sightings, 14% of the population was calves and juveniles; more than 70% was adult rhinos (Fig. 2). The adult sex ratio was equal, yielding an estimated calf for every 2.54 adult females. Most rhinos were observed to be solitary. Groups consisted of females with young calves, mating pairs, and male groups of subadult rhinos (Fig. 3). Groups ranged from one to a maximum of seven Rhinos. The average group size was 1.33 and the typical group size was 2.35.

Time Activity Budget and Temporal Variation in Activity Patterns

Over 90 hours observations were recorded from eight free ranging rhinos. Rhinos spent most time resting (43% ±7 SE) followed by foraging (33% ±6.1 SE) (Table 1). The frequency of urination was 0.46 per hour (±0.25 SE); this was because one of the sampled rhinos was a dominant male that was actively scent marking (Fig. 4). Rhinos were seen feeding mostly between 1600 and 1900 hrs (59% ±14.6 SE) followed by 1300 and 1600 hrs (44.9% ±11.6 SE). Only one adult female rhino with a calf was monitored through the night in addition to a full day session (24 hours): this rhino showed a foraging peak (60.14%) followed by resting (23.59%) during the night time. Rhinos were seen wallowing during the hotter hours (1300 to 1600 hrs with 18.70% ± 10.02 SE) (Table 1).

Habitat-wise Activities and Preferences

The habitats used by rhinos were grassland, riverine mixed forest and ecotone (riverine mixed forest interspersed with grassland). The area enclosed by the 100% MCP joining all extreme rhino locations was 7.45 sq. km. This intensive study area was dominated by grassland habitats (34.76%). Other habitats were riverine mixed forest (33.55%), ecotone (12.88%), river bed (16.64%) and barren land/sand (2.16%).

