

Dry season diet composition of four-horned antelope *Tetracerus quadricornis* in tropical dry deciduous forests, Nepal

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Assessment of feeding strategies of threatened species during the resource-scarcity season is essential to understand their dietary niche breadth and inform appropriate habitat management measures. In this study, we examined the diet composition of Four-horned antelope (FHA) *Tetracerus quadricornis*, one of the least studied ungulate species, in Banke National Park, Nepal. A total of 53 fresh pellet groups were collected during December 2015 to January 2016 and analyzed using micro-histological fecal analysis technique. First, we prepared 133 micro-histological photographs of different parts of 64 reference plants species. Then we compared 1,590 fragments of 53 fecal samples with photographs of reference plants to assess the percentage of occurrence of different plant species in FHA diet. A total of 30 plant species belonging to 18 different families were identified in fecal samples. Chi-square goodness of fit test showed that percentage of occurrence of plant species in FHA diet were uniform at the species level but varied considerably at family, functional and broad category level. Out of 30 species, twenty species were dicots and ten were monocots. Dicots represented two-thirds (67%) of the identified plant fragments suggesting that FHA might be adopting a browser strategy at least during winter when grasses are low in abundance and their nutritive quality is poor. Tree species had the highest contribution in the diet (46.54 %) followed by shrubs (24.53 %) and Graminae family was consumed in highest proportion (27.67 %) followed by Euphorbiaceae (11.95 %). Overall, our results suggest that FHA has the feeding plasticity to adapt to resource fluctuation. Based on the findings of this study, we recommend that

dicot plant species particularly, fruit trees and shrubs, which are the major source of nutrients for FHA during resource lean dry season, be conserved and natural regeneration be promoted.

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Abstract

It is essential to assess the feeding strategies of threatened species during resource-scarce seasons is essential to understand their dietary niche breadth and inform appropriate habitat management measures. In this study, we examined the diet composition of Four-horned antelope (FHA) *Tetracerus quadricornis*, one of the least studied ungulate species, in Banke National Park, Nepal. A total of 53 fresh pellet groups were collected between December 2015 and January 2016 and analyzed using micro-histological fecal analysis technique. First, we prepared 133 micro-histological photographs of different parts of 64 reference plant species. Then we compared 1,590 fragments of 53 fecal samples with photographs of reference plants to assess the percentage of occurrence of different plant species in FHA diet. A total of 30 plant species belonging to 18 different families were identified in fecal samples. Chi-square goodness of fit test showed that percentage of occurrence of plant species in FHA diet was highly diverse at multiple taxonomic and functional levels. Out of 1520 identified fragments in fecal samples, 1300 were browse species and 220 were grass species. Browse represented 85.5 % of the identified plant fragments suggesting that FHA might be adopting a browser strategy at least during winter when grasses are low in abundance and their nutritive quality is poor. Tree species had the highest contribution in the diet (46.55 %) followed by shrubs (24.52 %), and Gramineae family was consumed in highest proportion (27.68 %) followed by Euphorbiaceae (11.95 %). Overall, our results suggest that FHA has the feeding plasticity to adapt to resource fluctuation. Based on the findings of this study, we recommend that dicot plant species particularly, fruit trees and shrubs, which are the major source of nutrients for FHA during resource lean, dry season, be conserved and natural regeneration of these taxa be promoted.

Introduction

Knowledge of the diet composition of endangered wildlife species is very important to understand foraging ecology and devise conservation management actions for their long-term persistence (Belovsky 1997; Ahrestani et al. 2016). Such knowledge is particularly important for ungulates in seasonal environments (Parker et al. 2009) where resource availability is pulsed in summer and scarcity is particularly acute during the arid winter season (Styles & Skinner 1997; Ahrestani et al. 2012). This seasonal flux in quality and quantity of resource availability (e.g., forage) often has nutritional costs for ungulates (Parker et al. 2009). For example, reduced availability of preferred forage has been found to alter the composition of graminoid and browse in the diet negatively influencing the maintenance of body mass of American elk *Cervus elaphus* during winter (Christianson & Creel 2009). In the Mediterranean region, hares were found to eat herbs (preferred food) in the wet season but increase their diet breadth in the dry season consuming herbs, fruits, and grains (Sokos et al. 2015). In the Indian trans-Himalaya, a medium-sized ungulate grazer, the blue sheep bharal, (*Pseudois nayaur*) was found to have a mixed diet (mainly browse) during resource limited winter seasons due to reduced availability of graminoids, resulting from competition with domestic livestock (Mishra et al. 2004; Suryawanshi et al. 2010). Change in diet balance affects reproduction, growth, and survival of animal influencing life history parameters such as body mass of adult females, which correlates with vital rates like birth mass, growth rates and survival of young (Pekins et al. 1998). Understanding the diet composition of a species during resource lean season is therefore critical to understand diet plasticity and inform forage management measures.

