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continued on the back inside cover

Cover: Illuminating the cruelty of Pangolin trade in India for the purpose of black magic, for the sanctity of protection. Using an animal's shell, ripping its armor against the world to protect oneself. When does one become the evil they are trying to ward off? — Acrylic on wood. © Maya Santhanakrishnan.

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ARTICLE

Dietary composition of Black-necked Crane *Grus nigricollis* Przewalski, 1876 (Aves: Gruiformes: Gruidae) in its winter habitat: insights from fecal analysis in Bumdeling, Trashiyangtse, Bhutan

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Abstract: Gaining comprehensive insights into the dietary habits and food preferences of the Black-necked Crane (BNC) is crucial for developing effective conservation plans to safeguard this globally near-threatened species. The choice of habitats by these birds is primarily influenced by the availability of diverse food sources and overall environmental security. This study was conducted in 2019–2020 in Bumdeling, one of three wintering sites for BNC in Bhutan. It was prompted by concerns over a declining crane population, largely due to habitat alteration that threatens food sources. This study aimed to examine the dietary preferences of cranes by collecting and analyzing fecal samples from foraging and roosting sites. Results revealed that paddy-fields were the primary foraging areas. The presence of domestic grains after harvest, herbaceous plants, and invertebrates are crucial components of the food structure of cranes. Fecal samples contained 79 species from domestic crops, herbaceous plants, and invertebrates. Fecal dry weight exhibited significant differences from December to February compared to March, suggesting a decline in rice intake and an increase in invertebrate consumption, resulting in lower fecal weight. These results also showed that as the months progress rice decreases with a shift to a protein-rich diet of invertebrates before cranes migrate back to their summer grounds. Traces of plastics were found in feces from all feeding sites, highlighting the need for better waste management. Changes in agricultural practices have had significant impacts on the availability of food sources for cranes in Bumdeling. Collaboration among conservationists, local government, and communities is recommended to enhance winter habitats and provide food supplements when rice supplies start to diminish.

Keywords: Changing agricultural practices, conservation strategy, declining crane population, fecal dry weight, foraging and roosting behaviour, herbaceous plant, paddy-fields, protein-rich diet, winter habitat.

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INTRODUCTION

Black-necked Crane (BNC) *Grus nigricollis* is a migratory species in the Central Asian Flyway (CAF) that prefers high-elevation habitats for beeding in summer and low-elevation areas for foraging in winter (Image 1). The largest population occurs at the Tibetan-Qinghai Plateau in western China (Lhendup & Webb 2009; Dong et al. 2016), and a small population occurs in Ladakh in India. During winter, cranes typically migrate to a lower altitudes of 2,000–3,000 m (Harris & Mirande 2013), including Qinghai-Tibet and Yunnan-Guizhou Plateaus in China, Arunachal Pradesh in northeastern India, and Bhutan (BirdLife International 2020). Their wintering habitats are mainly attributed to food availability and favorable climatic conditions. BNC is a globally 'Near Threatened' species (BirdLife International 2024), listed on CITES Appendices I and II. Its habitats continue to accrue significant destruction (Li & Li 2012) and access to food sources continues to reduce due to anthropogenic activities (Dong et al. 2016). The knowledge about dietary habits, food preferences, and choice of habitats is important evidence that will help devise conservation plans for the management of this species effectively (Dong et al. 2016).

Bhutan has three main areas where the BNC winters: Phobjikha in the west, Bumdeling in the east, and Bumthang in the center (Lhendup & Webb 2009; Namgay & Wangchuk 2016). In these wintering grounds, BNC typically feed on domestic crops like paddy, wheat, barley, buckwheat, potatoes, turnips, and cereals where conventional agriculture is practiced by local communities, however, elsewhere outside Bhutan grassland constitutes primary foraging areas (Bishop et al. 1998; Dong et al. 2016). Birds feed on herbaceous plants, especially the soft shoots found on roots, dwarf bamboo, tubers, and seeds, and also on invertebrates such as snails, and earthworms, which are crucial for their survival and health (Dong et al. 2016). They roost in shallow water, on riverbanks, or in small ponds. The population is threatened by significant changes in agricultural practices, industrial development, climate change, habitat loss (Lhendup & Webb 2009; Namgay & Wangchuk 2016), and predation (Choki et al. 2011). The world population totals over 10,000 birds (Li 2014). Bhutan hosts more than 600 individuals annually during the winter season between October and March (Phuntsho & Tshering 2014). The BNC population in Bumdeling declined steadily between 1980–2020 while it increased in Phobjikha (Namgay & Wangchuk 2016; BNC 2021). If this trend persists, the BNC may gradually abandon Bumdeling as a wintering area as there were few instances reported in the distant past from Samtengang, Tshokana, Gongkhar (Lhendup & Webb 2009), Gaytsa, and Rodhungthang (Namgay & Wangchuk 2016). The decrease in BNC numbers can be attributed

Image 1. Black-necked Crane *Grus nigricollis* feeding. © Tshering Chophel.

