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Research article

Food composition of greater one-horned rhino (*Rhinoceros unicornis*) in Chitwan National Park, Nepal

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Abstract

Greater one-horned rhino (*Rhinoceros unicornis*) in the Chitwan National Park (CNP), central Nepal exhibit distinct grazing behavior and rely on the riverine forest and grasslands along the Reu, Rapti, and Narayani and their tributaries. In this study, we aimed to investigate the food composition and underlying causes of the abundance of food species for the rhino in CNP. We used quadrat sampling in riverine forests and grassland to examine the cover percent, frequency, and relative importance value of food species for understanding the composition of food and assess the relationship between food composition and the shifting patterns of rhinos from the eastern to the western area of CNP over time. Scan animals used for determining most preferred food species of rhino in CNP. Our findings revealed 23 preferred food species in the rhino's diet, with 7 being grasses, 8 trees, and 8 herbs and shrubs with no significant differences in the food composition of rhinos among different parts of CNP. The grasses species were the most preferred food species contributed 85% in diet of rhino in CNP. These results contribute valuable information for the implementation of effective long-term conservation strategies for large mammals, particularly the rhino in CNP and similar ecosystems.

Keywords: Food abundance; Diet of rhino; Quadrat sampling; Riverine grassland; *Saccharum spontaneum*

1 | Introduction

Greater one-horned rhinos (*Rhinoceros unicornis*) are mixed feeders while white rhinos (*Ceratotherium simum*) are grazers, black rhinos (*Diceros bicornis*), Sumatran rhinos (*Dicerorhinus sumatrensis*), and Java rhinos (*Rhinoceros sondaicus*) are browsers (Dinerstein 2003). The greater one-horned rhinos (hereafter called rhino) are found in Nepal, India, and Pakistan (Laurie 1978; Ellis & Talukdar 2019; Talukdar 2020). The nationwide census (2021) estimated more than 752 rhinos in four national parks of Nepal (Bardia, Chitwan, Parsa, and Shuklaphanta), an increase of 107 from the previous survey in 2015 (Amin et al. 2006; DNPWC 2015; Subedi et al. 2017; DNPWC 2021). The Chitwan National Park (CNP) currently holds the largest population of rhinos (n=694 individuals) in Nepal (DNPWC 2021). Although the increase in the overall population of rhino in Nepal is encouraging, the decline in growth rate, from 5% in 2015 to 3% in 2021, habitat loss, and increased infestation of invasive species over the past few years are the major ongoing concerns for their protection (DNPWC 2015, 2021).

Due to the greater availability of grazing and browsing species in Chitwan and Bardia: rhinos in CNP spent more time grazing, and rhinos in Bardia National Park (BNP) spent equally as much time browsing and grazing (Jnawali & Wegge 1993; Jnawali 1995; Dinerstein 2003; Talukdar 2021). The main food sources for rhinos in CNP include four species grass, including *Saccharum spontaneum*, *Saccharum bengalense*, *Cynodon dactylom*, and *Narenga porphyrocoma*, as well as three browse species, including *Coffea benghalensis*, *Murraya paniculate*, and *Litsea monopetala* (Dinerstein 2003). Rhinos in CNP are fed by riverine forests and grasslands in the flood plains of Reu, Rapti, and Narayani (Dinerstein 1992; Jnawali & Wegge 1993; Jnawali 1995). They live in the Ganges, Brahmaputra, Sindu, and their tributary rivers' alluvial floodplains. Their primary food sources are the riverine grasslands along the banks of rivers (Dinerstein 1992; Talukdar et al. 2008; WWF 2013; Pant et al. 2021).

According to Subedi et al. (2017), rhinos' preferred vegetation's were early successional stage. Regular yearly flooding regenerates the early successional stage of vegetation, which is dominated by the food source of rhinos and deer, *S. spontaneum* (Dinerstein 2003). About 5% of wild species every year were wiped out by floods in 1993, 2003, and 2017 (DNPWC 2005, 2015; Subedi et al. 2017; DNPWC 2021). Mikania (*Mikania micrantha)*'s invasion changed the range and accessibility of food species for rhinos in CNP. Mikania infestation is a serious issue because it reduces the availability of food species and adequate habitat. According to Subedi et al. (2017), Mikania infected 15% of the CNP's total area and 49% of the rhinos' probable habitat and mikania is growing in the CNP at a rate of 2% yearly.

