Insights into the Spatial Ecology of Sambar Deer (Cervus unicolor) in Bhutan's Protected Area at Phrumsengla National Park: Habitat Preferences and Conservation Challenges

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Research Article

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Insights into the Spatial Ecology of Sambar Deer (*Cervus unicolor*) in Bhutan's Protected Area at Phrumsengla National Park: Habitat Preferences and Conservation Challenges

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Abstract

Sambar (*Cervus unicolor*) is considered an important prey species of Tiger and other carnivores throughout South and Southeast Asia. However, the ecological information on Sambar deer in Bhutan is scarce. Therefore, this study represents a pioneering effort to evaluate habitat preferences and assess the impacts of both natural and anthropogenic disturbances on Sambar occurrence within Phrumsengla National Park, a designated National Protected Area. The study area was stratified into three forest types and the standard line transect method was employed for data collection. A total of 90 plots were established, comprising 45 already used by Sambar and 45 control plots representing other available habitats. The study analysis revealed that Sambar highly preferred an elevation range of 2356 - 2680 masl with northeast-facing slopes of 0 - 15^{o}, preferred a canopy cover of 51 - 75%, a ground cover of 61 - 76%, distance to water sources of 101 - 200 m. The study also identified preferred vegetation types, with Sambar showing a marked association with tree species such as *Taxus baccata* and *Betula utilis*, shrub species like *Sarcococca hookeriana*, and herbaceous plants including *Stellaria vestita*. Furthermore, Sambar favored cool broadleaved forests over mixed conifer and fir forests. Livestock grazing was the prominent anthropogenic disturbance, followed by timber extraction, which had a strong negative correlation with significant difference ($p < .05$). The findings underscore the necessity for stringent regulations regarding livestock grazing and resource extraction within protected areas. To build on this foundational study, long-term monitoring and further research are essential for developing targeted conservation strategies and interventions, ensuring the sustainability of this vital species and its habitat.

Keywords: Sambar deer, Habitat preference, Disturbances, Forest type, Conservation, Anthropogenic, Tiger, Forest Ecology

Introduction

The Himalayas are among the largest complex mountains in the world, and they are home to millions of flora and fauna and are also rich in unique biodiversity (Mani, 1974). Ungulates comprise a major proportion of Himalayan mammals and also constitute the highest number of prey species for wild predators (Wang, 2008). In total, 19 species of ungulates inhabit the upper Himalayas, and these species belong to four families viz., Moschidae, Cervidae, Bovidae, and Equidae (Bhatnagar, 1993). The family Cervidae is commonly referred to as the Deer family.

The Sambar deer (*Cervus unicolor* Kerr, 1792) is a large ungulate distributed throughout South and Southeast Asia among deer (David and Leslie, 2011). It belongs to the order Artiodactyla. The Sambar deer is categorized as vulnerable on the International Union for Conservation of Nature and Natural Resources [IUCN] Red List (Timmins *et al*., 2008). It is native to tropical southeast Asia, however, it is distributed across Bangladesh, Bhutan, Brunei Darussalam, Cambodia, China, India, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, Nepal, Sri Lanka, Taiwan, Province of China, Thailand, Vietnam (David and Leslie, 2011). This species became a pest after its introduction to countries such as Australia (Gormley et al., 2011), and populations in its native range declined as a result of extensive hunting and habitat loss (Timmins *et al*., 2008). It remains regionally abundant only in well-secured areas. Although some countries, such as Thailand, have banned hunting, the recovery rate of Sambar deer populations remains slow, requiring further evaluation of population distributions and dynamics (Steinmetz *et al*., 2009).