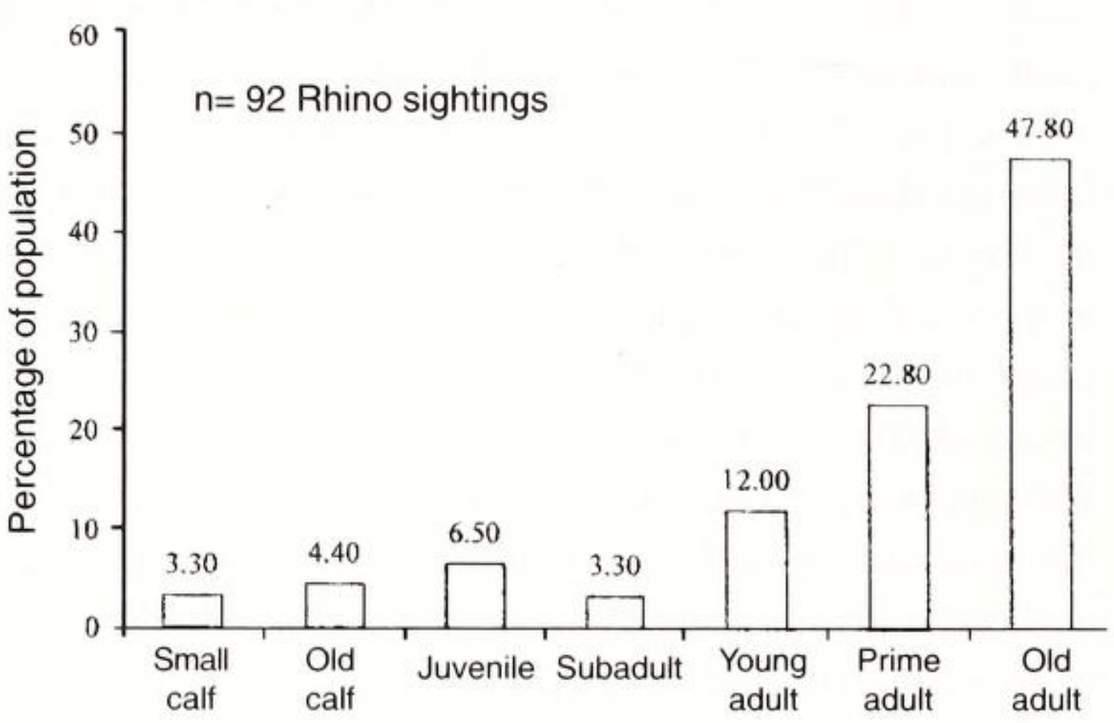

Fig 2: Age structure of the rhinos population in Chitwan, Nepal, 2002-2003

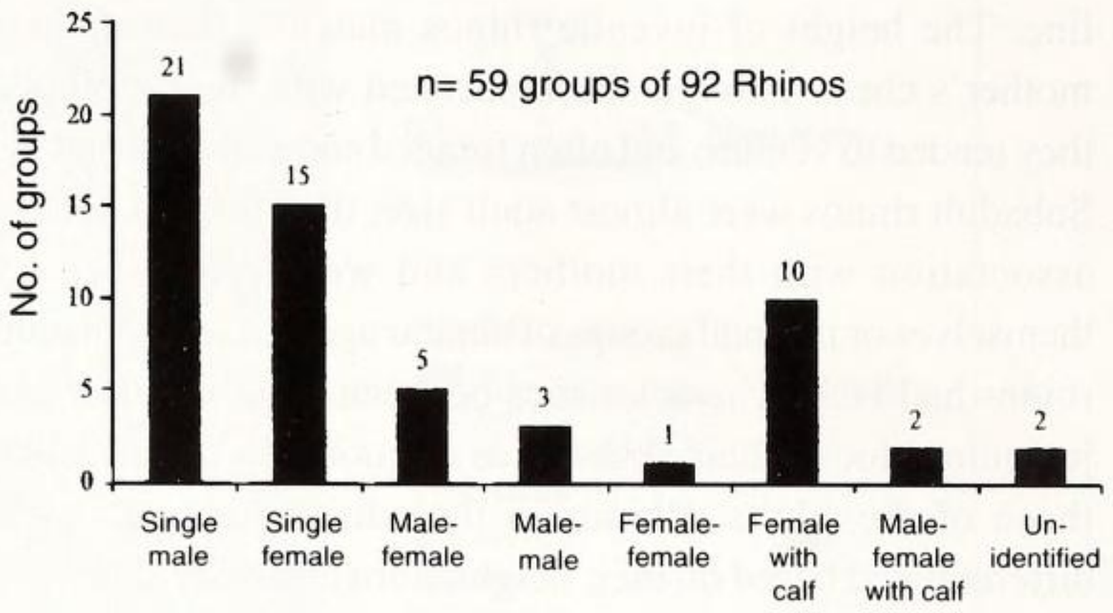

Fig. 3: Group composition of rhinos in Chitwan, Nepal, 2002-2003

Rhinos spent about 30% of the time in the grassland, 57% in riverine mixed forest and 12% in the ecotone. The maximum proportion of time spent feeding was in the grassland (50.76% ±9.9 SE) followed by riverine mixed forest (30.71% ±12.12 SE) and 18.52% (±7.7 SE) in the ecotone (Fig. 5). Rhinos used riverine mixed forests a lot (73.2% ±16 SE) for resting during the afternoon hours (Fig. 5). Standing, moving and wallowing were also more in riverine forests. Compositional Analysis showed that rhinos did not use habitats in proportion to their availability ($F_{(4, 28)} = 3.228$, $p < 0.05$). Compositional analysis for overall habitat use by rhinos (Fig. 6a) ranked the habitats in order of preference as: riverine mixed forest>ecotone>grassland>barren land>river bed. The habitat preference for foraging by rhinos (Fig. 6b) was rated as: grassland>ecotone>riverine mixed forest>barren land>river bed. On the other hand, riverine mix forest was used (66.2%) more than its availability (33.6%) for resting (Fig. 6c). The preference ranking by compositional analysis for resting was: riverine mixed forest>grassland>ecotone>barren land>river bed.