Over last few years rhino has been shifted in CNP, ecologists have paid little attention to the current habitat preferences, food availability, abundance, and diet composition of rhinos in the eastern, middle, and western parts of CNP to explain the habitat shifting of rhinos in the Chitwan. Previous studies carried out on

diversity of food species (Laurie 1978), availability and preferred food species (Jnawali 1995), impact of invasive species on composition of food (Subedi 2012). Threre is gap to compare composition of food species in different parts of CNP. This study explored the preference, availability, and abundance of food species of rhinos through time in CNP. The study uses quadrat sampling to assess the cover percent, frequency, and relative importance value of the preferred food species of rhinos, which is an essential examination of rhino movement in CNP.

2 | Materials and methods

2.1 | Study area

Chitwan National Park is located in the south of Nepal's Bagmati Province in the subtropical lowlands of the inner Terai and spans 952.63 km². In recognition of its distinctive ecosystems and collection of threatened species, including the larger one-horned rhino (DNPWC 2021), Asian wild elephant (*Elephas maximus*), and Bengal tiger (*Panthera tigris*), the region was gazetted as the nation's first national park in 1973. In 1984, CNP was designated a World Heritage Site by UNESCO. The Park is made up of a variety of ecosystems, such as the Ox-bow lakes, the Churia hills, and the flood plains of the Reu, Rapti, and Narayani rivers. Its boundaries span 84°28'43"E to 84°29'40"E longitude and the Churia hills range in elevation from 150 m to more than 815 m (Fig. 1).

The Park has a range of climatic seasons each offering a unique experience. The minimum temperature in February is 9°C and the maximum temperature can reach as high as 43°C in May. Vegetation consists of Sal forest, mixed riverine deciduous forest, tall grassland, and short grassland (DNPWC 2016). Sal woods are a common forest type that make up 70% of the park and are mostly covered with *Shorea robusta* trees. They are found on well-drained, highland slopes that are frequently visited by wild elephants but are rarely used by rhinos (Laurie 1982). Rhinos regularly use the riverine forest association, which is made up of *Trewia nudiflora*, *Bombax ceiba*, *Acacia concinna*, and *Dalbergia sissoo*. During the summer, they search for the fruits of *T. nudiflora* (Dinerstein & Price 1991; Dinerstein 1992; Jnawali & Wegge 1993; Lehmkuhl 1994; Dinerstein 2003; Subedi 2012).

The tall grass species of *Saccharum spontaneum* (4–6 m), *S. benghalense*, *N. porphyrocoma*, (5–7 m) are found in monospecific stands in the grassland habitat associations, as are several other short grass species such as *Imperata cylindrica*, *Chrysopogon aciculatus*, *Eragrostis spp*., and several others (Dinerstein & Price 1991; Dinerstein 2003; Subedi et al. 2013).

2.2 | Food sampling

The study compared abundance of food species of rhino found particularly in grassland and riverine forests of CNP. Data were collected from three sites in CNP, the eastern part of CNP (Amrite, Icharni, and Marchuli) of 33.5 Km² used by 23 rhinos, the middle part (Dumaria and Kasara) of 31.6 Km² inhabited by 41 rhinos and the western area (Sukibhar and Rapti-Reu junction) of 29.3 Km² occupied by 194 rhinos. A total of 60 quadrats of 1m x1m for grasses and 10m x 10m for trees, shrub, and herbs fell in study area. Among them 20 were in the eastern, 20 in the middle and20 in the western part. Out of them 10 laid on grasslands and 10 on riverine forests of major rhino habitats. The field works was done during January 25 to August 2, 2018.

