INTERNATIONAL JOURNAL OF ENVIRONMENT

Volume-10, Issue-2, 2021/22 ISSN 2091-2854

Received: 26 September 2021 *Revised: 7 January 2022* *Accepted: 10 January 2022*

HABITAT USE, FEEDING BEHAVIOUR AND CONSERVATION THREATS OF BLACK-NECKED CRANES AT GANGTEY-PHOBJI VALLEY, WANGDUE PHODRANG, BHUTAN

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Abstract

Black-necked Cranes are revered as sacred birds and are considered the epitome in their biological range. They function as an umbrella species in terms of ecology ensuring that biodiversity is protected across a wider range of habitats. The study was carried out at Gangtey-Phobji valley to determine the habitat use, feeding behaviour and conservation threats of the Black-necked crane. Stratified non-random sampling was used and plot sizes of 1 x 1 m^2 for herbs and 5 x 5 m^2 for shrubs were used for determining the habitat use and feeding behaviour. To understand the conservation threats, a total of 129 households were surveyed. PC-ORD software was used for cluster analysis and to compute the indicator species of the habitat. A total of 50 herbs and 10 shrubs belonging to 37 families were recorded from the study area. *Yushania microphylla*, *Juncus chrysocarpus*, *Rosa sericea* and *Rhododendron thomsonii* were the indicator species of the preferred habitat. The peak flying hours were at around 08:00 a.m. and 05:00 p.m. The foraging was intensive from 09:00 a.m. to 11:00 a.m. and 03:00 p.m. to 04:00 p.m. The social (31%) and natural (31%) threats were found to be the most serious threats, followed by political threats (30%). Habitat degradation triggered by anthropogenic activities was the main threat.The cranes preferred the artificial roosts over natural ones recommending more artificial roosts for its conservation. The protection of habitats by limiting the farm road within the habitat, managing waste and stray dogs were deemed crucial.

Keywords: Black-necked Crane, conservation, Gangtey-Phobji, habitat preferences, threats.

DOI: https://doi.org/10.3126/ije.v10i2.42822

Introduction

Observable patterns such as foraging habitat selection by birds represent complex behavioural and environmental processes (Wu et al., 2020). Understanding the preferences of birds to their habitat areas is critical for the conservation of winter migratory birdsand overwintering habitat management (Jones, 2001; Wu et al., 2020). The Black-necked Crane (BNC) (*Grus nigricollis* Przevalski, 1876) is the only member of the crane family living at high altitudes among the 15 crane species worldwide (BirdLife International [BL], 2021). Owing to its population stability, the BI has currently categorized BNC as the Near Threatened (BL, 2021) and it is among 23 legally protected (Schedule I) wild fauna under the Forest and Nature Conservation Act (FNCA) 1995 of Bhutan (Phuntsho and Tshering, 2014; Namgay and Wangchuk, 2016; Tshering et al., 2021). Its wild population is estimated between 6,600 and 6,800 individuals. Between 2020 to 2021, 552 BNC visited Bhutan. BNC visit Bhutan during the winter season from late October to mid February (Royal Society for Protection of Nature [RSPN], 2022). Wetlands are an indispensable source of food providing ample water resources and vegetation (Farrington and Xiulei, 2013; Jia et al., 2019). The major habitats of BNC include swampy meadows, shallow water marsh, mudflats, lakeshore, marshy grassland, small ponds, sedge meadows, small streams, and riparian marshes along the secondary channels (Meine and Archibald, 1996; Phuntsho and Tshering, 2014; Dong et al., 2016; Namgay and Wangchuk, 2016; BL, 2021). Their diet encompasses rodents, small birds, shrimps, snails, roots and tubers, voles, waste grains, small-sized mammals, reptiles, and other vertebrates (Smirenski et al., 2018).

The feeding habit exhibits at least one individual taking the charge of the flock's security and close vigilance to the flock while feeding. If there is any danger sign, the crane of duty gives an alarm call to signal that the flock is in danger (Johnsgard, 1983). The flocks travel as a single unit from the roosting grounds when the dawn breaks but split up into family groups, each with its small feeding groups in the marshes or fields (Johnsgard, 1983). The flocks travel a considerable distance during the day and forage about 75% of the day with the highest reported in the mornings and afternoons (Collar et al., 2001).

The continued growth of human populations and per capita consumption have resulted in unsustainable exploitation of biological diversity, exacerbated by climate change, ocean acidification, and other anthropogenic environmental impacts (Mustin et al., 2017). Globally, the bird is threatened due to loss of habitat triggered by anthropogenic pressure, land-use change, infrastructure growth (De-Jun et al., 2011; Tshering et al., 2021), uncontrolled grazing, mechanized farming, use of synthetic chemical inputs in

agricultural farming, eutrophication of wetlands, (Tomer et al., 2009), wetland degradation (Meine and Archibald, 1996; Lhendup and Webb, 2009), stray dog predation and climate change (Phuntsho and Tshering, 2014; Namgay and Wangchuk, 2016; Namgay, 2018; Tshering et al., 2021). Despite some conservation achievements (particularly at the local level) and augmented by public and government interest towards sustainable development, biodiversity continues to decline (Rands et al., 2010). Such issues are observed at an alarming rate in relation to the habitat of BNC and its associated species in Bhutan (Tshering et al., 2021). The changes in the valley such as land degradation, smaller farm sizes, and unplanned construction activities are rapidly depriving cranes of their natural habitats (Wangda and Ohsawa, 2006).

Understanding how animals select habitat, forage and behave concerning the environment is of cardinal importance for basic and applied ecology (Chudzińska et al., 2015). Concomitantly, for BNC, habitat selection and feeding behaviour in its breeding home range have been well documented, however, information on its winter habitat, particularly in the Gangtey-Phobji valley is sparse. The study aimed to assess the habitat use and preferences in the winter habitat, determine the feeding behavioural pattern, evaluate the conservation risks and population trends of BNC within Gangtey-Phobji valley.

Materials and methods

Study Area

Gangtey-Phobji valley (27.49°N, 90.15 °E to 27.41°N, 90.20°E) is situated in the central highlands of Bhutan with a mean altitude of 2800 meters above sea level (RSPN, 2017). The valley is the largest high-altitude natural wetland in the country and the plant diversity in the wetlands represents an important aspect of the overall wetland ecosystem (Lhamo et al., 2020), corroborating its recognition as a Ramsar site (Ministry of Agriculture and Forests [MoAF], 2016). More than 5,000 people inhabit the winter habitat, whose livelihoods are primarily based on agriculture and livestock. Summers are wet, damp, and dreary, whilst winters are cold and reasonably dry (Tshering et al., 2021). The lowest temperature was recorded in January (-4 degrees Celsius [^{o}C]) and the highest temperature was recorded in July (15 ^{o}C) (Lhamo et al., 2020). Out of 552 BNC visited within the 2020 to 2021 in Bhutan, 500 BNC were reported in the study site (RSPN, 2022).

Research Design

The study used both qualitative and quantitative approaches for data collection. Vegetation and social surveys were conducted to gather information on the crane habitats and local inhabitants' perception towards the BNC conservation. Subsequently, the daily behavioural patterns were studied through visual observation for a week

To study the emerging conservation threats and diet, the whole study area was stratified into five strata corresponding to five *Chewogs* (sub-blocks) and a stratified simple randomized sampling was adopted with a sample size of 50% of the total household (N = 278) in the vicinity of the crane's habitat (Howell et al., 2020).

