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Research Article

Habitat use and diurnal activity budget of blue bulls (*Boselaphus tragocamelus*) in the Lumbini Heritage Site, Nepal

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Abstract

Blue bulls (*Boselaphus tragocamelus*) in Nepal are found near human settlements, crop fields and forest patches of lowland Terai and their management is becoming challenging due to conflicts with locals. This study explored habitat use and diurnal activity pattern of blue bulls at the Lumbini Heritage Site (LHS), one of the UNESCO World Heritage Sites from Nepal between 29 February and 31 March 2022. The habitat availability was quantified from classified land use land cover data of 10 m resolution and habitat use of the blue bulls was studied by direct observation. Activities of the blue bulls were recorded by the focal animal sampling method to determine the diurnal time budget for three observational phases 7:00–10:30 AM, 10:30–2:00 PM, and 2:00–5:30 PM; morning, afternoon and late-afternoon, respectively. The behavioral states recorded were grazing, locomotion, resting, alert and other activities (running, fighting, etc.). A total of 73 individuals of blue bulls were recorded along the 20 line transects each of 200–300 m in length. The majority of the blue bull individuals (52.05%) were observed in grassland that occupied only 7.14% of the LHS while lesser were found in dense forests (44.44% of the LHS) and agricultural land. Blue bulls spent the majority of their diurnal time on feeding followed by resting and locomotion. Feeding peaked during the morning and late-afternoon observational phases when the temperature was low whereas resting was the major activity in the afternoon. Because the grasslands are the most used habitats by blue bulls in the LHS, especially for feeding, we emphasize the proper management of the grasslands.

Keywords: Bovids; Focal animal sampling; Habitat use; Land cover; Lumbini

1 | Introduction

Blue bull/Nilgai (*Boselaphus tragocamelus*), a bovid ungulate, is one of the largest antelopes in Asia that is endemic to Peninsular India and small parts of Nepal and Pakistan (Leslie 2008; IUCN 2016). Blue bull is sexually dimorphic; adult males are dark gray varying from bluish to brownish gray except for mane while females, calves and young males are pale brown (Schaller 2009). Both sexes have a mane on the neck and develop a tuft of long hair on the throat. Males are larger than females with the average weight of an adult being about 200 kg (Nowak & Walker 1999). Males have about 20 cm long cone-like horns while females are hornless and noticeably small. They are shy and have strong eyesight and hearing capacity (Schaller 2009). They are social animals, found in single or mixed sex herds of varying sizes. They have clumped distribution with an average herd size of 5–6 individuals per herd (Vaghela et al. 2020). This species is widely distributed in India and Nepal's lowlands, extending into Pakistan's border areas. Recently, they have been introduced to the United States and Mexico (Corbet & Hill 1992; Dinerstein 1980).

Blue bulls are one of the nationally threatened animals living in close proximity to human settlements (Mallon 2017). IUCN Red List of Threatened Species has listed the species under the 'Least Concern' category (IUCN 2016); however, in Nepal, it is vulnerable and is often considered as a problem animal for its crop raiding habit (Jnawali et al. 2011). They usually avoid the densely wooded areas and inhabit undulating plains

with grass and patches of scrub (Schaller 2009), and often encountered in agricultural crop fields raiding crops (Chauhan & Singh 1990; Babbar et al. 2022). They are both grazer and browser, but grasses constitute bulk of their diet (Mirza & Khan 1975; Sankar & Vijayan 1992). In Nepal, blue bulls are found in the plains, hillsides, arid areas, grassy steppe woodlands, scrub areas, flood plains, dry deciduous forests, and agricultural areas outside of the country's protected area network; where they compete for resources like fodders with human populations (Aryal 2007). They have a direct effect on the local livelihoods of the farmers; destroy large quantities of crops and vegetables due to which human-blue bull conflict arises (Aryal 2007). In the Rupandehi District of central lowland Nepal, they are found in the riverine forests of the Tinau River, small patches of community forests, grasslands and agricultural fields (Aryal 2007). Destruction of habitat and lack of food has resulted in a noticeable reduction in the number of blue bulls in the Lumbini area of Rupandehi District as well as surrounding areas (Aryal et al. 2016).

Proper management of crop pests and conservation of such conflict-causing wild animals requires a good piece of knowledge about their behavior (Berger-Tal et al. 2011). Behavioral studies focus on how an organism responds to their physical, social and biological environments and the reactions they realized to shape up their survival strategy through the action of natural selection and sexual selection (Cacioppo et al. 2000; Sachser et al. 2013). Behaviors are variable between individuals in terms of forms and frequencies. Blue bulls are tolerant to other ungulates and can be seen feeding with cows and buffalo (Vaghela et al. 2020). Blue bulls are considered a pest animal as they destroy crops both by trampling and eating plants, especially in fields that are close to forest areas (Rahmani 2001). They have even been reported to cause serious injuries to humans by their sharp horns (Gorchiya et al. 2022).

Forest patches and adjoining areas of Rupandehi and Kapilvastu districts are important blue bull habitats but conservation and management measures for the species in Nepal have not been taken yet that has led to a decline in their population (Subedi 2001; Koirala et al. 2020). Blue bulls are found near human settlements and crop fields outside the protected areas. Their natural habitat is being lost due to over-exploitation, pollution, habitat destruction, poaching, human and livestock pressure, etc. (Tiwari & Ghimire 2021). Their presence in the open farmland has produced major challenges for wildlife managers and local farmers. However, blue bulls are among the least studied mammals in Nepal. Thus, we require baseline information about the habitat choices of blue bulls and identification and prediction of the blue bull activities, such that we can better formulate the management strategy by reducing crop depredation and ensuring the survival of a healthy population of blue bulls. Therefore, this study aimed to explore the habitat uses and the diurnal activity pattern of the blue bulls in various hours of the day at Lumbini Heritage Site (LHS), one of the UNESCO World Heritage sites in Nepal.

