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Mineral Composition and Behaviour of Mammals at Natural Saltlicks in Jomotsangkha Wildlife Sanctuary, Bhutan

Jigme Thinley[1,*], Ugyen Dorji[2], Ugyen Tshering[1], Arjun Nepal[3], Lekey Chaida[1], Chaten[1], Kiran Rai[1], Sonam Tobgay[1], Bep Tshering[1], Tshering Dorji[1], Pema Thinley[1], Tenzin Rabgay[1], Pema Yondrup[4] and Yeshey Wangchuk[2]

Abstract

Natural saltlicks are used by mammal species mainly to supplement mineral deficiency playing critical role in animal ecology. There is information gap on the use of natural saltlicks by mammals in Bhutan. Nine natural saltlicks from Jomotsangkha Wildlife Sanctuary were purposively selected to fill this gap of information. The study aimed to assess mineral composition and ecological behaviour of mammals at natural saltlicks. Nine composite soil samples were randomly collected and nine camera traps were set up at nine saltlicks for a duration of 56 days from 2 January to 28 February, 2019. Data management and analysis were carried out using *camerabase* and *R* software. Potassium, phosphorus and sodium elements were found in the saltlicks. Camera traps yielded 419 independent events of 12 species under 10 families. Herbivores were most common (n = 390) and non-herbivores the least (n = 12). Wild dog was also captured licking salts (n = 1) which is least reported across the world. Mineral composition (r = 0.70, $p < .05$) and anthropogenic activities (r = 0.60, $p < .05$) were key factors affecting the visitation rate and ecological behaviour of mammal species. Disturbed saltlicks from Samdrupcholing Range revealed fewer individuals of mammals (n = 71) with disturbed ecological behaviour while undisturbed saltlicks from Jomotsangkha Range revealed higher individuals of mammals (n = 340) with undisturbed ecological behaviour. Therefore, anthropogenic activities at disturbed saltlicks call for planned monitoring.

Keywords: camera-trap, ecological behaviour, mammals, minerals, natural saltlicks

Introduction

Saltlick or mineral lick refers to a mineral rich site actively used by lower trophic mammal species for consuming minerals, through licking (Rea *et al.*, 2013). This activity of licking for ingesting minerals from saltlick is termed as geophagy (Panichev *et al.*, 2013). It is common among frugivores and herbivores otherwise called game species under family of ungulates, primates, rodents and birds (Voigt *et al.*, 2008; Baptista *et al.*, 2013).

Game species depend on plants to derive every nutrient

[1]Department of Forest and Park Services, Ministry of Agriculture and Forests
[2]Department of Forest Science, College of Natural Resources, Lobesa
[3]Mountain Hazelnut Ventures Private Limited, Lingmithang, Mongar
[4]Ministry of Education, Royal Government of Bhutan
[*]Corresponding author: jthinley@moaf.gov.bt
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element except sodium (Krishnamani and Mahaney, 2000; Bravo *et al*., 2012). Saltlicks play critical role in supplementing sodium deficiency in game species (Montenegro, 2004). Keystone predators survive on game species (King *et al*., 2016). Therefore, saltlicks are building blocks for healthy ecosystem in animal kingdom (Molina *et al.*, 2014).

Game species visit saltlicks at any time remaining cathemeral in natural state (Blake *et al*., 2013). These species are disturbed by human activities affecting their ecological behaviours (Tobler *et al*., 2009). Game species divide their time and space to avoid threats (Hon and Shabita, 2013; Alvarez *et al*., 2014). Hardin's (1960) principle of competitive exclusion holds truth for non-overlapping of animals with threats while using food and resources.

Bhutan is home to more than 200 mammal species (Wangchuk *et al*., 2004). Distribution for most of these species have been studied (Ahmed *et al*., 2017). Ecological behaviour of these species at different environments and habitats including that of natural saltlicks has however remained least studied in Bhutan (Dorji *et al*., 2012).

Jomotsangkha Wildlife Sanctuary (JWS), the second smallest among 10 national parks and sanctuaries in Bhutan is being selected for filling up the gap of study. The Sanctuary is reported to be rich in floral and faunal species (Ahmed *et al*., 2017). It is also reported to have few patches of natural saltlicks at its southern parts used by mammal species (JWS, 2018). There is limited study on mineral composition and ecological behaviour of mammal species at natural saltlicks of the Sanctuary. Current study shall thus assess mineral composition of natural saltlicks and determine diversity and activity pattern of mammals at natural saltlicks.