Food Habits

Forty-two species of plants were recorded to be eaten by rhinos during this study (Table 2). The Shannon-Weiner diet diversity was computed to be H'=1.06. Of these 42 species, 16 species contributed more than 1% to the total dry biomass consumption. These 16 species summed up to

Table 1: Proportion of time (mean ± SE) spent in different activities by eight free ranging rhinos during different time intervals of the day

Activities	Total Time	0700-1000 hrs	1000-1300 hrs	1300-1600 hrs	1600-1900 hrs	Night
Resting	0.43±0.07	0.58±0.13	0.36±0.10	0.07±0.03	0.00±0.00	0.23
Standing	0.03±0.01	0.03±0.01	0.06±0.02	0.08±0.03	0.04±0.03	0.06
Feeding	0.33±0.06	0.18±0.07	0.33±0.08	0.52±0.10	0.67±0.13	0.60
Moving	0.08±0.03	0.04±0.01	0.09±0.04	0.06±0.01	0.27±0.12	0.10
Running	0.01±0.01	0	0.01±0.01	0	0	0
Wallowing	0.14±0.06	0.15±0.12	0.12±0.12	0.24±0.11	0.003±0.003	0

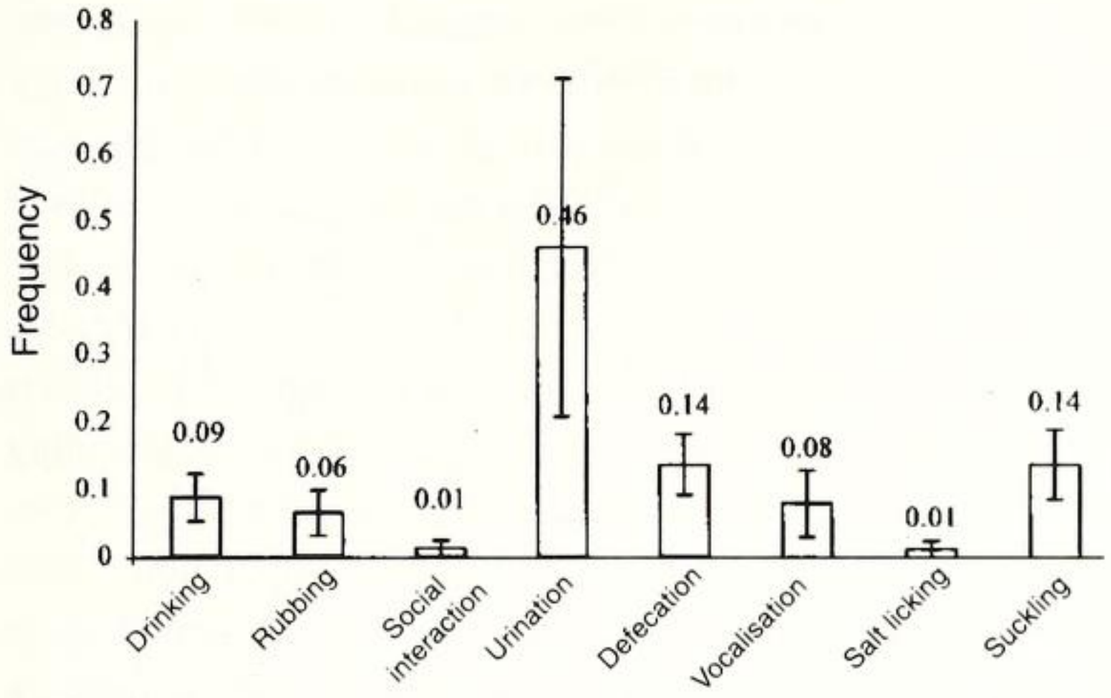

Fig. 4: Frequency of activity events (per hour) of eight free ranging rhinos in Sauraha, Chitwan National Park, Nepal (n= 94.5 hours observation, error bars are SE)