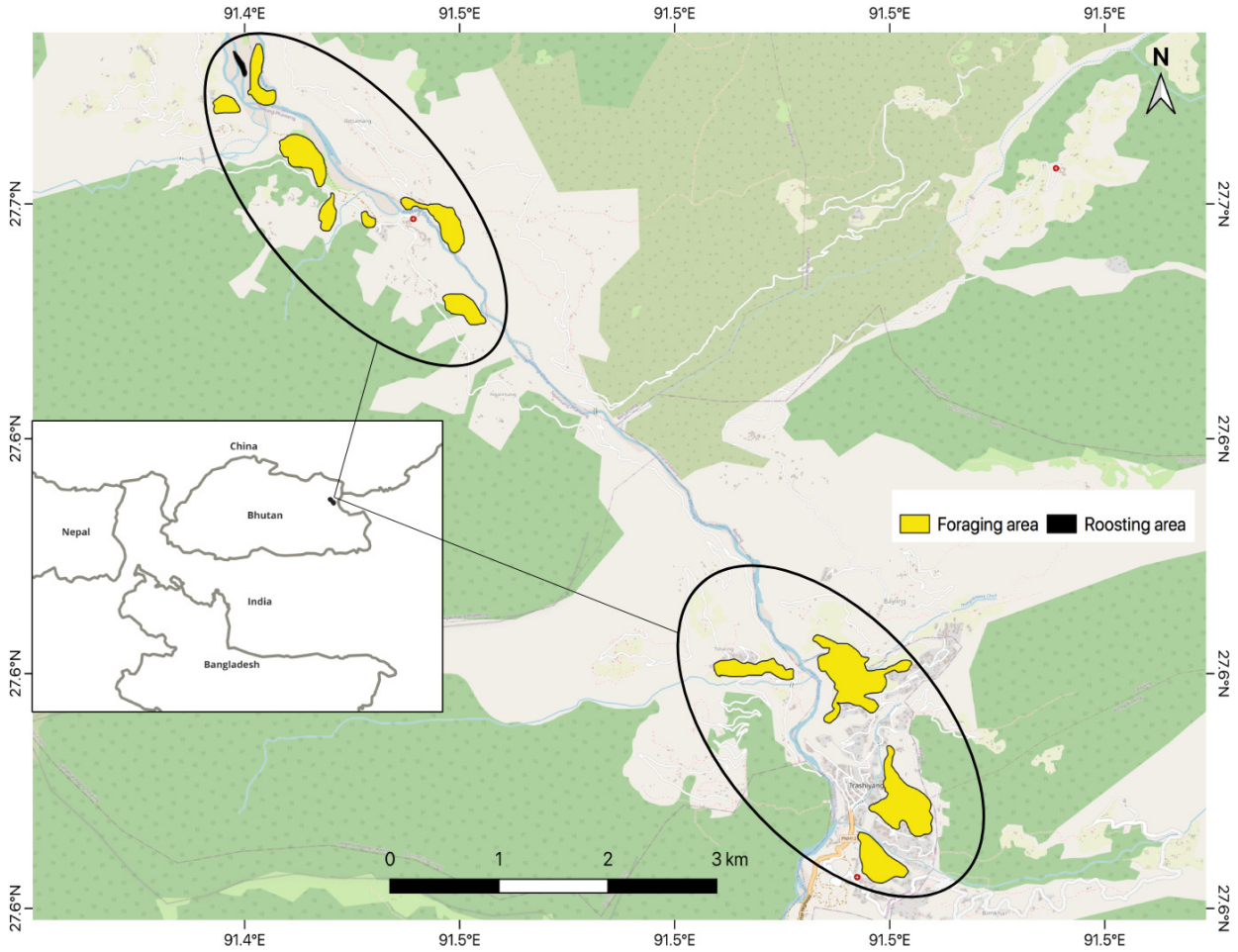

Figure 1. Map showing the study area, consisting foraging and roosting sites in Bumdeling and Yangtse, in Trashiyantse District.

to both anthropogenic activities, such as infrastructure development, and a series of natural events such as flash floods in Bumdeling in 1999, 2003, 2005, and 2007 (NCHM 2018), which have disrupted their feeding and roosting grounds. On the other hand, it is likely that the cultivation of winter crops in recent years after the rice harvest has reduced the availability of critical foraging and roosting areas which may have resulted in fewer BNCs visiting the sites.

The BNC plays a vital role in wetland ecosystems by regulating the population of invertebrates at cascading trophic levels. Culturally, these birds are considered sacred and believed to bring blessings, which helps to protect their habitats. Conservation efforts, including the designation of RAMSAR sites, habitat restoration, research on migration and habitat preferences, and the integration of community agricultural practices are being implemented. However, there is a lack of study on the dietary habits of BNC during winter months at their foraging and roosting sites. This study aims to address this gap by analyzing the dietary composition using fecal samples of BNC from their wintering grounds. By determining dietary needs and preferred food types, these findings are expected to enhance understanding of their habitat interactions and contribute to the development of long-term conservation plans (Dong et al. 2016) in Bhutan.

MATERIALS AND METHODS

Study area

The study was conducted in Bumdeling Wildlife Sanctuary (BWS) which falls within the northeastern part of Trashiyangtse District, Bhutan. The Sanctuary covers an area of 1,545 km^2 encompassing parts of the Lhuntse, Trashiyangtse, and Mongar districts (Figure 1). It shares international borders with the Tibetan region of China in the north and India in the north-east. Our study area is limited to Trashiyangtse, where the site is used as the

wintering grounds by BNC. The sites include seven crane foraging areas: Bayling, Baychen, Batsemang, Gilingbo, Maidung, Tshaling, and Yangteng, and one roosting area: Dewalingjuk, scattered along Bumdeling valley. The study area has an altitudinal range of 1,785–1,921 m. The mean temperature varies 15–25 ^{0}C. The annual rainfall received in the area measures 2,000–3,000 mm. The study area covered all the foraging and roosting sites used by the BNC in the locality. The foraging site is located on farmland, where the main food crops grown by the local communities are rice, maize, millet, potatoes, and chillies. The roosting area consists of a shallow braided river with several pools and grasslands.

Sampling design and data collection

Local forest officials and resident communities were consulted to locate BNC annual foraging sites before starting fieldwork. Seven foraging sites and one roosting site were identified for fecal sample collection. Consultation of local people, observation, and involvement of local forest officials were key to site selection, and the transect method was employed for collecting fecal samples from the foraging and roosting sites.

We collected 350 and 40 fecal samples from the foraging and roosting sites, respectively. A transect walk was conducted from December 2019 to March 2020. BNCs start to arrive in their winter habitats by the end of November and leave for their summer habitats by March each year. The first 10 fresh fecal samples (intact) were collected from seven foraging and one roosting site. The fecal samples were sun-dried and wrapped in paper, and transported to the laboratory in zip-lock bags. While collecting, safety gear such as masks, hand gloves, and sanitizer were used to avoid fecal contamination and transfer of avian zoonotic diseases. At each collection site, a quadrat measuring 1 m^2 was laid on where the feces were observed. Firstly, at the foraging sites, surface-dwelling invertebrates were identified and counted, followed by herbs enumeration within the plot. Those unidentified invertebrates' specimens were collected and later identified in the laboratory. Secondly, within a 1 m^2 quadrat, a 10 cm^2 plot with a depth of 10 cm was dug and the invertebrates were identified and counted. Thirdly, at the roosting sites, freshwater invertebrate samples from the pools, runs, and riffles were collected using a kick net measuring 30 X 30 cm with a mesh size of 500 µm, and taxa were recorded.