Materials and Methods

Study area

The study was carried out in JWS. It is second smallest protected areas in Bhutan with area of

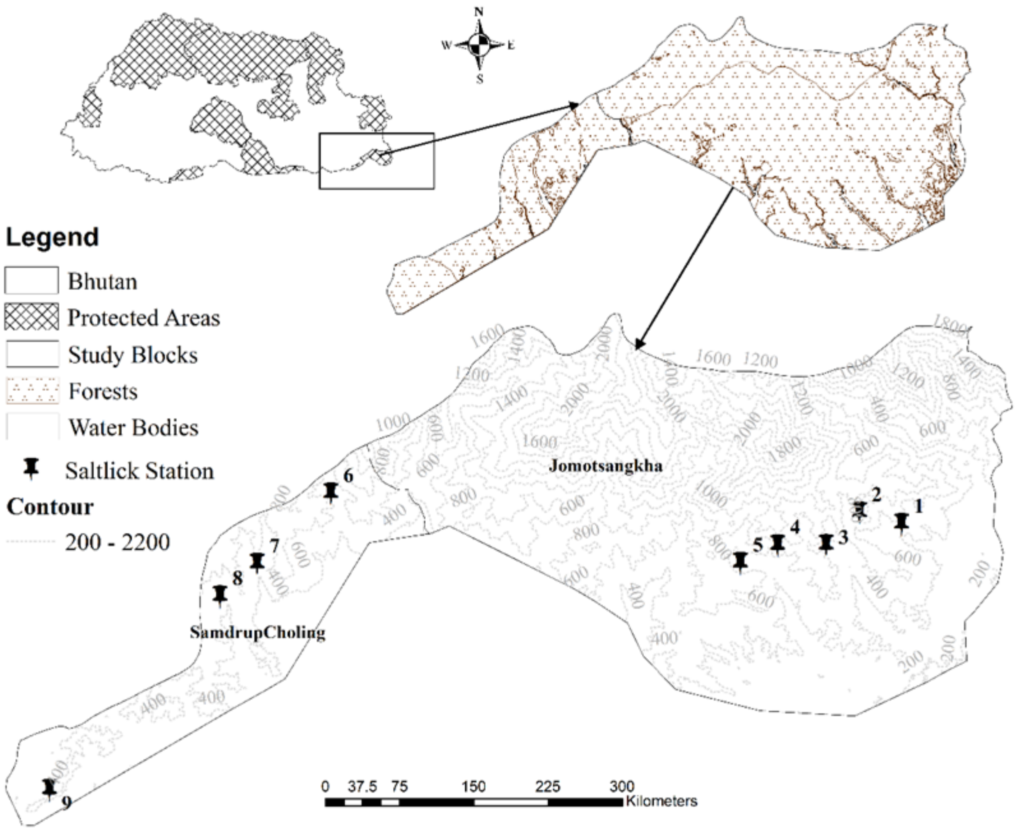


Figure 1: Saltlick stations in Jomotsangkha Wildlife Sanctuary

Table 1: Survey information

Lick ID	Station Name	Lat. (N)	Lon. (E)	Elevation (m)	Habitat
SL_1	Damtsang 1	26.55	92.41	451	Dry
SL_2	Damtsang 2	26.55	92.42	448	Dry
SL_3	Laishingri	26.54	92.24	524	Wet
SL_4	Nathucamp	26.54	92.24	493	Dry
SL_5	Rongchuthang	26.54	92.03	540	Wet
SL_6	Kalanadi	26.55	91.5	489	Wet
SL_7	Boteykhola	26.54	91.48	444	Dry
SL_8	Andari	26.53	91.47	457	Dry
SL_9	Orongri	26.52	91.39	768	Dry

Note: Start date: 02-01-2019, End date: 28-02-2019, Camera days: 56, Total: 504

362.49 km^2 (JWS, 2018). It lies at latitude of 26°48’ to 26°60’ E and longitude of 91°42’ to 92°08’ N, and its elevation ranges from 178 to 2228 meter above sea level connecting with Royal Manas National Park through biological corridor number 5 (JWS, 2018). It has two Ranges (blocks) (Jomotsangkha and Samdrupcholing) (Figure 1).