The four-horned antelope (FHA) *Tetracerus quadricornis* is a medium-sized, solitary ungulate (shoulder height 55–65 cm and weigh 18–21 kg at adult) endemic to the Indian sub-continent (Leslie & Sharma 2009). It is widely but patchily distributed with fragmented populations in dry deciduous forests from the Himalayan foothills in Nepal to the Gangetic floodplains and the Peninsular mainland in India (Rahmani 2001; IUCN SSC Antelope Specialist Group 2017). Estimates suggest that less than 10,000 FHA remain in the wild (IUCN SSC Antelope Specialist Group 2017). However, the population of FHA is suspected to have declined throughout its range mainly due to habitat loss and fragmentation (Sharma et al. 2009). Although presently it is classified under the ‘Vulnerable’ category, the assessment of the IUCN Red List of threatened species states that “no subpopulation is estimated to contain more than 1000 mature individuals and it is possible that it is already close to reaching the Endangered category (IUCN SSC Antelope Specialist Group 2017)”. In Nepal, FHA is reported to occur in dry deciduous hill sal *Shorea robusta* and mixed Shorea-Terminalia forests in four protected areas of Nepal: Bardia National Park (Pokharel 2010; Kunwar et al. 2016) Chitwan National Park (Pokharel et al. 2015b), Parsa National Park and Banke National Park (DNPWC 2017b). Its distribution is restricted to open canopy dry deciduous mixed forests, characterized by short grassland patches, sparse understory and undulating terrain (Krishna et al. 2009; Sharma et al. 2009; Baskaran et al. 2011). It has been found to be sympatric with barking deer *Muntiacus muntjak* in monsoon season in Nepal (Pokharel et al. 2015a). Nepal’s National Parks and Wildlife Conservation Act, 1973 has listed this species under the protected species list, prohibiting hunting (GoN 1973).

To date, studies on wild populations of FHA have been focused on its distribution (Krishna et al. 2008; Sharma et al. 2013; Pokharel et al. 2015b) and habitat ecology (Sharma et

al. 2009; Baskaran et al. 2011) with few studies on its feeding ecology (Sharma et al. 2009; Baskaran et al. 2011; Pokharel et al. 2015a; Kunwar et al. 2016). Although these previous studies have been useful in improving our understanding of the natural history of the species, ecology, and behavior, we still know little about the responses of the species to changes in habitat components, interspecific interaction with other sympatric species, habitat requirements and population abundance. Since it continues to lose its habitat to agricultural development, livestock grazing, fire, and encroachment by invasive species like Banmara (*Lantana camara*) (Krishna et al. 2009) information on diet composition is particularly important for conservation management interventions. Previous studies show that FHA predominantly consumes the browse dominated diet with highly nutritious plant parts such as fruits, flowers and fresh leaves dominating its diet (Baskaran et al. 2011; Pokharel et al. 2015a; Kunwar et al. 2016). In summer, when the availability of grass is high, FHA has been found to increase its diet breadth and consume grass species including the forb species *Ageratum conyzoides* (Kunwar et al. 2016). *Cynodon dactylon* and *Acacia nilotica* were identified as main winter dietary species of FHA in Madhya Pradesh, India (Sharma et al. 2009). The browse to grass ratio was high in the dry winter season and low in wet monsoon season in the diet of FHA in Bardia, Nepal (Kunwar et al. 2016).