Fecal analysis

Fecal sample analysis was carried out in the laboratory. Samples were oven-dried for three hours at 60^{o}C to eliminate moisture content and avoid fungal growth. We measured the dry sample weight of all the fecal samples using a digital weighing scale and then stored them at room temperature. Samples to be analyzed were put in petri dishes and soaked in water overnight, and the next morning, the contents were gently stirred to separate the plant fiber and invertebrate components. The supernatant of the fecal mixture was decanted into other petri dishes as invertebrate components remained afloat, and heavier invertebrate parts were also hand-picked with forceps. This method was adopted from Ralph et al. (1985) and Moreby (1988). The samples were repeatedly diluted and decanted until the undigested fecal materials (fibers, seeds, husk, invertebrate parts) were thoroughly cleaned and became identifiable under a microscope. The parts of undigested fiber and exoskeleton were placed on a glass slide and examined using a microscope, photographed, and identified. For the identification of undigested plant fiber, the method was adapted from Fengshan et al. (1997) and Liu et al. (2014), while for the identification of the exoskeleton of invertebrates, we used established methods by Moreby (1988), Ralph et al. (1985), and Liu et al. (2019). Depending on the size of the undigested fecal fragments, identifications were made to their taxonomic order, family, and species. The taxa names identified from fecal fragments, quadrat sampling, and kick net sampling were validated and confirmed by a national botanist and an entomologist. Soft-bodied organisms that may have been fully digested were beyond the scope of our study, however, those observed were included in our checklist.

Data analysis

To analyze the dietary compositions from fecal samples, both descriptive and inferential statistics were employed. For descriptive analysis, we calculated the percent composition of different diet components, including herbaceous plants, invertebrates, and domestic crops. For inferential analysis, we used Kruskal-Wallis tests in R software to compare diet composition and fecal dry weight across various months and sites. To compare diet composition and fecal dry weight between roosting and foraging sites, we applied the Mann-Whitney U test (also known as the Wilcoxon Rank Sum test). Given the non-normality of the data and unequal group size, we used a non-parametric effect size measure Cliff's delta to compare fecal weight data between March (Group 1) and each of the other months (December, January, February) treating each as group 2 in separate comparisons. We calculated Cliff's delta

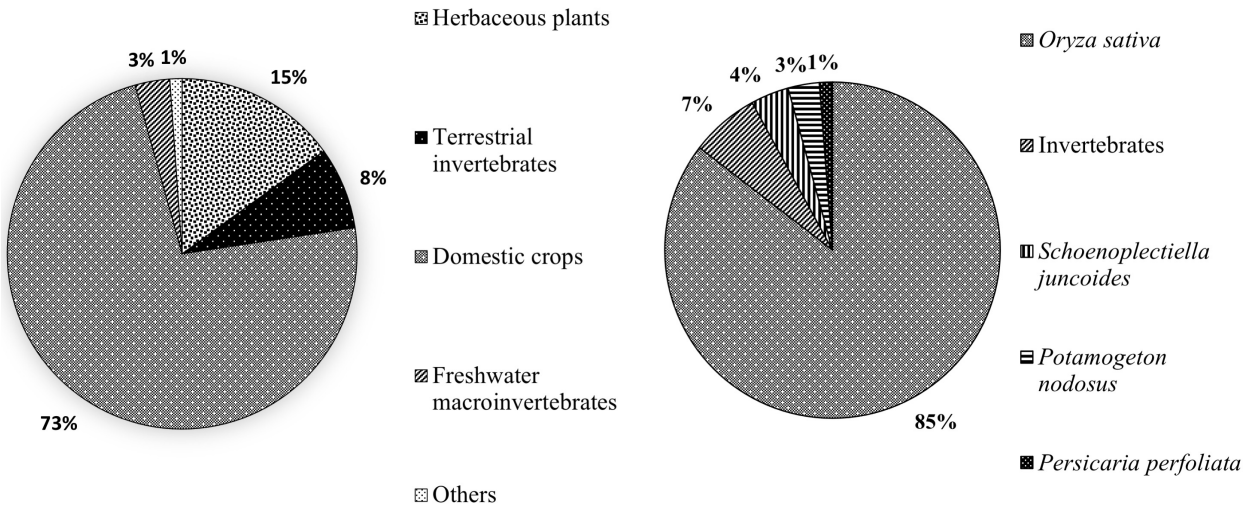

Figure 2. Left—Primary composition of food sources of the BNC | Right—five major diet constituents of the BNC.

(1993) using the equation: δ = (D-U)/(*n*1 ∗ *n*2). In this D is the number of instances where a score from group 1 is greater than a score from group 2, U is the number of scores from group 1 that are smaller than group 2, and n1 and n2 are the number of observations in respective groups. The values of 1 are given when a score from group 1 is greater than group 2, -1 when it is smaller, and 0 when they are equal.

RESULTS

Dietary composition of BNC

A total of 3014 fragments of ingested materials were counted from 390 fecal samples constituting 79 different types of dietary sources, mainly herbaceous plants (41), followed by invertebrates (30), and domestic crops (4) respectively, apart from small traces of plastics, fine pebbles (2–4 mm diameter), feathers of birds, and fish scales were also evident in the fecal samples (Table 1). However, in terms of composition, rice constitutes the highest food source. This is certainly obvious as the remains of rice grains are readily available in the farmland after the harvest. The results show that domestic crops, herbaceous plants, and invertebrates constituted the main dietary structure of the BNC. Domestic crops comprised the highest proportion (70%) of the diet, followed by herbaceous plants (14%) and invertebrates (13%). About 1% constitutes other diatary components such as bird feathers, fish, plastics, and pebbles (Figure 2). The occurrences of plastic waste, pebbles, and bird feathers were circumstantial, however, plastic traces were present at almost all the feeding sites.

The main diet of BNC during the wintering months appeared to be rice *Oryza sativa*, followed by herbaceous plants and invertebrates. Data on diet composition in winter from December 2019 to March 2020 showed insignificant differences in the Kruskal-Wallis rank sum test; H = 1.269 (3), p = 0.05. The composition of diet content appears to have a similar pattern throughout the months. The diet composition exhibited no variation across different sites; H = 11.337 (7), p = 0.124. This showed that all sites had similar composition of dietary sources chiefly rice grains from paddy land. The top five food sources constitute *Oryza sativa*, invertebrates, *Schoenoplectiella juncoides*, *Potamogeton nodosus*, and *Persicaria perfoliata* (Figure 2). *Oryza sativa* is an essential dietary source followed by invertebrates which are attributed to the higher number of fragments in feces samples. However, it should be noted that most fragments which were not identifiable due to ingestion were grouped together.

Dietary composition at roosting and foraging sites

Dietary sources in roosting and foraging sites are likely to have differences, the former being in the braided river and island, and the latter in cultivated paddy-fields. Our in-depth analysis showed that roosting sites had species that were not present in other sites. This is primarily attributed to the composition of aquatic plants (*Cladophora* sp. *Dicranum viride, Digitaria sanguinalis, Marsupella emarginata, Eriochloa villosa, Seleginella* sp, and *Urochloa ramosa*) and freshwater invertebrates (Aeshnidae, Athericidae, fish, Hydropsychidae, Hydroptilidae, and Scirtidae) which were observed only from the roosting sites. On the other hand, foraging

Table 1. The percentage composition of species in the dietary intake and the remnants of identical parts present in the Black-necked Crane's fecal samples.