In Bhutan, there are about four known deer species under the Cervidae family that have been listed: Chital (*Axis axis*), Hog deer (*Axis porcinus*), Barking deer (*Muntiacus muntjak*) and Sambar deer. Among these, Sambar is the largest deer in Bhutan, with adult males attaining the size of domestic cattle (Wangchuk *et al*., 2004). It is an important prey species of the Tiger due to its widespread distribution in South Asia, South China and Southeast Asia (Corbett and Hill, 1992). As a primary prey of the endangered Tiger (*Panthera tigris*), Sambar is a critical species that has an important role in the effective conservation and management of fragile ecosystems and top predators (Wang, 2008). The presence of Tigers, other carnivores and Sambar in the study area was confirmed (Thrumshingla National Park [TNP], 2008); however, ecological information on Sambar was lacking. Therefore, to fill the existing gap, this study aimed to assess the habitat preference of Sambar deer at Chumey geog under Phrumsengla National Park and to analyze the effect of natural and anthropogenic disturbances on the occurrence of Sambar deer.

Materials and Methods

Study area

Phrumsengla National Park (27°16'59" N and 90°58'40" E) is one of the national parks in the country, with an area of 905 km^2 located in central Bhutan. The park contains the largest and richest temperate broadleaved forest eco-region in the eastern Himalayas, and it is considered to protect some of the last remaining stands of old growth of Fir (*Abies densa*) forest and cool temperate broadleaved forest in the entire Himalayas (As given in Bhutan Biodiversity Portal in https://biodiversity.bt/group/Phrumsengla_National_Park__). Elevation in the park ranges from 900 - 4550 masl, with a mean annual rainfall of 700 - 1500 mm, with most precipitation falling during May and August as part of the Asian monsoon (Dendup *et al*., 2016).