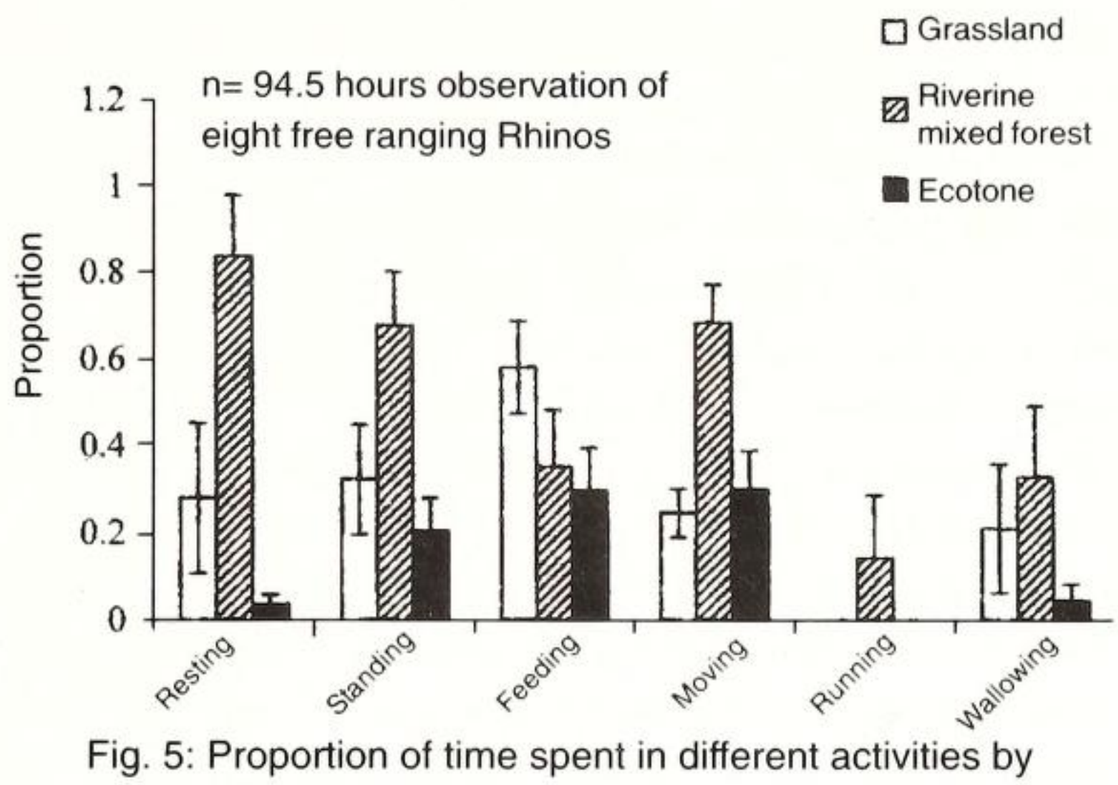

Fig. 5: Proportion of time spent in different activities by wild rhinos in different habitats in the Sauraha area of Chitwan National Park, Nepal

95.3% of the total bite counts. The maximum number of bites was recorded for *Saccharum spontaneum* (34.20%) followed by *Imperata cylindrica* (10.98%), *Dryopteris cochleata* (9.42%) and *Coffea bengalensis* (8.18%).

On converting bite counts to dry biomass consumption based on hand simulated rhino bites and further correcting each food species' contribution by the proportional foraging activity in different habitats, the rhinos' actual diet in the Sauraha area was estimated (Table 3). *Saccharum spontaneum* contributed 32.69% dry biomass to the diet of the Rhino, followed by *Phragmites karka* (16.71%) and *Imperata cylindrica* (16.22%) (Table 3). These three species together contributed more than 65% of the dry biomass to the rhino's diet. Other species such as *Clerodendron viscosum*, *Tetrastigma serrulatum*, and *Equisetum debile*, though avidly eaten, contributed <1% dry matter to its overall diet due to limited availability.

DISCUSSION

Age and Sex Composition

Information on the age and sex composition of the rhino population provides a valuable insight into the

Table 2: List of plant species eaten by rhino in Sauraha, Chitwan National Park, Nepal

S. No.	Species eaten	Habit	S. No.	Species eaten	Habit
1	*Ageratum conyzoides*	Browse	22	*Flemengia strobilifera*	Browse
2	*Albizzia julibrissin*	Browse	23	*Hemarthrea compressa**	Grass
3	*Artemisia dubia*	Browse	24	*Imperata cylindrica**	Grass
4	*Bombax ceiba*	Browse	25	*Lantana camara*	Browse
5	*Caesalpinia decapetala*	Browse	26	*Litsea monopetala**	Browse
6	*Callicarpa macrophylla**	Browse	27	*Michenia chinesis*	Browse
7	*Cannia bichotoma*	Browse	28	*Mucuna nigricans*	Browse
8	*Chrysopogon aciculatus*	Grass	29	*Murraya paniculata*	Browse
9	*Clematis gouriana*	Browse	30	*Narenga porphyrocoma**	Grass
10	*Clerodendron viscosum*	Browse	31	*Phragmites karka**	Grass
11	*Coffea bengalensis**	Browse	32	*Progesterone bengalensis*	Browse
12	*Coix* sp.	Grass	33	*Saccharum bengalense**	Grass
13	*Colebrookea oppositifolia*	Browse	34	*Saccharum munja*	Grass
14	*Cynodon dactylon*	Grass	35	*Saccharum spontaneum**	Grass
15	*Cyperus rotundus*	Sedge	36	*Scoparia dulcis*	Browse
16	*Desmostachya bipinnata**	Grass	37	*Selaginella monospora*	Browse
17	*Disoxylum binnectiforum*	Browse	38	*Spiranthes sinensis*	Browse
18	*Dryopteris cochleata**	Browse	39	*Tetrastigma serrulatum*	Browse
19	*Equisetum debile*	Browse	40	*Themeda arundinacea*	Grass
20	*Eragrostis tenella**	Grass	41	*Typha angustifolia*	Sedge
21	*Eupatorium adenophorum*	Browse	42	*Vallaris solanaceae*	Browse