	Family	Species	Part of organ	Frequency of fragments	Percentage
Herbaceous plants					
1	Adoxaceae	*Viburnum* sp.	Leaf	1	0.033
2	Asteraceae	*Chromolaena corymbosa*	Seed pod	3	0.100
3	Asteraceae	*Bidens tripartita*	Seed	9	0.299
4	Brassicaceae	*Cardamine hirsuta*	Leaves, stem	3	0.100
5	Ceratophyllaceae	*Ceratophyllum demersum*	Needle leaves with stem	1	0.033
6	Cladophoraceae	*Cladophora* sp.	Undigested filaments of algae	16	0.531
7	Commelinaceae	*Commelina* sp.	Whole plant, leaf, stem	4	0.133
8	Cyperaceae	*Carex* sp.	Flower, seed, seed pod	23	0.763
9	Cyperaceae	*Schoenoplectiella juncoides*	Seed	94	3.119
10	Dicranaceae	*Dicranum viride*	Leaf	2	0.066
11	Equisetidae	*Equisetum* sp.	Stem	3	0.100
12	Eriocaulaceae	*Eriocaulon nepalense*	Petal	27	0.896
13	Fabaceae	*Trifolium hybridum*	Seed	7	0.232
14	Funariaceae	*Funaria hygrometrica*	Seed and leaves	10	0.332
15	Gymnomitriaceae	*Marsupella emarginata*	Leaf	2	0.066
16	Hydrocharitaceae	*Elodea densa*	Leaf	7	0.232
17	Hydrocharitaceae	*Hydrilla verticillata*	Leaf	6	0.199
18	Juncaceae	*Juncus effusus*	Naked seed	4	0.133
19	Lamiaceae	*Pogostemon stellatus*	Leaf, stem	9	0.299
20	Lamiaceae	*Pogostemon erectus*	Leaf	2	0.066
21	Lythraceae	*Rotala cordata*	Twigs, leaves, stem	13	0.431
22	Lythraceae	*Rotala indica*	Flower, twig	18	0.597
23	Nostocaceae	*Nostoc* sp.	Alike jelly fungus	1	0.033
24	Plantaginaceae	*Plantago asiatica*	Leaf	2	0.066
25	Poaceae	*Alopecurus aequalis*	Seed pod	2	0.066
26	Poaceae	*Poa annua*	Seed with cover	5	0.166
27	Poaceae	*Poa pratensis*	Seed	17	0.564
28	Poaceae	*Setaria italica*	Seed, seed pod	12	0.398
29	Poaceae	*Panicum* sp.	Seed pod, seed	5	0.166
30	Poaceae	*Eriochloa villosa*	Seed	1	0.033
31	Poaceae	*Digitaria sanguinalis*	Seed	5	0.166
32	Poaceae	*Urochloa ramosa*	Seed with case	1	0.033
33	Polygonaceae	*Polygonatum aviculare*	Sheath	12	0.398
34	Polygonaceae	*Persicaria perfoliata*	Stem with spike	32	1.062
35	Potamogetonaceae	*Potamogeton nodosus*	Leaf	77	2.555
36	Araliaceae	*Hydrocotyle sibthorpioides*	Leaf	6	0.199
37	Selaginellaceae	*Selaginella* sp.	Stem and leaf	1	0.033
38	Xyridaceae	*Xyris capensis*	Awn	1	0.033
39	Xyridaceae	*Xyris* sp.	Seed, seedpod, flower	7	0.232
40	Zygnemataceae (Algae)	*Spirogyra* sp.	Leaf	2	0.066
	Domestic crop				
41	Amaranthaceae	*Amaranthus hybridus*	Seed	5	0.166

	Family	Species	Part of organ	Frequency of fragments	Percentage
42	Poaceae	*Oryza sativa*	Husk, seed, sheath, leaf, stem digested remains	2182	72.395
43	Poaceae	*Triticum aestivum*	Seed	1	0.033
44	Poaceae	*Eleusine coracana*	Seed	13	0.431
	Terrestrial invertebrates				
45	Acrididae	Acrididae	Legs	12	0.398
46	Agriolimacidae	*Deroceras* sp.	Whole body (Observed)	2	0.066
47	Carabidae	*Bradycellus* sp.	Elytra and legs	4	0.133
48	Carabidae	Harpalinae	Elytra and legs	5	0.166
49	Carabidae	*Stenolophus* sp.	Elytra and legs	2	0.066
50	Carabidae	*Platynus* sp.	Elytra	5	0.166
51	Cerambycidae	Cerambycidae	Legs, exoskeleton, ommatidium	8	0.265
52	Chrysomelidae	*Altica* sp.	Elytra	1	0.033
53	Chrysomelidae	*Chrysolina* sp.	Legs	2	0.066
54	Dermaptera	Dermaptera	Exoskeleton	1	0.033
55	Fanniidae	*Fannia* sp.	Exoskeleton	7	0.232
56	Lucanidae	*Lucanidae*	Elytra	2	0.066
57	Lumberculidae	Lumbriculidae	Whole body (Observed)	8	0.265
58	Ptinidae	*Stegobium paniceum*	Full body	1	0.033
59	Invertebrates	Invertebrates	Elytra, exoskeleton, legs, Mesonotum, scutellum,	169	5.607
	Freshwater invertebrates				
60	Aeshinidae	Aeshnidae	Exoskeleton	1	0.033
61	Athericidae	Athericidae	Whole body (Observed)	2	0.066
62	Aphelocheiridae	*Aphelocheirus* sp.	Elytra	2	0.066
63	Blephariciidae	Blephariceridae	Exoskeleton	1	0.033
64	Belostomatidae	*Diplonychus* sp.	Legs and wings	3	0.100
65	Chironomidae	*Chironomidae* (red)	Exoskeleton	10	0.332
66	Corixidae	*Hesperocorixa interrupta*	Wavy leopard pattern elytra	21	0.697
67	Dytiscidae	*Rhantus* sp.	Dotted leopard pattern elytra	19	0.630
68	Hydropsychidae	Hydropsychidae	Femur	1	0.033
69	Hydroptilidae	Hydroptilidae	Case with insect	1	0.033
70	Lymnaeidae	*Orientogalba ollula*	Part of shell	9	0.299
71	Potamidae	Potamidae	Legs, carapace, exoskeleton	16	0.531
72	Psychomyiidae	Psychomyiidae	Trochatin	2	0.066
73	Scirtidae	Scirtidae	Exoskeleton	1	0.033
74	Sphaeriidae	*Pisidium* sp.	Shell	5	0.166
75	Tipulidae	Tipulidae	Whole body	3	0.100
	Others				
76		Birds	Feather	2	0.066
77		Fish	Scale/skin	2	0.066
78		Plastics	With different colors: White, red, pink, yellow, green, blue	17	0.564
79		Pebbles	With color and patterns: black stripe, white, and yellow	13	0.431
				3014	100.00