2 | Materials and methods

2.1 | Study area

Lumbini is one of the UNESCO World Heritage Sites of Nepal which occupies 7.7 km^2 area (Aryal 2007). Lumbini Heritage Site (LHS) lies in the Lumbini Sanskritik Municipality of Rupandehi District, Lumbini Province in the Terai region of Nepal. The LHS was formed by the Lumbini Development Trust Act 1985 for the purpose of restoring the Lumbini Garden under the master plan. The LHS lies at longitude 83°16.1' to 83°17.2' E and latitude 27°27.5' to 27°30.67' N at an elevation of 150 m above sea level. With implementation of the Master Plan, the LHS was divided into three sections: The Scared Pond Zone, The Lumbini Village Zone, and The Monastic Zone. The holy site of Lumbini has ancient monasteries, a sacred Bodhi tree, an ancient bathing pond, the Ashoka Pillar and the Mayadevi Temple, where the supposed place of birth of Buddha is located(DDC 2013).

Lumbini has a humid subtropical, dry winter climate. Lumbini typically receives about 106.2 millimeters (4.18 inches) of precipitation and has 80.55 rainy days (22.07% of the time) annually. The garden of LHS contains a total of 65 different tree species (angiosperms and gymnosperms). *Callistemon citrinus*, *Albizzia lebbek* and *Dalbergia sisoo* are few most common trees. In the LHS, 79% of the potential habitat for the blue bull is covered by forest, while the remaining 21% is grassland or open land. Roughly 43% of the study area had dense crown cover (75–100%), 27% had moderate crown cover (50–75%), 14% had sparse crown cover (25–50%), and the remaining 16% had very sparse crown cover. The garden has a diverse range of flora and wildlife, with both terrestrial and aquatic vegetation present (DDC 2000).

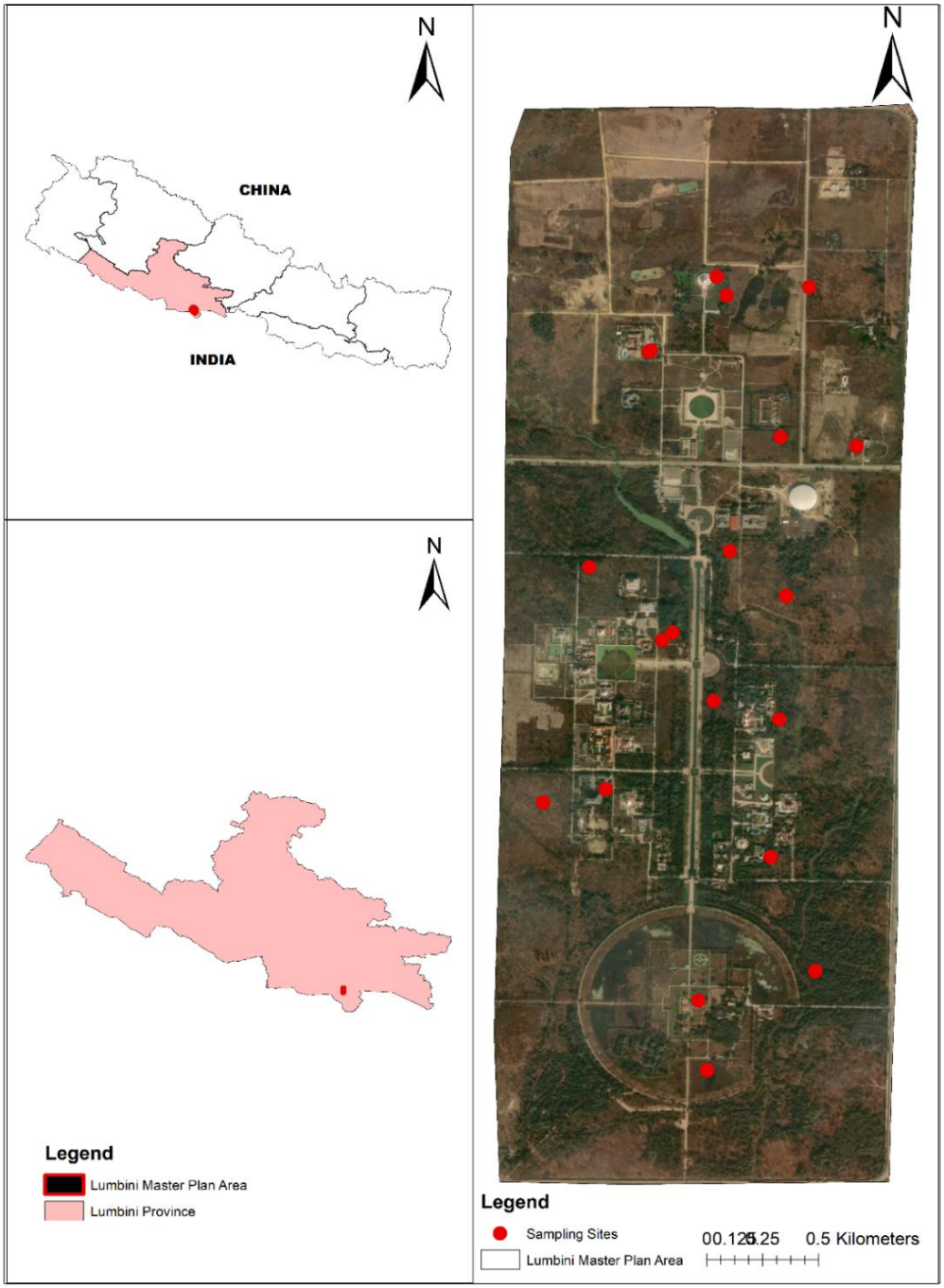

Figure 1. Map of the study area. (a) Map of Nepal showing Rupandehi District; (b) Map of Rupandehi showing LHS; and, (c) Map of LHS showing behavioral sampling sites