The Sanctuary is an important part of Himalayan subtropical broadleaved forest ecosystem forming an important element in the Himalayan eco-region and Indo-Malayan realm (Lham *et al.*, 2019). It forms a part of TraMCA (Transboundary Manas Conservation Area) area (Rajaratnam and Sangay, 2016). Therefore, this Sanctuary has rich floral and faunal diversities (JWS, 2018). It is home to many critically endangered species including Royal Bengal tiger (*Panthera tigris tigris* L.), Asian elephant (*Elephas maximus* L.), pigmy hog (*Porcula salvania* Hod.) and hispid hare (*Caprolagus hispidus* Pear.) (Dorji *et al.*, 2012). It has mean annual temperature of 23.8 °C and precipitation of 2,749 mm (JWS, 2018).

The Sanctuary is reported to have few patches of saltlicks at its southern parts used by mammal species (JWS, 2018). There is limited documentation on mineral composition and the ecological behaviours of mammals at natural saltlicks of the Sanctuary.

Research design for camera trap survey

A total of nine natural saltlicks were identified (JWS, 2018) from Jomotsangkha and Samdrupcholing Ranges, elevation varying from 444 to 768 m (Table 1). Five saltlick stations were identified in Jomotsangkha Range (SL_1 to SL_5) and four in Samdrupcholing Range (SL_6 to SL_9). Nine camera traps (*Cuddeback IR* and *Panthera*, USA) were set up at these saltlick stations. Each camera trap was set up at a height of approximately 80 cm above the ground with a spacing of 2 to 3 m away from the saltlick (Link *et al.*, 2011; Lameed and Adetola, 2012). To avoid damages on camera traps from wildlife, camera traps

Table 2: Composition and concentration (mg/kg) of minerals in saltlicks

Station ID	Station name	pH	Phosphorous (P)	Potassium (K)	Sodium (Na)
SL_1	Damtsang 1	8.95	0.81	1.07	2.22
SL_2	Damtsang 2	8.91	1.97	0.07	3.16
SL_3	Laishingri	9.05	0.29	0.33	1.73
SL_4	Nathucamp	7.18	1.86	0.08	2.08
SL_5	Rongchuthang	9.18	1.29	0.24	2.68
SL_6	Kalanadi	6.8	1.8	0.22	1.22
SL_7	Botey Khola	5.55	2.4	0.19	1.03
SL_8	Andari	9.52	1.03	0.78	4.11
SL_9	Orongri	9.37	7.88	0.69	1.83

were covered with dried leaves, wooden chips and elephant dung. Coordinates of each camera trap were collected. Sampling effort was 56 days/station or 504 days (Table 1) for 9 stations (2 January to 28 February, 2019).

Data collection

Camera stations were visited every two weeks for downloading animal image data and replacing batteries. Four mineral samples were randomly collected from every saltlicks amounting to 36 samples in total (Molineux *et al.*, 2014). The four samples from each saltlick were mixed to make one composite sample producing nine samples in total. These samples were dried for a week, crushed with hammer and sieved to remove rock and debris. Each composite sample was weighed to make a sample of 20 gram/sample. Samples were sent to National Soil Service Centre (NSSC) for analysing nutrient content.

Data management and analysis

Camera trap images were archived using *camerabase* for sorting by species, hour and date (Tobler *et al.*¸ 2009). Time interval of one hour was used to treat image as an independent event (IE) (Hon and Shabita, 2013). Independent events were pooled for analysis. Analyses were done using *R* software (Team, 2013).

Species were classified into family and species to determine species diversity (Wangchuk *et al*., 2004). Capture frequency (CF) was calculated by dividing IE by sampling effort (expressed for 100 days) (Hon and Shabita, 2013). Species diversity and CF were used for assessing spatial activity pattern of mammal species (King *et al*., 2016).

Temporal activity pattern was determined based on time of visit of mammal species using package 'activity' (Rowcliffe *et al*., 2014) and 'overlap' (Meredith and Ridout, 2014) of *R* programme. Diurnal activity occurred between 0701 and 1700 hrs, nocturnal between 1901 and 0500 hrs and crepuscular between 0501 to 0700 hrs and 1701 to 1900 hrs. Morales' (2009) criteria were used for classification of species requiring >70% of camera trap images.

Mineral composition of the saltlicks was analysed at the laboratory of NSSC, Bhutan. pH, potassium (K), phosphorus (P), aluminium (Al), calcium (Ca) and sodium (Na) were accordingly determined. pH was measured using pH meter (Colla *et al*., 2006). P was analysed using Bray method (Gilbert *et al*., 2009). Al, Ca, K and Na were analysed using ammonium acetate (NH_4OAc) solution method (Yang and Post, 2011).