The conservation threats to the BNCs in Gangtey-Phobji were grouped into three major categories following Namgay and Wangchuk (2016): political, social, and natural. Threats arising from the conversion of wetland for other purposes, lack of well-defined policies and law in the species conservation were grouped under political threats; the threats which were associated with anthropogenic activities such as a change in the farming practices, land encroachment in the wetland (habitat), retaliatory threatening and predation by stray dogs were grouped under social threats. Threats such as wild predators, diseases, climate change, flash floods and resources competition were grouped as natural threats.

Vegetation Sampling

Vegetation survey was conducted to understand the winter habitat and vegetation composition of BNCs. Stratified randomized sampling was used. The Ramsar region was divided into grids of 300 x 300 m^2 and stratified into two strata *Gewogs* (blocks), i.e., the site was divided into two *Gewogs* (Figure 1). A table of computer-based randomly generated numbers was used to pick 30% of the total grid (37 plots) for the vegetation survey. In each grid, sampling quadrat sizes of 1 x 1 m^2 and 5 m x 5 m^2 for herbs and shrubs assessment were used respectively (DoFPS, 2020). Species encountered in each quadrat were identified and classified based on the tallest height (cm) and the coverage (%) of each species.

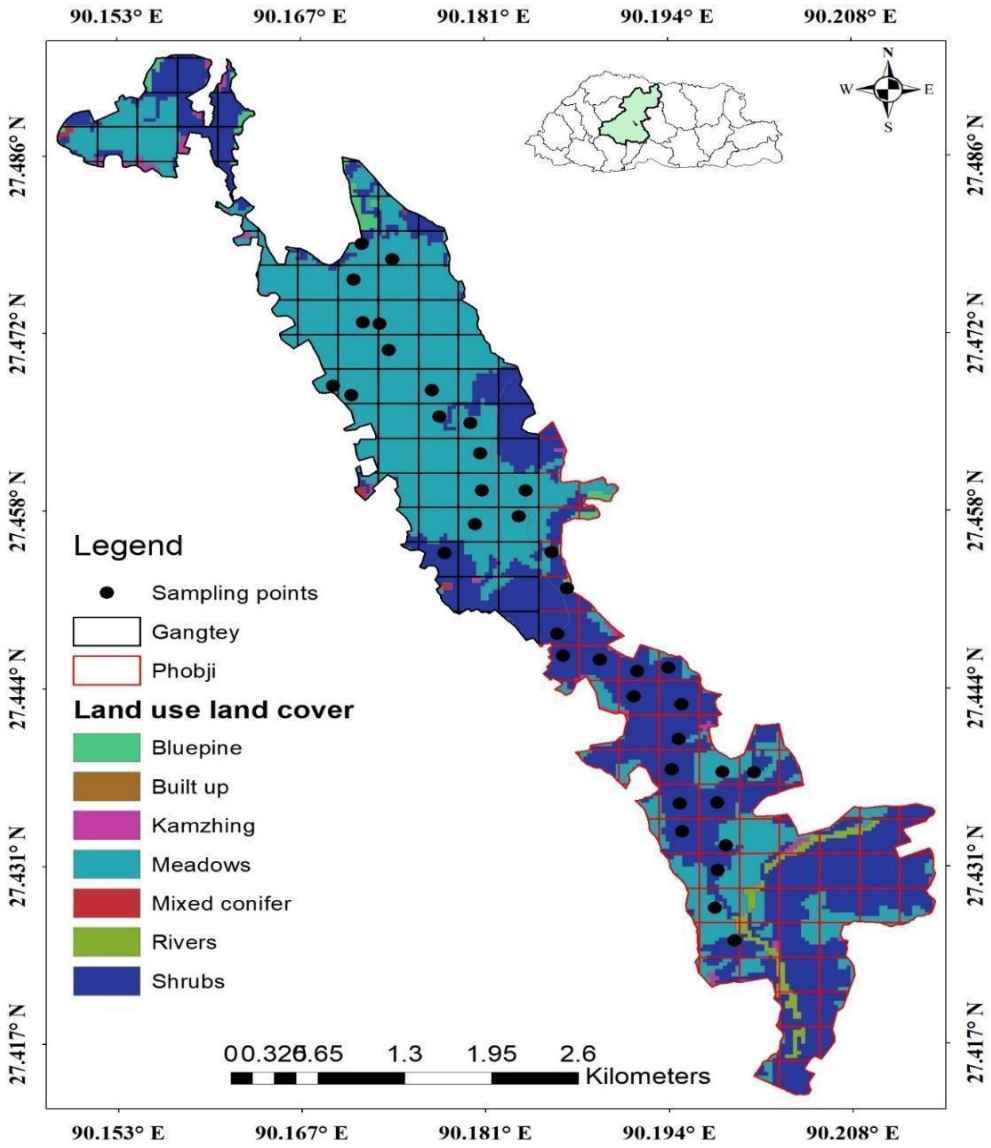

Figure 1: Map of the study area showing land use land cover and 300 x 300 m^2 grid stratification.

Feeding Behaviour Observation

Five roosting sites were identified after consultation with forest officials and residents. Land verification and assessment of those sites were conducted during the day to minimize the disturbances to the birds. The road and footpath passing through the habitat were selected for the study as the vantage point and sites through which distance observations could be made. A non-invasive approach (distance observation) was used to understand daily foraging behaviour for five days in February 2021. Their activities were recorded from 06:00 a.m. to 08:00 a.m. against their habitat types and a safe distance of 60 to 80 meters was maintained.

Understanding the dietary composition of the animals is crucial to know how they interact with their niche and accordingly, for identifying their preferred food types (Dong et al., 2016). The contents of the stomachs of small birds and other vertebrates were used to determine dietary specifics (Ralph et al., 1985). Killing the

birds to examine the crop and gizzard contents raises ethical issues including the conservation of the species (Barrett et al., 2007). Therefore, identification of dietary compositions of BNC through fecal analysis was adopted with the modification following Ralph et al. (1985).

A total of 15 fecal samples (five fecal samples each from three roosting sites) were collected and transferred to laboratory. The samples were transferred into the 50 millilitre cylinder and mixed with distilled water. The samples were rotated in a rotating shaker machine (1200 rotations per minute) for an hour and left to settle for 12:00 p.m.. The settled mixture was then sorted using the 15 mm x 16 mm petri dish and the contents were examined under a Stereo Nikon microscope (10x).

Social Household Survey

The semi-structured questionnaire was used to collect the data on habitat use, threats and perception on crane conservation. A total of 129 household respondents or 50% of the total household (N = 278) in the vicinity of the crane's habitat (Howell et al., 2020) were interviewed for the study from five villages (Table 1): 25 households from Dogseyna and seven households from Gangphel under Phobji *Gewog*; 37 households from Gangtey, 25 households from Aeko and 35 households from Eusa under Gangtey *Gewog*. The mean age of the respondents was 44.3 (SD = 13.8) years.

Table 1: Gender wise respondents from five *Chewogs* (sub-block).

Gender	Chewog Gangphel	Gangtey	Aeko	Dogseyna	Eusa	Total
Male	4 (57%)	18(49%)	15(60%)	7(28%)	20(57%)	64(49.6%)
Female	3 (43%)	19 (51)	10 (40%)	18 (72%)	15 (43%)	65(50.4%)
Total	7	37	25	25	35	129

Data Analysis

Descriptive and inferential statistics were used to analyze the data. Herbaceous data was analyzed by multiplying the height of the herb species (cm) with its coverage (percentage) within the sampling quadrat to get the volume estimate. The volume estimate and relative biomass were used for dominance or indicator species analysis and to calculate the Shannon-Wiener Diversity Index (H'). The preliminary data were processed using Microsoft Excel's pivot table and analyzed using PC-ORD. A cluster analysis was made to examine the composition class using distance measure of Relative Sorensen and Group Average as linkage method in SPSS. The information gathered through social survey and visual observation on habitat preferences and their daily activity pattern were cross-tabulated in R software.

