

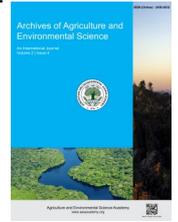


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ORIGINAL RESEARCH ARTICLE



Effectiveness of salt licking sites for wild animals in Bardia National Park, Nepal

Aliza Subedi^{1*} , Prakash Ojha², Umesh Poudel³ and Shailendra Kumar Yadav¹

¹Tribhuvan University, Institute of Forestry, Hetauda Campus, Hetauda, Nepal

²College of Forestry, Wildlife and Environment, Auburn University, Auburn, AL, US

³National Trust for Nature Conservation, Bardiya, Nepal

*Corresponding author's E-mail: aliza.subedi2110@gmail.com

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ABSTRACT

Salt licks are naturally occurring spots vital to numerous wildlife species worldwide. This study aimed to examine the use of natural salt licks by wild animals inside Bardia National Park (BNP), Nepal. Five camera traps were installed at five selected salt licks for a period of 18 days. A total 6 families and 10 species, were recorded at the salt lick sites were recorded during the investigation. The sites, Baghaura A and Baghaura C emerged as the most diverse salt licks in terms of species richness. The Shannon-Weiner diversity index was highest at Baghaura C, while the species evenness index was also highest there and lowest at Patthar Bandha South. The Simpson diversity index was highest in Patthar Bandha South and lowest at Baghaura B. Spotted deer, followed by rhino, were the most frequent visitors with the highest Capture Frequency (CF) and Relative Abundance Index (RAI). Carnivores and omnivores were least abundant. Temporal activity pattern was varied with species and habitat, with maximum activity during the day. The soil analysis also showed the highest pH and exchangeable sodium at Patthar Bandha South and the lowest at Baghaura A. Among the five identified threats, Habitat destruction and human interference were identified as the most severe threats. Disease transmission and poisoning ranked high and medium threats, respectively. Therefore, this study provides science-based evidence for the protection of salt lick sites for effective wildlife management in Bardia National Park, Nepal.

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INTRODUCTION

Mineral licks are naturally occurring spots that can be found all over the world and these tiny, spatially confined places, also referred to as salt licks, are vital to numerous wildlife species (Simpson *et al.*, 2020). Geophagy involves the process of licking to ingest saltlick minerals (Panichev *et al.*, 2013, 2017). Salt licks support a variety of animal species, especially herbivores, vital minerals for food digestion, assimilation, and other bodily metabolisms (Wahab *et al.*, 2020). Both temperate and tropical ecosystems have salt licks, which are unique landscape features where species with diets based on plant materials, mainly birds and mammals, exhibit geophagical activities (Blake *et al.*, 2010). Lack of salt is frequently cited as a major factor in the visitation

of natural licks (Holdø *et al.*, 2002; Powell *et al.*, 2009; Bravo *et al.*, 2012). Thus, herbivores need a different supply of the minerals (primarily sodium) that plants lack in order to survive, especially in tropical forests like those found in Nepal (Razali *et al.*, 2020). Though other substances like calcium and magnesium might also operate as driving forces (Ayotte *et al.*, 2006) when key cations are deficient in soils and consequently in plants (Emmons & Stark, 1979; Vitousek & Sanford, 1986).

Consumption of soil at natural licks is related to the users' dietary ecology and/or health. Many kinds of terrestrial mammals utilize natural salt licks continuously; however, in an inland tropical forest, the environmental factors can change how often mammals visit these sites (Mojjol & Lim, 2022). The existence of salt storage in plants that are consumed by wildlife may encour-

age the animal to consume a lot of soil at the lick (Ajayi & Halstead, 2018). During a considerable period of desiccation, water-soluble sodium salts are being leached out during heavy rain, which is the cause of the shortage. Some plants even absorb potassium ions instead of sodium ions from the soil without displaying signs of mineral inadequacy (Lameed & Adetola, 2012). The frequency and consumption of salt licks by wildlife imply nutritional deficits brought on by either an overpopulation problem, a deteriorating habitat, or both (Ajayi & Halstead, 2018). Analyses on how different animals use natural salt licks in various settings have been published from all over the world, and these studies highlight geophagy as a form of nutritional ecology (King et al., 2016). Several attempts to explain their importance in the ecology of the numerous species that inhabit them have been made (Subedi et al., 2022; Subedi & Bashyal, 2022).