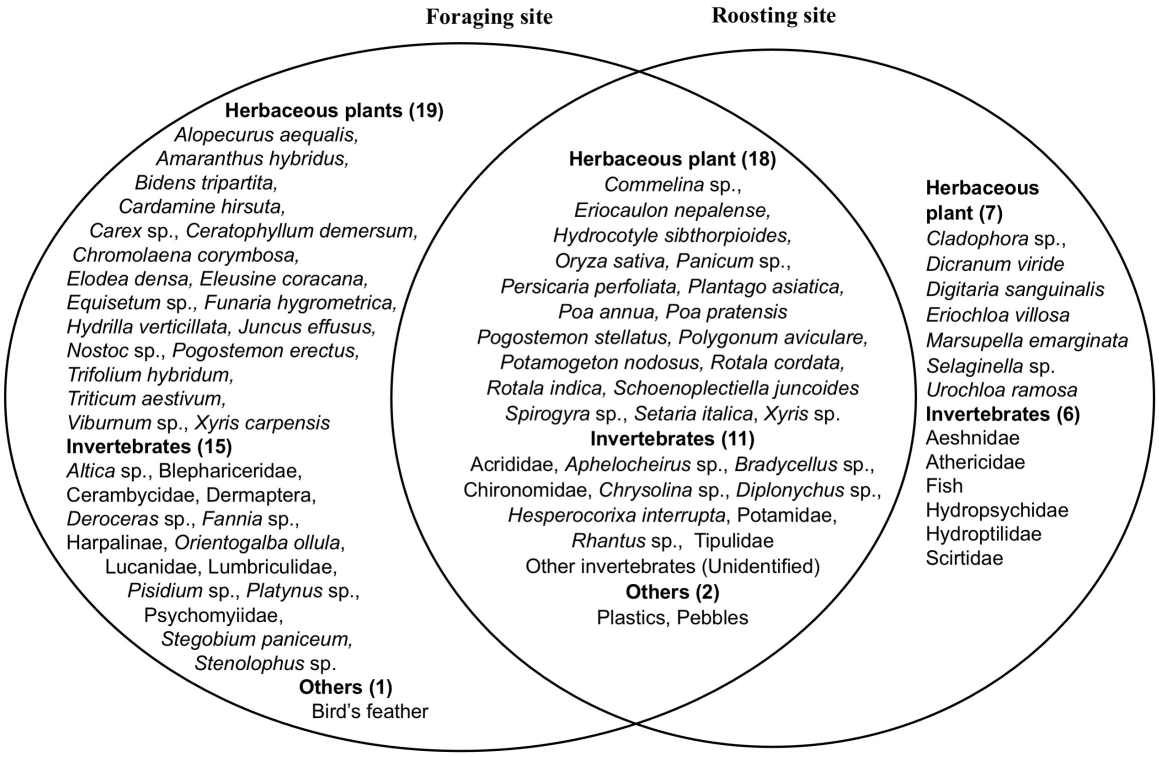

Figure 3. Dietary sources identified at roosting and foraging sites, indicating common dietary preferences and variations. The bold text represents major diet groups of the Black-necked Crane.

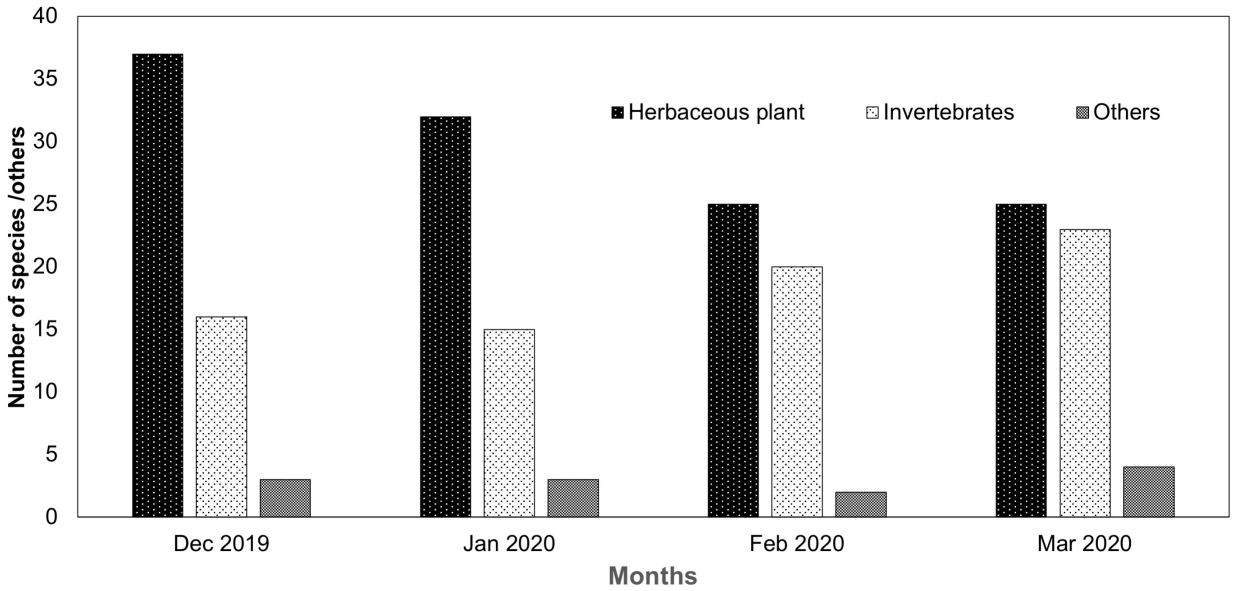

Figure 4. Number of species within taxonomic groups identified in the feces of Black-necked Crane across different months.

sites had the highest species composition and richness, possibly because these sites comprised seven localities (Figure 3). To understand the difference between the roosting sites (Dewalingjuk) and the foraging sites, a Wilcoxon rank sum test revealed significant differences in two of the seven site pairs; Batsemang vs Roost, W = 2491.5, p = 0.016, δ = 0.05 and Tshaling vs Roost site, W = 2397, p = 0.001, δ = 0.10. The other five pairs had

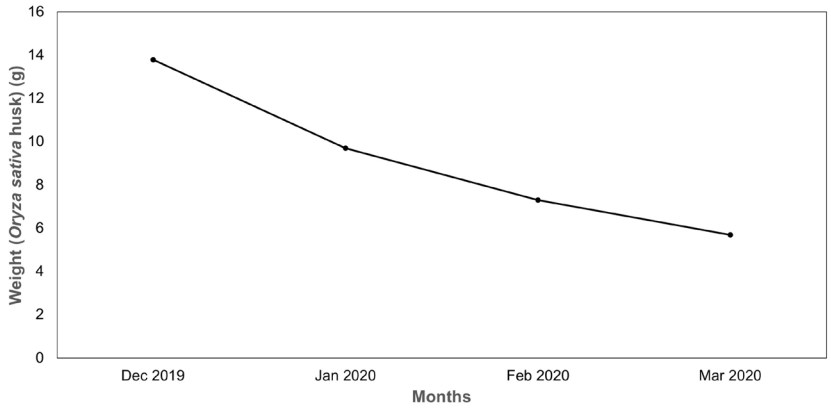

Figure 5. Dried weight of *Oryza sativa* residues in the feces of Black-necked Crane during different months.