Results and Discussion

Mineral composition of saltlicks

Exchangeable bases (Na, P and K) were present in mineral samples (Table 2). Na was the principal element shown by one sample *t*-test ($t_{(8)} = 6.9$, $p < .001$, mean = 2.2, *SD* [standard deviation] = 0.9) followed by K ($t_{(8)} = 3.4$, $p < .01$, mean = 0.4, $SD = 0.3$), P ($t_{(8)} = 2.9$, $p < .05$, mean = 2.14, $SD = 2.4$). Na positively correlated with pH ($r = .68$, $p > .05$) indicating an increase in sodium with increase in pH.

Composition and diversity of mammals across the saltlicks

Nine camera trap stations with sampling effort of 504 days recorded 2,559 photographs making up 419 independent events (IE) of mammal species. The records consisted of 10 families and 12 species. Bovidae, Cervidae, Cercopithecoidea and Elephantidae under herbivore food habit were most common at the saltlicks (n = 2,538, IE = 399, 99.2%) (Table 3).

Sambar deer was most common species at the saltlicks (n = 296, 70.5%) followed by Asian elephant (n = 38, 9.07%), gaur (n = 37, 8.83%) and barking deer (n = 22, 5.25%). Carnivore (common leopard, clouded leopard and wild dog) and omnivore (Indian grey mongoose, Himalayan black bear and wild pig) were least common (n = 12; 2%). Observed significant difference in mean for independent events of mammal species under different feeding habits ($\chi^2_{(1)} = 10.95$, $p < .05$) indicated higher preference of saltlicks by herbivores.

Table 3: Generic information for mammal species from the saltlick stations

Family	Common Name	Zoological Name	Independent Event (IE)
Herbivore			
Cervidae	Barking Deer	*Muntiacus muntjac* (Zimermann, 1780)	22
Bovidae	Gaur	*Bos gaurus* (Smith, 1827)	37
Bovidae	Himalayan Serow	*Capricornis thar* (Hodgson, 1831)	4
Cervidae	Sambar	*Rusa unicolor* (Kerr, 1792)	296
Cercopithecoidea	Capped Langur	*Trachypithecus pileatus* (Blyth, 1843)	2
Elephantidae	Asian Elephant	*Elephas maximus* L., 1758	38
Total no. of herbivores			**399**
Omnivore			
Suidae	Wild Pig	*Sus sucrofa* L., 1758	2
Ursidae	Himalayan Black Bear	*Ursus thibetanus* G. (Baron)	1
Herpestidae	Indian Grey Mongoose	*Herpestes edwardsii* (E. Geoffroy Saint-Hilaire, 1818)	3
Carnivore			
Canidae	Wild Dog	*Cuon alpinus* (Pallas, 1811)	3
Felidae	Common Leopard	*Panthera pardus* (L., 1758)	2
Felidae	Clouded Leopard	*Neofelis nebulosa* (Griffith, 1821)	1
Total no. of non-herbivores			**12**
Total no. of herbivores and non-herbivores			**411**

Benjamin (2007) and Kibra *et al.* (2018) found herbivores licking salts to buffer the effect of plant's toxin but not much has been reported for non-herbivores such as the wild dog (Figure 2).

Figure 2: Wild dog licking mineral salts

Spatial activity pattern of mammal species across the saltlicks

Saltlicks from Jomotsangkha (SL_1 to 3) recorded the highest number of mammals (n = 329, 80.4%) making the saltlicks hotspots for mammals (Figure 3) and Samdrupcholing the least (n = 71, 19.6%). Stations (SL_1, 2 and 8) from lower elevations (448 to 457 m) recorded the highest captures (n = 361, 87.8%) and higher elevation (768 m) the