Mineral licks are considered a significant microhabitat and are necessary to sustain, in general, a high herbivore richness (Devkota et al., 2025). Since licks may fluctuate in their physical and chemical qualities, and the species that visit a given lick may change over time and from one lick to another, it is vital to preserve several such sites in conserved regions (Blake et al., 2010). The preservation of significant locations like salt licks must be considered while managing wildlife and vital habitat places (Hon et al., 2020). The open setting of a mineral lick offers a good prospect of seeing huge creatures in their native habitats (Chew et al., 2014). As a result, mineral licks are recognized as animal hubs, and in recent years, salt-lick sightseeing has begun to take off on the worldwide wildlife tourism industry (Chong et al., 2005). Besides offering nutrients, the salt licks serve as gathering places for animals, promoting interpersonal interactions (Couturier & Barrette, 1988; Ruggiero & Fay, 1994). The primary causes of soil consumption at salt lick sites in the chosen BNP location remain unknown. Knowing the purpose of salt licks and how the environment influences the animals that use them is key for landscape-level conservation initiatives or localities where conservation is of immense importance, such as the BNP. This study analyzed the effectiveness of salt licking sites, including the use pattern of natural salt licks by wild animals, their biophysical components, and threats to them in Bardia National Park.

MATERIALS AND METHODS

Study area

The study was carried out in Bardia National Park (Figure 1) (BNP) (28°21'53.51" N and 81°33'34.71" E), which is the largest national park in the lowland Terai covering an area of 968 sq. km, as well as surrounded by a buffer zone of an area 327.00 sq. km (DNPWC, 2022). It is a part of the trans-boundary Terai Arc Landscape (Wikramanayake et al., 2004). The altitudinal elevation of the park ranges from 152 to 1564 m above the mean sea level (BNP, 2016). It covers an array of habitats, from early successional tall alluvial floodplain grassland to peak stage *shorea* forest on highlands. The Park is mostly covered by Chirpine woodland, hill Sal Forest, lower tropical Sal, and mixed broad-leaved forest. Sal (*Shorea robusta*) (Ojha et al., 2023) makes up about 70% of the forest cover of the park with a mixture of grassland and riverine forests. The park is a habitat for a total of 56 species of mammals, including five species of deer alone, 438 species of avifauna, 52 species of herpetofauna, and 121 species of fish (Figure 2) (BNP Management Plan, 2016-2020). It inhabits threatened wildlife species, including tigers (*Panthera tigris*), one-horned rhinoceros (*Rhinoceros unicornis*), and elephants (*Elephas maximus*) (BNP, 2016). In addition to the resident species, several migratory birds visit the park (DNPWC, 2022). The reptiles, gharial and python, belong to the same category. BNP has numerous salt lick sites in various locations.

Data collection

At the beginning, a reconnaissance survey was conducted with national park authorities, biologists, and indigenous communities (Molina et al., 2014; Joshi et al., 2022) to identify potential locations of salt lick sites within the study area. The geographic locations of the saltlick sites were recorded. Four CUDDLEBACK C1 and one CUDDLEBACK E1 camera traps were used and set up at a height of 60 cm from the ground to capture the photographs of animals visiting the salt lick sites. The camera traps were deployed for 18 camera trap days in 5 sites. All cameras were set to record two pictures per trigger event and were operational 24 hours/day. The trigger event was set at 3

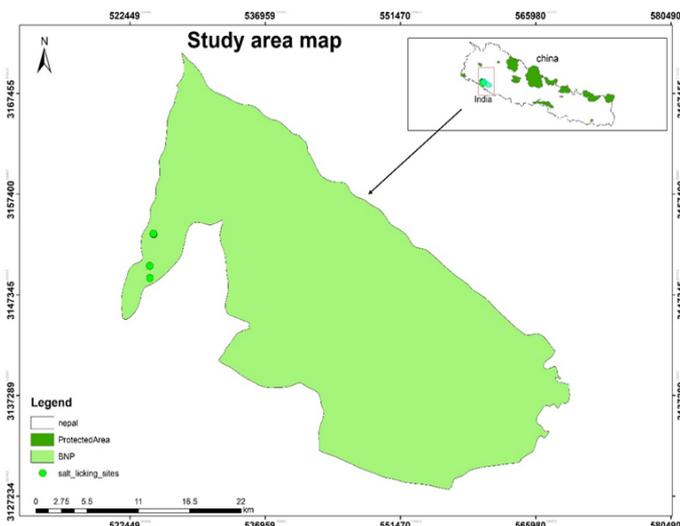


Figure 1. Map of study area.