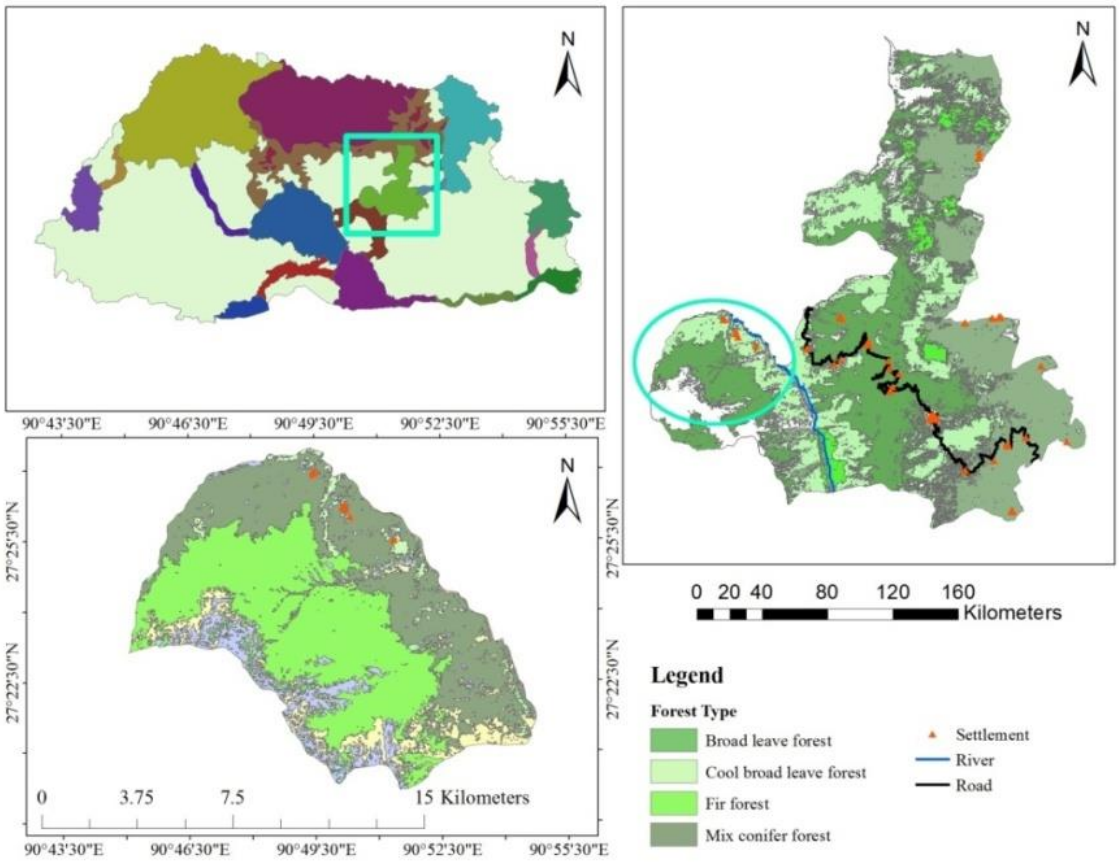

Figure 1. Map showing the study area

The park is also critical for Tiger (*Panthera tigris*) distribution in Bhutan because of its strategic location and the corridors through which it links with Royal Manas National Park and Jigme

Singye Wangchuck National Park to the southwest, Bumdeling Wildlife Sanctuary to the east and Wangchuck Centennial National Park (TNP, 2008). The proposed study area (Chumey) covers 119 km^2. It falls under the southwest of the park. It connects with Royal Manas National Park and Jigme Singye Wangchuck National Park through a string of biological corridors (Figure 1). The distribution of Sambar was also predicted to be high in the proposed study during the Rapid Biodiversity Assessment. Further, the National Tiger Survey of the year 2014 - 2015 confirmed the presence of Tigers in the area through camera trapping (Thinley et al., 2015). Therefore, the proposed study site serves as a critical Tiger habitat in Phrumsengla National Park.

Sampling Design and Method

The study area was stratified into three different compartments based on the forest types. They were i) Cool-Broadleaved Forest (CBL), ii) Mixed Conifer Forest (MC), and iii) Fir Forest (F). In each stratified random sample block, line transects comprising 30 sample plots in each forest type were laid out with an interval of 200 m (15 used plots where signs of Sambar were detected and another 15 habitat-available plots/ control plots). In each plot, 20 m radius circular plots were laid to search for indirect signs of Sambar and detect anthropogenic and natural disturbances following the published methodology laid by Dorji *et al*. (2011). Also, the pellet group count method was applied for its detection, just like in the classic methods used by Rogers e*t al*. (1958). The used plot refers to sites where it showed the presence of Sambar deer by signs such as pellets, rubbing, wallowing, hoof marks, and debarking. The habitat availability plots were laid out in a random direction (0 - 360^o) at a distance of 100 – 150 m from the used plots, following and adapting the earlier published methodology (Aryal, 2006; Subedi, 2012).

For vegetation assessment, as suggested by Schemnitz (1980), a quadrate size of i) 10 m x 10 m was laid for the tree layer, i.e., plants > 3 m height and 10 cm diameter at breast height [dbh]), ii) A 4 m x 4 m subplot was laid for shrubs, i.e., woody plants of < 3 m height and iii) A 1 m x 1 m for the herbs layers (plants up to 1 m in height) were demarcated in both the habitat used plot (U) and available plot (A). Furthermore, other parameters such as 1. Slope, 2. Altitude, 3. Aspect 4. Canopy cover, 5. Ground cover, 6. Distance from the nearest road, 7. Distance to the nearest settlement, 8. Water source, and 9. Open grazing grounds, were also recorded.

Material Required

Field equipment, including the Global Positioning System (Garmin GPS eTrex), was used to record the coordinates of the plot and to maintain the distance between plots. The altimeter was used to record the altitude of plots and Sambar signs. Diameter tape was used for tree measurement. The plot size was measured using 50 m measuring tape. Aspect and slope information were collected with the help of a compass and a clinometer. Furthermore, a DSLR camera was used to collect photographic evidence and to take photographs of unidentified plants and animal signs.