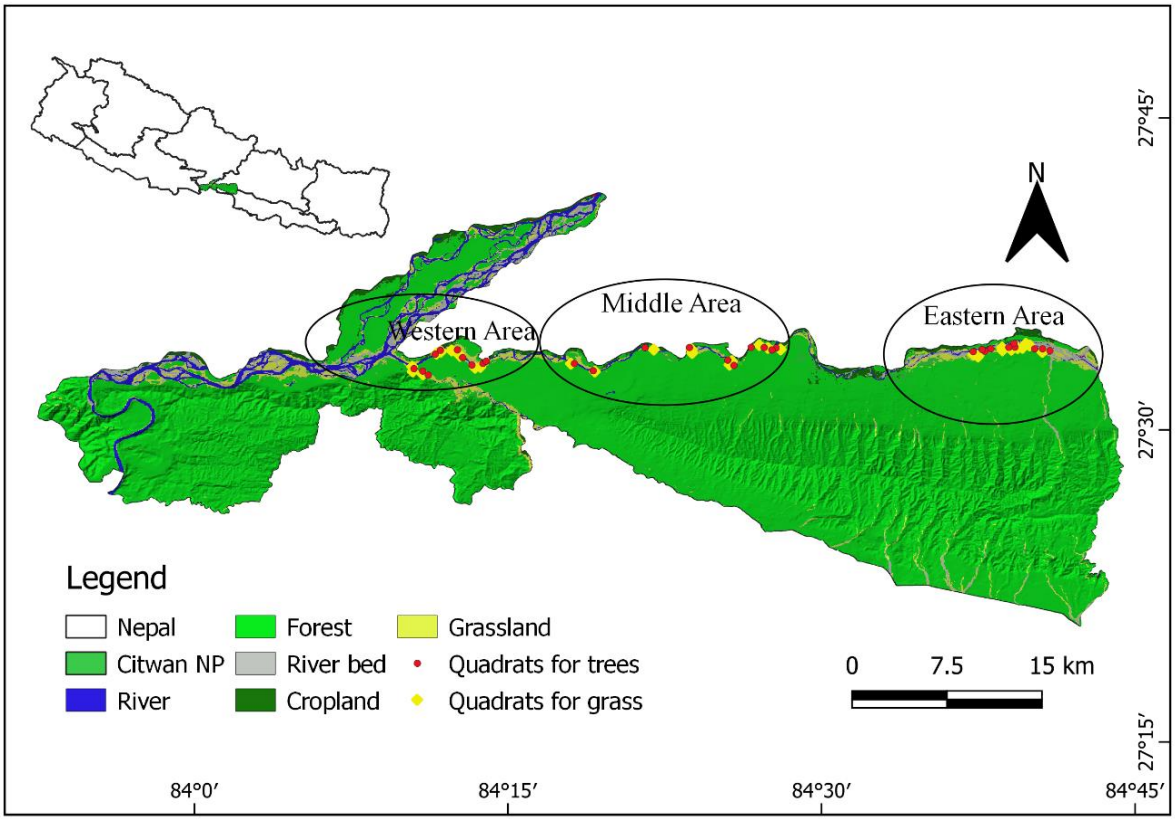

Figure 1. Study Area: Chitwan National Park of Nepal showing eastern, western and middle area as per the study performed.

Table 1. Abundance of preferred food species of Rhino in study area.

Food Species	Eastern		Middle		Western	
	Cover %	Freq	Cover %	Freq	Cover %	Freq
Saccharum spontaneum	36.37	78	36.77	57	38.75	62
Saccharum bengalense	22.03	32	22.66	30	18.86	30
Narenga porphyrocoma	12.53	18	12.53	18	14.33	23
Cynodon dactylon	6.12	8	6.27	9	6.21	10
Imperata cylindrica	3.35	5	3.64	6	4.41	7
Themeda spp.	1.98	3	2.01	3	1.53	2
Cymbopogon spp.	1.57	2	1.75	2	1.42	2
Phragmites karka	1.34	2	1.4	2	1.53	2
Callicarpa macrophylla	1.28	2	1.29	2	1.31	2
Litsea monopetala	1.11	2	0.9	1	0.98	2
Coffea benghalensis	0.93	1	0.78	1	1.04	2
Murraya paniculata	0.76	1	0.62	1	0.65	1
Mallotus philippensis	0.64	1	0.73	1	0.6	1
Dalbergia sissoo	0.52	1	0.67	1	0.65	1
Trewia nudiflora	2.27	3	1.9	3	1.53	2
Bombax ceiba	1.87	3	1.79	3	1.96	3
Colebrookea oppositifolia	1.57	2	1.45	2	1.42	2
Ehretia laevis	0.99	1	0.73	1	0.82	1
Acacia concinna	0.64	1	0.5	1	0.76	1
Triumfetta spp.	0.35	1	0.39	1	0.27	1
Urena lobata	0.47	1	0.34	1	0.33	1
Cirsium wallichii	0.23	1	0.17	1	0.16	1
Mikania micrantha (mikania)	1.05	2	0.9	2	0.49	1