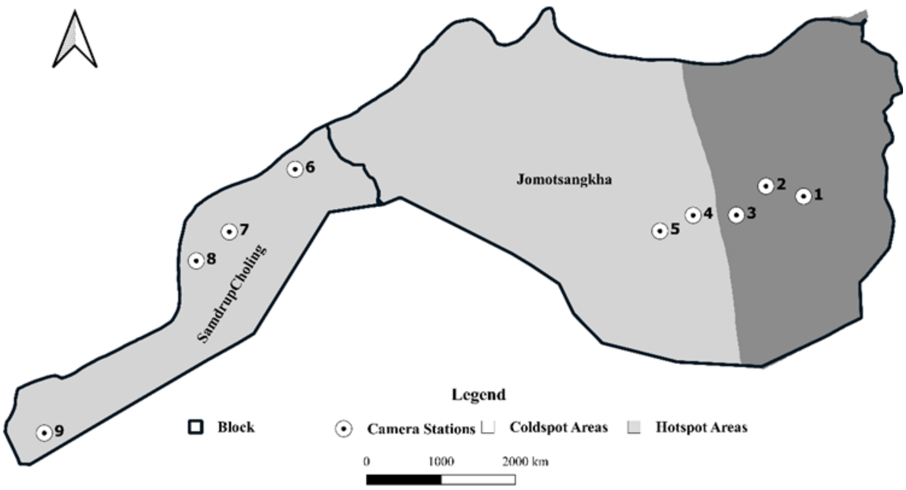


Figure 3: Hotspot map for mammal species visiting saltlicks in JWS

least (n = 1, 1%, CF = 0.1 captures). Station 1 (451 m) recorded the highest captures (n = 204, 48.7%, CF = 20 captures) followed by Station 2 (n = 91, CF = 19 captures), Station 8 (n = 32, 3.1 captures) (Table 4).

Spearman correlation test showed that sodium was the key factor significantly determining the rate of capture frequency of mammals at saltlicks (r = 0.70, $p \leq .01$) followed by human disturbance (r = 0.6, $p < .05$), elevation (r = -0.4, $p \leq .05$). Gaur (r =0.64, $p \leq .05$) and elephant (r =0.60, $p \leq .05$) preferred wetter saltlicks from lower elevations (SL_3, SL_5, SL_6). Capped langur (r = -0.31, $p > .05$), serow (r = -0.09, $p > .05$) and sambar (r = -0.5, $p > .05$) preferred drier saltlicks (SL_1, SL_2, SL_4, SL_7, SL_8). Barking deer had no specific preference over types of saltlicks (r = 0.06, $p > .05$).

Need for sodium in winter (December to February) is explained by flushing of grasses (Voigt *et al.*, 2008; Link *et al*, 2011) and physiological need of the animals (Benjamin, 2007). Grasses consumed by animals contain toxic plant secondary metabolites (PSM) (Alvarez *et al.*, 2014), suggesting the need for the mammals to consume minerals from saltlicks to buffer the effect of PSM (Reimers and Colman, 2009; King *et al.*, 2016). Preference of mammal species for different elevations and types of saltlicks was also reported by Datta and Naniwadhekar (2008) from Namdapha National Park, North-east India.

Temporal distribution of mammal species across the saltlicks

Mammal species showed different temporal activity patterns at saltlicks (Figure 4). Herbivorous mammals visited saltlicks mostly during night hours remaining nocturnal (n = 331, 80.5%) except barking deer which remained diurnal (n = 20, > 70%). Sambar and gaur

Table 4: Capture frequency (CF) (captures per 100-day) of herbivorous mammal species

	Jomotsangkha Range Stations					Samdrupcholing Range Stations				
Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Average**
Asian Elephant	7.1(4)	3.5(2)	28(16)	10(6)	7(8)	1(1)	-	1(1)	-	6.55(38)
Barking Deer	7.1(4)	-	-	-	1(1)	-	-	28(16)	1(1)	4.37(22)
Capped Langur	1.7(1)	-	-	-	-	-	-	1(1)	-	0.4(2)
Gaur	10(6)	3.5(2)	21(12)	-	12(10)	-	5(3)	5(3)	-	6.55(37)
Himalayan Serow	-	1.7(1)	-	-	-	-	5(3)	-	-	0.79(4)
Sambar	330(185)	153(86)	-	5(3)	3(2)	8(9)	-	19(11)	-	57.94(296)
Clouded Leopard	-	-	-	-	-	-	3(1)	-	-	0.4(1)
Common Leopard	-	-	-	-	-	-	1(2)	-	-	0.2(2)
Wild Dog	-	-	-	-	-	1.7(1)	3.5(2)	-	-	0.6(3)
Indian Grey Mongoose	5.3(3)	-	-	-	-	-	-	-	-	0.6(3)
Himalayan Black Bear	-	-	-	-	1.7(1)	-	-	-	-	0.2(1)
Wild Pig	1.7(1)	-	-	-	-	-	1.7(1)	-	-	0.4(2)
Total	**20(204)**	**19(91)**	**3(34)**	**1(9)**	**1.6(22)**	**0.6(11)**	**1.8(7)**	**3.1(32)**	**0.1(1)**	**5.6(411)**

