Nep J Environ Sci (2024), 12(2), 33-45
https://doi.org/10.3126/njes.v12i2.71434
ISSN 2350-8647 (Print) 2542-2901 (Online)

Research Article

Mammal and Herpetofauna Diversity and Activity Patterns in the Lumbini Crane Sanctuary Nepal

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(Received: 10 November 2024; Revised: 28 December 2024; Accepted: 31 December 2024)

Abstract
The Lumbini Crane Sanctuary (LCS) within the New Lumbini Village located in the north block of the Lumbini Master Plan Area (LMPA) under the jurisdiction of the Lumbini Development Trust (LDT), is a vital ecological site harboring diverse mammal and herpetofauna species. This study, conducted in the Lumbini Crane Sanctuary during September and October 2022, documented mammals, reptiles, and amphibians, and analyzed mammal activity patterns in relation to human and livestock activity. The study documented 17 mammalian species and 12 herpetofaunal species (8 reptiles and 4 amphibians), utilizing both direct methods, such as camera traps, and line transects and indirect approaches such as sign surveys and key informant interviews. Five mammal species- Blue Bull (*Boselaphus tragocamelus)*, Golden Jackal (*Canis aureus),* Indian Hare (*Lepus nigricollis)*, Indian Grey Mongoose (*Herpestes edwardsi)*, and Wild Boar (*Sus scrofa)* exhibited distinct activity patterns. The Blue Bull displayed consistent daytime activity, peaking in the late afternoon, while the Golden Jackal and Wild Boar showed bimodal patterns, avoiding peak human activity hours. The Indian Hare and Wild Boar were most active in the early morning when human and livestock presence was minimum. These activity patterns suggest possible behavioral adaptations to human pressures, highlighting conservation challenges such as habitat destruction, pollution, and impacts from feral livestock in the area. Promoting sustainable tourism is crucial and future research should prioritize long-term studies to better understand the biodiversity and behavior of mammals and herpetofauna in the Lumbini Crane Sanctuary.

Keywords: Anthropogenic pressures, biodiversity, herpetofauna, Lumbini Crane Sanctuary, mammals

Introduction
The Lumbini Master Plan Area (LMPA) under the jurisdiction of the Lumbini Development Trust (LDT) is one of the most sacred sites for Hindus and Buddhists, as the birthplace of Lord Buddha (Bhattarai & Baral, 2008; Rai, 2013; Weise, 2013). Designated a UNESCO World Heritage Site in 1997, it has been a significant pilgrimage destination attracting millions of visitors globally. The Mayadevi Temple, marking Buddha's birth in 623 BC, stands as an important archaeological and biodiversity-rich site ((UNESCO, 2006).

The Lumbini Crane Sanctuary (LCS), located within LMPA in the Rupandehi District, Lumbini Province of Nepal, represents a critical ecological and cultural heritage site (Aryal, 2004). Established in 1994 through a collaborative effort between LDT and the International Crane Foundation, LCS supports as mosaic of wetlands, grasslands, and forest patches that sustain a variety of species (Suwal et al., 2002; Bhuju et al., 2007). While LCS is internationally recognized for its efforts to conserve the endangered Sarus Crane (*Antigone antigone*), it also harbors a rich diversity of mammals and herpetofauna, making it a biodiversity hotspot of national and global importance (Suwal, 1999; Thapa et al., 2016).

LCS integrates Buddhist principles of environmental harmony with the region's religious, cultural, and ecological restoration (Suwal et al., 2002). Conservation activities focus on sanctuary management (Suwal et al., 2003), wetland restoration, habitat expansion, and Sarus Crane protection. LCS also promotes outreach programs to engage local communities in the Lumbini region, fostering a connection between crane conservation and community development (Aryal, 2004). This collaborative approach encourages sustainable practices, mutual respect for wildlife, and the preservation of cultural heritage (Suwal, 1999; Suwal et al., 2003; Aryal, 2004). The wetlands are important for ecological conservation and have been recognized internationally as an Important Bird and Biodiversity Area (IBA) (Thapa et al., 2016). Despite its success, LCS faces multiple challenges including human-wildlife conflict, habitat degradation, livestock grazing, and impacts of climate change (Suwal et al., 2002; Nyaupane, 2009; Pandey, 2015). It offers valuable insights into the integration of biodiversity conservation, human activities, and cultural values, serving as a model for sustainable ecosystem management and the peaceful coexistence of people and nature.

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Mammal activity patterns are influenced by habitat conditions, resource availability, and human disturbances (Norris et al., 2010; Gaynor et al., 2018). The use of camera traps has emerged as an indispensable tool for wildlife studies, particularly for detecting elusive and nocturnal species in dense habitats (Whitworth et al., 2016; Moore et al., 2021; Awasthi et al., 2024b). These non-invasive tools provide critical insights into population density, species demographics, and reproductive behavior (Galvis et al., 2014). Compared to direct observation, camera traps effectively capture secretive and nocturnal behaviors, minimizing field disturbance and logistical challenges (Thomas et al., 2020; Awasthi et al., 2024). This technique is essential for comprehending biodiversity and activity dynamics in ecologically and culturally significant sites.