The vegetation sampling followed fodder tracks of scan sample rhino (N=10) in the respective area of CNP (Altmann 1974). We followed 10 habituated rhinos (3 rhinos in the eastern part, 3 rhinos in the middle part, and 4 rhinos in the western part) in CNP to examine preferred food species commonly uptake by focal species rhinos. For this purpose, we used the 24-hour activity field observation method as done by (Dinerstein 2003).

Preferred food species were identified based on their abundance in the study site. Abundance of food was then calculated by relative importance value, covering percent with frequency of food species. The relative importance value of food was determined by multiplication of cover percent with the square root of the frequency of available food species in the study site. Coverage of food species was set into five categories of less than 1% cover as (1), 1-5% cover as (2), 6-25% cover as (3), 26-75% cover as (4), and >75% cover as (5) (Lehmkuhl 1994).

2.3 | Statistical analysis

A statistical analysis was conducted using the chi-square method to assess the significance of differences in the food and its composition in three regions: eastern, western, and middle of CNP. Preferred food species composition in different area of CNP was judged at 5% significance level.

3 | Results

3.1 | Abundance of the food species

Twenty-three most preferred food species were identified in study area. Out of the preferred 23 food species of rhinos, 7 were grasses, 8 were trees, and 8 were herbs, shrubs, and bushes. The most abundant food species of rhino were *Saccharum spontaneum*, *S. bengalense, N. porphyrocoma*, *C. dactylon*. An abundance of the most preferred food species *S. spontaneum* was higher in the western part (Table 1). The availability of food species for rhinos were, *S. spontaneum*, *S. bengalense*, *N. porphyrocoma*, *C. dactylum*, *I. cylindrica*, *M. paniculata*, *C. benghalensis*, *T. nundiflora*, *Callicarpa macrophylla*, *L. monopetala*, *Phragmites karka*, *Cymbopogon* spp., *Colebrookea oppositifolia*, *B. ceiba* in CNP.

3.2 | Distribution of food species

Saccharum spontaneum had the highest cover percentage in all three areas, with the highest in the Western area (38.75%), followed by the Eastern (36.37%) and Middle (36.77%) areas. *S. bengalense* had the second-highest cover percentage in all three areas, with the highest in the Middle area (22.66%), followed by the Eastern (22.03%) and Western (18.86%) areas. *N. porphyrocoma* has consistent cover percentages across all three areas, with the highest in the Western area (14.33%), followed by the Eastern (12.53%) and Middle (12.53%) areas. We also found mikania which is an invasive plant in our samples and the percentage increased from the eastern region to the western region, with the percentage eastern (1.05), middle (0.9), and western (0.49).

The remaining species also have varying cover percentages and frequencies, indicating their presence as food sources for rhinos in different areas of CNP. There were no significant differences in food species and food composition in the eastern, middle, and western parts of CNP when tested chi-square at 5% level (χ^2 = 4.17, d.f. = 3).

There are 23 favored food species in the diet of rhinos in CNP, according to an analysis of food species. Grasses, trees, herbs, shrubs, and bushes were the three basic groupings into which these species were further divided. In the CNP, out of the preferred 23 food species of rhinos, of which 7 were grasses, 8 were trees, and 8 were herbs, shrubs, and bushes. In every region of CNP, grasses made up more than 85% of the dietary types (Fig. 2).