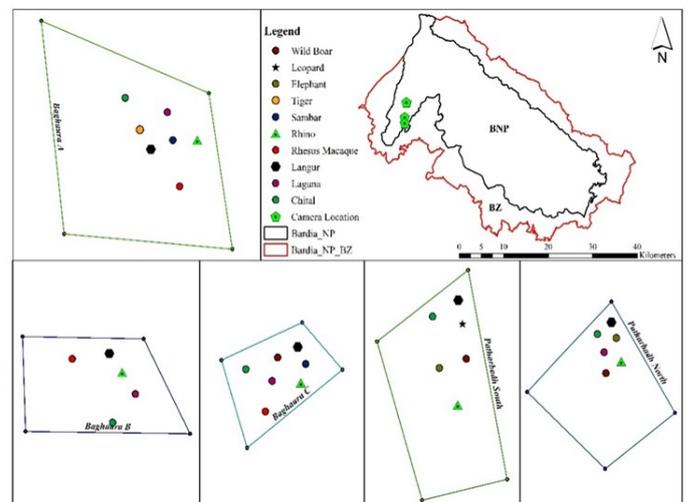


Figure 2. Distribution map of species at selected sites.

minutes. When two or more photographs of the same species were obtained within 30 minutes, only one was counted as an event visitation (Matsubayashi et al., 2007a; Thapa et al., 2013). In addition, four mineral samples were collected from each salt lick site. The soil samples were analyzed for pH, texture, and exchangeable sodium (ppm), and also analyzed for the identification of the amount of sand, silt, and clay. A total of 10 key informants (national park officials, NTNC officer, CFUGs, and BZCFUGs chairperson) surveys were done to identify the existing conservation threats to the salt lick sites.

Data analysis

Structural analysis of different salt licking sites was performed by calculating CTDs, CF, and RAI.

Total collection efforts/camera trap days (CTDs) refers to the total number of days that camera traps were operational in the field, given by:

$$CTD = \text{Number of camera used} \times \text{Number of days cameras were operational}$$

Capture Frequency (CF) refers to the number of times a specific species is captured or detected by the camera traps within a given time period (Jenks et al., 2011) given as:

$$CF = \frac{\text{Total number of photos of individual species}}{\text{Total collection efforts}}$$

Relative Abundance Index (RAI) is a measure used to estimate the population abundance of individual species within a given habitat. It provides a relative comparison of the abundance of different species, given as:

$$RAI = \frac{\text{Number of independent events of a species}}{\text{Total number of independent events of all species}} * 100$$

Animal species diversities

Species richness index (R) (Margalef, 1958)

$$R = \frac{S - 1}{\ln(N)}$$

Where R is the species richness index, S is the total number of species, N is the total number of individuals of all the species

Shannon-Weiner diversity index (Michael, 1984).

$$H = - \sum pi \times \ln(pi)$$

Where H is the Shannon-Weiner diversity index; pi is the number of individuals of one species/Total number of individuals in the sites.

Species evenness index (Pielou, 1966).

$$E = \frac{H}{\ln(S)}$$

Where E is the species evenness index, H is the Shannon-Weiner diversity index, S is the total number of species.

Simpson diversity index (Magurran, 1988).

$$D = \sum pi \times \ln(pi)$$

Where D is the Simpson index; Pi is the number of individuals of one species/Total number of individuals in the sites. As biodiversity increases, the Simpson index decreases (Rahman et al., 2011).