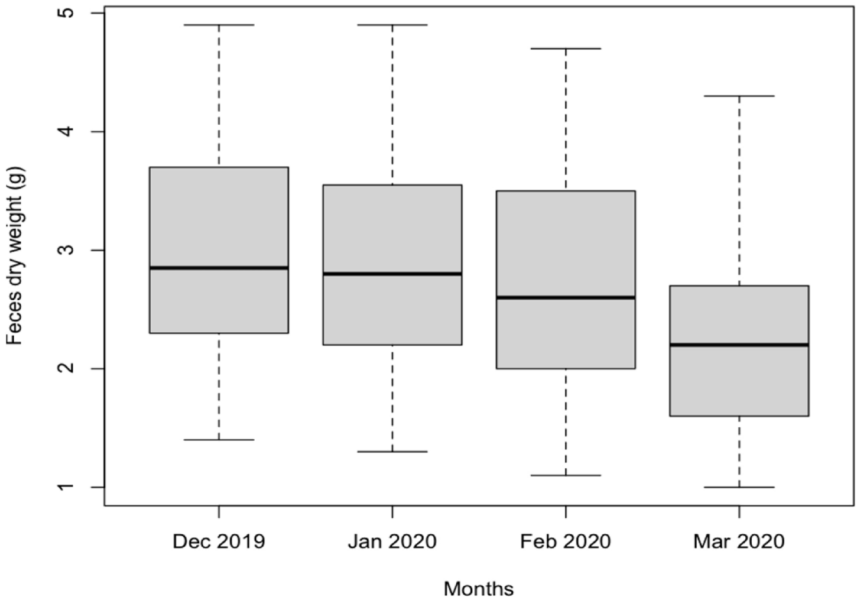

Figure 6. Variation in the dry weight of Black-necked Crane fecal samples during the winter months.

no significant differences; Roost site vs Maidung, W = 2736, p = 0.150; Bayling vs Roost site, W = 2999.5, p = 0.651; Choetenkora vs Roost site, W = 2889.5, p = 0.390; Gilingbo vs Roost site, W = 2937.5, p = 0.491 and Roost site vs Yangteng, W = 2720.5, p = 0.132. Cliff's delta effect size (≤ 0.1) in the significant comparisons suggests that the difference between the two groups was small.

Monthly variation of food

All 390 samples showed the presence of herbaceous plants when pooled with domestic crops and plants. Undigested materials from invertebrates were found in 281 samples, while 17 samples contained traces of plastics, pebbles (13), feathers of birds (2), and fishes (2). Species richness varied slightly over the four months, with December 2019 having the highest number of species. However, there was a steady decline in the following month before increasing in March 2020 (Figure 4). The cranes had access to more food sources at the time of their arrival in December, while access to food resources declined in the following months after they fed on them. Before migrating, the crane prefers invertebrates to store more energy for their long flight to their summer grounds. The Poaceae family was the most dominant species among the herbaceous plants, while Coleoptera was the most abundant food constituent in the invertebrate group. Overall, species richness slightly fluctuates over the four months, with herbaceous plant species decreasing and invertebrate species increasing.

Dry weight of feces and rice grains across different months

Of the 390 samples collected, 311 contained *Oryza sativa* which is the primary food source for the BNC. An in-depth analysis was conducted to determine the weight of undigested rice remains, including husk, stem, and seeds, and it was found that the fecal weight decreased over the months (Figure 5). In December, when BNC arrived at their wintering grounds, there was a large amount of rice residuals (~14 g) that had been harvested a month earlier. Over the following months, the availability of rice grains gradually decreased, reaching a low point (~6 g) just before the cranes left for their summer habitat. The decrease in rice intake was probably compensated by an increase in the consumption of invertebrates.

The dry fecal weight corroborates the food availability and access for BNC. The weight of BNC feces was highest in December, then gradually decreased from January to February, with a sharp drop in March, indicating reduced food availability due to repeated foraging in the area (Figure 6). The mean dry weight per dropping of the BNC is 2.70 ± 1.06 g and they gain more energy by feeding on invertebrates before flying back to their summer habitat. The Kruskal-Wallis rank sum test revealed that dry weight data from December 2019 to March 2020 had significant differences among the months H = 34.657 (3), p = 0.001. To determine which specific months had contributed to differences in dry weight, a post-hoc test was performed. The months of December 2019, January 2020, and February 2020, when compared to March 2020, exhibited significant differences based on the Wilcoxon rank sum test. These significance pairs were evaluated to understand the magnitudes and strength of effect size between independent paired months for March 2020 vs December 2019, W = 4612.5, p = 0.001, δ = 0.42; March 2020 vs January 2020, W = 4427.5, p = 0.001, δ = 0.43; and March 2020 vs February 2020, W = 3837, p = 0.001, δ = 0.32. The main observed differences with all three comparisons have positive data values indicating second months (December 2019, January 2020, and February 2020) have higher values than the first group (March 2020) respectively. However, the effect sizes are relatively small (0.3–0.4). This can be attributed to the fecal dry weight in March 2020, with an increased intake of invertebrates, which have higher protein content and constitute less indigestible material compared to plant matter. Conversely, for the other months, no significant differences were exhibited December 2019 vs January 2020, W = 3384.5, p = 0.052; December 2019 vs February 2020, W = 3514.5, p = 0.061, January 2020 vs February 2020, W = 3357, p = 0.20. These results were largely due to the crane's higher preference for herbaceous plants and lower intake of invertebrate diet during these months consistent with the earlier results.