Results and discussion

Floristic Composition

A total of 60 plants species (50 herbs and 10 shrubs) belonging to 30 families were found in 37 plots. Of the total 30 families, 26% of the families were represented by a single species, 11% by two species, 11% by three species, 7% by four species, 10% by five species, 22% by 6 species and 13% by seven species. The highest diversity of herb was found in Phobji with 43 species (H' = 0.72) while Gangtey had 34 species (H' = 0.71). Under the herbs, grasses dominated the composition with 51.8% (n = 17) and the least was dominated by mosses and orchids with 3% (n = 1) each respectively (Figure 2) . Under the shrubs, deciduous sub-shrubs were the most dominant comprising 64% (n = 5) while the least dominants were the evergreen sub-shrubs with 17% (n = 3) (Figure 3).

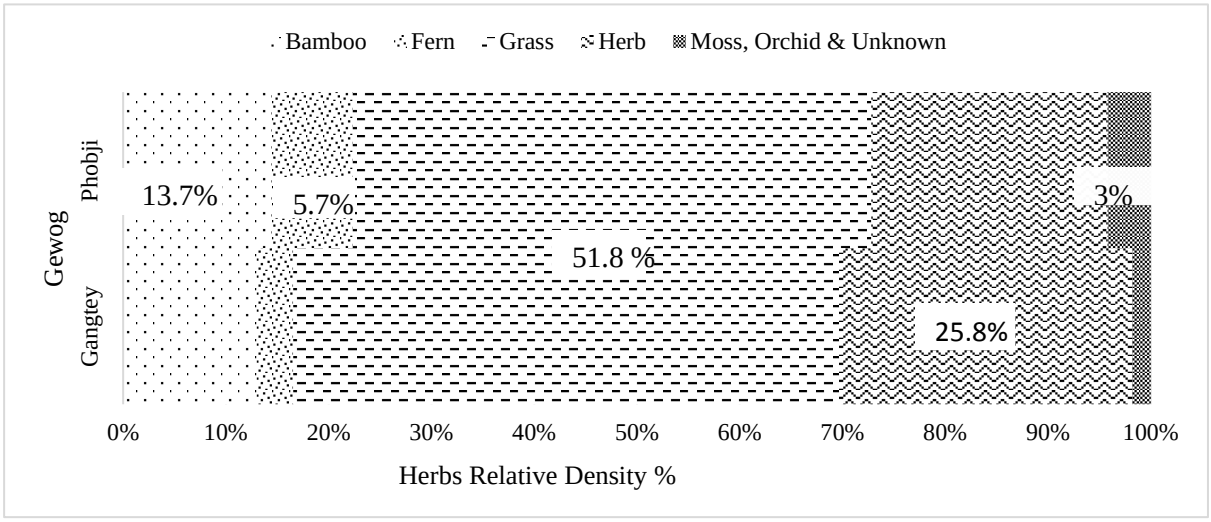

Figure 2: Distribution of herbs in Black-necked Crane habitat.

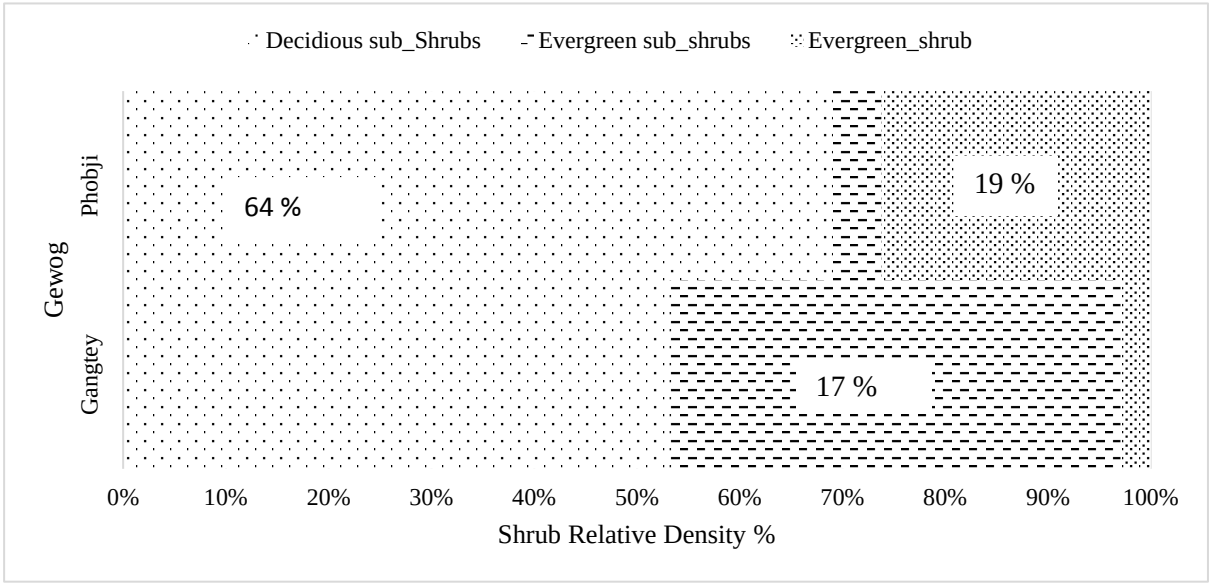

Figure 3: Distribution of shrubs in Black-necked Crane habitat.

The relatively low diversity could be attributed to the study period, which was in the winter season as the study aimed particularly to understand the winter vegetation composition of BNC habitat. The diversity is expected to be higher in spring and summer, and then slightly lower in autumn seasons.It could also be due to the limited span of the study area which focused only on the Ramsar site. However, around 55 tree species, 73 shrubs, and 264 herbs (including ferns, mosses, and fungi) were known to be found in the whole valley of Gangtey-Phobji(RSPN, 2006) while the study reported only 50 herbs and 10 shrubs during the winter

Species Accumulation Curve

The species-area curve based on Euclidean distance for 37 plots did not flatten completely. (Figure 4). The first-order Jackknife estimates 61 species while the second-order estimates 69. However, the curve for the shrubs flattened indicating an adequate sample size. Unlike the species of the herb, the first-order Jackknife estimates 11 species shrubs and the second-order estimates 10 species shrubs showing not much variation from the observed values (Figure 4 and 5). This disparity may be due to vegetation sampling taking place in the winter when annual herbs would have perished (Gairola et al., 2008; Dorji and Gurung, 2018).