Mammals and herpetofauna play vital ecological roles in maintaining ecosystem balance (Aynalem & Mengistu, 2017; Khawarizmi et al., 2024). Mammals contribute to seed dispersal, predator-prey dynamics, and nutrient cycling (Lacher Jr et al., 2019; Awasthi et al., 2024a), while herpetofauna regulate insect populations, serve as bioindicators, and connect aquatic and terrestrial ecosystems (West, 2018). Despite their ecological importance, these groups remain understudied in Nepal's religious and cultural landscapes, where habitat degradation and human-wildlife interactions challenge conservation efforts. Understanding the diversity, and activity patterns of mammals and herpetofauna is crucial for developing effective conservation strategies.

This study integrates field surveys with local people's ecological knowledge to provide a detailed assessment of these faunal groups in LCS. By documenting biodiversity, activity dynamics, and conservation threats, this research aims to inform sustainable conservation practices that harmonize conservation with the cultural and spiritual significance of LCS. The findings will support sustainable management practices, mitigating human-wildlife conflicts and ensuring the preservation of this unique ecological and cultural heritage for future generations.

Materials and Methods

Study Area

LCS is situated within the New Lumbini Village of LMPA in the Lumbini Sanskritik Municipality in the Tarai plains of southwestern Nepal of Rupandehi District and covers 265 hectares in area. Geographically, it lies at 27°49.9544' N latitude and 83°27.8949' E longitude, with an elevation of 119 meters above sea level and is characterized by a humid subtropical, dry winter climate (Pandey et al., 2022).The LCS was established in 1994 through a collaborative effort between the Lumbini Development Trust and the International Crane Foundation (ICF).

LMPA is divided into three zones: The Sacred Garden marking the birthplace of Buddha in the south, the Monastic Zones hosting monasteries in the center, and the New Lumbini Village providing accommodation to visitors in the north (Fig 1). Excavations conducted by the Department of Archaeology during 1970-71, collected valuable faunal remains including carp, the common soft-shelled box turtle (*Lissemys punctata*), the soft-shelled river turtle (*Chitra indica*), boar (*Sus scrofa cristatus*), cattle (*Bos indicus*), buffalo (*Bubalus bubalis*), goat (*Capra hircus aegagrus*), sheep (*Ovis aries dolichura*), horse (*Equus caballus*), and spotted deer (*Axis axis*) (Nath & Biswas, 1979). Ecologically, the garden supports 26 mammalian species, 39 herpetofauna species, and numerous bird species (Bhuju et al., 2007). Despite facing increasing urban pressures, the sanctuary remains a vital refuge for wildlife, offering both opportunities and challenges for biodiversity conservation (Aryal, 2007; Bhuju et al., 2007;Aryal et al., 2009). The garden is home to 65 tree species and Sissoo (*Dalbergia sissoo*) occupies 85% of the garden, and the other dominant species are *Shorea robusta*, *Terminalia* spp., *Lagerstroemia parviflora* (Bhattarai & Baral, 2008). Recently, the trust has started horticulture plantation mostly of mango in the sacred garden area replacing Sissoo (*Dalbergia sissoo*) (Bhuju, 2021; unpublished). Efforts to restore wetlands and habitats have enriched the region's biodiversity, attracting various birds and animals; among them are Blue bulls, which have become permanent residents since the 1990s (Weise, 2013; Gosai et al., 2016).

Mammal Surveys: Camera Trapping

Mammals were investigated using both direct and indirect methods. Diurnal species were directly observed during fieldwork, while crepuscular species, including carnivores, were identified through sign surveys and scat analysis. Detailed methodologies for these methods are outlined in Hunter (2011) and DNPWC (2017). From September 19 to October 10, 2022, during the monsoon season, single camera traps (Bushnell and Campark) were deployed at ten locations within the Lumbini Crane Sanctuary (Fig 1). These stations were carefully positioned along wildlife trails, near water sources, and at forest edges to optimize the detection and documentation of mammal diversity. The selection criteria ensured that each station was separated by at least 300 meters to maximize coverage and reduce overlap in the detection of wildlife activity. The cameras were positioned 12-18 cm above the ground and recorded 10-second videos and photos triggered by motion, with a 5-second delay between triggers. The cameras were inspected every 3-4 days, with batteries and SD cards replaced as necessary cameras operated for periods ranging from four to 15 days, with a median duration of 12.8 days per site. However, four camera traps were stolen, and one camera trap recorded numerous false triggers, resulting in the loss of 60 camera trap nights of data. Due to the loss of four camera traps, data from only 64 camera trap nights was available, resulting in six functioning units. The images captured by the camera traps were subsequently downloaded, renamed, and organized into separate folders based on species. Data cleaning involved the removal of blank and unusable images and videos. Captures were categorized by independent visitation events, with each photo and video considered independent if separated by more than 30 minutes (O'Brien et al., 2003; Koju et al., 2024). The number of individuals and species identity were recorded. GPS coordinates were documented during camera installation using a Garmin eTrex 10. QGIS was employed for mapping purposes.