DISCUSSION

In this study, the diet of BNC comprises 44 plant species, 31 invertebrate species, and four other food sources. Of the combined 87 herbaceous plant species reported elsewhere in the cranes-inhabiting regions by various authors Fengshang et al. (1997) (48 species), De-jun et al. 2011 (5 species), and Lui et al. 2014 (43 species); and *Plantago* sp., *Trifolium* sp., *Poa annua*, *Polygonum* sp., *Epilobium* sp., *Carex* sp., *Eriochloa villosa*, *Juncus effusus*, *Potamogeton* sp. *Hydrilla verticillata*, and *Polygonatum* sp. were also found in the feces samples of BNC from the present study. These species are largely grown on the edge of the terraces and are occasionally found growing along with the *Oryza sativa.* The primary diet of the BNC in the Bumdeling consisted of domestic crops, particularly *Oryza sativa*. The high food quantity and density of paddy seeds in the farmland, where residues are left after the harvest is the main reason why the cranes have established their wintering grounds in this locality.

Several studies have documented that the diet of cranes consists of fish, young birds, clams, shrimps, amphibians, molluscs, and invertebrates (Chacko 1992; Han 1995, Li et al. 1997; Li & Li 2005; Liu et al. 2014a,b, 2019). In this study, we report one fish species and two other molluscs (*Deroceras* sp. and *Orientogalba ollula*). The roosting sites characterized by shallow water provide the best habitat for cranes to feed on fish. The slightly marshy wetlands left after the harvest of paddy-fields support molluscs which is a food source for cranes in the locality.

The invertebrate taxa consumed by the BNC, identified at various taxonomic levels, include Coleoptera, Hymenoptera, Diptera, Lepidoptera, and Araneae (Di-jun et al. 2011; Liu et al. 2019), along with specific species such as *Chorthippus hsiai* and *Geotrupes* sp. (Wu 2007). In our study, we report several invertebrates identified down to the lowest possible taxa levels, from terrestrial and freshwater systems that were limited in previous studies. The fecal analysis revealed the presence of 16 freshwater and 15 terrestrial invertebrate species. Taxa such as Lumbriculidae, Tipulidae, Athericide, and Diplonychus

sp. are soft-bodied and were recorded through field observations. In contrast, others, largely comprising Coleopterans (Liu et al. 2019), were discovered from the crane feces. Undigested fragments that were not identifiable were grouped under invertebrates, which may constitute multiple species. Although Coleopterans appear to be a supplementary food source for BNC, they form an important food source after herbaceous plants. Fragments of *Hesperocorixa interrupta* and *Rhantus* sp. were quite common compared to other species. However, this list is underestimated, as many digested soft tissues were difficult to examine and could not be accounted for. Although feces provide an easy method for analyzing diet, completely digested soft-bodied fragments and smaller indigestible particles make identification more challenging. This highlights the need for future studies to incorporate eDNA methods to improve accuracy.

The main factors that determine the arrival and departure of cranes are influenced by the availability of food in the farmland after the harvest. In December, just after the harvest, droppings of paddy grains are most abundant and gradually decrease in the following months. Animal matter, including protein- and fat-rich invertebrates from soil and freshwater habitats (Liu et al. 2014a), is crucial for cranes, with higher intake observed before migration to their summer grounds. Over the years, the gradual decline in visiting BNC in the localities may be attributed to the decrease in foraging areas, as nearby open spaces, including some agricultural land, have been colonized by vegetation. Additionally, food availability has decreased as the land used for rice production has been cultivated following the paddy harvest, resulting in a reduction of the food supply. Studies conducted elsewhere have shown that BNC forages in meadow habitats are rich in calcareous food resources. Grazing effects in the meadows provide a wide range of food for invertebrates, which are the main food source for BNC (Horgan 2002). However, in our study area, a foraging area solely consists of paddy-fields, where cranes depend on the dropping of a variety of rice grains. Occasional foraging has also been observed in the farmlands of localities where communities grow food grains such as *Eleusine coracana*.

Several challenges are causing degradation of habitat for BNC, with issues emerging such as the discovery of plastics in the feces of BNC from the study area. Different ingested plastic colors, such as white, green, and blue, were evident in the feces. Plastics, though present in small traces (<1%), were detected in feces across all sites and throughout the study months. Such evidence is likely to affect the health of the cranes and the surrounding environment in the long run. This highlights the need for decision-makers to develop effective habitat management and conservation strategies to address the increasing waste in crane foraging areas.

CONCLUSIONS

We found that the Black-necked Crane prefers cultivated land near human settlements, which provides them with easy access to grains left on the ground after harvest. Their preferred winter foraging habitat is closely tied to the local rice cultivation, which is crucial for crane survival. Future changes in cropping patterns for rice cultivation may impact crane wintering habitats. Localized rice cultivars that yield more paddy seeds and drop a sufficient quantity of seeds to support cranes must be prioritized. The crane spends the night in shallow streams, ponds, and marshy areas, separated from the rest of the localities, allowing them to remain secure from predators, which is important for their safety. The fate of the crane population is intertwined with human activities and their continued existence of wintering habitats in the study area depends on agricultural practices. Changing farming practices and colonization of foraging areas by trees would be a challenge for crane habitats in the future. We recommend the collaboration of conservationists, agriculturalists, and local communities to develop a suitable strategy that can enhance the winter habitats of the BNC and supplement food gains for the cranes when their rice supplies start to diminish.