Conservation threats

The top five rated conservation threats were ranked following a method of relative threat ranking (WWF, 2007) by considering four classification criteria, i.e., scope, severity, urgency, and irreversibility (Table 1) suggested by Chhetri et al. (2020). These six significant threats were assigned a relative rank ranging from 6 to 1, where 6 implies very high with severe effects and 1 indicates very low with minor consequences. Later, the total values of scope, severity, urgency, and irreversibility were used to rank the threats under four scales: very high (18.1- ≤ 24); high (12.1- ≤ 18); medium (6.1- ≤ 12); low (≤ 6) (WWF, 2007; Koirala et al., 2020).

Table 1. Conservation threats criteria and their definitions.

Threat criterions	Definitions
Scope	The percentage of a target (area for ecosystems, population for species) that will presumably become threatened within ten years if the present situation and patterns continue.
Severity	Within the scope, the extent caused by the threat to the target can reasonably be expected in the next ten years if the present situation and patterns continue.
Urgency	The sense of emergency involved when taking measures to counter the threat and to avert the local extinction of the targeted population.
Irreversibility	The degree to which the effects of a threat can be undone and the target affected by the threat restored if the threat is stopped.

RESULTS AND DISCUSSION

Description of the distribution of wild species

A total of 10 animal species were discovered across all sites. Spotted deer, Laguna, Sambar, Indian grey langur, Rhesus, Tiger, Wild boar, Elephant, Common leopard, and Rhino are among the animals that have been captured on camera traps. Some species, however, were confined to a single location. Tigers and common leopard were only observed in Baghaura A and Patthar Bandha South, respectively. In every salt lick, spotted deer and langurs were observed. Laguna is also seen in almost all locations, with the notable exception of Patthar Bandha North (Table 2). According to Razali et al. (2022), feeding guilds were allocated to the wildlife that visited all five salt licks, with the HF type being the most prevalent (240 individuals, 7 species), followed by Carnivore (10 individuals, 2 species). Omnivores have occasionally been observed (3 individuals, 1 species). Numerous animals frequented all five mineral licks both during the day and at night, but there were distinct variations in the diurnal patterns of visitation among the various species. Many species of mammals, both herbivores and omnivores, use natural licks in lowland Nepal. Seven species that were observed at the salt licks appeared to practice geophagy. Spotted deer, Rhino, Indian grey langur, and Rhesus visited the sites frequently and/or for extended periods, suggesting the licks may be particularly significant to the ecology of these species. Spotted deer were the most captured species. This may be due to its highest abundance in BNP, as recorded by previous studies (Adhikari & Khadka, 2009; Ghimire et al., 2022). Soil investigations are needed to verify the precise benefit they are receiving. Some species were only occasionally captured on camera while simultaneously using the same salt lick spot. These occurred when rhesus monkeys joined a group of spotted deer at the same site, a laguna with a group of spotted deer.

Wild animal species composition and capture frequency

The five cameras gave a total sampling effort of 90 Camera trap days with independent events in 18 days. Wild animals, consisting of 6 families and 10 species, were recorded at the salt lick sites. Herbivores, including a few omnivores and carnivores, were found frequently visiting the salt lick sites. Cervidae (79.41%, n=7147) was the most dominant family, followed by Rhinocerotidae (2.19%, n=197), and Ceropithecidae (2.01%, n=181). The CF of Felidae is (0.10%, n=9). Elephantidae (0.09%, n=8) and Suidae (0.09%, n=8) were the least encountered species at the lick sites. Among all species captured at these salt licks, the CF of spotted deer is highest, followed by Rhino and

Indian grey langur. The CF of Rhesus is 0.80, while the captured frequency of Sambar is also good to some extent, which is 0.28. Laguna was also sighted in some salt licks with CF (0.12). Wild boar and elephant CF (0.09) seem to be similar. Common leopard followed by tiger were the least encountered species in the salt licks with CF 0.07 and 0.03, respectively (Figure 3 and 4). The majority of the non-salt lick animals observed at the natural salt licks and the area around them belonged to the carnivore and omnivore categories. According to Matsubayashi et al. (2007b), unlike herbivores and frugivores, carnivorous and omnivorous animals get all of the sodium they need directly from their prey, suggesting that these predators rely on salt licks to catch prey that rely on the natural licks. Carnivores are known to use lick areas for hunting, although there is little evidence of them actively seeking them out (Denton, 1982). The sparse plant cover can assist carnivores in hunting for prey by providing excellent visibility and effortless movement, as observed in leopard cats (Rajaratnam et al., 2007) at the Patthar Bandha South location.