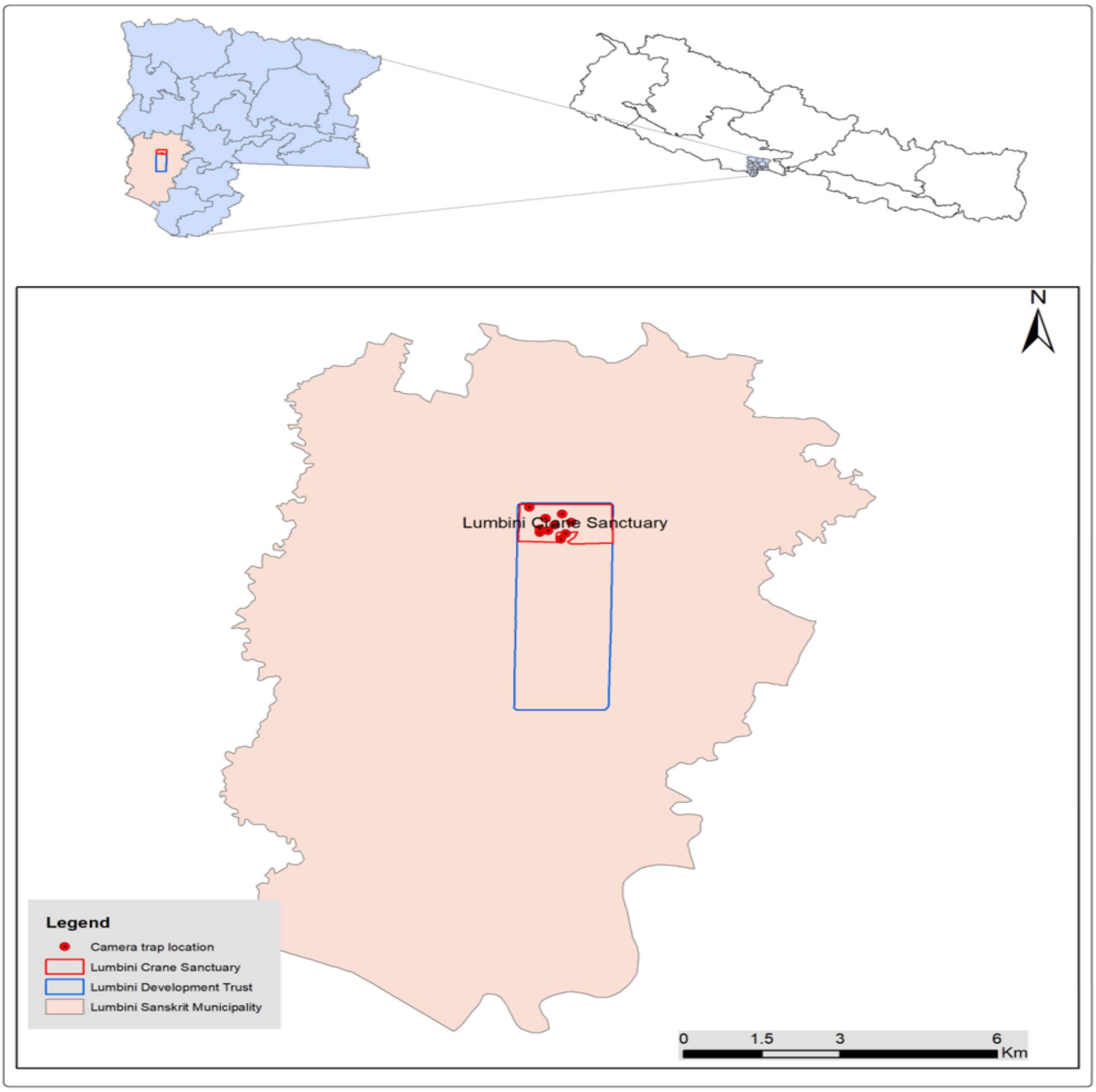

Figure 1. Camera trap locations (red dots) in Lumbini Crane Sanctuary (LCS)

Herpetofauna Study

In the field survey of herpetofauna conducted in September 2022, transect placement was not randomized. Over three days, six transects, each measuring 10 × 200 meters, were strategically selected to represent a variety of habitats, including forested areas, roads, and wetlands (Nepali & Singh, 2018; Rawat et al., 2020). Transects were spaced at least 300 meters apart to ensure comprehensive coverage and minimize overlap, enhancing habitat representation and diversity in sampling. Opportunistic surveys in other regions were also conducted using transect lines (Gardner et al., 2007). Surveys were carried out in the mornings (06:30 to 12:00) and late afternoons (16:00 to 18:30). Species observations were recorded using a Canon HxS 50X camera and identified with the field guide Herpetofauna of Nepal (Shah & Tiwari, 2004).