Data Analysis

SPSS (Statistical Package for Social Science, version 23.0) and Microsoft Excel were used for data analysis. The non-parametric Kruskal-Wallis test was used to see the significant difference in habitat preference of Sambar over different forest types. The relationship and effect of natural and anthropogenic disturbances on the occurrence of Sambar deer were analyzed with a non-parametric Spearman correlation test and crosstabs. The chi-square test was employed to see the significant difference between the natural and anthropogenic disturbances. The Importance Value Index (*IVI*) and Shannon-Wiener Index (H) were used to calculate the dominance of tree species and the diversity of vegetation in the forest types. Ivlev's Electivity Index (*IEI*) was used to analyze the habitat preference of Sambar deer, which includes various habitat parameters such as vegetation, slope, elevation, aspect, vegetation composition, cover, and distance from nearest water sources as illustrated in the study and method by Ivlev (1961).

$$IEI = \frac{(U\% - A\%)}{(U\% + A\%)}$$

The value of the index ranges from -1.0 to +1.0, where positive values imply preference, negative values refer avoidance, and 0 values indicate random use. Where "A" indicates "availability plots" and "U" infers "use plots." Furthermore, habitat preference between the three forest types was calculated using the following formula derived by Aryal (2005).

$$HP = \frac{PPE}{TPP} \times 100$$

Where: HP = Habitat preference. PPE = Pellets present in each habitat in plots. TPP = Total pellets present in habitat types in all plots.

Results and Discussion

General floristic composition in Sambar habitat

In total, 28 tree species belonging to 12 families, 14 shrub species belonging to eight families and 23 herb species from 15 families were recorded in the study area. In Fir forest, *Abies densa* (*IVI* = 161.15) was the dominant tree species, and *Rhododendron falconerii* (*IVI* = 2.59) was the least dominant tree species. However, in mixed conifer, *Tsuga dumosa* (*IVI* = 128.63) was the dominant tree species, followed by *Taxus baccata (IVI* = 51.66*)* and *Abies densa (IVI* = 2.95) was the least dominant species. In the cool broadleaved forest, out of 18 tree species recorded, *Persea clarkeana* (*IVI* = 49.85) dominated the area, and *Rhododendron kendrikii (IVI = 2.93)* was the least dominant tree species. As per the Shannon diversity index (*H'*), the cool broadleaved forest had the highest diversity of trees (*H'* = 2.47) and shrubs (*H'* = 3.45), and the fir forest had the highest herb diversity (*H'* = 4.85).

Habitat preference of Sambar deer

Aspect preference

The Sambar used six aspects in the study area. It revealed that Sambar mostly preferred northeast facing slope (*IEI* = .22) followed by northwest (*IEI* = .20). The Southeast (*IEI* = -.43), east (*IEI* = -.33), west (*IEI* = -0.43) and southeast (*IEI* = -0.43) facing slope were avoided by Sambar. The North (*IEI* = 0) facing slope was randomly used by Sambar, as shown in Figure 2. This may be because the northwest and northeast aspects are warmer than others, making the environment conducive to survival during cold winters. However, according to Yen *et al*. (2015), Sambar deer were found to be distributed in the north- and south-facing slopes of the Himalayas and Southeast Asia.

Further, Bhattacharya and Sathyakumar (2011) also found that Sambar in India has its presence in the west-facing aspect. Likewise, in Royal Manas National Park, Sambar preferred the south aspect but avoided the northwest, southwest, and west (Tshering *et al*., 2017). Therefore, Sambar preferred different aspects in different study sites, which could be attributed to the location of the study area since the present study was conducted in a relatively higher altitude region (2356 – 3655 masl).

Elevation preference

Sambar deer was found between 2356 and 3655 masl (meters above sea level) in the study area. Sambar mostly preferred an elevation range from 2356 - 2680 m (*IEI* = 0.40), and preference gradually decreased. Sambar also preferred the altitude range of 2681- 3005 m (*IEI* = 0.04). However, the Sambar avoided areas in the higher altitude range of 3006 - 3330 m (*IEI* = -.13) and highly avoided areas in the range of 3331 - 3655 masl (*IEI* = -0.27), as shown in Figure 3.