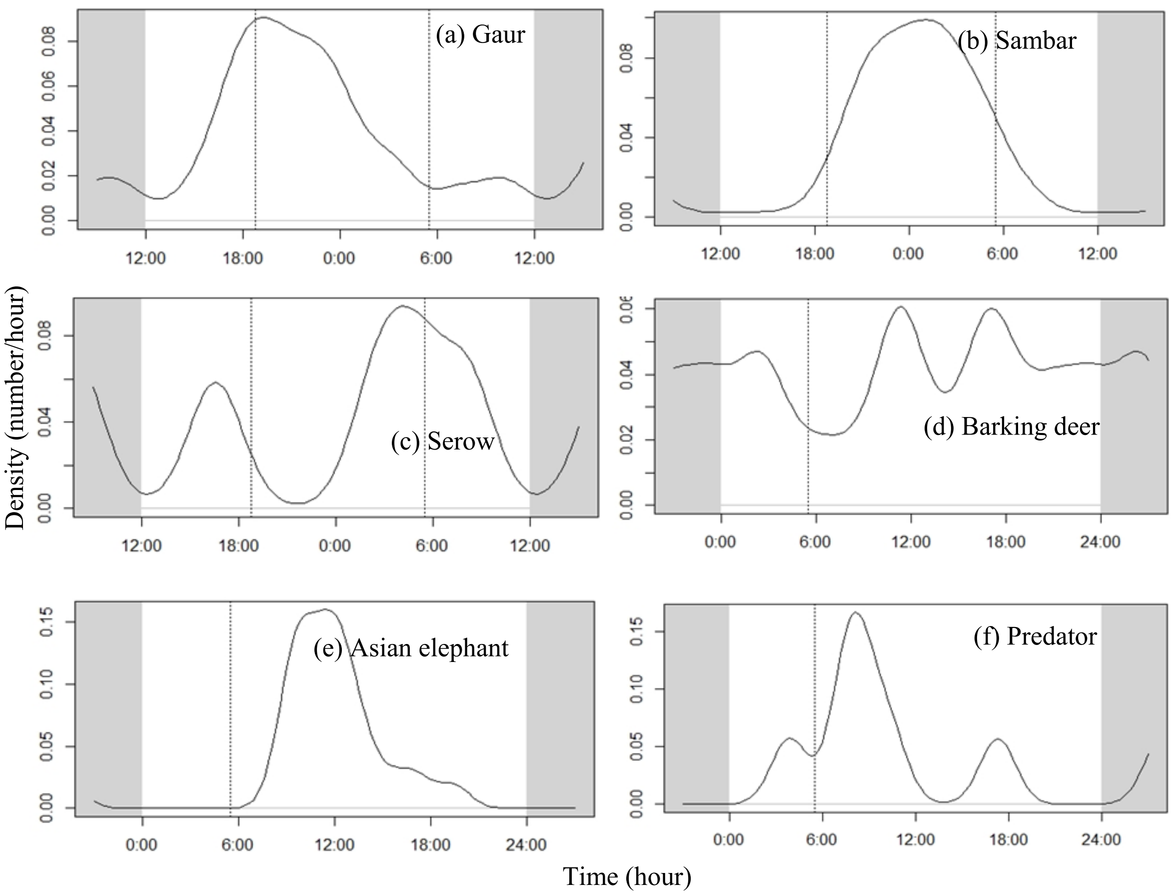
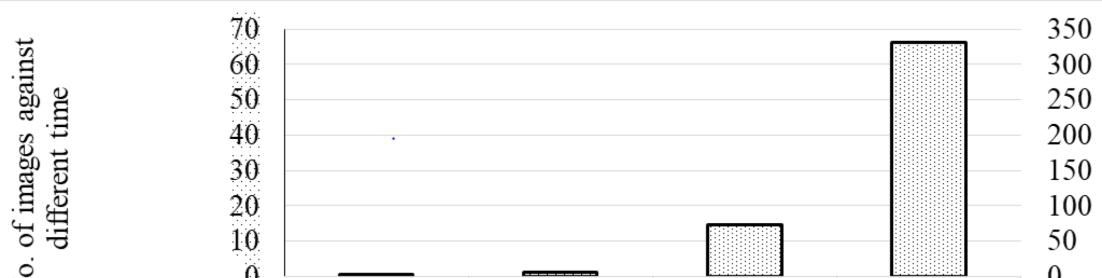