Key informant survey

Furthermore, interviews were conducted with staff from the Lumbini Crane Sanctuary (LCS) and locals to gather additional information. Informed consent was obtained from all participants, who were briefed on the study's purpose and assured that their participation was voluntary. A total of 12 individuals were interviewed, including six LCS staff and six locals. Locals present at the LCS were selected based on their familiarity with the area and knowledge of local wildlife. They were shown color photographs from the field guide and asked to describe distinguishing features and provide local names for the observed animals, amphibians, and reptiles. This approach enriched the data with valuable local insights, enhancing the accuracy of species identification

Data analysis

The relative abundance (RA) was calculated using the methodology outlined by Shankar et al. (2020). This approach involves determining the RA by dividing the number of individual capture events (€) by the total number of camera trap nights (c), followed by multiplying the result by 100. The formula is expressed as:

RA = (€ / c) * 100 (see Table 2).

We analyzed all detection events to construct 24-hour activity patterns, as described by Rowcliffe et al. (2014) and Blašković et al. (2022). Additionally, we assessed the temporal overlap between the activity patterns of the recorded mammal species, human daily activities, and domestic bovids (livestock) using R software (R Core Team, 2023). The overlap was quantified using the Overlap package, which estimates the coefficient of overlap (Δ) by applying kernel density functions to two temporal datasets and visualizing the results through graphical representations (Ridout & Linkie, 2009; Meredith & Ridout, 2023). For datasets with fewer than 50 observations, the Dhat1 (Δ1) estimator is recommended, while the Dhat4 estimator is employed for larger samples. Given that our sample sizes for each species were below 50, we utilized the Δ1 estimator as recommended (Meredith & Ridout 2023). The overlap coefficients were categorized into three levels: Δ < 0.50 as low overlap, 0.50-0.80 as moderate overlap, and Δ > 0.80 as high overlap (Tian et al., 2020; Koju et al., 2024). The formulas for calculating the overlap coefficients are provided below:

$$\Delta_1 = \frac{2\pi}{T}\sum_{i=1}^{T} \min\{\hat{f}(t_i), \hat{g}(t_i)\}$$

Where T is equally spaced times, between 0 and 2π,
The overlap coefficient (Δ) ranges from 0 (no overlap) to 1 (complete overlap), with lower values indicating temporal avoidance. We obtained 95% confidence intervals (CI) for Δ for each pairwise comparison using 1000 bootstrapped samples to ensure accuracy (Meredith & Ridout, 2023).

Results and Discussion

Mammal Diversity

A total of 1,266 videos and 1,266 photographs were collected during the study. Our field survey documented 17 mammal species (Table 1), seven of which were captured using camera traps. These included the Blue Bull (*Boselaphus tragocamelus*), Wild Boar (*Sus scrofa*), Jungle Cat (*Felis chaus*), Golden Jackal (*Canis aureus*), Indian Crested Porcupine (*Hystrix indica*), Indian Hare (*Lepus nigricollis*), and Indian Grey Mongoose (*Herpestes edwardsi*) (Fig 2). In addition to our findings, local residents reported sightings of the Large Indian Civet (*Viverra zibetha*), Spotted Deer (*Axis axis*), and Small Indian Civet (*Viverricula indica*) in the vicinity. Additionally, Rhesus Monkey (*Macaca mulatta)*, Terai Gray Langur (*Semnopithecus hector*), and House Rat (*Rattus rattus*) were also reported by the locals. The scat of Yellow-throated Marten (*Martes flavigula*) was also found. Among the recorded species, five are classified as nationally threatened, while three are recognized as globally threatened (see Table 1). Moreover, feral and domestic cattle as well as dogs were commonly recorded in camera traps as well as directly sighted in the region.

The Blue Bull (*Boselaphus tragocamelus*) and Golden Jackal (*Canis aureus)* were the most commonly recorded species, with relative abundance indices of 29.68% and 28.12%, respectively. Human activity exhibited the highest relative abundance at 46.87%. Other species, including Wild Boar (*Sus scrofa*), Jungle Cat (*Felis chaus*), and Indian Porcupine (*Hystrix indica*), were observed less frequently. Livestock accounted for a lower relative abundance of 4.68% (see Fig. 2; Table 2).

Despite documenting several species, including the Blue Bull and Jungle Cat, the diversity recorded was relatively low compared to the Lumbini Sacred Garden, which supports 26 mammal species and 39 herpetofaunal species (Bhuju et al., 2007). The relatively low number of recorded species can be attributed to the survey's limited duration, the small study area, flooding, and challenges associated with surveying in dense vegetation (Thomas et al., 2020; Porter & Dueser, 2024). Despite these obstacles, our findings indicate the presence of both common and threatened species within the LCS. The Golden Jackal (*Canis aureus*) was the most frequently observed species, suggesting its adaptation to the habitat and potential benefits from anthropogenic activities (Katuwal & Dahal, 2013; Rai, 2016; Tsunoda & Saito, 2020; Gonji et al., 2024). In contrast, the Indian Crested Porcupine (*Hystrix indica*) (Khan et al., 2000; Coppola et al., 2022) and the Jungle Cat (*Felis chaus*) were each recorded only once, possibly due to lower population densities or avoidance behaviors in response to human presence (Mishra et al., 2020; Ünal & Eryilmaz, 2020).