* Species that contributed >1% (dry matter) to the Rhinoceros' diet.

demographic process and the health of the population (Caughley 1977). The population structure reported by Laurie (1978) in Chitwan was 52% adult, 21% subadult and 26.5% juvenile, and the adult sex ratio was 62 males to 100 females. Seidensticker (1976) reported 38 males to 100 females with 83 young Rhinos, and Dinerstein (1991) reported a calf for every 1.64 adult females, an adult sex ratio of 66 males to 100 females and a population structure of 23% calves, 13% subadult rhinos and 63% adult rhinos in the same place. Spillet (1967) reported 81 males to 100 females in Kaziranga National Park (India). Comparing the population over time (Laurie 1978; DNPWC 2000) suggests that the proportion of adult Rhinos in the population is increasing in relation to the subadults and calves.

The population of Black Rhinos *Diceros bicornis* was reported to have an excess of males with >60% adults, and <20% of sub-adults and juveniles, while the White Rhino *Ceratotherium simum* population was composed of adult males (19%), females (27%), subadults (32%) and calves (22.5%) (Owen-Smith 1988). The adult sex ratio of Black Rhino was similar to the present adult and male/female ratio of the Greater One-horned Rhino in Chitwan. Seidensticker (1976) reported a rhino calf for every 1.2 adult females while Laurie (1982) reported a calf for every 1.31 adult females for the late 1970s in Chitwan. The present study reports 1 calf for every 2.54 adult female rhinos with calves forming 14% of the population. The adult female population was 36%, adult males 35% and subadults 15% of the population. These statistics are comparable to the 1975 population (Laurie 1978), and the 1988 population as reported by Dinerstein (2003). A greater proportion of adult rhinos and a smaller calf-to-cow ratio is suggestive of a decline in the growth rate of the rhino population in Chitwan. This trend is a cause for concern since the Chitwan rhino population serves as a source population for introducing and supplementing rhino populations in other areas of Nepal (DNPWC 2000; Dinerstein 2003).

Table 3: Dry biomass contribution of different plant species to the Rhinos' diet from bite count and habitat use data in Sauraha area of Chitwan National Park, Nepal

S. No.	Food items (species)	Habitats (n = 11,101 bites)			A	B		C
		GL * 7,643 bites	RMF** 1,025 bites	EF*** 2,433 bites	Total percent in diet	Dry wt (g) per bite	Dry wt (g) in 100 bites	Percent dry biomass in diet
1	*Clerodendron viscosum*	0.00	0.99	0.00	0.99	1.81	1.79	0.8
2	*Tetrastigma serrulatum*	0.00	1.17	0.04	1.21	1.51	1.82	0.8
3	*Desmostachya bipinnata*	0.00	1.41	0.01	1.42	2.44	3.45	1.6
4	*Equisetum debile*	0.00	0.00	1.49	1.49	0.14	0.21	0.1
5	*Cynadon dactylon*	2.03	0.00	0.02	2.05	0.95	1.95	0.9
6	*Litsea monopetala*	0.00	2.04	0.03	2.07	3.74	7.73	3.6
7	*Narenga porphyrocoma*	1.61	0.00	0.58	2.19	4.97	10.86	5.0
8	*Eragrostis tenella*	1.67	0.00	0.69	2.36	1.46	3.45	1.6
9	*Hemarthrea compressa*	3.78	0.00	0.00	3.78	2.78	10.51	4.8
10	*Saccharum bengalense*	3.51	0.00	0.40	3.91	3.35	13.08	6.0
11	*Callicarpa macrophylla*	0.01	5.36	0.05	5.42	2.05	11.09	5.1
12	*Phragmites karka*	2.74	0.00	2.98	5.71	6.37	36.36	16.7
13	*Coffea bengalensis*	0.00	8.18	0.00	8.18	0.62	5.07	2.3
14	*Dryopteris cochleata*	0.09	9.32	0.02	9.42	2.49	3.78	1.7
15	*Imperata cylindrica*	10.98	0.00	0.00	10.98	3.22	35.30	16.2
16	*Saccharum spontaneum*	23.80	0.00	10.41	34.21	2.08	71.15	32.7
	Others				4.80			
	Proportion of time spent feeding in each habitat (SE)	0.507 (0.09)	0.307 (0.121)	0.185 (0.077)				