Figure 4: Temporal distribution of mammal species (prey (a-e) and predator (f) species)

were nocturnal ($n1$ = 276, $n2$ = 29, >70%). Himalayan serow (n = 4) and Asian elephant (n = 20) appeared during both day and night hours (50%). Predator species (non-herbivores) were also nocturnal but less frequent (n = 8). Overall, capture frequency for night hours was 65.67 captures (n = 331) comparatively higher than the overall capture frequency of 14.30 captures (n = 72) for day hours (0701 to 1700 hrs) and 1.19 captures (n = 6) for crepuscular hours and 0.39 captures for cathemeral hours (n = 2) (Figure 5).



	Cathemeral	Crepuscular	Day	Night
Capture Frequency	0.39	1.19	14.3	65.67
Independent Event	2	6	72	331

Figure 5: Capture frequency of mammal species per 100 days against independent events

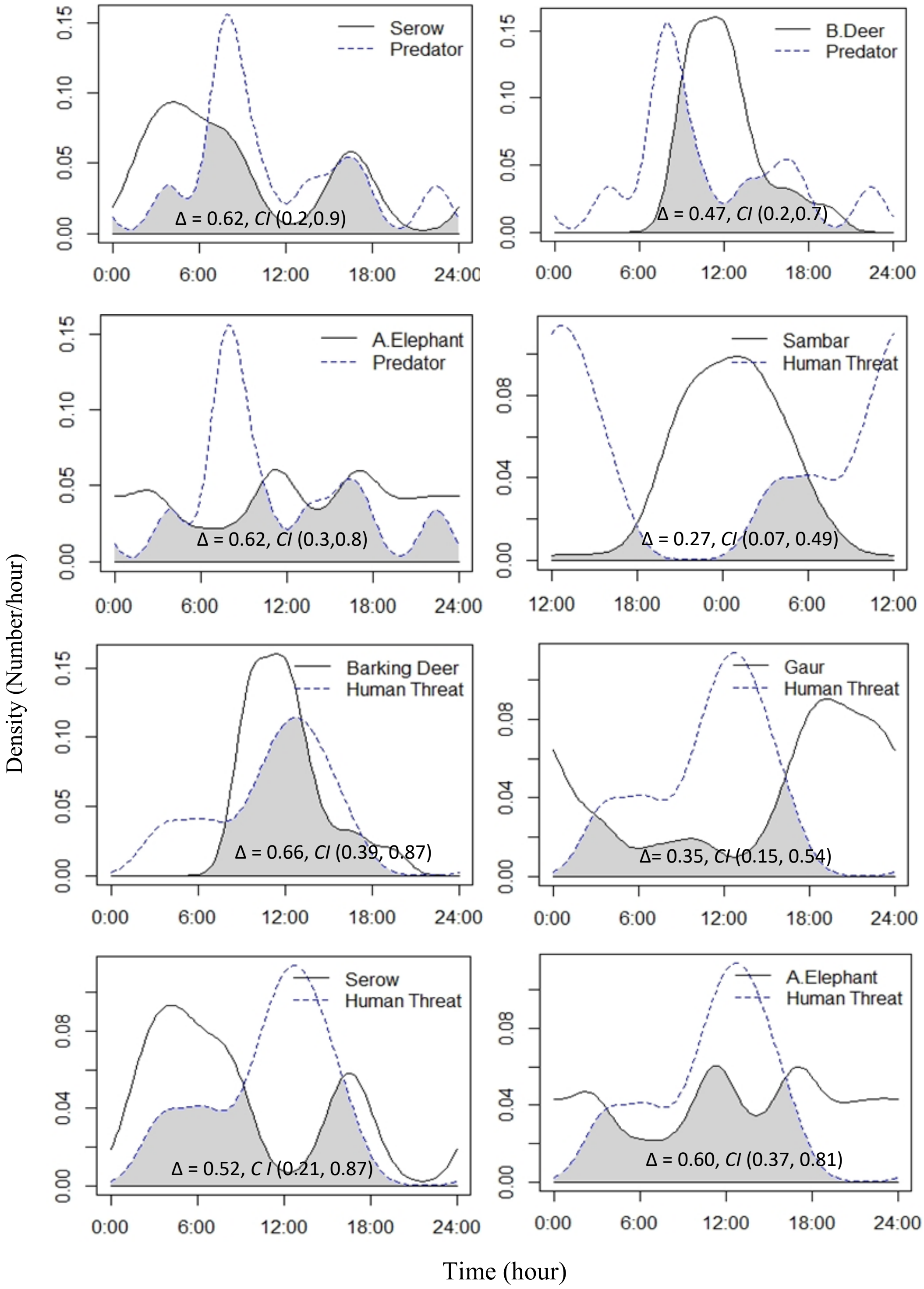


Figure 6: Coefficient of temporal overlap (delta / Δ) between saltlick visitors and threats