The presence of Blue Bull (*Boselaphus tragocamelus*) and the Jungle Cat underscores the conservation significance of the LCS (Suwal et al., 2002; Aryal et al., 2009). However, the area faces considerable anthropogenic pressures, including construction activities, road development, and livestock grazing, which could adversely affect habitat quality and mammal populations (Suwal et al., 2002; Nyaupane, 2009; Gosai et al., 2016). Additionally, reports from local residents regarding species such as the Large Indian Civet (*Viverra zibetha*) and Spotted Deer (*Axis axis*) highlight the necessity for more extensive and long-term monitoring efforts to comprehensively assess the region's mammal diversity.

Table 1. List of mammals in Lumbini Crane Sanctuary

S.N.	English Name	Scientific Name	Nepali Name	Conservation Status		Family	Sources
				National	Global		
1.	Blue Bull	*Boselaphus tragocamelus*	Nilgai	VU	LC	Bovidae	Camera Trapping and Direct Sighting
2.	Wild Boar	*Sus scrofa*	Bandel	LC	LC	Suidae	Camera Trapping and Direct Sighting
3.	Jungle Cat	*Felis chaus*	Ban Biralo	LC	LC	Felidae	Camera Trapping
4.	Golden Jackal	*Canis aureus*	Syal	LC	LC	Canidae	Camera Trapping and Direct Sighting
5.	Indian Crested Porcupine	*Hystrix indica*	Jure Dumsi	DD	LC	Hystricidae	Camera Trapping
6.	Indian Hare	*Lepus nigricollis*	Khairo Kharayo	LC	LC	Leporidae	Camera Trapping
7.	Indian Grey Mongoose	*Herpestes edwardsi*	Thulo Nyaurimusa	LC	LC	Herpestidae	Local people and scat (camera traps)
8.	Rhesus Macaque	*Macaca mulatta*	Rato badar	LC	LC	Cercopithecidae	Direct Sighting
9.	Terai Grey Langur	*Semnopithecus hector*	Kalomukhe Bandar	LC	NT	Cercopithecidae	Direct Sighting
10.	Spotted Deer	*Axis axis*	Chittal	VU	LC	Cervidae	Local people
11.	Five-striped Palm Squirrel	*Funambulus pennantii*	Pachdharke lokharke	LC	LC	Rodentia	Direct Sighting
12.	Yellow-throated Marten	*Martes flavigula*	Malsapra	LC	LC	Mustelidae	Local people
13.	Large Indian Civet	*Viverra zibetha*	Thulo Nir Biralo	NT	LC	Carnivora	Scat, local people
14.	Small Indian Civet	*Viverricula indica*	Sano Nir Biralo	LC	LC	Carnivora	Scat, local people
15.	Small Asian Mongoose	*Herpestes javanicus*	Sano Nyaurimusa	LC	LC	Herpestidae	Local people and Direct Sighting
16.	Hog deer	*Axis porcinus*	Laguna	EN	EN	Cervidae	Local People
17.	Fishing cat	*Prionailurus viverrinus*	Malaha Biralo, Pani Biralo	EN	VU	Felidae	Local People

List of mammals recorded in Lumbini Crane Sanctuary (LCS). Species were classified based on Bhuju, et al., 2007; Jnawali *et al.* 2011; Amin et al., 2018, where LC is Least Concern, NT is Near Threatened, VU is Vulnerable, EN is Endangered and CR is Critically Endangered

Diversity of Herpetofauna

We recorded 12 herpetofaunal species, comprising six snake species, two lizard species, and four amphibians (Tables 3 and Table 4). Local interviews revealed the presence of species such as the Burmese Python (*Python bivittatus*) and Golden Monitor Lizard (*Varanus flavescens*), underscoring the value of integrating local knowledge into biodiversity assessments (Shrestha, 2013; Paudel et al., 2023). However, reliance on interviews introduces uncertainty, as local reports may not always be reliable (Shrestha, 2013; Ghimire et al., 2014; Adhikari & Chhetry, 2017; Shrestha & Shah, 2017; Shrestha & Gurung, 2019). Adverse conditions, including rainfall and waterlogged terrain, likely led to an underestimation of herpetofaunal diversity. Future surveys conducted under more favorable conditions and over an extended duration are necessary to obtain a more comprehensive inventory of the herpetofauna in this area (Shrestha, 2013; Shrestha & Gurung, 2019; Nepali & Singh, 2020; Paudel et al., 2023).

https://doi.org/10.3126/njes.v12i2.71434

Figure 2. Mammals captured by camera traps at the Lumbini Crane Sanctuary (LCS): (A) Blue Bull, (B) Golden Jackal, (C) Jungle Cat, (D) Indian Crested Porcupine, (E) Indian Hare, (F) Indian Grey Mongoose. The images depict these species' activities within their natural habitats, highlighting their presence in the wetlands and forested areas of LCS.