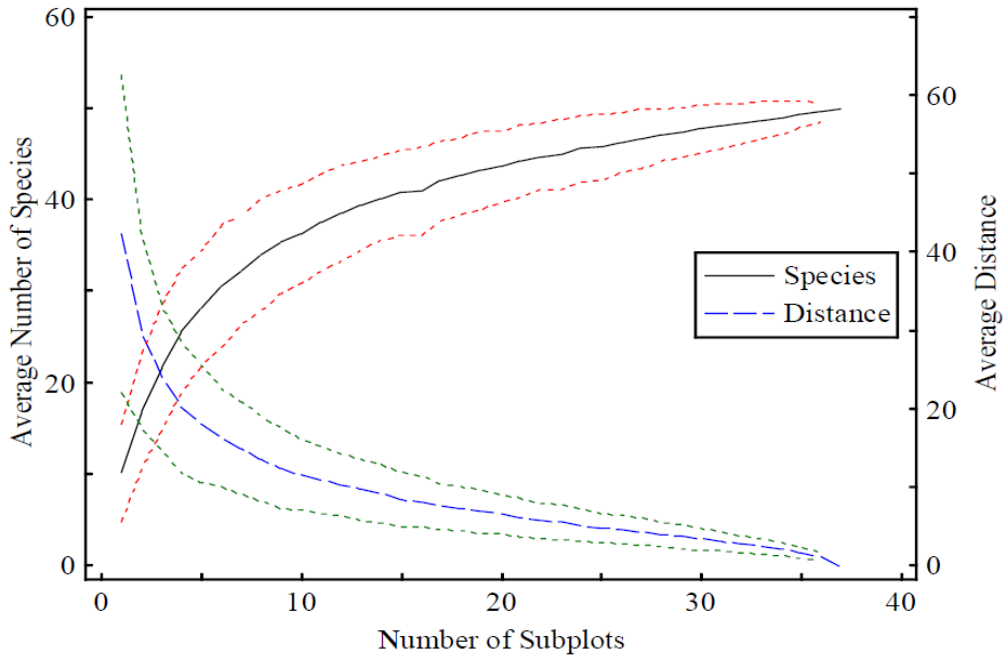

Figure 4: Herbs species-area curve with Euclidean distance showing the likelihood of recording additional species by increasing the sample size.

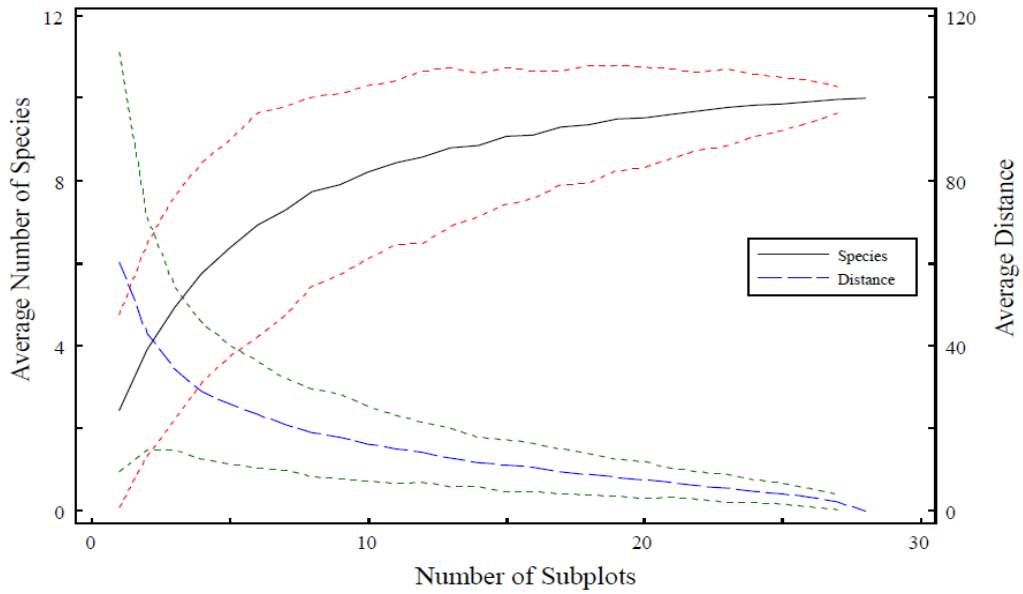

Figure 5: Shrubs species-area curve with Euclidean distance showing the likelihood of recording no more species even by increasing the sample size.

Indicator Species

A similarity cluster analysis was carried out for herbs (n = 50) with Adjusted Relative Abundance from the total composition (Figure 6). Similarly, for shrubs (n = 10), the two different clusters were arbitrarily marked at 25% (Figure 7). Following Dufrene and Legendre method, Monte Carlo test of indicator species was calculated to generate proportional abundance of a particular species in a particular group relative to the abundance of that species in all groups. It was found that *Yushania microphylla* recorded the highest indicator value (IV = 66, p <.05) followed by *Poa annua* (IV = 31.4, p >.05), *Senecio* sp. (IV = 24.7, p >.05) in class I (P1, P31, P35, P3, P24, 23, P4, P6, P7, P11, P32, P16, P17, P10, and P19). *Yushania microphylla* was found to be a significant indicator for the plots because of the high frequency and RD% of the species. The dependency of BNC on the species at the study sites was also found to be high (Choden, 2016).

Similarly, *Pteridium aquilinum* (IV = 55.6, p <0.5), *Halenia elliptica* (IV 40.7, p >.05) and *Potentilla* sp. (IV = 36.3, p >.05) were the indicator species in class II (P2, P21, P37, P13, P18, P25, P33, P28, P27, P20, P22, P30, P36, P12, P29, P14, P26, and P34), however, only *Pteridium aquilinum* was found to be significant. *Juncus chrysocarpus* (IV = 84.4, p <.05), *Gentiana capitata* (IV = 37.3, p >.05) and *Aletris pauciflora* (IV 30.4, p >.05) were the indicator species in class III (P5, P15, P9 and P8) with only *Juncus chrysocarpus* recorded to be significant.

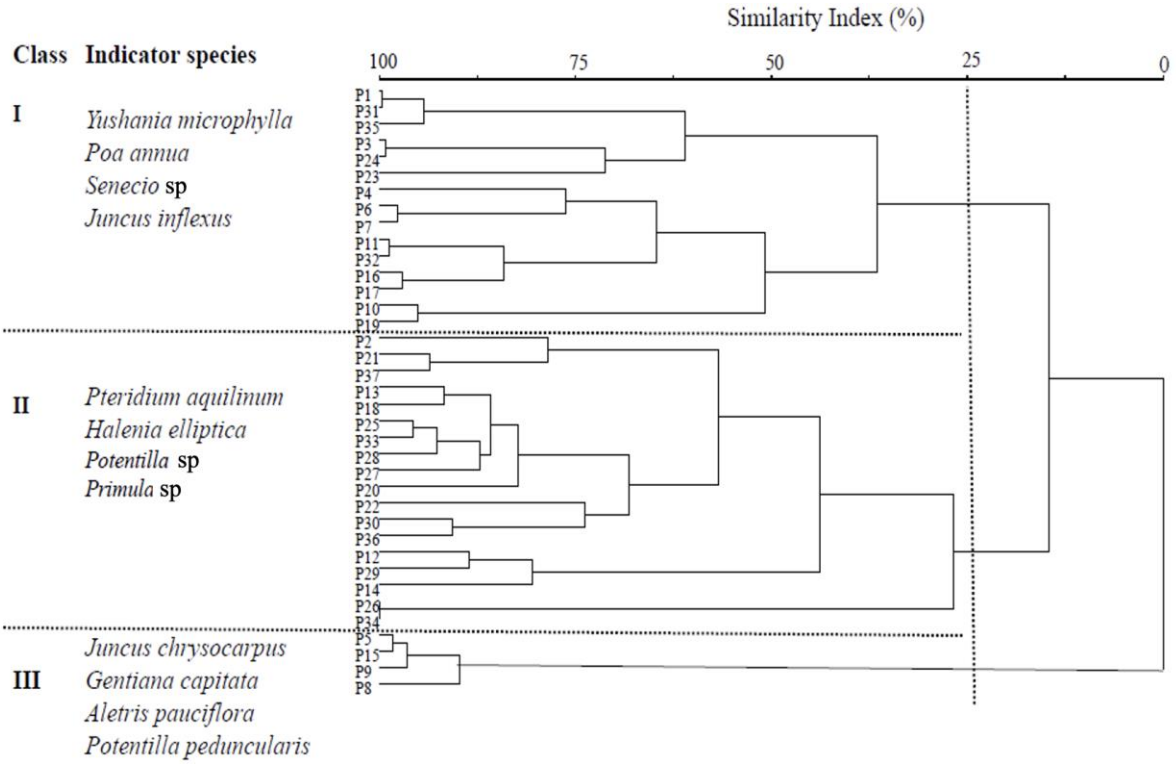

Figure 6: Cluster-dendrogram of herbs showing similarity index (%) arbitrarily marked at 25%, and also showing three cluster solutions with dotted lines their indicator species.