While previous studies on food habits of FHA have provided important insights into its seasonal pattern of feeding revealing its generalized feeding strategy, more in-depth and rigorous studies are needed to confirm if the findings of these species are applicable to all habitat condition. Most of the previous studies had a small sample size (e.g., 20 pellet samples for dry winter season feeding analysis; Kunwar et al. 2016) to making it difficult to draw any broad generalization of their diet patterns. Studies with sufficient sample size are needed not only to understand the variability present in diet but also to ensure the reliability of results to make a

broad inference. It has been documented that an ungulate species may be forced to consume different food species in different sites due to difference in food density and composition, as well as the density of other co-occurring species, habitat, predation risk, monsoon seasonality and competition with sympatric species including livestock (Fritz et al. 1996; Wilsey 1996; Valeix et al. 2009). Site-specific studies on diet composition can thus be very useful not only in informing site-specific habitat management and species conservation measures but also in improving our understanding of the species feeding ecology in diverse **habitat types-developing** a general theory. Banke National Park, which lies in the foothills of the Siwalik mountain range, has diverse habitat types from pure *Shorea robusta* forests to mixed dry deciduous Shorea-Terminalia-Albizia forests. Before it was established as a national park in 2010, it was managed as a **production forest** for timber and fuel wood **production**. Livestock grazing and human use of the landscape for the collection of fodder and non-timber forests products was also common under previous management regime. The density of other sympatric ungulates (e.g., barking deer, spotted deer *Axis axis*) and the density of potential predators is less in comparison to other national parks where FHA occurs (e.g., Bardia National Park). These peculiarities offer a unique opportunity to assess if food habits of FHA in this national park are consistent with findings from other protected areas.

In this study, we examined the dietary composition of FHA in Banke National Park, Nepal, which **is first** of its kind in this park. We specifically examined whether FHA consumes all potential forage plant species equally when the availability of such species is low. We hypothesized that if FHA is a selective browser, it would include a high proportion of browse in its diet. We also predicted that if this species has a more flexible generalized grazer- browser mixed feeding or intermediate feeding **strategy. It would** continue to consume grasses despite

their low quality in dry season while also balancing the composition of dicots, which retain their nutritive quality even during winter. The findings are useful for the Government of Nepal and conservation stakeholders for planning forage and habitat management measures.

Materials and Methods

Study area

This work was conducted with research permission (1082-2072-9-2) from Department of National Parks and Wildlife Conservation for research in Banke National Park (N 27°58'13" to N 28°21'26" latitude; and E 81°39'29" to E 82°12'19" longitude). This park is stretched along the Churia foothills of the western part of the Terai Arc Landscape of Nepal (Figure 1). Established in 2010 as an effort to conserve the tropical deciduous ecosystem and double the tiger *Panthera tigris* population in Nepal, it covers an area of 550 km² in its core zone and 343 km² in its buffer zone (DNPWC 2017a). The park connects the Bardia National Park in the west and Suhelwa Wildlife Sanctuary of India through the forests in the southern part, with its buffer zone. Its elevation ranges between 153 to 1247 m above the mean sea level. Mean maximum temperature is around 40°C in summer but drops to very low during winter. Seasons are of four types, monsoon (Jun-September; the wet season with abundant rainfall), autumn (Oct-Nov), dry winter (Dec-Feb) and spring (Mar-May). The park contains eight ecosystem types: *Shorea robusta* forest, deciduous Riverine forest, savannas and grasslands, mixed hardwood forest, floodplains, Bhabar and foothills of Chure range (DNPWC 2017a).

Figure 1: The smaller map with the boundary of Nepal shows the protected areas of Nepal. Different colors denote the different categories of the protected areas. The large map is the study area, Banke National Park, which shows the core zone and buffer zone of the

National Park as well as the locations of sample collection (source of shape file: UNEP-WCMC& IUCN, 2017).

Data collection

Field surveys were conducted between December 2015 and January 2016 to collect the pellets of FHA and vegetation samples. Before going to the field for data collection, 22 key informant interviews were conducted with local people and park staffs to identify the possible locations where the species occurs. Based on information obtained from the key informant interview, we identified FHA hotspots and randomly laid transects of 500 m long and 20 m width in the map. Transect surveys are widely used method to collect fecal samples of ungulates (Pokharel et al. 2015a; Kunwar et al. 2016). The survey team, which included the first author, three field assistants and an expert from National Trust for Nature Conservation - Bardia Conservation Program walked along the 40 transects to collect the pellets samples. Wherever we recorded pellets, we established a plot of 10 m X 10 m around the pellet and collected the fecal samples and sample of all species of vegetation within these plots for lab analysis. This is recommended and widely used plot size for the study of dietary patterns of wild animals (Schemnitz 1980; Panthi 2011; Panthi et al. 2012; Aryal et al. 2015a). Leaves, twigs, fruits, and barks of all plants were collected.