Table 2: Photographic rate and relative abundance of mammals species and cattle recorded by camera traps in the study site (CT days, 64).

Scientific name	No. of Recorded CT locations	Events (total photographs) (80)	Relative abundance index	Percentage of records individual record/total
Boselaphus tragocamelus	4	19	29.68	23.75
Sus scrofa	2	4	6.25	5
Felis chaus	1	1	1.56	1.25
Canis aureus	3	18	28.12	22.5
Hystrix indica	1	1	1.56	1.25
Lepus nigricollis	1	2	3.12	2.5
Herpestes edwardsi	1	2	3.12	2.5
Human (Tourist)	2	30	46.87	37.5
Livestock	2	3	4.68	3.75

Mammal activity pattern and overlap

The results indicated distinct activity patterns among the Blue Bull, Golden Jackal, Indian Hare, Indian Grey Mongoose, and Wild Boar in relation to human and livestock activity. The animals with the highest overlap in activity patterns with humans were the Golden Jackal (Δ=0.33), Blue Bull (Δ=0.31), and Indian Gey Mongoose (Δ=0.28), with each species spending about one-third of their active time aligning with human activity. In contrast, the Indian Hare and wild boar had much lower overlaps with humans, at Δ=0.04 and Δ=0.06, respectively. The animals with the highest overlap in activity patterns with livestock were the Indian Grey Mongoose exhibited the highest overlap in activity patterns (Δ=0.63), followed by the Golden Jackal (Δ=0.29) and Wild Boar (Δ=0.19). The Blue Bull and Indian Hare showed the lowest overlap with livestock, both at Δ=0.10 (Table 5). Overall, these species exhibit distinct temporal activity patterns that likely facilitate the avoidance of competition and disturbances from humans and livestock. Significant alterations in activity were observed for the Indian Hare, Jungle Cat, and Wild Boar in response to human presence, suggesting a negative impact on their habitat utilization during peak human activity periods (Fig. 3; Table 5).

Table 3. List of Reptiles in Lumbini Crane Sanctuary (LCS)

SN	Scientific Name	English Name	Nepali Name	Family	IUCN	Source
1.	*Python bivittatus*	Burmese python	Ajingar	Pythonidae	NT	Interview
2.	*Ptyas mucosa*	Oriental Rat Snake	Dhaman	Colubridae	LC	Interview
3.	*Fowlea piscator*	Checkered keel/back water snake	Pani Sarpa	Colubridae	Common	Interview
4.	*Amphiesma stolatum*	Striped Keelback	Har hara	Colubridae	LC	Interview
5.	*Bungarus fasciatus*	Banded krait	Krait	Elapidae	LC	Interview
6.	*Bungarus caeruleus*	Common krait	Krait	Elapidae	LC	Interview
7.	*Varanus flavescens*	Yellow Monitor	Sun Gohoro	Varanidae	EN	Interview
8.	*Calotes versicolor*	Oriental Garden lizard	Baghaiche Chheparo	Agamidae	LC	Direct observation

Table 4. List of Amphibians in Lumbini Crane Sanctuary (LCS)

SN	Scientific Name	English Name	Nepali Name	Family	Conservation Status	Sources
1	*Duttaphrynus melanosticuts*	Asian Common Toad	Vyaguta , Paha	Bufonidae	LC	Direct observation
2	*Firouzophrynus stomaticus*	Marbled toad	Matangre Khasre Bhyaguto	Bufonidae	LC	Direct observation
3	*Euphlyctis cyanophlyctis*	Indian skipper frog	Sano Vyaguta	Dicroglossidae	LC	Direct observation
4	*Hoplobatrachus tigerinus*	Bull Frog, Golden Frog	Vyaguta	Dicroglossidae	LC	Direct observation

** List of Herpetofauna recorded in Lumbini Crane Sanctuary (LCS. Species were classified based on Bhuju et al., 2007; Rawat, et al., 2020; Nepali, & Singh,2018; Nepali, & Singh,2020; Rai, et al., 2022), where LC is Least Concern, NT is Near Threatened, VU is Vulnerable, EN is Endangered and CR is Critically Endangered