Sambar showed a high preference for elevation range from 2356 - 2680 masl; this could be because higher elevations received snowfall during the winter, and the ground vegetation remained with snow cover. Another reason could be the presence of *Persea clearkenea, Taxus baccata and Alnus nepalenesis*, which were debarked in those elevation ranges and acted as their supplementary diet in the winter. However, Tshering *et al*. (2017) reported that Sambar deer mostly preferred an elevation higher than 1000 masl in Royal Manas National Park. This difference could be attributed to the difference in geographical location of the study area. A similar result was reported in Taiwan, where Sambar deer was found in wide elevation ranges from 150 to 3825 masl; however, most numbers lived at 2000 - 3500 m (Payne *et al*., 1985). Further, Yen *et al*. (2013) reported that in the Himalayan foothills, Myanmar and Eastern Taiwan, their presence ranges up to 3500 m as well.

Slope preference

Sambar used the slope 0 - 60^{o} in the study area. They mostly preferred the slope 0 - 15^{o} (*IEI* = 0.32) and less preferred 16 - 30^{o} (*IEI* =.26) and avoided slope > 31^{o} as shown in Figure 4. This could be because Sambar is nocturnal in nature; they do more nightly movements (Kawanishi and Sunquist, 2004). So Sambar might have preferred a gentle slope for safe traverse and easy escape from predators. The findings of this study are also consistent with the study by Tshering *et al*. (2017), who reported that Sambar usually preferred a flat and gentle slope in Royal Manas National Park. Similar findings were also attested by Simcharoen *et al*. (2014) that Sambar are positively associated with relatively flat areas in Huai Kha Khaeng Wildlife Sanctuary and avoids steep terrain (Trisurat *et al*., 2010) for their safety measures.

Ground cover preference

In the study area, Sambar used the ground cover from 15 - 76. Sambar mostly preferred 61- 76% (*IEI* = 0.75), and less preferred 46 - 60% (*IEI* = .33) of ground cover. However, Sambar highly avoided ground cover of 15 - 30% (*IEI* = 0.33) and 31 - 45% (*IEI* = .27) as shown in Figure 5.

Sambar is the largest of the tropical Asian deer and prefers a habitat of thick and dense cover (Whitehead, 1972; Bentley, 1978). This study also indicated that Sambar preferred thick ground cover as it is traditionally regarded as an intermediate feeder that consumes a variety of grass (Hofmann and Stewart, 1972). Ground cover must have been used for camouflage and thermal regulation. Simcharoen *et al*. (2014) also found that Sambar preferred dense understorey vegetation in Thailand, which offered better concealment from predators

Canopy cover preference

The canopy cover was divided into four categories for analysis. The Sambar mostly preferred canopy cover from 51 - 75% (*IEI = .58*) and preferred 76 - 100% *(IEI = 1.0*). However, 26 - 50% (*IEI = 0*) canopy cover was found to be randomly used and canopy cover 0 - 25% (*IEI* = - 0.56) was avoided in the study area, as shown in Figure 6. From the above result, it is understood that Sambar deer required adequate canopy cover. This may be because the canopy is a very important component of habitat as it determines the understorey vegetation. It may provide shelter during the hot summer months and heavy snowfall in the winter months. So, the canopy must have been used to protect it from heat and cold. According to Leslie (2011), Sambar found in dense evergreen with closed canopy forests in the Southeast Asian regions, which is similar to the present study findings. However, Tshering *et al*. (2017) reported that in Royal Manas National Park, Sambar preferred a canopy cover of 26 - 40%, which is random use in the present study.

Distance from Water Source

Sambar signs were found at a distance of 0 - 400 m, far from the nearest water sources in the study area. The findings showed Sambar was less preferred to distances 0 - 100 m (*IEI* = -0.03), mostly preferred within 201 - 300 m (*IEI* = -.04) and decreased preference from 201 - 300 m (*IEI* = -.04). Whereas, it avoided the distance 301 - 400 m (*IEI* = -0.40) from nearest water sources as shown in Figure 7.