S. spontaneum, S. bengalense, and *N. porphyrocoma* had the highest relative importance values, respectively (Table 2). In the

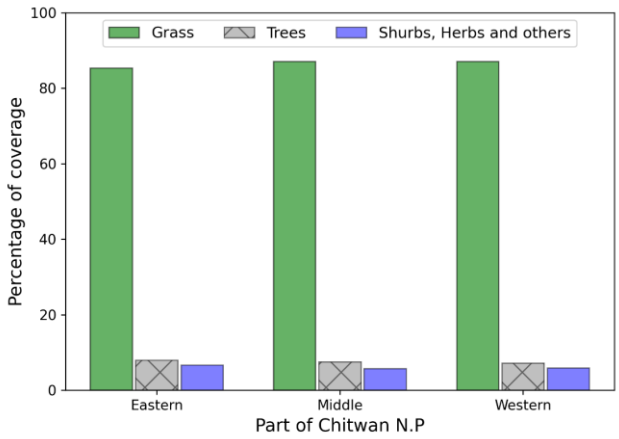

Figure 2. Percentage of coverage of different food types of rhinos in eastern, middle and western region of CNP. Green bars indicate grass, grey hatched bars indicate trees and blue bars indicate shurbs, herbs and others.

Eastern region, *S. spontaneum* (321.21), *S. bengalense* (124.62), and *N. porphyrocoma* (53.16) had the highest relative importance values. *S. spontaneum* continues to have the highest relative importance value (277.61) in the Middle area, ahead of *S. bengalense* (124.11) and *N. porphyrocoma* (53.16). *S. spontaneum* continues to be the most prevalent species in the Western region (305.12), followed by *N. porphyrocoma* (68.72) and *S. bengalense* (103.30).

Table 2. Relative importance value of preferred food species of rhino according to (Dinerstein, 2003).

Food Species	Relative importance value in regions		
	Eastern	Middle	Western
Saccharum spontaneum	321.21	277.61	305.12
Saccharum bengalense	124.62	124.11	103.30
Narenga porphyrocoma	53.16	53.16	68.72
Cynodon dactylon	17.31	18.81	19.64
Imperata cylindrica	7.49	8.92	11.67
Themeda spp.	3.43	3.48	2.16
Cymbopogon spp.	2.22	2.47	2.01
Phragmites karka	1.90	1.98	2.16
Callicarpa macrophylla	1.81	1.82	1.85
Litsea monopetala	1.57	0.90	1.39
Coffea benghalensis	0.93	0.78	1.47
Murraya paniculata	0.76	0.62	0.65
Mallotus philippensis	0.64	0.73	0.60
Dalbergia sissoo	0.52	0.67	0.65
Trewia nudiflora	3.93	3.29	2.16
Bombax ceiba	3.24	3.10	3.39
Colebrookea oppositifolia	2.22	2.05	2.01
Ehretia laevis	0.99	0.73	0.82
Acacia concinna	0.64	0.50	0.76
Triumfetta spp.	0.35	0.39	0.27
Urena lobata	0.47	0.34	0.33
Cirsium wallichii	0.23	0.17	0.16
Mikania micrantha	1.48	1.27	0.49

4 | Discussion

The results indicate that grasses are the most preferred food source for rhinos in CNP. Over 85% of the food consumed by rhinos in every part of the CNP consists of grasses. This suggests that grasses play a vital role in meeting the dietary needs of rhinos in CNP. According to Pradhan et al. (2008), tall grasses like *Saccharum spontaneum* were a key component of the rhino's diet. The most nutrient-dense species of tall grass in the Chitwan Valley is *S. spontaneum*, hence the rhino prefers these sorts of grasslands (Mishra 1982, Dinerstein & Price 1991, Lehmkuhl 1994, Dinerstein 2003). The presence of a diverse range of food species, including grasses, trees, and herbaceous plants, in the rhino diet demonstrates the adaptability and flexibility of rhinos in selecting food sources. However, the dominant presence of grasses indicates their significance as a primary food source (Jnawali 1995).

The majority of a rhino's diet consists of grasses, which are plentiful in CNP and make up more than 85% of each area. According to Dinerstein (2003) and Thakur et al. (2014), rhinos eat mostly grasses but they also consume leaves, and branches from shrubs and trees, fruits, and submerged and floating aquatic plants. Only 23 of the 283 plant species, including various grass species (*C. dactylon, E. tenella, I. cylindrica, P. karka, S. spontaneum*, and *S. bengalnese*) that rhinos eat have been identified (Jnawali 1995, Dinerstein 2003, Thakur et a.l 2014). The identification of only 23 plant species in our research can be attributed to the relatively small number of quadrats sampled and study carried out only in riverine grassland of CNP.