2.2 | Field surveys

A preliminary field visit of the study area was carried out in the first week of February 2022. The main objective of the visit was to become familiar with different features of the study area such as geography, local community, and types of flora and fauna found. The study area was divided into the blocks of each 500 × 500 m² by using ArcGIS 10.4. and was assigned the numbers from 1 to 20. A total of 10 of those blocks were randomly selected. The line transect method was used as the tool for surveying the population of blue bulls. Altogether 20 line transects (two from each block) of lengths 200–300 m were surveyed. Data on habitat use, time budget, activity pattern and movements of free ranging blue bulls were recorded. The data collection was conducted from 29 February to 31 March, 2022. Whenever the blue bulls were recorded, population was counted and habitat features along with GPS coordinates were noted.

Table 1. Ethogram of behaviors sampled during the study

Behavior	Definition
Resting	Animal is lying on the ground and in inactive state.
Alert	Standing, ears raised to perceive some external stimuli
Locomotion	Animal is moving/walking without any accompanying behavior
Running	Moving at a speed faster than a walk
Grazing	A condition in which animal feeding on grass in the field
Fighting	Engage in physical combat with another member of the herd

2.3 | Behavioral observations

Behavior was observed daily from 7:00 AM to 5:30 PM dividing into three shifts of each three hours- 7:00–10:30 AM; 10:30–2:00 PM; and 2:00–5:30 PM. Behavioral data of blue bulls were sampled by the 'focal animal sampling' method (Altmann 1974). An individual from a group was identified based on its morphological features such as the shape of horns, any mark on the body pelage, tail hairs etc. and all behavioral states and events from the focal animal were recorded (Altmann 1974). A well-identified animal was observed for an observational shift of three hours and all interactions involving that animal was recorded during this specific period. Total duration of focal sampling of the blue bull was 154 hours. Behavior was broadly divided and further regrouped into five major categories of behavior such as feeding (grazing and browsing), locomotion (moving), resting (standing, sitting, lying, sleeping), alert, and other activities such as running, fighting, etc. using an ethogram (Table 1). The proportion of time spent in each category of behavior was referred to as the activity budget. The focal individual of the blue bull was recognized by sex (male, female, juvenile and infant) and further was distinguished by the body color, size and genital parts. Observations were done from hidden points in bushes and trees in potential areas to avoid disturbance to the animals.

2.4 | Data analysis

Using Google Earth, a polygon was drawn to cover the entire Lumbini Master Plan area and the extracted kmz file was converted to a shape file. The classified land use land cover data of 10m resolution from ESRI (Karra et al. 2021) was used to quantify the land use land cover types in the area. A land use map for the study area was extracted and classified into seven major categories: water bodies, forest, grassland, flooded vegetation, agricultural land, shrub land and built up areas. All of the different types of habitats in the study area were color-coded to make a land use map. ArcGIS version 10.4 was used to construct the geographical map. One-way ANOVA test was used to test the difference in foraging/ grazing, resting, locomotion and alert behavior of blue bulls in three observational phases of a day for statistical significance level of 0.05.