The pellets of FHA were identified checking the shape, size, and texture of pellets following Pokharel (2010) who has confirmed size and shape details of FHA pellets by installing camera traps in the suspected middens of FHA in Bardia National Park. These FHA pellets were available as a reference for the verification of the pellets at Bardia National Park. Those reference pellets along with a trained wildlife technician (Mr. Binti Ram Tharu) were hired from

NTNC-BCP helped to minimize misidentification of pellets during the field survey. In drier habitat, the pellets can decay very rapidly, and further laboratory analysis can be difficult (Jung & Kukka 2016) so fresh pellets, not more than seven days old, were identified on the basis of texture and moisture content. We randomly sub-sampled 25 % each sample group for further analysis. These samples were air dried for five days in the field to remove moisture and prevent fungal growth. The collected plant samples were preserved in the herbarium and stored in the well ventilated dry room of Banke National Park Office, Overy Banke and sent to Central Department of Botany, Tribhuvan University, Kathmandu for further verification.

Micro-histological analysis

Micro-histological fecal analysis technique was used to determine plant composition of FHA fecal matter (Sparks & Malechek 1968; Holechek & Gross 1982). This method is widely used as a diet analysis tool to investigate the dietary composition of ungulates (Shrestha et al. 2005; Nagarkoti & Thapa 2007; Aryal et al. 2015b; Jung et al. 2015; Wangchuk et al. 2016). This method involves microscopic recognition of indigestible plant fragments of plant groups and preparation of reference and fecal slides and their interpretation. Samples of plant parts were dried in the oven at 60 °C in the laboratory and grounded separately into powder using an electric blender. The powder of each sample was sieved in mesh size 212 microns. The micro-histological slides of reference plants, as well as fecal sample slides, were prepared using the methods of Norbury (1988). In this method reference samples or fecal samples were placed in Petri dishes and bleached with 50 ml of 4% Sodium hypochlorite for 6-24 hours at room temperature to remove mesophyll tissue and to render the epidermis identifiable. The bleached contents were then rinsed well in a sieve, and then the rinsed fragments were treated

with few drops of staining substance-gentian violet solution (1 g/100 ml water) for 10 seconds and again well rinsed. The stained fragments were mounted on standard microscope slides in a DPX Mountant medium and covered with a cover slip (Norbury 1988). Both reference slides and fecal pellet slides were observed immediately after preparation at magnification 400X with a digital microscope, and each fragment was auto-photographed using bel photonics (Norbury 1988; Panthi et al. 2015). A diet analysis expert (Mr. Binod Shrestha) trained the first and fourth authors to identify the plant fragments. A total of 133 micro-histological photographs of different features of 64 plant species were prepared for the reference library. For each sample, 30 non-overlapping and distinguishable fragments were observed by moving the slides from left to right in the microscope. Specific histological features such as cell wall structure, shape and size of cells, trichomes; and shape and size of stomata were identified as key features to match the features of fecal plant fragments with reference plant (Panthi 2011; Aryal et al. 2012).

Data analysis

The plant fragments identified from the micro-histological analysis of the pellet samples were assigned into one of the following four levels of classification with different categories under each classification: (1) Functional group: (i) grasses, (ii) forbs, (iii) shrubs, (iv) climbers (vine plants) and (v) trees; (2) Broad taxonomic group: (i) monocots and (ii) dicots; (3) Family level; and (4) Species level. The idea behind this classification was to assess the relative contribution of different categories of plant taxa under each classification to the diet of FHA. We added the total number of fragments in each species and then calculated the proportion of each group. Diet composition was expressed as the percentage of occurrence of plant species (O %) (Cavallini & Lovari 1991).

$$\text{Percentage of Occurrence (0\%)} = \frac{\text{Number of fragments of each food}}{\text{Total number of plant fragments read}} \times 100$$

We performed the goodness of fit Chi-square test to identify whether FHA ate all plants uniformly. Our research hypothesis was that FHA would not eat all plants species, family, functional categories (grass, forb, climber, shrub, and tree) and broad categories (monocot and dicot) uniformly. We also hypothesized that FHA is a browser during winter. All tests were performed using Microsoft Excel and R software version 3.4.1 (R Core Team 2013) and 5 % level of significance was used for testing.