The Sambar showed less preference within the 0 - 100 m. This could be due to the possible threats from the occurrence of other predators visiting the water source. It shows a strong negative association with a highly significant difference (r_s = -.642, p = .001). Bagchi *et al*. (2003) also suggested that Sambar preferred grassland and dense shrubs closer to water in India.

However, Simcharoen *et al*. (2014) found that distance to the main river had the highest correlation with pellet group abundance, but there was no correlation between Sambar pellet

abundance and the distance of smaller permanent streams. In this study, water sources were considered as all the available streams, and it was found that there is a strong negative association. However, Wang and Ying (1996) found that Sambar in Jinggangshan preferred up to 400 m from the water source.

Tree preference

There were 28 tree species recorded at the study site. Out of which, 18 tree species were preferred by the Sambar and seven species were avoided, and three species were randomly used. Mostly preferred trees were *Betula utilis* (*IEI* = 0.80) and *Taxus baccata* (*IEI* = 0.80), followed by *Tsuga dumosa (IEI= 0.60. Acer caesium (IEI = 0)*, *Benthemedia capitata (IEI = 0) and Engelhardia spicata* (*IEI* = 0) were randomly used. However, *Populus ciliata (IEI = 0.60) and Rhododendron arborium (IEI = - 0.48)* were highly avoided by the Sambar. Among 18 tree species preferred by the Sambar, *Taxus baccata,* and *Persea clarkeana* were found debarked in the study. According to Khan *et al*. (1994), in Gir Lion Sanctuary in India, 13 plant species were found debarked, out of which *Wrightia tinctoria, Xeromphis spinosa and Xeromphis uliginosa* were found heavily debarked. The study suggested that Sambar occasionally eats the bark of several plant species when there is inadequate other diet (Yen *et al*., 2015).