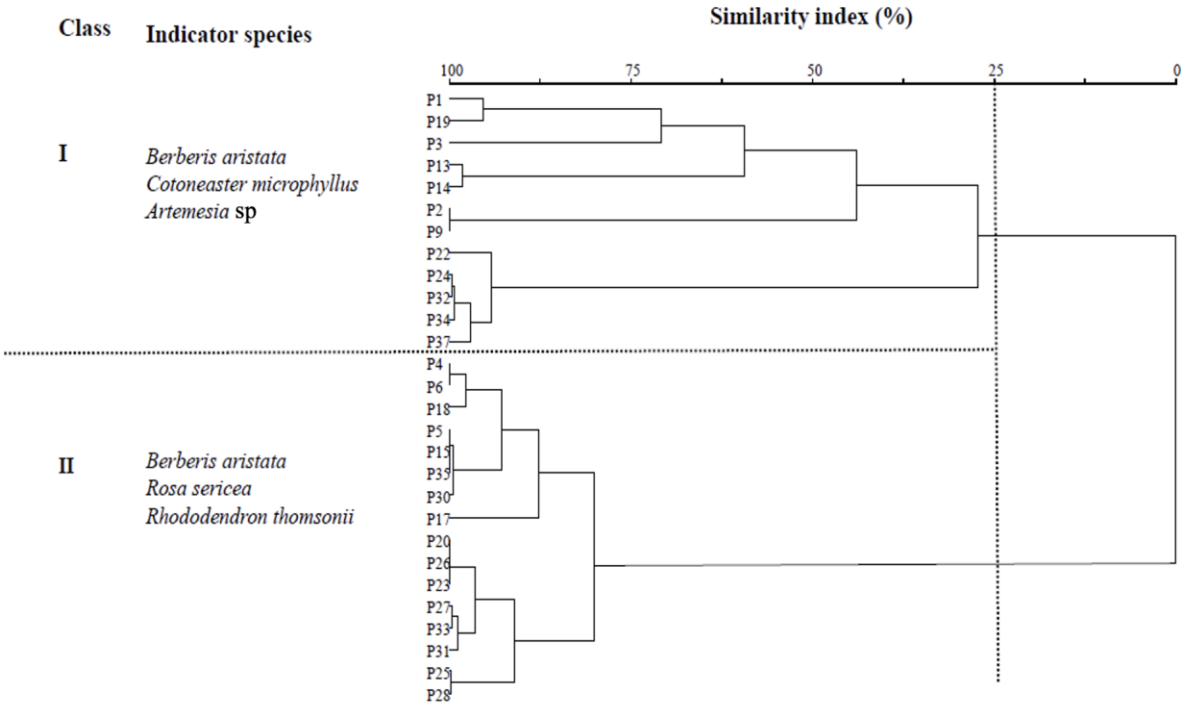

Figure 7: Cluster-dendrogram of shrubs showing similarity index (%) arbitrarily marked at 25% and also showing two cluster solutions with dotted lines and their indicator species.

Two clusters for shrubs were arbitrarily marked at 25% similarity index (Figure 8). *Berberis aristata* (IV = 30.2, $p > .05$), *Cotoneaster microphyllus* (IV = 31.6, $p > .05$) and *Artemesia* sp. (IV = 27.8, $p > .05$) were the indicator species in class I (P1, P19, P3, P13, P14, P2, P9, P22, P24, P32, P34 and P37), however none of the shrub species was significant. Whereas, *Berberis aristata, (*IV = 61.2, $p < .05$), *Rosa sericea* (IV = 58.8, $p < .05$) and *Rhododendron thomsonii* (IV = 13.9 $p > .05$) were the indicator species in class II (P4, P6, P18, P5, P15, P35, P30, P17, P20, P26, P23, P27, P33, P31, P25 and P28) and *Berberis aristata* and *Rosa sericea* were found to be significant indicators.

Habitat Selection

A total of five habitats: farmland, open grassland, riverbank, shallow pond, and swampy meadow were identified based on their feeding and behavioural pattern observed from 06:00 a.m.to 06:00 p.m. Of the five identified habitats, the shallow pond was used only for roosting As the ripple and water splash are created when the predators enter the pond, the cranes prefer ponds due to easy escape from predators which commonly includes stray dogs, red fox and leopard (Kuensel, 2018). The swampy meadows were mostly found around the roosting sites, which were heavily used for marching when leaving for feeding (06:00 a.m to 08:00 a.m.) and returning for roosting (05:00 p.m. to 06:00 p.m.). Such habitat around their roosting sites also prevented predation at night. Of the two types of roosting sites: natural and artificial, the cranes were found to use more artificial than the natural roost site. This could be due to the artificial site encompassing all required elements such as thicker mud layer, a higher-ratio of open water, long distance to roads, villages and farmland, and water depth (He et al., 2011) for a natural habitat while the natural roosting sites were observed to have degraded over the years.

The open grassland was found to be an evenly used habitat throughout the day. The farmers were found cultivating potatoes during the day using machinery. With no human disturbances in the farmland during the morning hours, the use of farmland habitat was found high in the morning as compared to evening (Figure 8), coupled withthe tilled land with potatoes plantation easy to unearth and spot their foods (insects, worms, potatoes, etc.). Riverbank was sparsely used as compared to other habitat types due to the higher river depth and fewer feeding areas around the bank. The birds divided their time between various habitat types (Figure 8 and 9). The roosting sites were in a shallow pond surrounded by wetland characterized by sage, with no shrubs and tall grasses around ensuring inaccessibility to the predators and threats.

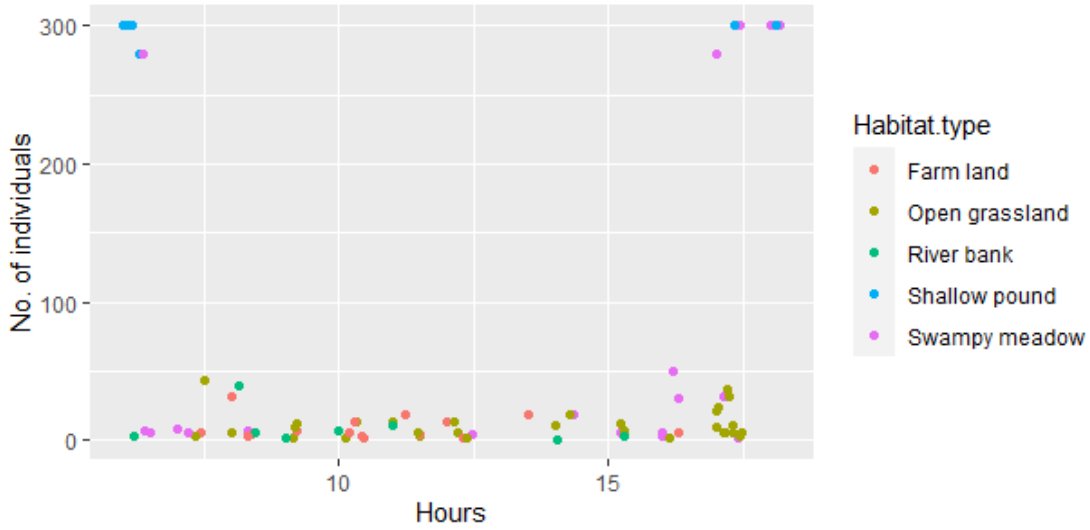

Figure 8: Habitat type and the number of individuals recorded against time.