* Percentage of bites of a food item in the grassland multiplied by proportional grazing activity in grassland (GL).

** Percentage of bites of a food item in the riverine mixed forest (RMF) multiplied by proportional grazing activity in the riverine mixed forest.

*** Percentage of bites of a food item in the ecotone forest (EF) habitat multiplied by proportional grazing activity in the ecotone.

A= sum of proportions for each food species from all the three habitats.

B= contribution by dry weight of food items in 100 bites (A* dry weight per bite).

C= percentage contribution in dry weight to the actual diet, (B/∑B)*100.

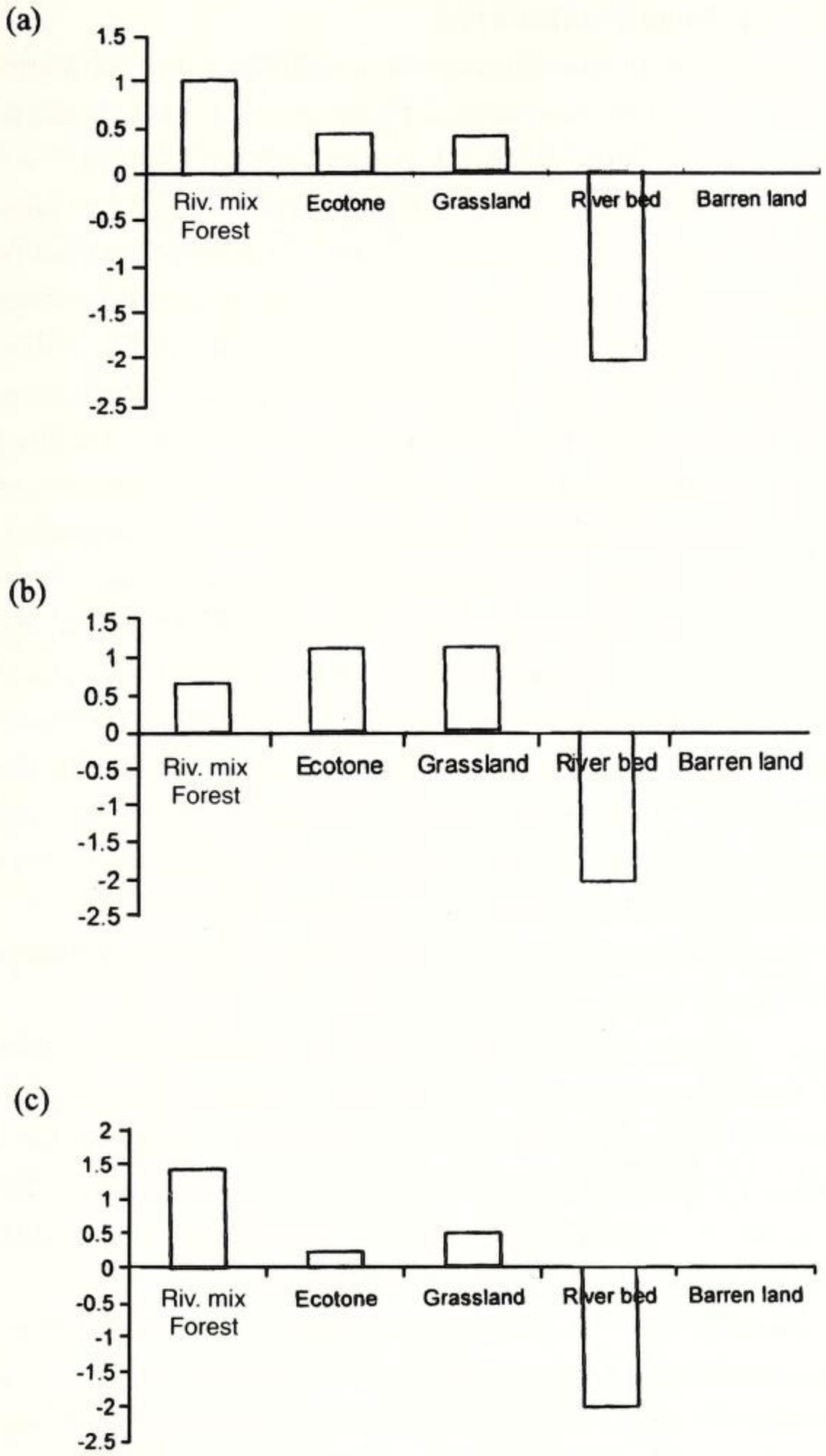

Fig. 6: Results of the difference matrix of Compositional Analysis: (a) overall habitat preference; (b) habitat preference for foraging; (c) habitat preference for resting by Rhinos in the Sauraha area of Chitwan National Park, Nepal

Habitat Use

Rhinos are obligate floodplain habitat specialists (Dinerstein 2003). In this study we defined the intensive study area by joining the outermost rhino locations, thereby restricting further analysis of use and preference within rhino habitats. In the intensive study area, rhinos had access to a variety of habitats including Sal forests and agricultural fields. Rhinos clearly preferred riverine mixed forest and grasslands. However, from the Compositional Analysis results for specific activities, it was evident that rhinos have different habitat preferences for different activities. For foraging they preferred grasslands and ecotones, and for resting there was a clear preference for riverine mixed forests. Thus, by just considering the overall habitat preference of rhinos, one would tend to miss the critical needs of certain habitats for specific activities. It is evident that a landscape that has a mosaic of grassland, ecotone and riverine forests would be ideal for rhinos since these would meet all the various needs of the species.

Diet