Results

A total of 1590 plant fragments from 53 pellet samples were analyzed through micro-histological technique. Out of the total plant fragments, 70 were unidentified, and these were excluded from statistical analysis. A total of 30 species belonging to 18 different families were identified in the pellets of FHA. Out of 30 species, FHA diet included 14 tree species, eight shrubs, two forbs, five grasses, and one climber (Table 1). The dicot shrub species *Phyllanthus emblica* had the highest percentage of occurrence in FHA diet (6.92%) whereas the dicot shrub *Clerodendrum viscosum* was the least contributor to the diet (0.94 %). FHA appeared not to feed all plant species uniformly ($\chi^2=312.56$, $df=29$, $p<0.50$) at the species level. Similarly, at the family level, FHA did not consume all plant families uniformly ($\chi^2=1982.41$, $df=17$, $p<0.05$). The family Gramineae which consists of 9 species contributed 27.68 % of the diet whereas Verbenaceae contributed only 0.94 % of the diet (Table 1). At the functional categories level, FHA did not consume all functional category (grass, forb, climber, shrub, and tree) uniformly ($\chi^2=1001.71$, $df=4$, $p<0.05$). In general, trees constituted a large proportion of diet contributing

46.55 %, followed by shrubs (24.52 %), grasses (13.84 %), forbs (8.18 % and climber (2.52 %) (Table 1).

Similarly, FHA did not have the equal choice at broad category (monocotyledonous and dicotyledonous) level ($\chi^2=229.01$, $df=1$, $p<0.05$). A Total of 66.36 % of FHA's diet was composed of dicotyledonous plants, and 29.25% of FHA's diet was covered by monocotyledonous. Only 4.4 % of the diet of the FHA remained unidentified during this study. The study identified 1300 fragments of browse (forbs, climbers, shrubs, and trees) and 220 fragments of grass in FHA's diet. The ratio of browse to grass was found to be 85.53%: 14.47 %, showing a strong affinity towards browse plant species in the dry season.

Table 1: Percent composition of various plant categories identified in pellets of FHA

Discussion

Assessment of the dietary choices of a species during low resource availability period is critical to understand its foraging plasticity and inform subsequent habitat and forage management measures. In this study, we studied the winter season food habit of four-horned antelope, a sparsely distributed yet threatened species native to Nepal and India (IUCN SSC Antelope Specialist Group 2017), based on micro-histological analysis of the collected fecal pellet samples. We hypothesized that if FHA is a selective browser during winter, it should show evidence of selectively foraging on browse in its diet.

Our result shows that dicots had a significantly higher percentage of occurrence in FHA pellets than monocots (suggesting that FHA might be adopting a browser strategy at least during winter when graminoids and grass species are low in abundance). Plant species differ in protein and fiber contents which influences animals' food choice (Klaus-Hügi et al. 1999). Smaller

antelopes have smaller stomachs compared to larger ruminants but have high metabolic requirements. This prohibits them from feeding large quantities of coarse grass species that are high in fiber and low in protein contents (Owen-Smith 1992). In dry deciduous tropical forests, graminoids lose their palatability and nutritive quality during the dry season in comparison to wet season (Sukumar 1989; Baskaran 1998). This could probably explain why monocots were not eaten as much as dicots. Berwick (1974) and Sharma et al. (2009) concluded that FHA is a selective feeder. The food selectivity by FHA may result from nutritional requirements, the need to decrease fiber intake, and maximization of protein intake in order to increase digestibility.