The Blue Bull (*Boselaphus tragocamelus*) shows consistent activity throughout the day, with a slight increase in the late afternoon. This pattern may reflect its natural grazing habits or ecological factors rather than a direct response to human or livestock disturbance (Gaudiano et al., 2021; Feng et al., 2021; Wiskirchen et al., 2022; Kumar et al., 2023). However, its timing might also suggest a degree of tolerance to human presence, allowing resource use during less crowded periods. The Golden Jackal, with its crepuscular activity peaking in the early morning and late evening, likely avoids peak human activity. This reduces conflict potential while aligning with its typical behavior across landscapes (Katuwal & Dahal, 2013; Schuette et al., 2013; Bulmer, 2015). However, there is still significant overlap between the Golden Jackal and human activity. Early morning overlap with livestock activity raises the risk of predation or scavenging, though further studies are needed to confirm if this is due to human avoidance or natural behavior (Yom-Tov et al., 1995). The Indian Hare is primarily nocturnal, peaking just before dawn, reducing interactions with humans and livestock while minimizing predation risks (Carricondo-Sanchez et al., 2019; Dahya et al., 2023). Similarly, the Indian Grey Mongoose (*Herpestes edwardsii*) shows early morning activity tapering off by mid-morning, potentially avoiding human presence, though this may align with its natural rhythms (Cronk & Pillay, 2019; Hussain et al., 2017; Shameer et al., 2022).

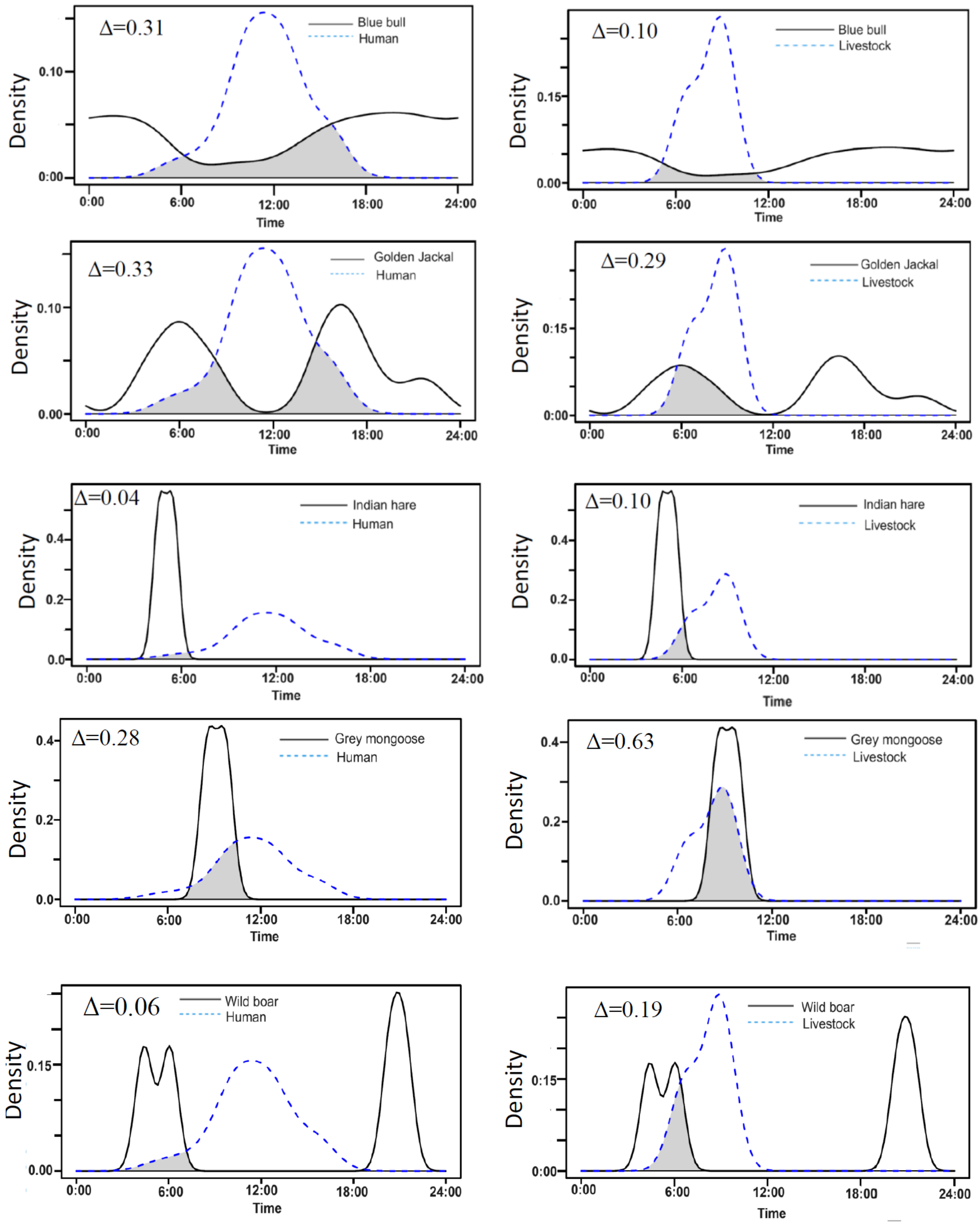

Figure 3. Temporal overlap between Blue Bull (a), Golden Jackal (b), Indian Hare (c), Indian Grey Mongoose (d), and Wild Boar (e) compared with human activity and cattle is depicted. The x-axis represents the time of day, while the y-axis shows activity measured by kernel density. The shaded area in each plot indicates the coefficient of overlap (Δ).