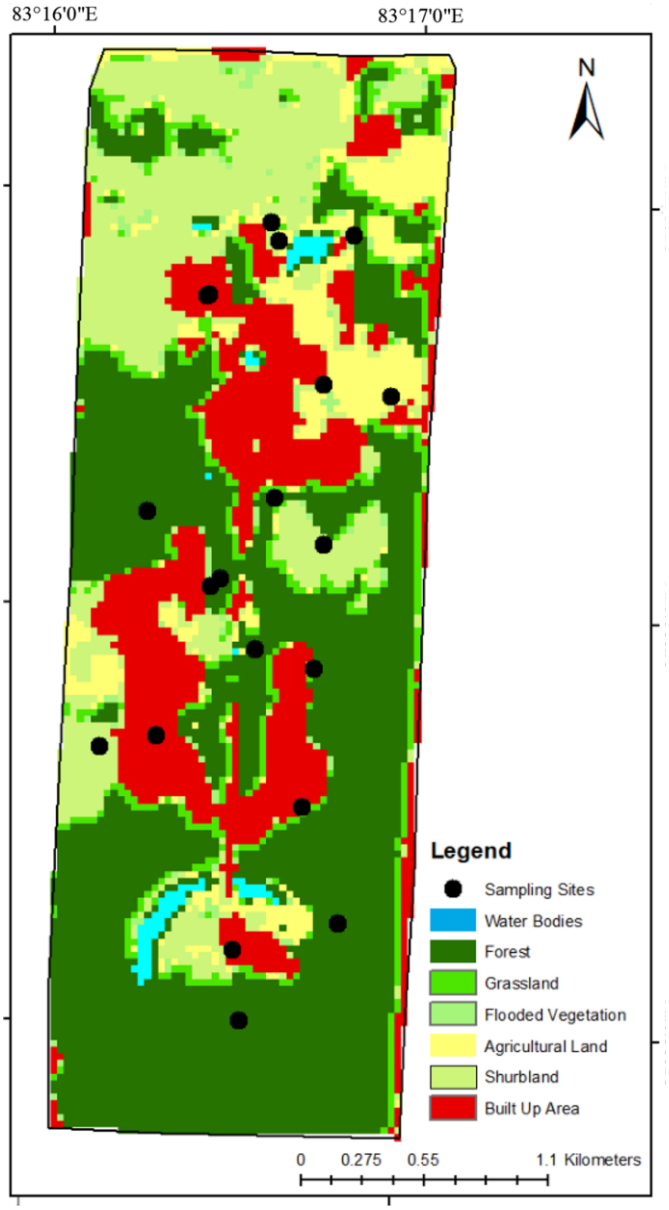

Figure 2. Land use land cover analysis of the LHS showing the major habitat types in the study area

3 | Results

3.1 | Habitat availability and use by blue bulls

The Lumbini Heritage Site (LHS) has seven major land cover types- forest, shrub land, built up area, agricultural land, grassland, flooded vegetation and water body (Fig. 2). The forest (44.4%) occupied the highest land area of the LHS. It was followed by shrub land (18.92%), built up area (17.73%), agricultural land (8.88%), grassland (7.14%), flooded vegetation (1.93%) and water body (1%).

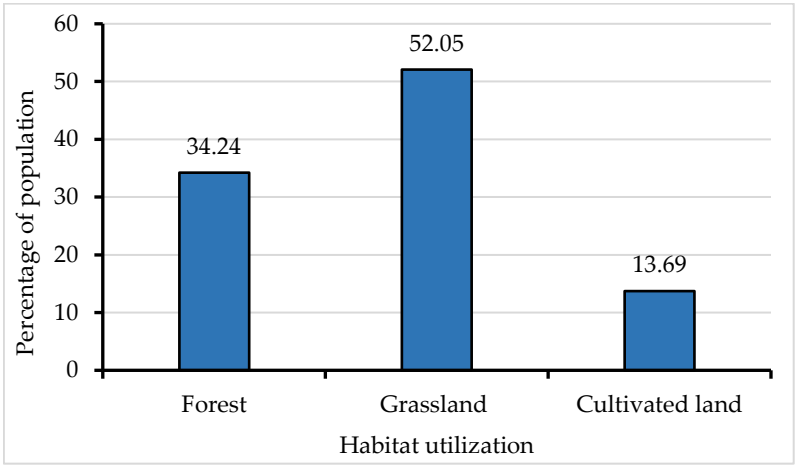

Figure 3. Percentage of population of blue bull in different habitats.

A total of 73 individuals of blue bulls were observed during the study period along the 20 line transects. Among those 73 individuals, 24 were males, 29 were females and 20 were calves. Out of total recorded population of blue bull, more than half (52.05%) were observed in the grassland followed by the forest and agricultural land (Fig. 3).

On analysis of the population observed in different habitats, the forest habitat contained 40% of males, 48% females and 12% calves. Out of total blue bulls observed in the grasslands, 28.94% were males, 36.82% were females and 34.21% were calves. In the agricultural fields, 30% were males, 30% females and 40% were calves.

3.2 | Diurnal activity pattern of blue bulls

Blue bull spent majority of the diurnal time on foraging/grazing (39%) followed by resting (27%) and locomotion (23%) (Fig. 5).

Foraging/grazing was the most prevalent behavior shown by blue bulls in the morning (7:00–10:30 AM) which accounted for 27.14% of the time. Blue bulls spent 26.03% time on locomotion, 24.60% on resting, and 22.91% on alert. In the afternoon (10:30–2:30 PM), the animals remained alert for majority of the time (44.47%) followed by resting (41.48%). In evening time (2:30–5:30 PM), blue bull spent more time on grazing (40.98%) followed by locomotion and resting. ANOVA revealed significant difference on time invested in grazing, resting and locomotion by the blue bulls during the three observational phases ($F = 5.002$; $df = 2, 42$; $P = 0.01$). However, the difference was not statistically significant for alert behavior (Table 2).