Temporal overlap of mammal species at the saltlicks

Herbivorous mammal species showed temporal partitioning among themselves and with threats (predators and humans) at saltlicks. Temporal partitioning of mammal species is supported by Hardin's (1960) principle of competitive exclusion where species do not co-exist. Mann Whitney Sum Rank test showed significant avoidance of common leopard by sambar (W = 187.5, $p \leq .000$), barking deer (W = 54.2, $p \leq .001$) and gaur (W = 40.13, $p \leq .01$). Coefficient of overlap of kernel density (delta/Δ) also revealed the similar activities (Figure 6). Among the ecologically similar species, barking deer avoided sambar (W = 15.1, $p \leq .001$), Asian elephant (W = 21.5, $p \leq .001$), gaur (W = 5.56, $p \leq .020$), serow (W = 5.4, $p \leq .030$). Asian elephant was avoided by sambar (W = 6.7, $p \leq .010$) and gaur (W = 4.6, $p \leq .050$). There was no temporal overlap of sambar with serow and gaur ($p \leq .050$).

Regular saltlick visitors showed temporal avoidance of human threats as revealed through coefficient of temporal overlap (Figure 7). Human threats least overlapped with sambar (Δ = 0.27, mean = 0.27, CI = 0.07, 0.49) and significantly overlapped with barking deer (Δ = 0.66, mean = 0.62, CI = 0.39, 0.87) and Asian elephant (Δ = 0.60, mean = 0.54, CI = 0.37, 0.81).

Significant influence of human threats with mammals is also supported by Spearman correlation (r = 0.6, $p \leq .05$) (Figure 5). Images of hunters carrying weapons and other human activities had also been captured by camera traps (n = 8). Informal interviews with local communities also revealed that local people hunt wild animals at saltlicks. Therefore, these clearly indicate human activities affecting ecological behaviours of mammal species at saltlicks. Blake *et al.* (2013) had also reported minimum activity of mammal species at hunted areas in Yasuni National Park of eastern Ecuador.

Conclusion

Natural saltlicks revealed presence of potassium, sodium and potassium elements. pH for saltlicks varied from acidic (5.55) to mild-alkaline (9.37). Concentration of sodium increased with increase of pH showing their direct relation (r = .68, p > .05). These saltlicks were visited by diverse mammals with different trophic levels or food habits. Herbivorous mammals were most common (n = 340). Non-herbivorous mammals (n = 2) like wild dog and wild pig were also recorded licking minerals from saltlicks. Ingestion of minerals from saltlicks by herbivores is reported worldwide but least with non-herbivores particularly carnivore species, by wild dog in this case.

Mammals behaved differently at different saltlick stations in response to anthropogenic, ecological, environmental and geological (mineral composition) factors. Geological factor where sodium element forms main component played critical role in ecological behaviour of mammal species at saltlicks (r = 0.70, p < .05). Elevation (r = -.4, $p \leq .05$) and types of saltlicks also affected the visit of mammal species at saltlicks. Gaur (r = 0.64, p < .5) and elephant (r = 0.60, p < .5) preferred wetter saltlicks at lower elevations while sambar, serow and barking deer preferred drier saltlicks without particular preference for elevation.

Anthropogenic activities affected visitation rate and ecological behaviour of mammals at saltlicks (r = 0.60, p < .05). Saltlicks from Jomotsangkha reported higher number of mammals (n = 340) with undisturbed ecological behaviours while saltlicks from Samdrupcholing reported fewer number of mammals (n =71) with disturbed ecological behaviours. Therefore, anthropogenic activities at saltlicks from Samdrupcholing Range have to be monitored for healthy ecological behaviour of mammals at saltlicks. Careful examination of artificial salts (containing sodium and chlorine) is also felt important while supplementing licks with artificial salts for mammals because natural saltlicks contain more than sodium element. Extensive study on mineral composition of natural saltlicks from higher elevation is also recommended for comprehensive understanding of every natural saltlick in Bhutan.

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