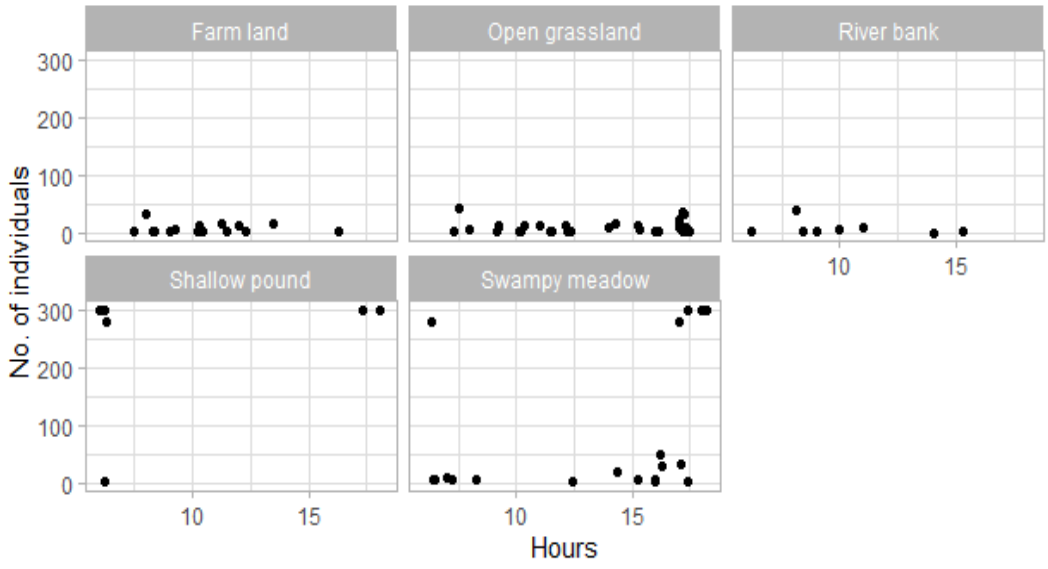

Figure 9: Habitat type and their used timing in hours.

Behavioural Observation

A few individuals in the flock at roosting sites keep on alarming throughout the night, intriguingly, progressive massive chores gradually increase when the dawn breaks and when assembling back to their roosting sites in the evening. As reported by Johnsgard (1983), while foraging, at least one member takes the charge of the group's safety and vigilance on any potential threats. The duty crane raises an alarm if any threats are seen or predicted. The peak flying hours were observed at 08:00 a.m. and 05:00 p.m. whereas searching, digging, and eating was shown to be intense between 09:00 a.m. and 11:00 a.m. and 03:00 p.m. to 04:00 p.m. The birds

take a break at noon by preening and basking in the sun. At about 05:30 p.m., a majority of BNC marched towards fixed roosting sites while a few latecomers were still flying and following the marching flocks.

The winter home of BNC is also shared by other wetland birds: Ruddy Shelduck, Common Teal, Common Merganser, Black Stock and Common Crane. A sympatric species, common cranes (*Grus grus* Linnaeus) display common character while foraging. The possibility of mistakenly adding Common Cranes as BNC cannot be ruled out since these two bird species almost always remain together.

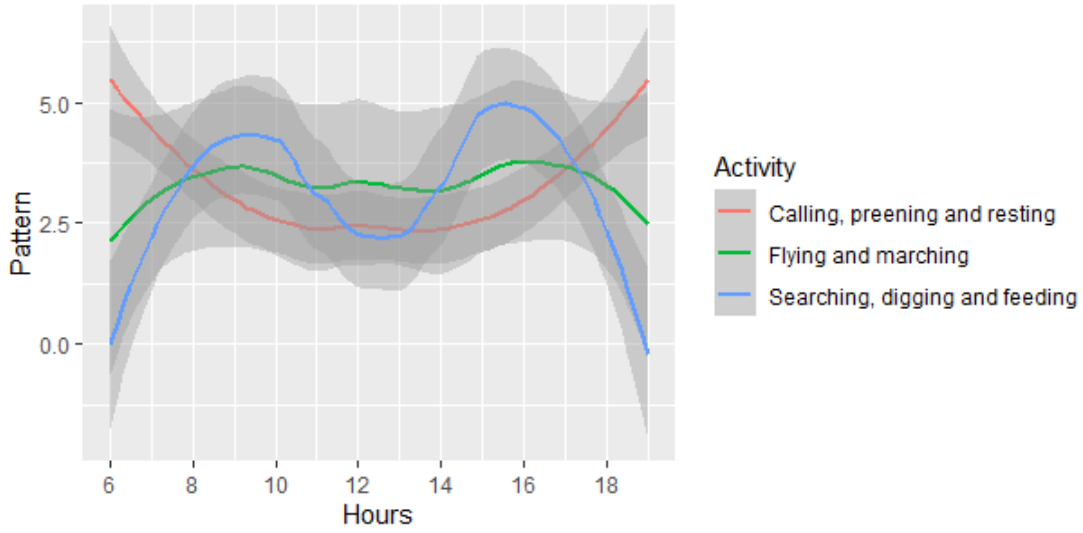

Figure 10: BNC daily behavioural pattern.

Furthermore, according to the local communities, BNC is associated with culture and traditions. The local communities claim that at least the first group lands and departs on auspicious days such as marking the end of the harvest seasons and beginning of the winter wheat cultivation. They also claim that the birds circumambulate Gangtey Monastery at least three rounds or more before making a final landing in the valley. They observed that the birds would practice long-distance flying surrounding and circumambulating Gantey Monastery before departure to their summer habitats. According to Choudhary (2020), these birds are cautious; contrarily, in some regions, they have become acclimated to local inhabitants who do not bother them, interestingly, they seem to be able to tell the difference between people dressed in traditional clothing with those who are not.

Dietary Analysis from Fecal Samples

The wild plants (tubers, grasses and bamboo) and earth materials (soil and sand) were found to be the major (28.3%) components of their diet, followed by low-density polyethene (13.2%), seeds of wild plants and grasses (11.3%), insects and rodents (7.5%), grains (5.7%) and high-density polyethene (5.7%) (Figure 11).

However, Dong et al. (2016) reported that domestic crops (grains and potatoes) and animals matters (invertebrates) comprised the highest diet consumed by the BNC. Albeit the general composition of the diet was found similar, the slight difference could be due to the location of the study site, which was near the human settlements which could have contributed to materials such as polyethene. Generally, in birds, the ingested plastic decreases the capacity of the stomach and hence results in smaller meal sizes and slower growth rate. It could also lead to obstruction of gastrointestinal tract which may lead to mortality. In some seabirds species, plastic ingestion is suggested being the major cause of injury and mortality (Blastic, 2017). The limitation of the method adopted could also have attributed to the difference in the finding in the current study.