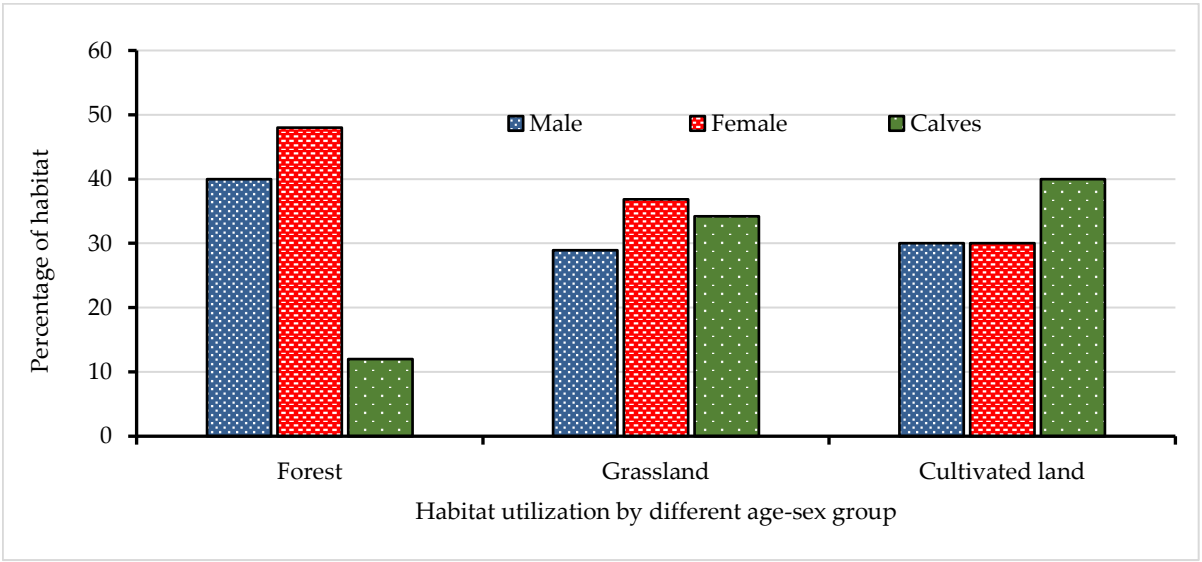

Figure 4. Habitat utilization by different age-sex groups of blue bull in the LHS

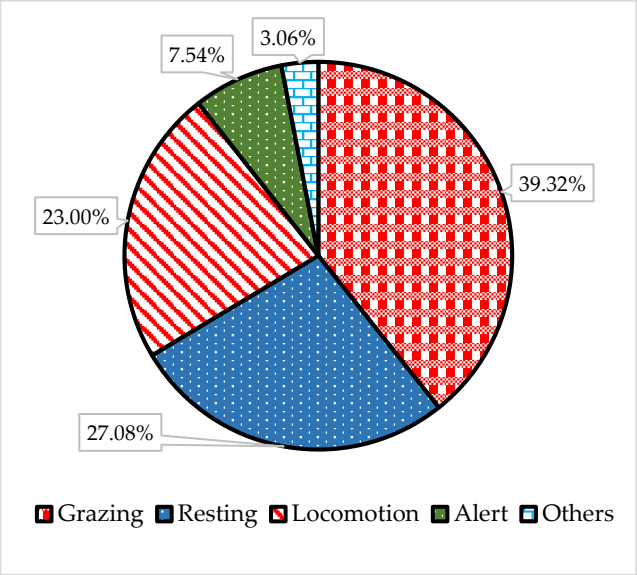

Figure 5. Percentage of time spent in major activities by blue bull as observed by the focal animal sampling method

4 | Discussion

This study explored habitat use by the blue bulls in the Lumbini Heritage Site (LHS) using direct observations. Based on the total number of animal observations (73), the grassland was most utilized by the blue bulls (52.05%) although the grasslands constituted only 7.14% of the total available habitats. Despite the presence of 44.44% of forest habitat, only 34.24% of the blue bulls were recorded in the forest. These results indicate the preference of blue bulls to grassland over forest. Similar type of results with higher occurrence in grassland and forest patches was observed by Aryal et al. (2016) and Bayani and Watve (2016).

During the study, blue bulls were found to prefer wooded grassland, usually avoiding very dense forests. Dense forests though have enough food source also faces many challenges like resource competition with other ungulates (like domestic cattles, barking deer and spotted deer) and presence of lurking predators make forest less preferable (Sheffield Jr et al. 1971; Kuijper et al. 2009; Quasin et al. 2014). Likewise, many agricultural aiding practices like fencing, shouting, and frequent encounter with human in agricultural field might be the reasons for less occurrence of blue bull in agricultural habitat (Gajera et al. 2014; Aryal et al. 2016).

Table 2. Result of ANOVA test of different behaviors during three observational phases of the days

Behavior	Df	F	P-Value	F critical
Grazing	2,42	27.649	0.0007	3.219
Resting	2,42	22.376	0.0022	3.219
Locomotion	2,42	5.0020	0.0112	3.219
Alert	2,42	2.1483	0.1293	3.219

Behavioral responses of animals are influenced by their physical and habitat conditions (Rahman & Candolin 2022). Our study was performed in LHS to assess the behavior of blue bull. During our study, we found that blue bull spent maximum time in grazing, resting and locomotion activities, and there were no records of grooming and ruminating activities throughout the study period. The present result of diurnal activity pattern of blue bull of behavioral time budget showed that the grazing time was highest (39%) followed by resting (27%), locomotion (23%), alert (8%) etc. Similar results were observed in behavioral study of blue bull around the world (Quasin et al. 2014; Babbar et al. 2022). Not only blue bulls, such types of behaviors are shown by many ungulates and herbivore species (Hudson & Frank 1987; Rosenbaum et al. 2019).

Animals perform wide variety of daily activities for their existence in natural habitat, but presence of some degree of differentiation in their activities is due to limitation in space, food, human presence (Hamel & Côté 2008; Schweiger et al. 2015). In addition to these factors, chronobiologically associated crepuscular activity rhythms and some uncommon environmental events like eclipse also governs the diurnal activity budget of ungulates like blue bull (Mahato et al. 2013; Ensing et al. 2014). In our study, feeding activity was found the major activity profile i.e. maximum feeding activity was found in morning and evening while minimum was found in day light time. Similarly, maximum locomotion was recorded in evening and minimum was in day time. Blue bull mainly feed on grasses and shrubs, foraging for daily dietary requirement in post winter season might have shown this huge time budget for feeding and locomotion. As this species is inhabitants of tropical climatic belt, they forage when the temperature is low. Many previous studies have clearly demonstrated similar type of foraging schedule (Quasin et al. 2014) and time budgeting for feeding and locomotion (Quasin et al. 2014; Bayani & Watve 2016).

Afternoon holds the maximum resting and morning and evening time period hold the minimum. For alert, maximum time was found in afternoon and evening and minimum was in morning time. Similar result having alerted huge resting time was observed by other researchers (Schaller 2009).