Relative abundance index

Among the species captured at the lick sites, Spotted deer was the most abundant species (RAI = 82.83), followed by Rhino (RAI = 7.66). The Indian grey langur and Rhesus abundance rate seems to be similar (RAI = 3.25). Likewise, Sambar (RAI = 0.81) and Laguna (RAI = 0.81) were spotted to the same extent in those sites. Among all species, Elephant, Rhino, Tiger, and Common leopard, with similar abundance (RAI = 0.35), were the least encountered species (Figure 5).

Temporal distribution of mammal species across the saltlicks

The temporal activity pattern was determined based on the time of visit of different species. The time period was classified into three categories as morning (3:00 am-11:00 am), day (11:00 am-19:00 pm), and night (19:00 pm-3:00 am) (Figure 6). Herbivorous mammals visited saltlicks mostly during the day, remaining diurnal. Among herbivores, spotted deer were seen mostly in the daytime, followed by the Indian grey langur and rhesus. Laguna was mainly spotted in the daytime, while sambar was seen mostly in the morning. A wild boar was observed visiting the site during the morning hours, while an elephant exhibited nocturnal activity as captured by the camera trap. Tigers have shown their activeness in the morning, though it is a less sighted species in salt-licking sites, while the common leopard is active in daytime. Rhinos were captured mostly at night time remaining nocturnal, while to some extent it is also captured in the morning and daytime. Spotted deer and Laguna were seen active in daytime

Table 2. Description of salt lick sites.

S. No.	Site	GPS		Dimensions (m)			Camera used	Habitat
		X	Y	Length	Width	Height		
1	Baghaura A	525014	3153372	10	8	0.6	CUDDLEBACK C1	<i>Shorea robusta</i> mixed forest
2	Baghaura B	524977	3153391	12	15	0.75	CUDDLEBACK C1	<i>Shorea robusta</i> mixed forest
3	Baghaura C	524980	3153428	8	6	0.75	CUDDLEBACK C1	<i>Shorea robusta</i> mixed forest
4	Patthar Bandha North	524593	3150260	5	4	0.5	CUDDLEBACK E2	<i>Shorea robusta</i> mixed forest
5	Patthar Bandha South	524591	3148998	4	4	1	CUDDLEBACK C1	<i>Shorea robusta</i> mixed forest

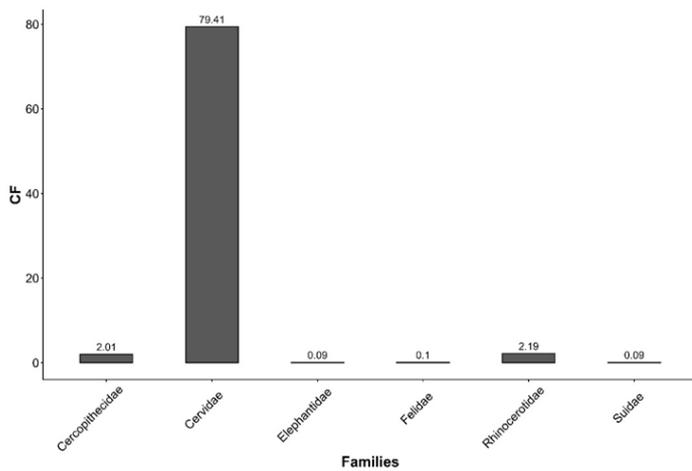


Figure 3. CF of different families.

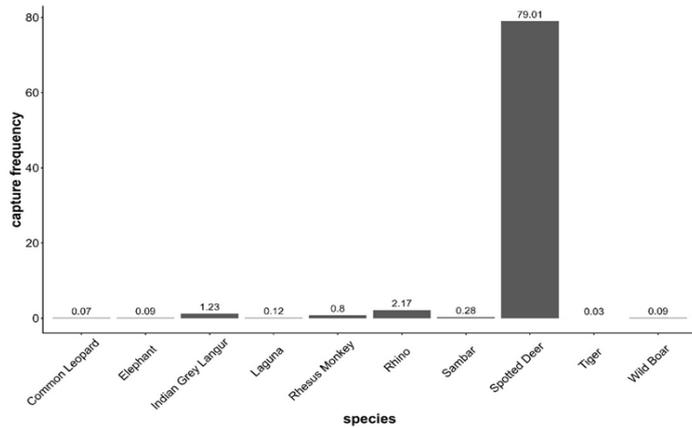


Figure 4. CF of different species.