The major portion of the rhino's diet was composed of *Saccharum spontaneum, Imperata cylindrica* and *Phragmites karka*; this shows that they largely rely on short grasslands, as also reported by Litvaitis *et al.* (1996), Peet *et al.* (1999), Laurie (1982) and Owen-Smith (1988), for obtaining food. Dinerstein (2003) reports that Rhinos attain their highest densities in *Saccharum spontaneum* grassland habitats. Other species such as *Clerodendron viscosum*, *Tetrastigma serrulatum* and *Equisetum debile* were eaten avidly, but they contributed <1% dry matter to the overall Rhino diet due to their low availability and highly seasonal habit. A greater proportion of time was spent in riverine forest and ecotones where food, shelter and wallowing places are in close proximity. Rhinos were observed to move between habitats for food resources, resting places or water. In Rhino habitats where water is scarce, the management of water sources in a well-dispersed manner is essential.

None of the study rhinos visited agricultural fields or sal forests that were in close proximity. This is likely due to a high risk of contact with humans in agricultural areas and poor forage availability and quality in the sal understorey. Rhino shared the *Saccharum spontaneum* dominated grassland areas with Spotted Deer, Sambar, Hog Deer and domestic livestock (cattle and buffalo). Domestic livestock used grassland habitats during the day. Though none of the sampled rhinos visited agricultural fields, crop raiding by rhinos in fields adjoining the protected area was known to occur. The magnitude of this conflict was not severe, suggesting that most rhinos obtained their nutritional needs from the protected area. Based on discussions with local villagers, rhinos were understood to raid crops at night. Since this study did not employ radio-telemetry, it was difficult to monitor rhinos through the night. Our limited sample of only one female rhino and calf pair that was followed through the night may under represent the use of agricultural fields by rhinos. However, data from an earlier study on radio-collared rhinos in the same study area (Dinerstein 2003) also do not highlight utilisation of crop fields for foraging.