Blue bull engaged maximum time in feeding during 7:00–10:30 AM and 4:00–5:30 PM when the temperature

was low, while blue bull spent the greatest amount of time in resting during 12:00–3:30 PM as temperature increases during the day time. It is found that the walking activity pattern was maximum during the evening hours in both male and female. The present study shows that the pattern of docility indicates that females graze with young ones (calves). Females and calves in the current study did not engage with males very much. Male blue bull was seen in a scattered form, whereas females were relatively social and grazing in groups with calves.

Regmi and Chalise (2019) found that animal spent more than 55% of diurnal time in grazing, 29% in rest and 12% of the time in wallowing which is similar to the present study. Intense feeding or grazing and locomotion or moving of blue bull as like in most of the diurnal herbivores in tropics occur early in the morning and later part of the day with a long resting period at the noon. This study indicated activity budget would have implication to habitat management with respect to animal behavior and food requirements. They are found to perform daily activities such as grazing, resting, locomotion, alert etc. interactions around the territories mainly at open areas with tall and short grasslands mostly in proximity to water-logged sites, and scrub or forests. Habitat condition is also a factor for variations in behavioral time budget at different observational phases which was noted to differ with the opening of the dense grassland. There were some observations of the daily active period of blue bull that was affected by other factors such as human disturbances so blue bull become highly sensitive and change the activity spontaneously. Besides that, the presence of other species such as domestic buffaloes, cattle, and cow affect on behavioral activities pattern in long run through the sympatrism, because sympatric species share the diet, space and intervene in social activities (Li et al. 2022). Since blue bull's day hours consists of portions of time to spend in grazing, resting, locomotion between food sources and essentially the social interactions, this is also true for many of the diurnal animals in performing such behaviors. Behavioral activities of the blue bull are directly related to the nature and frequency of the anthropogenic activities which affect the natural behavior of blue bull as like in other herbivorous animals.

5 | Conclusions

Forest was the most abundant land cover type in the Lumbini Heritage Site; however, the most used habitat of blue bulls was the grasslands. Low preferences to dense area could be associated to the adaptive behavior of the blue bull against predation. Feeding was found to be the most dominant activity of the blue bulls in their diurnal activity budget. The results revealed that blue bulls graze more in the evening than in the morning and afternoon. We emphasize for the proper management of grasslands in the Lumbini Heritage Site in order to sustain a viable population of the blue bulls.

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Authors' contributions

L. K. conceptualized the study. P. P. performed the field surveys; P. P. and N. P. analyzed data and wrote the manuscript. L. K. supervised the research and finalized the manuscript. All authors approved manuscript for submission.

Conflicts of interest

Authors declare no conflict of interest.

References

Altmann, J. 1974. Observational study of behavior: Sampling methods. Behaviour **49**(3-4):227–266. https://doi.org/10.1163/156853974x00534

Altmann, J. and Samuels, A. 1992. Costs of maternal care: Infant-carrying in baboons. Behavioral Ecology and Sociobiology **29**(6):391–398. https://doi.org/10.1007/BF00170168

Aryal, A. 2007. Blue bull (*Boselaphus tragocamelus*) in Lumbini– A world heritage site of Nepal. Tiger Paper **32**:4–9.

Aryal, M., Panthi, S., Bhatta, M., Magrati, T. P., Shrestha, A. K., Shrestha, P. B., et al. 2016. Population status, distribution and potential threats of the blue bull *Boselaphus tragocamelus* (Mammalia: Cetartiodactyla: Bovidae) along the Tinau River of Rupandehi District, Nepal. Journal of Threatened Taxa **8**(14):9638–9642. https://doi.org/10.11609/jott.2205.8.14.9638-9642

Babbar, B. K., Singla, N., Kaur, H., Verma, M., Rani, K., Bala, B., et al. 2022. Bio-ecology, behaviour and management of blue bull, *Boselaphus tragocamelus*. International Journal of Pest Management. https://doi.org/10.1080/09670874.2022.2104402

Bagchi, S., Goyal, S. and Sankar, K. 2003. Habitat separation among ungulates in dry tropical forests of Ranthambhore National Park, Rajasthan. Tropical Ecology **44**(2):175–182.

Bawri, M. and Saikia, P. K. 2014. Diurnal activity budgeting pattern of Wild Water Buffalo (*Bubalus arnee* Kerr, 1792) in Kaziranga National Park, Assam. Golden Research Thoughts **3**(9):1–8.

Bayani, A. and Watve, M. 2016. Differences in behaviour of the nilgai (*Boselaphus tragocamelus*) during foraging in forest versus in agricultural land. Journal of Tropical Ecology **32**(6):469–481. https://doi.org/10.1017/S0266467416000420

Berger-Tal, O., Polak, T., Oron, A., Lubin, Y., Kotler, B. P. and Saltz, D. 2011. Integrating animal behavior and conservation biology: a conceptual framework. Behavioral Ecology **22**(2):236–239. https://doi.org/10.1093/beheco/arq224

Bhattarai, K. R., and Baral, S. R. 2008. Potential role of sacred grove of Lumbini in biodiversity conservation in Nepal. Banko Janakari **18**(1):25–31. https://doi.org/10.3126/banko.v18i1.2163

Blanford, W. T. 1888. The Fauna of British India, Mammalia. Taylor and Francis, London. https://doi.org/10.5962/bhl.title.97003

Bohra, H., Goyal, S., Ghosh, P. and Prakash, I. 1992. Studies on ethology and eco-physiology of the antelopes of the Indian desert. Annals of Arid Zone **31**(2):83–96.