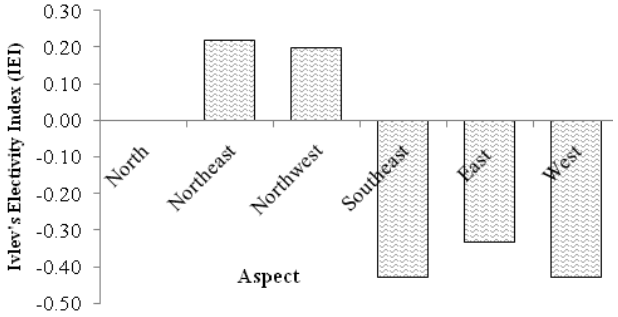

Figure 2: Aspect preferences

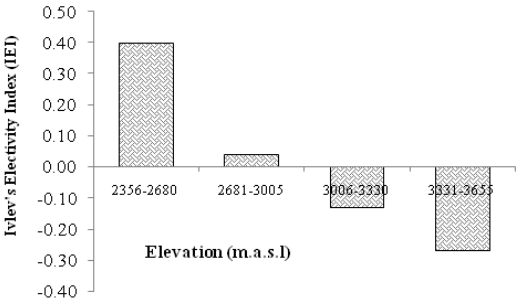

Figure 3: Elevation preferences

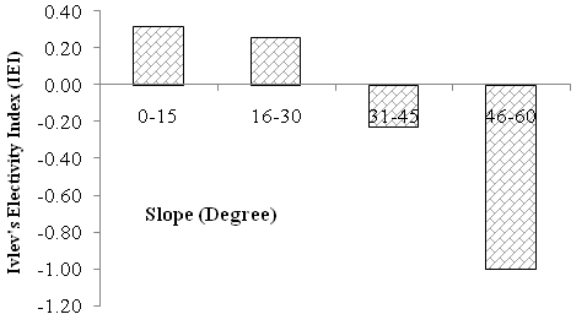

Figure 4: Slope preferences

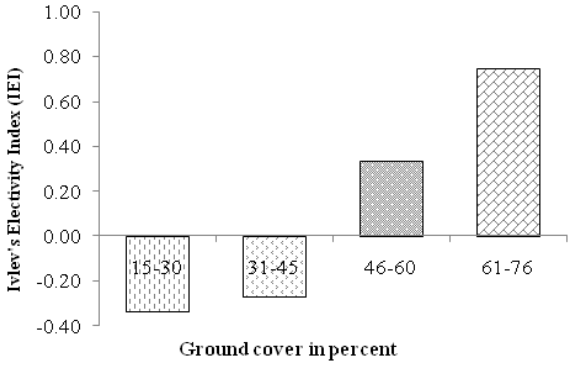

Figure 5: Ground cover preferences

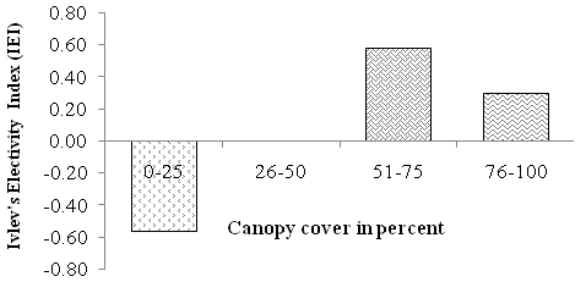

Figure 6:Canopy cover preferences

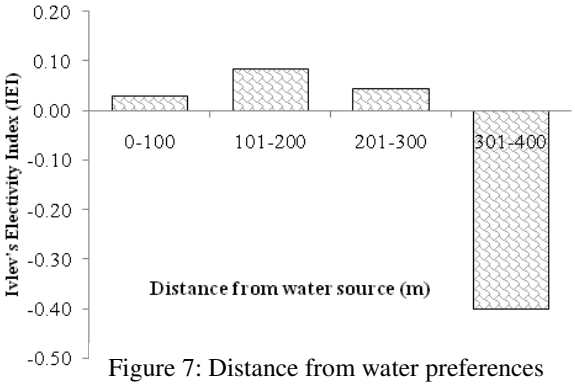

Figure 7: Distance from water preferences

Shrub preference

In total, 14 species were recorded in the Sambar habitat, 10 species of shrubs were preferred, and four species were avoided by the Sambar. Among those, *Sarcococca hookeriana* were mostly preferred with Ivlev's Electivity Index (*IEI* = 0.74) followed by *Eleagnus paryifolia* (*IEI* = 0.73) and *Aconogonon molle* (*IEI* = 0.46). However, the *Eurya accuminata* (*IEI* = -0.48), *Rhododendron barbatum* (*IEI* = -0.46), *Rhododendron cinnabarium (IEI = -0.52)* and *Rhododendron kendrickii*

(*IEI* = -0.21) were avoided by the Sambar. However, this does not show any feeding behaviour of the Sambar; it simply indicates the preference for vegetation as shelter or escape cover.

Herb preference

Twenty-three herb species were recorded in the Sambar habitat. Among those, 16 herb species were preferred by the Sambar. Some of those highly preferred species are *Stellaria vestita* (*IEI* = .81), *Carex filicinia* (*IEI* = .71), *and Vaccininum retusum* (*IEI* = 0.69). Two species, *Potentilla spp* (*IEI* = 0) and *Rumax nepalensis (IEI = 0)* were randomly used by the Sambar. Five herb species, *Galium aparine* (*IEI* =-.33), *Artemisia* sp (*IEI = -.37*), *Anaphalis adnata* (*IEI = -0.61*), *Ainsliaea aptera* (*IEI* = -.043), *Cucurma aromatic* (*IEI* = -.26) were avoided by Sambar in this present study site.