The Wild Boar (*Sus scrofa*) displays a bimodal activity pattern, peaking in the early morning and evening, likely a natural cycle rather than an adaptation to human presence (Johann et al., 2020; Rosalino et al., 2022; Li et al., 2022). Lastly, the Jungle Cat (*Felis chaus*) is primarily nocturnal, with activity around 19:59. This might indicate avoidance of humans and livestock, but more data is needed (Jiménez-Albarral et al., 2021; Blašković et al., 2022). These patterns suggest potential coexistence strategies with humans and livestock (Kumar et al., 2023; Johann et al., 2020; Lewis et al., 2021). Future research should explore how habitat type, resources, and human activity influence wildlife behavior (Wilson et al., 2020; Fehlmann et al., 2021).

Table 5. Coefficient of overlap (Dhat), and CI (95%) for temporal overlap between wildlife, human, and cattle based on Kernel Density Estimation (KDE).

Species pairs	Overlap coefficient (Δ)	Overlap level	(95% CI) Lower-Upper
Blue Bull– Human	0.31	Low	0.166 - 0.514
Blue Bull – Livestock	0.10	Low	0.008-0.331
Golden Jackal – Human	0.33	Low	0.210-0.561
Golden jackal – Livestock	0.29	Low	0.044 – 0.525
Indian hare – Human	0.04	Low	0.001 – 0.14
Indian hare - Livestock	0.10	Low	-0.005 – 0.43
Indian Grey Mongoose - Human	0.28	Low	0.098-0.549
Indian Grey Mongoose - Livestock	0.63	Moderate	0.043-0.859
Wild boar - Human	0.06	Low	0.000-0.193
Wild boar - Livestock	0.19	Low	-0.001-0.499

Conservation Implications

The documentation of diverse mammal species, including several threatened species highlight the ecological importance of Lumbini Crane Sanctuary (LCS) in supporting vulnerable wildlife population. However, challenges such as habitat encroachment, unregulated livestock grazing, tourism-related disturbances and pollution increase risks to the biodiversity of the LCS. Effective conservation measures must prioritize habitat restoration, sustainable tourism practices, and community engagement to ensure long-term sustainability. Long-term ecological monitoring and research are essential for informing evidence-based strategies that balance biodiversity conservation with human activities. Future research focusing on extended monitoring and ecological assessments will be essential for informing evidence-based conservation strategies that balance biodiversity conservation with human activities.

Conclusions

In conclusion, our field survey at the Lumbini Crane Sanctuary (LCS) yielded significant insights into the diversity of mammalian and herpetofaunal species. We documented 17 mammal species and 12 herpetofaunal species, including both common and threatened taxa. The presence of species such as the Jungle Cat and the threatened Blue Bull underscores the ecological significance of the sanctuary. However, anthropogenic pressures, including potential threats from construction activities and livestock grazing, may impact these populations, although further investigation is needed to assess their specific effects. Observations of the temporal activity patterns of species such as the Blue Bull and Golden Jackal suggest adaptive strategies for coexistence with human activities. To effectively address these challenges and promote sustainable wildlife conservation within the LCS, comprehensive long-term monitoring and robust management practices are imperative.

Acknowledgments: We would like to express our heartfelt gratitude to the World Wildlife Fund (WWF) Nepal, Lumbini Buddhist University (LBU), and the WWF-LBU Grant Agreement #NP11776 for their generous grant support. We would like to extend our special thanks to Mr Ukesh Raj Bhuju, Dean of the LBU School of Development Studies and Applied Sciences, and Mr Rajendra Nara Singh Suwal, director of WWF Nepal, for their key roles in expediting the project under the Grant Agreement #NP11776. We extend our thanks to the staff at Lumbini Crane Sanctuary and Lumbini Buddhist University for their ongoing assistance. Our sincere appreciation goes to Dr. Babu Ram Lamichhane for his expertise in animal identification, and to Yam Bahadur Rawat for his review of herpetofauna. We are also grateful to Kim McConkey for their insightful review and valuable feedback on the draft of this manuscript, which significantly contributed to its improvement. We sincerely thank Krishna Hengaju, Saraswati Thapa, Moona Adhikari, Kailash Jaishwal, Shankar Pandey and Amar Kunwar for their support to this study.

Author Contributions: BB: Conceptualization, methodology, visualization, project administration, writing, review, and editing; URB: Conceptualization, methodology, visualization, writing, review, editing, and funding acquisition; RNS: Conceptualization, methodology, visualization, writing, review, editing, and funding acquisition; BA: Conceptualization, methodology, visualization, investigation, data curation, analysis, writing original draft, review, and editing.

Conflict of Interest: The authors declare no conflict of interests.

Data Availability Statement: The data will be available from the corresponding author on reasonable request.

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