Food Habits

The high proportion of grasses in the diet of rhinos during the hot season in Chitwan was explained by the availability of high quality *Saccharum spontaneum* that keeps

sprouting immediately after grazing and grass cutting (Dinerstein and Price 1991) and burning (Laurie 1978) due to a high substrate moisture (Jnawali 1995). Rhinos ate a wide variety of food items, but the bulk of the diet consisted mainly of relatively few types, as also reported by Laurie (1982) and Dinerstein (2003). Rhinos are considered to be generalist bulk feeders (Owen-Smith 1988). However, Indian Rhinos are relatively selective of more preferable food parts for nutrients and palatability using their prehensile upper lip. Rhinos were observed to selectively feed on the tenderest of shoots of even the coarse grasses.

Laurie (1978) recorded over 100 species of plant eaten by rhino during a year-round study of a larger area from direct observations. Jnawali (1995) reported 28 species based on faecal analysis with a Shanon-Weiner diet diversity of H'= 1.12 in the same area of Sauraha where the current study was conducted. The present study reports a higher diet richness of 42 species of plants eaten with a diet diversity of H'=1.06. Most species reported to be important in the rhino's diet by Jnawali (1995) and Dinerstein (2003) were also observed to be avidly eaten in this study, e.g. *Saccharum spontaneum*, *Imperata cylindrica* and *Phragmites karka*. However, Jnawali (1995) reported a high occurrence of *Narenga porphyrocoma* in faecal analysis, which constituted only 5% of the dry biomass to the rhino's diet in this study. This could likely be due to a change in *N. porphyrocoma*'s availability or due to its coarse nature leading to a high content of undigested residue in the faeces.

Rhinos were observed to feed on 29 different species in the ecotone forests, 20 species in grasslands and 16 species in mixed forests. We did not observe rhinos feeding on the fruit of *Trewia nudiflora* since our study did not include the fruiting season of this species. Jnawali's (1995) report *Trewia nudiflora* fruits constituting 13.4% of the rhino's diet highlights the seasonal importance of certain food items to the rhino's diet (Dinerstein and Wemmer 1988; Dinerstein 2003). Though such seasonally available food items may contribute significantly to the micro-nutrient needs of the rhino (Robbins 1983), the bulk of the annual biomass and energy needs are met from the seven important food plant species, namely *Saccharum spontaneum*, *Imperata cylindrica*, *Phragmites karka*, *Saccharum bengalense*, *Callicarpa macrophylla*, *Narenga porphyrocoma* and *Hemerthrea compressa*, which constituted >85% of the dry biomass consumption by rhinos. This highlights the importance of managing short grasslands for productivity and reducing livestock pressure in these areas.

Management Perspectives

The single most important natural force that maintains the successional mosaic of habitats so critical for rhinos is the periodic floods of the Himalayan region (Burton *et al.* 1989). These floods destroy existing habitats, create new ones and enrich them with fertile sediments. Rhinos further modify their habitats like other mega herbivores, making them favourable for other ungulates (Dinerstein 1980, 2003). Ironically, these very rhino habitat sustaining floods now cause havoc to rhinos. This is because there is only a limited area available for rhinos to live in, the rest having been taken over permanently by humans for agriculture and settlement. When floods destroy existing rhino habitats, there are no "new" habitats formed that are available to rhinos. The Park management now needs to intervene with these natural processes and ensure that critical needs for the rhinos are met, e.g. by creating artificial wallows or by arresting the succession of grasslands to woodlands artificially (by burning and/or cutting woody species) (Dinerstein 2003). Areas likely to be utilised by rhinos for drinking such as streams, rivers, ox-bow lakes, small puddles and wallows need to be regularly maintained.

Though the duration of the study was short, it covers the pinch period for rhinos in Chitwan (late winter and dry season). The study highlights the importance of intermittent intensive studies to find the pulse of tropical systems. The population structure of rhinos with fewer calves per adult female is indicative of a reduction in the rate of increase (Caughley 1977). Based on the food habits and habitat use by rhinos, we highlight the importance of a few food plants like *Saccharum spontaneum, Phragmites karka* and *Imperata cylindrica* which constitute more than 65% of the dry matter intake by rhinos. The study highlights the relative importance of short grasslands and riverine mixed forest habitats for effective conservation of rhinos in Chitwan and similar Terai habitats as also reported by Dinerstein (2003).

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