Cacioppo, J. T., Berntson, G. G., Sheridan, J. F. and McClintock, M. K. 2000. Multilevel integrative analyses of human behavior: social neuroscience and the complementing nature of social and biological approaches. Psychological Bulletin **126**(6):829. https://doi.org/10.1037/0033-2909.126.6.829

Chauhan, N. and Singh, R. 1990. Crop damage by overabundant populations of nilgai and blackbuck in Haryana (India) and its management. Proceedings of the Fourteenth Vertebrate Pest Conference 1990. p. 13.

Corbet, G. B. and Hill, J. E. 1992. The mammals of the Indomalayan region: a systematic review (Vol. 488): Oxford university press Oxford.

DDC. 2000. Annual Report. District Development Committee Rupandehi District, Nepal.

DDC. 2013. Annual Report. District Development Committee Rupandehi District, Nepal.

Dinerstein, E. (1980). An ecological survey of the Royal Karnali-Bardia Wildlife Reserve, Nepal: part III: ungulate populations. Biological Conservation **18**(1):5–37. https://doi.org/10.1016/0006-3207(80)90063-4

Dinerstein, E. 1979. An ecological survey of the Royal Karnali-Bardia Wildlife Reserve, Nepal. Part I: vegetation, modifying factors, and successional relationships. Biological Conservation **15**(2):127–150. https://doi.org/10.1016/0006-3207(79)90030-2

Ensing, E. P., Ciuti, S., de Wijs, F. A., Lentferink, D. H., Ten Hoedt, A., Boyce, M. S., et al. 2014. GPS based daily activity patterns in European red deer and North American elk (*Cervus elaphus*): indication for a weak circadian clock in ungulates. PLoS One **9**(9):e106997. https://doi.org/10.1371/journal.pone.0106997

Gajera, N., Mahato, A. K. R. and Kumar, V. V. 2014. Habitat preference and social composition of antelopes in arid region of Kachchh, Gujarat, India. Asian Journal of Conservation Biology **3**:164–169.

Gorchiya, A., Jadav, D. and Singh Shekhawat, R. 2022. An unusual attack by a blue bull resulting in penetrating horn injuries. Wilderness & Environmental Medicine 33(2):232–235. https://doi.org/https://doi.org/10.1016/j.wem.2021.12.003

Goyal, S. and Rajpurohit, L. 2000. Nilgai, *Boselaphus tragocamelus*- a mammalian crop pest around Jodhpur. Uttar Pradesh Journal of Zoology **20**(1):55–59.

Hamel, S. and Côté, S. D. 2008. Trade-offs in activity budget in an alpine ungulate: contrasting lactating and nonlactating females. Animal Behaviour **75**(1):217–227. https://doi.org/10.1016/j.anbehav.2007.04.028

Hudson, R. J. and Frank, S. 1987. Foraging ecology of bison in aspen boreal habitats. Journal of Range Management **40**(1):71–75.

IUCN SSC Antelope Specialist Group. 2016. *Boselaphus tragocamelus*. The IUCN Red List of Threatened Species 2016: e.T2893A115064758. http://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T2893A50182076.en

Jnawali, S., Baral, H., Lee, S., Acharya, K., Upadhyaya, G., Pandey, M., et al. 2011. The Status of Nepal's Mammals: The National Red List Series. Department of National Parks and wildlife Conservation: Kathmandu, Nepal. ISBN: 978-0-900881-60-2.

Karanth, K. K., Nichols, J. D., Hines, J. E., Karanth, K. U. and Christensen, N. L. 2009. Patterns and determinants of mammal species occurrence in India. Journal of Applied Ecology **46**(6):1189–1200. https://doi.org/10.1111/j.1365-2664.2009.01710.x

Karra, K., Kontgis, C., Statman-Weil, Z., Mazzariello, J. C., Mathis, M. and Brumby, S. P. 2021. Global land use / land cover with Sentinel 2 and deep learning, 2021 IEEE International Geoscience and Remote Sensing Symposium IGARSS, Brussels, Belgium. pp. 4704–4707. http://dx.doi.org/10.1109/IGARSS47720.2021.9553499

Khan, K. A., & Khan, J. A. 2016. Status, abundance and population ecology of Nilgai (*Boselaphus tragocamelus Pallas*) in Aligarh District, Uttar Pradesh, India. Journal of Applied and Natural Science **8**(2):1080–1086. https://doi.org/10.31018/jans.v8i2.924

Khanal, S., Aryal, A., Morley, C. G., Wright, W. and Singh, N. B. 2018. Challenges of conserving blue bull (*Boselaphus tragocamelus*) outside the protected areas of Nepal. Proceedings of the Zoological Society **71**:352–362. https://doi.org/10.1007/s12595-017-0218-y.

Khatri, T. 1993. Status and food habit of Nilgai in Royal Bardia National Park. M. Sc. Thesis. Agricultural University of Norway. p. 65.