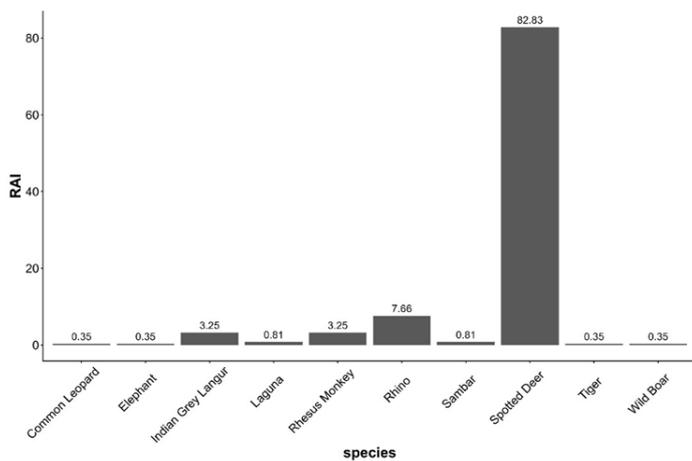


Figure 5. RAI of different species.

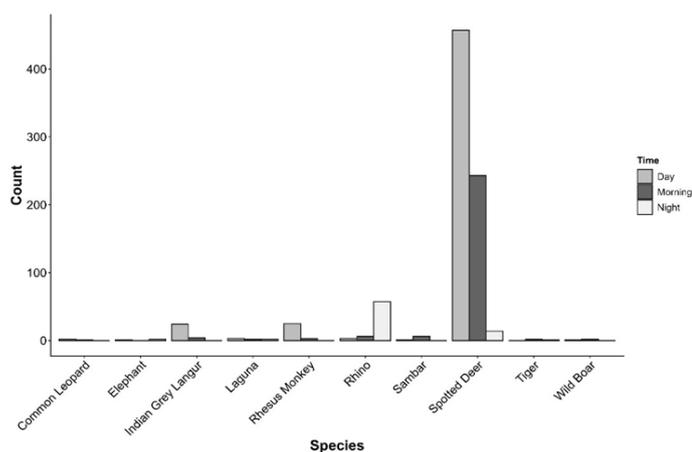


Figure 6. Count of species in different durations of a day.

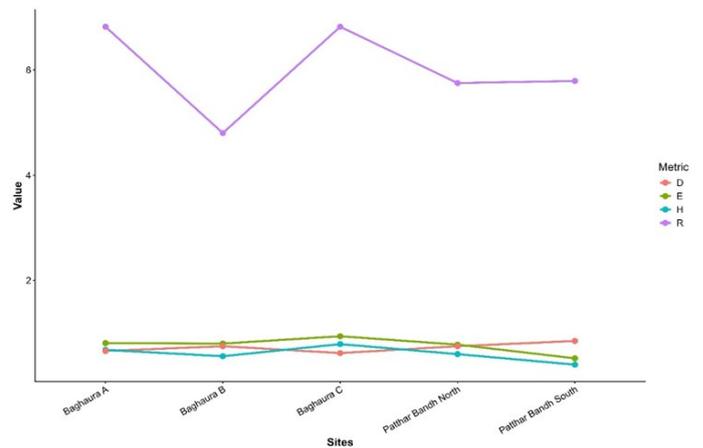


Figure 7. Different biological indices in selected saltlicks. Notes: H - Shannon-Winner diversity index, R - Species richness index, E - Species evenness index, D - Simpson diversity index.

when there is less movement of carnivores, specifically the Tiger, which suggests that they have less chance of being attacked in the daytime, but the common leopard is seen mostly active in daytime (Nakabayashi et al., 2021). However, Sambar is recorded as most active in the morning and has a higher risk of being attacked by a Tiger. Mostly herbivores were seen active in all salt lick locations; no data on carnivores attacking herbivores were recorded in the camera trap throughout the camera trap days. The study of Kohl et al. (2018) also supports high movement of prey species in bright hours. Predators' activity increased at dark hours, supporting their nocturnal nature as suggested by (Marinho et al., 2018; Steinmetz et al., 2013).