Our results support the hypothesis that FHA adopts a browser strategy during winter, but we cannot rule out the possibility that FHA is a mixed feeder with substantial feeding plasticity to balance nutritional requirements. Presence of grasses in 14.3 % of plant fragments suggests that grasses also have a substantial contribution to FHA diet. Our results of higher contribution of browse are consistent with the findings of Kunwar et al. (2016), who reported that browse constituted nearly two-thirds (66.95%) of the overall diet while grass species occurred only 13.68% (the rest, 19.77% remained unidentified). A study from India has, however, shown that FHA had more or less equal proportion of grass and browse in FHA diet in the winter season (14 grass, five herbs, four trees and one shrub) (Baskaran et al. 2011). This discrepancy in findings could be due to differences in study location, sample size and the high proportion of unidentified plants in their analysis. Baskaran et al. (2011) had 48 % of the plant remains in their FHA fecal samples which could not be identified whereas in our study we have only 4.40 % of the plant fragments that remained unidentified.

Our results showed plant species differ significantly in their contribution to FHA diet (Table 1). The shrub *Phyllanthus emblica* of the family Euphorbiaceae occurred most frequently

(6.92 %) in FHA diet. In their study in Bardia National Park, Kunwar et al. (2016) identified *Berlaria cristata* as the shrub species with the highest frequency of occurrence (5.33 % of total fragments identified) in FHA diet in the winter season. The cafeteria experiments of Berwick (1974) in Gir forest ecosystem, India, and Sharma et al. (2009) in Van Vihar National Park cum Zoo in Bhopal, India, showed that *Zizyphus mauritiana* contributed most to the diet of captive FHAs in winter. Our study also revealed a moderate contribution (4.40 %) of *Zizyphus mauritiana*. Although *Zizyphus mauritiana* is highly palatable, its thorns inhibit its consumption in the natural habitats (Berwick 1974). The FHAs in the Banke National Park do not appear to selectively consume towards climber species as indicated relatively low percentage of occurrence in fecal samples.

FHA distribution is determined by the tree species richness in India, and thus tree species richness has been considered as a good indicator of the FHA distribution (Sharma et al. 2009). In our study, tree species constituted a substantial proportion of FHA diet. On the whole, trees contributed the highest proportion (46.54 %) of diets of FHA followed by shrubs (24.53 %), grasses (13.84 %), forbs (8.18 %) and climbers (2.52 %). But Baskaran et al. (2011) showed in tropical forests of southern India during dry season revealed grasses were the major constituent of FHA diet (28.6 %) followed by trees (8.0 %), shrubs (5.6 %) and herbs (6.7 %). Our findings of the higher proportion of browse in FHA's diet supports the results of the feeding observations made on this species in Bardia National Park, Nepal (Kunwar et al. 2016) and captive antelopes in India (Solanki & Naik 1998). Our results also show the high proportion of the Gramineae family in the diet of this species similar to the findings of Kunwar et al. (2016). Although Baskaran et al. (2011) assert that FHA is the generalist in feeding strategy, our study showed that it consumes more browse plant species than grasses in the winter season. According to Hofmann

(1989), concentrate feeders choose a high quality diet and show a remarkable degree of forage selectivity. Some herbivores such as elephants graze in monsoon season and browse in the winter season (Pradhan et al. 2008). Our results show that FHAs in Banke National Park may have the plasticity to behave as concentrate feeders, consuming different proportions of various plant species and forage categories (grasses, forbs, shrubs, climbers, and trees).

During monsoon season grass availability is high so the ungulates behave more like pure grazers because they can find palatable grasses everywhere but they behave more like browsers in winter, a season of resource scarce (Pradhan et al. 2008). Consistent with that finding, we found the FHA to act as a browser in resource scarce seasons. Browse were major contributors of FHA's diet in all seasons but the proportion of trees in the diet was high in the winter season and low in summer and monsoon season (Kunwar et al. 2016). Similarly, we found a high browse to grass ratio in winter season.

Micro-histological analysis method, which we used for our study, includes multiple successive sampling from the individuals, pellets and epidermis fragments. Sampling size, therefore, could affect the estimates in all consecutive sampling steps (Katona & Altbäcker 2002). So, the larger sample size is required for the greater diversity of a species in the diet. In our study, we randomly read 30 plant fragments per slide per pellet from 53 independent pellet groups for determining FHA diet, which we hope provides a reasonable sample size. Of the total plant fragments, only 4.40 % diet remained unidentified in this study. This percentage was 48 % in Baskaran et al. (2011). In-vitro digestibility also greatly influenced the results of micro-histological analysis particularly in the estimation of grass and forb content (Vavra & Holeček 1980). FHA eats fruits, flowers and fresh leaves (Berwick 1974; Baskaran et al. 2011) which are highly digestible. Thus, this percentage of unidentified plants in the diet could be due to high

mastication and efficient digestion by the animal. We collected pellets and plants samples from only one protected area during a single season. Much rigorous and detailed information can be obtained from multi-season and multi-site study.