According to the study, CNP contained a suitable number of food species. While the western portion of CNP has pure stands of the most preferred food species, the eastern portion of CNP has a higher availability of the preferred food species for rhinos. 283 plant species that are available to rhinos in CNP were listed by Jnawali (1995). Tall grasses recorded the most (131), followed by riverine forests (117). Although the rhino's food was varied, less than 10 species made up more than 75% of it. More than 85% of the yearly diet in Chitwan was made up of four grasses (*S. spontaneum, S. bengalense, C. dactylon*, and *N. porphyracoma*) and three browsing plants (*C. benghalensis, M. panicalata, and L. monopetala*) (Jnawali 1995; Dinerstein 2003). The rivers were found to follow the natural nutrition of radiant plant species and foraging on them. So, as to have optional nutrient intake and digestibility (Subedi 2012; Karmakar 2022).

Study found the inverse relation between mikania infestation and the abundance and health of these preferred food species, and the growth rate of mikania is quite high at 2% per year. Mikania smothered, retarded, and even killed the most preferred food species of rhinoceros such as orderly *S. spontaneum, S. bengalense, Phagmatis karka, M. peniculata, L. monopetala*. The number of preferred food species of rhinos has decreased with increment infestation of mikania (Murphy et al. 2013). As the infestation of mikania increases, there is a noticeable decline in the number and vitality of the rhinoceros' preferred food sources. This highlights the detrimental impact of Mikania on the ecosystem, emphasizing its role in altering the composition and availability of crucial plant species in the rhino's diet. The findings underscore the need for effective management strategies to control mikania infestation and mitigate its adverse effects on the preferred food species of rhinoceros in the studied ecosystem.

The absence of a significant difference in the food composition among rhinos in the eastern, western, and middle regions can be attributed to disturbance regime and environmental factors. Firstly, the shared flood plain across these regions ensures a common availability and accessibility to food resources, fostering a consistent dietary base for rhinos (Jnawali 1995). Additionally, the uniformity in climatic parameters prevailing across the three regions contributes to a homogenous climate,

which in turn leads to similar vegetation patterns and habitat characteristics. This climatic consistency further reinforces the parallel nature of food sources for rhinos in these areas (Dinerstein 2003). Moreover, the lack of significant anthropogenic differences signifies those human activities, such as agriculture and development, exert similar types of influence across the regions (Subedi 2012). This harmonization in human impact implies that there are no substantial disruptions or variations in the rhinos' food sources due to human interference (Pant et al. 2021). In combination, the shared flood plain, uniform climatic parameters, and similar anthropogenic influences collectively contribute to a stable and comparable environment for rhinos, resulting in the observed lack of significant differences in food composition across the three regions.

5 | Conclusions

Study identified a total of 23 preferred food species, neatly categorized into three primary groups: grasses, trees, and herbaceous plants. This categorization underscores the remarkable adaptability and flexibility exhibited by rhinos in their discerning selection of food sources. Notably, within these categories, grasses emerged as the predominant component, underscoring their pivotal role as a primary dietary source for these majestic creatures. The presence of a diverse array of food species, ranging from grasses to trees and herbaceous plants, underscores the robust adaptability of rhinos. However, the overwhelming prevalence of grasses in their diet emphasizes the critical significance of these plants as a primary nutritional resource. This understanding is pivotal for effective management and conservation strategies aimed at preserving the rhino population in CNP.

To ensure the continued well-being and sustainability of rhino populations in CNP, conservation efforts must focus on the preservation and proliferation of grasses. This involves maintaining and safeguarding suitable grassland habitats and implementing strategic grazing area management. By addressing these aspects, we can provide the necessary support for the nutritional requirements of rhinos, contributing to their overall health and population stability within CNP.

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Authors' contributions

Kuikel P.R. carried out field work, designed research did data analysis, and wrote manuscript. Basnet K. designed and supervised the research.

Conflicts of interest

The authors declare no conflict of interest.

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