According to species-typical grouping behaviors, mammals preferred to visit the salt licks in either solitary or group settings, suggesting that the licks did not serve as places for gathering or mating (Morales, 2009). Rhesus and Indian Grey Langur were also captured in a herd most of the time. Link et al. (2011) observed that while visiting salt lick sites, these monkeys formed larger groups than usual because they believed the licks to be places with a high danger of predation, and larger groups offered some protection against this. The primates generally visited the location during the day, although observations of them at the same time were not common. In order to avoid a direct rival for the resource, this could be considered one aspect of niche separation (Rawson & Bach, 2011). Elephants and Rhinos are both large herbivorous mammals that inhabit various habitats, including areas with salt licks. Elephants were observed in small herds, sometimes with a small baby, while Rhinos were seen in herds with a baby as well as solitary individuals in the vicinity of salt licks. Razali et al. (2022) demonstrated that groups of young animals and reproductive females frequent salt licks more frequently, illustrating the significance of salt licks for enhancing the nutrition of their young. One interesting behavior captured in the images was that these mega herbivores spent a significant amount of time playing with mud. They would throw mud all over their bodies, and this behavior serves a specific purpose, which is to help regulate their body temperature. As the mud dries, it creates a barrier that helps to repel insects, protecting the animals from annoying bites and potential diseases. Mud also provides some relief from skin irritations or abrasions that

may occur during their daily activities. Ruggiero (1990) suggested that the area around licks is where Elephants spend a lot of time sleeping or feeding. Research has primarily concentrated on how mammals use salt licks since they are more recognizable from other animals due to their larger body size, willingness to use these resources, regular movement patterns, and a number of verified assumptions, such as mineral supplementation. In addition, certain birds rely on salt licks. In one of the identified saltlicks during this study, Peacocks were also captured. The complicated courtship rituals and social interactions of peacocks are well-known. These areas may serve as meeting places for prospective partners or as areas where dominance and social hierarchies emerge. Smaller animals or insects in seeking vital minerals may also be driven to salt licks. Despite their omnivorous nature, peacocks may visit salt licks to feed on these drawn-in species.

Animal species diversities

The Shannon diversity index and Species evenness index of wildlife at Baghaura C were higher, with 0.79 compared to other salt licks, while the Simpson diversity index (0.62) is lowest in that site. Similarly, Baghaura A and Baghaura C have the highest species richness index, while Baghaura B has the lowest species richness index among the other sites. Among the five sites, Patthar bandha south has the highest Simpson diversity index but the lowest Species evenness index and Shannon diversity index (Figure 7). The Agricultural Technology Center (ATC), Lalitpur, Nepal, classified the soil manually and discovered that it may be split into three classes: loam, sandy loam, and clay loam. The greatest pH among the five sites is achieved at Patthar Bandha South, which is 9.5, followed by Baghaura 3 at 8.7. Patthar bandha North has a pH of 8.5. The pH level is lowest in Baghaura 2 and Baghaura 1, which are 7.5 and 6.2, respectively. Ex. Na is highest at Patthar bandha South (331ppm), followed by Baghaura 3 (303ppm). The amount of Ex.na at Baghaura 2 is 239ppm. Patthar bandha south, followed by Baghaura 1, has the lowest Ex. Na, which is 119ppm and 92 ppm, respectively (Table 3).