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ཞིབ་འཚོལ་བཅུད་དོན།

འཛམ་གླིང་ནང་ ཉེན་ཁ་ཅན་ལུ་འགྱོ་ནའི་རིགས་ཅིག་ཨིན་མི་ ཁྲུང་ཁྲུང་སྐེ་ནག་གི་ཟ་འཐུང་གི་གདམ་ཁ་རྒྱབ་མི་ཚུ་ཡོངས་སུ་རྫོགསཔ་སྦྲི་ཧྲ་གོ་རྟོགས་པ་ཅིན་ ཕན་ནུས་ཅན་གྱི་སྲུང་སྐྱོབ་ཀྱི་འཆར་གཞི་ཚུ་ བརྩམས་ནི་ལུ་ཕན་ཐོགཔ་ཨིན། ཁྲུང་ཁྲུང་སྐེ་ནག་ཚུ་གིས་ སྡོད་སའི་ས་སྒོ་ཚུ་གདམ་ཁ་རྒྱབ་ནི་དེ་ གཙོ་བོ་ར་ ཟ་འཐུང་གི་འབྱུང་ཁུངས་མ་འདྲཝ་དང་མཐའ་འཁོར་གནས་སྟངས་ཀྱི་ ཉེན་སྲུང་ལུ་བརྟེན་ཨིན། ཞིབ་འཇུག་འདི་ སྤྱི་ལོ་༢༠༡༨–༢༠༢༠ ལུ་ཁྲུང་ཁྲུང་སྐེ་ནག་ཚུ་གནམ་དགུན་འཁྱམས་སའི་ ས་ཁོངས་གཙོ་བོ་གསུམ་ཡོད་ས་ལས་གཅིག་ཨིན་མི་འབུམ་སྡེ་གླིང་ནང་ འགོ་འདྲེན་འཐབ་ཡོདཔ་ཨིན། དེ་ཡང་ ཁྲུང་ཁྲུང་སྐེ་ནག་གི་འཁྱམས་སའི་གནས་སྟངས་འགྱུར་བཅོས་འགྱོ་བ་ལས་བརྟེན་ གྲངས་ཁ་མར་བབས་འགྱོ་ནི་དེ་གིས་ ཟ་འཐུང་གི་འབྱུང་ཁུངས་ལུ་གནོད་ཉེན་ཡོད་ཨིནམ་ལས་ ཞིབ་འཚོལ་འདི་གི་དམིགས་གཏད་འདི་ ཁྲུང་ཁྲུང་ཚུའི་བཞེས་སྒོ་གདམ་ཁ་ དབྱེ་ཞིབ་འབད་ནིའི་དོན་ལས་ ཟ་ས་དང་འཁྱམས་ས་ དེ་ལས་ཉལ་སའི་ས་སྒོ་ཚུ་ནང་ལས་ ཨ་ཕ་ཚུ་བསྡུ་ལེན་འབད་ཐོག་ལས་དབྱེ་ཞིབ་འབད་ཡི། རེད་འཛུགས་སྐྱོང་འབད་སའི་ ས་ཞིང་འདི་ཁྲུང་ཁྲུང་ཚུ་གི་ ཟས་བཅུད་ཀྱི་ས་ཁོངས་དོ་མ་ཅིག་ཨིན་སྦྲི་གྲུབ་འབྲས་འབྱུང་ཡི། ལོ་ཐོག་བསྡུ་བའི་ཤུལ་ལས་ འབྲུ་སྣ་དང་སྦོ་ཚལ་ དེ་ལས་སྐྲལ་མེད་སྲོག་ཆགས་ཚུ་ཁྲུང་ཁྲུང་གི་ཟས་བཅུད་གལ་ཆེ་ཤོས་ཅིག་ཨིན་པས། ཁྲུང་ཁྲུང་གིས་ཟ་མི་ཟས་རིགས་༧༨ ངོས་འཛིན་འབད་མི་དེ་ཡང་ འབྲུ་སྣའི་རིགས་དང་སྦོ་ཚལ་ སྐྲལ་མེད་སྲོག་ཆགས་ཚུ་ཨིན་པས། སྤྱི་ཟླ་༣ པ་དང་ཕྱེདཔ་ད་ སྤྱི་ཟླ་༡༢ པ་ལས་སྤྱི་ཟླ་༣ པ་ཚུན་གྱི་བར་ན་ ཨ་ཕ་སྐམ་གྱི་ལྗིད་ཚད་ལུ་ཁྱད་པར་སྦོམ་སྦྲི་རང་ འབྱུང་ཡོདཔ་དང་ དེ་ཡང་ འབྲུ་སྣ་དང་སྦོ་ཚལ་ཟ་ནི་མར་བབས་སོངམ་ལས་ སྐྲལ་མེད་སྲོག་ཆགས་ཟ་མི་ ཡར་སེང་སོང་མི་ལས་བརྟེན་ ཨ་ཕ་སྐམ་གྱི་ལྗིད་ཚད་ཡང་མར་བབས་སོང་ནུག། གྲུབ་འབྲས་དེ་གིས་ཡང་ཟླཝ་འདི་ཡར་འཕར་འགྱོཝ་ད་ ས་ཁ་རེད་བྱུད་མི་ཚུ་ མར་བབས་འགྱོཝ་ཨིནམ་ལས་ དེ་སྐབས་ ཁྲུང་ཁྲུང་ཚུ་གིས་ གནམ་རླུང་འཁྱམས་ས་ནང་ ལོག་མ་འགྱོ་བའི་ཧེ་མ་ སྐྲལ་མེད་སྲོག་ཆགས་ཚུ་ ཟས་བཅུད་སྦེ་ ཟ་དོ་ཡོདཔ་ཨིན་པས། ཁྲུང་ཁྲུང་འཁྱམས་སའི་ས་ཁོངས་ཆ་མཉམ་ནང་ལས་ཕར་ ཨ་ཕ་ནང་འགྲིབ་ཤོག་ཚུ་ཡང་ཨ་ཙི་རེ་འཐོང་ཡོདཔ་ལས་ ཕྱུགས་སློགས་འཛིན་སྐྱོང་ལེགས་ཤོམ་འབད་དགོཔ་དེ་ ཁག་ཆེཝ་སྦེ་མཐོང་ཡོདཔ་ཨིན། དེ་ལས་དེང་སང་སོ་ནམ་ལཱ་གི་འགྱུར་བ་གིས་སྦེ་ ཁྲུང་ཁྲུང་གྱི་ཟ་མི་ཟས་བཅུད་འཐོན་ས་ ཐོ་ཡོག་སྟེ་ཡོདཔ་ཨིན། དེ་འབད་ནི་འདི་གིས་ རིགས་སྲུང་སྐྱོབ་དང་ ས་གནས་ཀྱི་གཞུང་དང་མི་སྡེ་ཚུ་གི་བར་ན་ མཉམ་འབྲེལ་འབད་ཐོག་ལས་གནམ་དགུན་ཁྲུང་ཁྲུང་འཁྱམས་སའི་གནས་སྟངས་ ཡར་དྲག་གཏང་ནི་དང་ རེད་ཚུ་མར་བབས་འགྱོ་ནི་འགོ་བཙུགས་པའི་སྐབས་ ལྷན་ཐབས་ཀྱི་མཐུན་རྐྱེན་ཚུ་བཟོ་ནི་འདི་ཁག་ཆེ་བའི་གྲོས་འདེབས་ཞུཝ་ཨིན།

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Author contribuions: JIGME WANGCHUK designed, gathered and analyzed the data, and prepared and reviewed the manuscript; UGYEN TENZIN collected, processed, and analyzed fecal samples in the laboratory; KARMA WANGDI gathered data; TSHETHUP TSHERING collected data, identified fecal fragments and reviewed manuscript; SANGAY DRUKPA, TSHERING CHOPHEL, and UGYEN WANGMO gathered the field data. JIGME TSHEING planned the study, secured funding, and conducted the internal review. DR. SHERUB planned, designed, collected fecal samples, conducted the internal review, and analyzed results. He played a pivotal role in providing the overall supervision for the achievement of this study. All authors contributed to finalizing the manuscript.

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