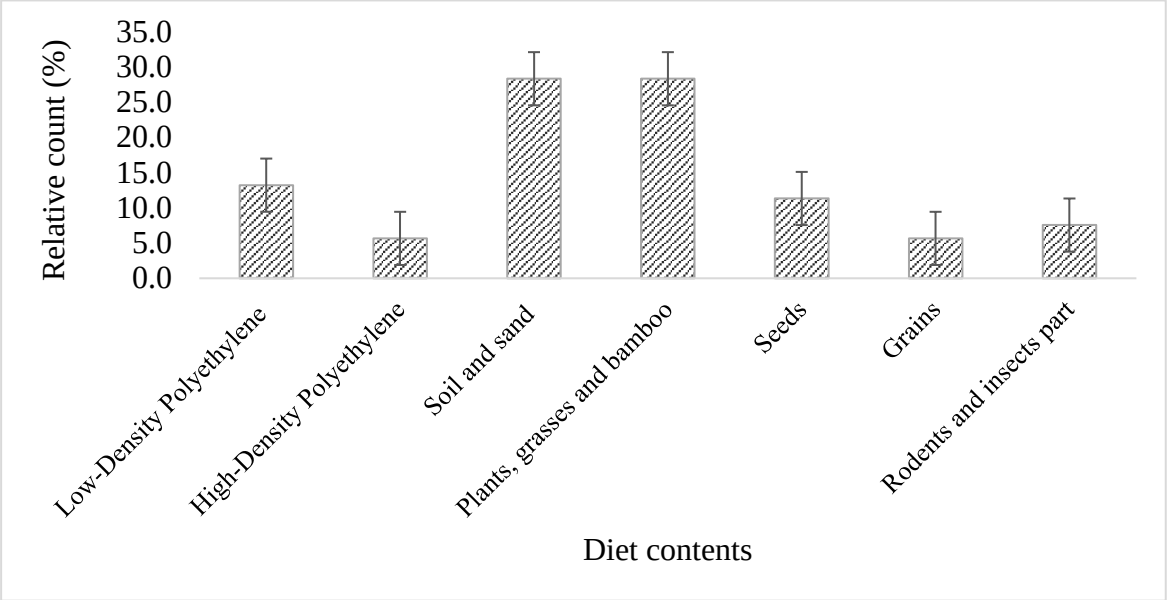

Figure 11: Dietary compositions identified through the fecal analysis.

Conservation Threats

The exposure of wetland to the residential development, land use expansion, and tillage modes have a major impact on BNC habitat (Lhendup and Webb, 2009; Phuntsho and Tshering, 2014). The social (31%) and natural (31%) threats were found to be the most serious threats to BNC conservation, followed by political threats (30%) (Namgay and Wangchuk, 2016) (Table 2). Field observation found habitat fragmentation due to road construction, tourism-based infrastructure development, free-range grazing, frequent movement of people and vehicles as the physical threats to the survival of the cranes. The habitat of the bird is also threatened by the disposal of solid waste and electric fencing, which were constructed to combat the wildlife predation on their crops and livestock. Subsequently, the discovery of plastics in the faeces of cranes was deemed to be another most serious threat (Gyeltshen, 2019). The use of synthetic chemical fertilizers, insecticides and weedicides were also observed in the valley, which would impact the habitat in the long run.

Table 2: Different threats to BNCs in the study area

Political threats	Social threats	Natural threats
Conversion of wetland for other purposes	Land-use conversion	Diseases and mortality
	Land encroachment	Predation by wild predators
Lack of well-defined policies and laws in species conservation	Predation by a stray dog	Resources competition
	Retaliatory threatening	Climate change
		Flood

Conclusion and Recommendation

A total of 60 plant species (50 herbs and 10 shrubs) belonging to 30 families were identified from the winter habitat of BNC with *Yushania microphylla, Pteridium aquilinum* and *Juncus chrysocarpus* as the significant indicators in the herb group. While in the shrub group, *Berberis aristata, Rosa sericea* and *Rhododendron thomsonii* were the indicator species.

Habitat preferences analysis revealed the preference to roost in shallow ponds with minimal vegetative cover and surrounded by safe and open marshes. For feeding and foraging patterns showed that open ground, farmland and wetlands with herb species were found to be preferred. In addition, they forage about 75% of the day with morning and evening being the busiest hours. Dietary analysis revealed that the tubers, grasses and bamboo, and soil and sand encompassed major (28.3%) components of their diet, followed by low-density polyethene (13.2%), seeds of wild plants and grasses (11.3%), insects and rodents (7.5%), grains (5.7%) and high-density polyethene (5.7%).

It was found that the natural habitats were degraded and artificial habitats were the important resort towards the conservation of cranes in such locality. For the welfare of the cranes, more artificial roost sites could be developed. Removal of tall shrubs and other grass species in roosting site III is highly recommended.

The vegetation sampling was carried out during the winter season, which hindered species identification for some of the plant species, thus, the data collected over a season does not represent the entire population. Additional sampling across seasons is needed to fully substantiate the total enumeration. However, there is a limitation of the method to identify the digested food, thus further study is recommended.

Conflict of interest statement

The authors declare that they have no affiliations or involvement in any organization or entity with any financial or non-financial interests in the matter to the work reported in this paper.

Authors contribution statement

Mr. Gyeltshen Dorji conceptualized the research and study design. The author was also involved in data collection and manuscript drafting.

Mr. Ugyen Dorji was also involved in research design while his main contribution was on data analysis and interpretation.

Acknowledgement

The authors would like to thank Professor DB Gurung (College of Natural Resources [CNR]), Mr. Jigme T Wangyal and Mr. Ngawang Gyeltshen (Department of Forest and Park Services [DoFPS]) for their unwavering assistance, relentless encouragement, and endless positive feedback until the completion of our research work besides their busy schedule. We would also like to thank Mr. Tshering Dorji (Thimphu Forest Division, DoFPS) for helping with his help and guidance. For sharing the additional information, we would like to thank Mr. Jigme Tshering (Royal Society for Protection of Nature). For assisting in data collection, we would like to immensely thank Mr. Wangchuk, Mr. Sangay Gyeltshen (Jigme Khesar Strict Nature Reserve, DoFPS), Mr. Pema Namgay, Mr. Dorji (Wangdue Forest Division, DoFPS) and Ms. Namgay Wangmo (MSc in Natural Resources Management, CNR). The authors remain forever grateful to all the people for their unwavering support and effort.

References

Barrett, R. T., Camphuysen, K., Anker-Nilssen, T., Chardine, J. W., Furness, R. W., Garthe, S., & Veit, R. R., 2007. Diet studies of seabirds: a review and recommendations. *ICES Journal of Marine Science*, 64(9), 1675-1691. DOI:https://doi.org/10.1093/icesjms/fsm152

Blastic, 2017. *Plastic ingestion by birds - Blastic*. Plastic Ingestion by Birds. https://www.blastic.eu/knowledge-bank/impacts/plastic-ingestion/birds/ (accessed on: 22 December 2021).

BirdLife International, 2021. Black-necked Crane (Grus Nigricollis) - BirdLife Species Factsheet. http://datazone.birdlife.org/species/factsheet/black-necked-crane-grus-nigricollis (accessed on: 19 June 2021).

Choudhary, V., 2020. Black Necked Crane (Grus Nigricollis) Complete Detail - Updated. http://natureconservation.in/black-necked-crane-grus-nigricollis-complete-detail-updated/ (accessed on: 26 May 2021).