Overall, our results suggest that FHA has the feeding plasticity to adapt to resource fluctuations. Future studies on nutrient content analysis of different diet plant species and causes of changes in diet composition across seasons would be particularly useful for habitat conservation and management. Based on the findings of this study, we recommend that dicots, particularly fruit trees and shrubs, which are the major source of nutrients for FHA especially during winter, be conserved and natural regeneration be promoted.

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Table 1 (on next page)

Percentage compositions of various plant categories identified in pellets of FHA

1 **Table 1: Percentage compositions of various plant categories identified in pellets of FHA**

Family	Species	Broad taxonomic group (Class)	Functional group (Growth form)	Percent occurrence
Gramineae	<i>Hemarthria compressa</i>	Monocot	Forb	6.29
	<i>Imperata cylindrica</i>	Monocot	Grass	4.09
	<i>Eulaliopsis binata</i>	Monocot	Grass	3.14
	<i>Bambusa vulgare</i>	Monocot	Tree	2.83
	<i>Thysanolaena maxima</i>	Monocot	Shrub	2.83
	<i>Themeda triandra</i>	Monocot	Grass	2.52
	<i>Heteropogon contortus</i>	Monocot	Grass	2.2
	<i>Cynodon dactylon</i>	Monocot	Forb	1.89
	<i>Digitaria</i> spp.	Monocot	Grass	1.89
Gramineae total				27.68
Compositae	<i>Termanalia alata</i>	Dicot	Tree	4.4
	<i>Termanalia chebula</i>	Dicot	Tree	2.52
	<i>Termanalia belerica</i>	Dicot	Tree	1.57
Compositae total				8.49
Euphorbiaceae	<i>Phyllanthus emblica</i>	Dicot	Shrub	6.92
	<i>Mallotus philippensis</i>	Dicot	Tree	5.03
Euphorbiaceae total				11.95
Leguminosae	<i>Acacia catechu</i>	Dicot	Tree	4.72
	<i>Bauhinia vahlii</i>	Dicot	Climber	2.52
Leguminosae total				7.24
Rubiceae	<i>Xeromphis spinosa</i>	Dicot	Tree	5.97
Rhamnaceae	<i>Zizyphus mauritiana</i>	Dicot	Tree	4.4
Oleaceae	<i>Nyctanthes arbortristis</i>	Dicot	Shrub	3.77
Apocynaceae	<i>Carissa spinarum</i>	Dicot	Shrub	3.46
Dipterocarpaceae	<i>Shorea robusta</i>	Dicot	Tree	3.46
Lythraceae	<i>Woodforbia fruticosa</i>	Dicot	Shrub	2.83
Anacardiaceae	<i>Buchanania lanzans</i>	Dicot	Tree	2.52
Myrtaceae	<i>Eugenia</i> spp.	Dicot	Tree	2.52
Sapindaceae	<i>Schleichera oleosa</i>	Dicot	Tree	2.52
Rutaceae	<i>Aegle marmelos</i>	Dicot	Tree	2.2
Tilaceae	<i>Grewia</i> spp.	Dicot	Shrub	2.2
Myrsinaceae	<i>Myrsine semiserrata</i>	Dicot	Tree	1.89
Liliaceae	<i>Asparagus phillipensis</i>	Monocot	Shrub	1.57
Verbenaceae	<i>Clerodendrum viscosum</i>	Dicot	Shrub	0.94
	Unidentified			4.4
Identified total				95.6
Dicot total				66.36
Monocot total				29.25

Tree total	46.55
Shrub total	24.52
Grass total	13.84
Forb total	8.18
Total	100

Figure 1

The small map with boundary of Nepal **is showing** the protected areas of Nepal.

Different colors are denoting the different categories of the protected areas. The map with large scale is the study area, Banke National Park, which is showing the core zone and buffer zone of National Park and locations of sample collection (source of shape file: UNEP-WCMC& IUCN, 2017).