Major threats to the salt-licking sites

This study ranked habitat destruction and human interference as the most severe threats to salt-licking sites (Table 4). Similarly, poisoning and disease transmission were classified as medium and high threats, respectively. In contrast, predation and competition were classified as low level threats. Key informants were questioned about the existing salt licks inside the parks. Most of them were unaware of those sites, as there is not much more research performed on this topic in BNP, and there is not much evidence to clarify it before. According to the respondents, the existing salt-licking sites impose some of the threats, among which human interference and site depression seem to harm the site. A few NTNC employees claim that there was a scenario where a few hunting parties placed poison near the salt licks with the intention of killing wild animals. According to them, spotted deer and other wild animals appeared dead, but there was insufficient proof to draw any further conclusions. It is impossible to pinpoint precisely what occurred at that time. There is a greater threat to herbivores as carnivores can use those sites as a site of predation and competition. Salt licks seem to be one of the favourable locations for wildlife due to their significance. It provides mineral supplementation and nutritional diversity. It may be sometimes mating sites for wild animals due to their aggregation in those sites. Camera traps placed at salt licks have captured images of not only wildlife, but also humans, primarily nature guides and tourists. It is possible that these individuals unknowingly passed through these areas or had limited knowledge about salt licks. They may have visited these locations with the intention of observing wildlife in their natural habitat for sightseeing purposes. Eight out of the ten identified species documented at these sites have been classified by the IUCN as Near Threatened, Vulnerable, or Endangered; thus, these resources must be effectively maintained to save users from snares, human hunting, and habitat loss. The frequent consumption of salt licks in this spot and other places, which readily shows their value to the wildlife communities, highlights the necessity to give conservation areas top priority by utilizing the complementarities of lick sites (Burger & Gochfeld, 2003; Cabrera, 2012).

Table 3. Soil properties at salt lick sites in Bardia National Park, Nepal.

S. No.	Site	pH	Sand%	Slit%	Clay%	Soil Texture	Ex. Na ppm
1	Baghaura A	6.2	46.0	40.7	13.3	L	92.00
2	Baghaura B	7.5	54.0	35.7	10.3	SL	239.20
3	Baghaura C	8.7	56.0	31.7	12.3	SL	303.60
4	Patthar bandha North	8.5	32.0	51.7	16.3	SL	119.60
5	Patthar bandha South	9.5	35.0	32.7	32.3	CL	331.20

Table 4. Relative ranking of the most severe threats recorded from the direct field survey and the key informant interview.

Major threats	Scope	Severity	Urgency	Irreversibility	Total	Threat classification
Habitat destruction	6	5	6	6	23	Very high
Human interference	5	6	4	5	20	Very high
Poisoning	3	3	3	3	12	Medium
Disease transmission	4	4	5	4	17	High
Predation and competition	1	1	2	2	6	Low

Conclusion

Natural salt licks are an important habitat that needs various conservation efforts. Diverse mammals with various trophic levels or feeding preferences frequented these salt licks. Herbivore mammals were most common (n=853). Non-herbivore mammals (n=9) like the Tiger, Common leopard, and Wild boar were also recorded in licking sites. Ten species were observed in five salt-licking sites. Baghaura A and Baghaura C were found to be the most diverse sites with seven species. Our study found that the abundance of spotted deer is highest in BNP. Eight out of the ten identified species documented at these sites have been classified by the IUCN as Near Threatened, Vulnerable, or Endangered. Habitat destruction and human interference were identified as the most severe threats. Disease transmission and poisoning ranked high and medium threats, respectively. To former NTNC staff, there was an incident of poisoning of the salt lick by some hunters, as a result of which some spotted deer were found dead. Isolated salt licks should be preserved to prevent species decline and vegetation loss. Active and passive salt licks must be identified, and further study should be done to determine why those sites were abundant. The park authority can provide funding for scientific studies on salt licks and the ecosystems that inhabit them. Insights from research may drive strategies for management and enhance understanding of these special locations.

DECLARATIONS

Author contribution statement: Conceptualization: A.S and S.K.Y.; Methodology: A.S., P.O., U.P.; Software and validation: A.S, P.O., and S.K.Y.; Formal analysis and investigation: A.S., P.O.; Data curation: A.S., P.O.; Writing—original draft preparation: A.S., P.O.; Writing—review and editing: S.K.Y., U.P.; Supervision: S.K.Y.; All authors have read and agreed to the published version of the manuscript.

Conflicts of interest: The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Ethics approval: This study was conducted by following the ethical guidelines on survey studies of the institute and Bardia National Park, Nepal.

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Data availability: The data that support the findings of this study are available on request from the corresponding author.

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