Chudzińska, M. E., van Beest, F. M., Madsen, J., & Nabe- Nielsen, J., 2015. Using habitat selection theories to predict the spatiotemporal distribution of migratory birds during stopover–a case study of pink- footed geese Anser brachyrhynchus. *Oikos*, 124(7), 851-860. DOI: https://doi.org/10.1111/oik.01881

Collar, N., Andreev, A., Chan, S., Crosby, M., Subramanya, S., & Tobias, J., 2001. *Threatened Birds of Asia*. BirdLife International. DOI: http://dx.doi.org/10.1642/0004-8038(2004)121[0619:TBOATB]2.0.CO;2

De-Jun, K., Xiao-Jun, Y., Qiang, L., Xing-Yao, Z., & Jun-Xing, Y., 2011. Winter habitat selection by the Vulnerable Black-necked Crane Grus nigricollis in Yunnan, China: implications for determining effective conservation actions. *Oryx*, 45(2), 258-264. DOI: https://doi.org/10.1017/S0030605310000888

Dong, H. Y., Lu, G. Y., Zhong, X. Y., & Yang, X. J., 2016. Winter diet and food selection of the Black-necked Crane Grus nigricollis in Dashanbao, Yunnan, China. *PeerJ*, 4, e1968. DOI: https://doi.org/10.77177/peerj.1968

Dorji, T., & Gurung, D. B., 2017. Grassland communities, graminoid composition, and their diversity pattern on the eastern mountain slope of Dochula, Bhutan. *Bhutan Journal of Natural Resources and Development*, 4(2), 19-19. DOI: https://doi.org/10.17102/cnr.2017.06

Farrington, J. D., & Xiulei, Z., 2013. The black-necked cranes of the longbao national nature reserve, Qinghai, China. *Mountain Research and Development*, 33(3), 305-313. DOI: https://doi.org/10.1659/MRD-JOURNAL-D-12-00134.1

Gairola, S., Rawal, R. S., & Todaria, N. P., 2008. Forest vegetation patterns along an altitudinal gradient in sub-alpine zone of west Himalaya, India. *African Journal of Plant Science*, 2(6), 042-048. http://www.academicjournals.org/AJPS (accessed on: 24 June 2021).

He, P., Kong, D.-J., Liu, Q., Yu, H.-Z., Zhao, J.-L., & Yang, X.-J., 2011. Roosting-site characteristics of wintering Black-necked Cranes (*Grus nigricollis*) at Napahai, Yunnan. *Zoological Research*, 32(2):150-6. DOI: http://dx.doi.org/10.3724/SP.J.1141.2011.02150

Howell, C. R., Su, W., Nassel, A. F., Agne, A. A., & Cherrington, A. L., 2020. Area based stratified random sampling using geospatial technology in a community-based survey. *BMC Public Health*, 20(1), 1-9. DOI: https://doi.org/10.1186/s12889-020-09793-0

Jia, R., Ma, T., Zhang, F., Zhang, G., Liu, D., & Lu, J., 2019. Population dynamics and habitat use of the Black-necked Crane (Grus nigricollis) in the Yarlung Tsangpo River basin, Tibet, China. *Avian Research*, 10(1), 1-8. DOI: https://doi.org/10.1186/s40657-019-0170-9

Johnsgard, P. A., 1983. Cranes of the World: Black-necked Crane (Grus nigricollis). *Cranes of the World, by Paul Johnsgard*, 5. https://digitalcommons.unl.edu/bioscicranes/ (accessed on: 24 June 2021).

Kuensel, 2018. Manmade pond invites black-necked cranes. *Kuensel*. https://kuenselonline.com/manmade-pond-invites-black-necked-cranes/ (accessed on: 25 December 2021).

Lhamo, P., Kabir, A., & Uddin, S. M. N., 2020. Assessing the influence of human settlements on the plant diversity in wetlands of Phobji and Gangtey, Bhuta. *Recent Research in Science and Technology,* 12(1). DOI: https://doi.org/10.25081/rrst.2020.12.6085

Lhendup, P., & Webb, E. L., 2009. Black-necked Cranes Grus nigricollis in Bhutan: migration routes, threats and conservation prospects. *Forktail*, 25(2009), 125-129. https://static1.squarespace.com/static/5c1a9e03f407b482a158da87/t/5c2100e64ae237eaa78bceab/1545666790958/Lhendup-Black-neckedCranes.pdf (accessed on: 25 June 2021).

Meine, C., & Archibald, G., 1996. *The cranes: status survey and conservation action plan*. IUCN, 282. https://portals.iucn.org/library/node/7024 (accessed on: 24 June 2021).

Ministry of Agriculture and Forests, 2016. Gangtey-Phobji Declared As The Third Ramsar Site Of Bhutan | Ministry Of Agriculture And Forests. http://www.moaf.gov.bt/gangtey-phobji-declared-as-the-third-ramsar-site-of-bhutan/ (accessed on: 7 April 2021).

Mustin, K., Carvalho, W. D., Hilário, R. R., Costa-Neto, S. V., Silva, C., Vasconcelos, I. M., & Toledo, J. J., 2017. Biodiversity, threats and conservation challenges in the Cerrado of Amapá, an Amazonian savanna. *Nature Conservation*, 22. DOI: https://doi.org/10.3897/natureconservation.22.13823

Namgay, R., 2018. Habitat Mapping and Conservation Threats to Black-Necked Cranes in Bumthang, submitted to the College of Natural Resources, Lobesa. DOI: https://doi.org/10.13140/RG.2.2.32070.78405

Namgay, R., & Wangchuk, S., 2016. Habitat preferences and conservation threats to Black-necked Cranes wintering in Bhutan. *SpringerPlus*, 5(1), 1-6. DOI: https://doi.org/10.1186/s40064-016-1923-0

Phuntsho, T., & Tshering, J., 2014. Black-necked Crane (Grus nigricollis) in Bhutan: Current population status and conservation initiatives. *Zoological Research*, 35, 10-9. DOI: https://doi.org/10.13918/j.issn.2095-8137.2014.s1.0010

Ralph, C. P., Nagata, S. E., & Ralph, C. J., 1985. Analysis of droppings to describe diets of small birds. *Journal of Field Ornithology*, 56(2), 165-174. https://sora.unm.edu/sites/default/files/journals/jfo/v056n02/p0165-p0174.pdf (accessed on: 2 March 2021).

Rands, M. R., Adams, W. M., Bennun, L., Butchart, S. H., Clements, A., Coomes, D., & Vira, B., 2010.

Biodiversity conservation: challenges beyond 2010. *science*, 329(5997), 1298-1303. DOI: https://doi.org/10.1126/science.1189138

RSPN, 2022. RSPN Bhutan – Royal Society for Protection of Nature. *Royal Society for Protection of Nature*. https://www.rspnbhutan.org/ (accessed on: 25 December 2021).

Smirenski, S. M., Danner, G., & Harris, J. T., 2018. Agriculture program of Muraviovka Park: integrating wetland conservation with farming. *Cranes and Agriculture*, 243. https://www.savingcranes.org/wp-content/uploads/2018/10/cranes_and_agriculture_web_2018.pdf (accessed on: 7 April 2021).

Tshering, J., Letro, Tandin, & Wangdi, S., 2021. Black-necked Crane Conservation Action Plan for Bhutan (2021-2025) Black-necked Crane Conservation Action Plan for Bhutan. Department Of Forests and Park Services Ministry of Agriculture and Forests Royal Government of Bhutan in collaboration with Royal. http://www.rspnbhutan.org/wp-content/uploads/2021/03/Final_BNC_Conservation_Action_Plan_March1_2021-1.pdf (accessed on: 24 June 2021).

Wu, D., Hu, C., Zhang, M., Li, Z., & Su, H., 2020. Foraging habitat selection of overwintering Black-necked Cranes in the farming area surrounding the Caohai Wetland, Guizhou Province, China. *Avian Research*, 11(1), 1-9. DOI: https://doi.org/10.1186/s40657-020-00192-y