Koirala, P., Neupane, B., Silwal, T., Dhami, B., Regmi, S. and Dahal, D. 2020. Distribution of Blue Bull (*Boselaphus tragocamelus*) and its Conservation Threats in Bardia National Park, Nepal. Journal of Forest and Natural Resource Management **2**(1): 50–60. https://doi.org/10.3126/jfnrm.v2i1.40220

Kuijper, D. P., Cromsigt, J. P., Churski, M., Adam, B., Jędrzejewska, B. and Jędrzejewski, W. 2009. Do ungulates preferentially feed in forest gaps in European temperate forest? Forest Ecology management **258**(7):1528–1535. https://doi.org/10.1016/j.foreco.2009.07.010

Leslie, D. M., Jr. 2008. *Boselaphus tragocamelus* (Artiodactyla: Bovidae). Mammalian Species **813**:1–16. https://doi.org/10.1644/813.1

Li, Z., Wang, J., Khattak, R. H., Han, X., Liu, P., Liu, Z. and Teng, L. 2022. Coexistence mechanisms of sympatric ungulates: Behavioral and physiological adaptations of blue sheep (*Pseudois nayaur*) and red deer (*Cervus elaphus alxaicus*) in Helan Mountains, China. Frontiers in Ecology Evolution **10**:925465. https://doi.org/10.3389/fevo.2022.925465

Mahato, A., Majumder, S., De, J. and Ramakrishna, A. 2013. Activities of Blue bull, Boselaphus tragocamelus during partial solar eclipse: a case study in captivity. Ethology Ecology Evolution **25**(3):269–274. https://doi.org/10.1080/03949370.2013.767860

Mallon, D. 2017. *Boselaphus tragocamelus* 2008. IUCN red list of Threatened species version 2013. International Union for Conservation of Nature.

Mirza, Z. and Khan, M. 1975. Study of distribution, habitat and food of nilgai *Boselaphus tragocamelus* in Punjab. Pakistan Journal of Zoology **7**:209–214.

Nowak, R. M. and Walker, E. P. 1999. *Walker's Mammals of the World*. JHU Press. p. 1936

Oguya, B. and Eltringham, S. 1991. Behaviour of nilgai (*Boselaphus tragocamelus*) antelope in captivity. Journal of Zoology **223**(1):91–102. https://doi.org/10.1111/j.1469-7998.1991.tb04751.x

Prajapati, M. and Singh, S. 1994. A beneficial aspect of Nilgai (*Boselaphus tragocamelus*) in scientifically utilised ravines-an observation. Indian Forester **120**(10):890–897.

Prasad, S. and Prabhakar, C. S. 2020. Docility behavioral development in Nilgai (*Boselaphus tragocamelus*), a sign of taming towards domestication. Current Journal of Applied Science and Technology **39**(41):30–39. https://doi.org/10.9734/cjast/2020/v39i4131117

Quasin, S., Mahato, A. K. R., Ganguly, K. and De, J. K. 2014. Activity pattern of blue bull (*Boselaphus tragocamelus*) in captivity at zoological garden, Kolkata, India. International Journal of Pure and Applied Zoology **2**(3):275–280.

Rahman, T. and Candolin, U. 2022. Linking animal behaviour to ecosystem change in disturbed environments. Frontiers in Ecology and Evolution **2022**:893453. https://doi.org/10.3389/fevo.2022.893453

Rahmani, A. R. 2001. India. In: D.P. Mallon & S.C. Kingswood (Eds.), Antelopes. Part 4: North Africa, the Middle East, and Asia. Global Survey and Regional Action Plans, pp. 178–187. IUCN, Gland, Switzerland.

Rosenbaum, B., Reading, R. P., Tsogtjargal, G., Amgalanbaatar, S. and Comte, S. 2019. Seasonal variation in the foraging activity of desert argali (Ovis ammon) in Mongolia. Canadian Journal of Zoology **97**(10):931–939. https://doi.org/10.1139/cjz-2018-0239

Sachser, N., Kaiser, S. and Hennessy, M. B. 2013. Behavioural profiles are shaped by social experience: when, how and why. Philosophical Transactions of the Royal Society B: Biological Sciences, 368(1618), 20120344. https://doi.org/10.1098/rstb.2012.0344

Sankar, K. and Vijayan, V. 1992. Notes on the food habits of nilgai *Boselaphus tragocamelus*. Journal of the Bombay Natural History Society **89**:115–116.

Schaller, G. B. 2009. *The Deer and the Tiger: Study of Wild Life in India*. University of Chicago Press. p. 384.

Schweiger, A. K., Schütz, M., Anderwald, P., Schaepman, M. E., Kneubühler, M., Haller, R., et al. 2015. Foraging ecology of three sympatric ungulate species–behavioural and resource maps indicate differences between chamois, ibex and red deer. Movement ecology **3**(1):1–12. https://doi.org/10.1186/s40462-015-0033-x

Shah, R., Tripathi, S. and Bhatta, B. 2017. Translocation of Wild Asian Buffalo (*Bubalus arnee*): a way forward to conservation in Nepal. Proceedings of the International Buffalo Symposium.

Sheffield Jr, W. J., Ables, E. D. and Fall, B. A. 1971. Geographic and ecological distribution of nilgai antelope in Texas. The Journal of Wildlife Management **35**(2):250–257. https://doi.org/10.2307/3799598

Subedi, N. 2001. Status and ecology of Nilgai in Nepal with particular emphasis on Royal Bardia National Park. M. Sc. Dissertation. Centre for International Environment and Development Studies, Agricultural University of Norway, Norway.

Tiwari, A. and Ghimire, N. P. 2021. Ecological restoration in Gautam Buddha's Birthplace Lumbini. Journal of Tourism Himalayan Adventures **3**(1):1–10. https://doi.org/10.3126/jtha.v3i1.39113

Vaghela, M. V., Dodia, P. P. and Shukla A. H. 2020. Study on group composition of blue bull (*Boselaphus tragocamelus*) In Bhavnagar District, Gujarat, India. Ela Journal of Forestry and Wildlife **9**(3): 747–754.