Forest type preference

Overall pellet group encounter rate was higher in the cool broadleaved forest (n = 109) with a mean pellet group count of 9.08 ± 7.09 followed by mixed conifer forest (n = 61) with a mean pellet group count of 3.67 ± 4.00 and lowest in the fir forest (n = 44) with mean pellet group count 3.33 ± 3.54. The pellet density was also higher in the cool broadleaved forest (54.64/ha), followed by mixed conifer forest (28.99/ha) and fir forest (17.73/ha). Calculation of habitat preference (HP) also showed that Sambar deer preferred the cool broadleaved forest (50.93 %), mixed conifer forest (28.50 %), and fir forest (20.56 %), as shown in Figure 8. The overall mean number of pellet groups recorded in all study areas was 4.75 ± 3.53. The occurrence of Sambar deer differed significantly among forest types (H (2) =13.49, p = .001).

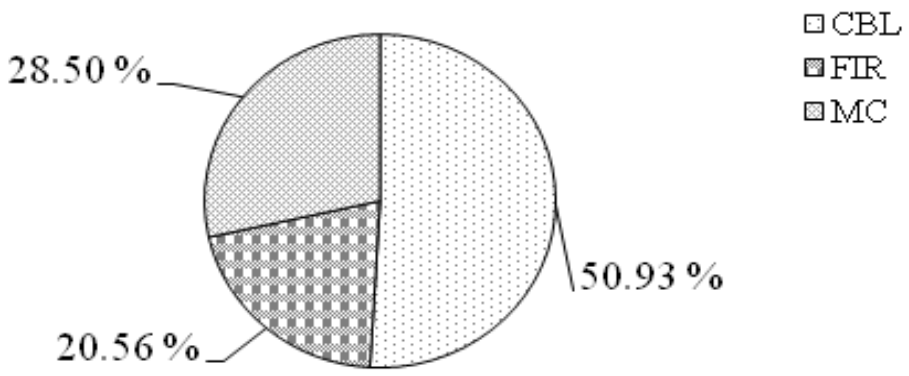

Figure 8: Forest type preference

The Sambar preference for the cool broadleaved forest over the other two forest types might be contributed by the presence of preferred elevation (2356 - 2680 masl) and canopy cover and high diversity of tree (*H'* = 2.47), shrub species (*H'*= 3.45) herb species (*H'* = 4.84). Another probable reason could be less anthropogenic disturbances in the cool broadleaved forest. The *Alnus nepalensis* and *Persea clarkeana* were also found debarked in the cool broadleaved forest, which could be a preferred diet in winter. According to Gill (1992), ungulates feed on fruits and seeds of forage tree species during dry winter in the absence of grasses. Therefore, the presence of fruiting trees such as *Persea clarkeana* and *Benthemedia capitata* could be the probable reason for their preference in the present study site. Therefore, Yen *et al*. (2015) also found that coniferous forest was preferred mainly by Sambar than broadleaved trees in winter in Taiwan. Similarly, Wang and Ying (1996) also found that Sambar preferred coniferous forests among the evergreen broadleaved, mixed coniferous and broadleaved forests in Jinggangshan in winter. The findings of this study were similar to those of Gormley *et al*. (2011) and Bagchi *et al*. (2003), who stated that Sambar preferred lower elevation with grassland in India.

Disturbances in Sambar habitat

Disturbances were broadly categorized as natural and anthropogenic disturbances. In the Sambar used plots, only three natural disturbances parameters, such as naturally fallen logs, dead bamboo, and signs of predators, were recorded: Naturally fallen logs (57.9%, *n* = 22), dead bamboo (39.5%, *n* =15) and the presence of other carnivores sign (2.6%, *n* = 1). The Spearman's rho correlation test between natural disturbances and Sambar pellet group counts showed a weak negative correlation with no significant difference. Anthropogenic disturbances such as livestock (50.0%, *n* = 45), fire (16.7%, *n* = 15), timber and NTFP harvest (17.8%, *n* = 16), girdling (14.4%, *n* = 13) and hunting sign (1.1%, *n* = 1) were observed. Livestock was the most dominant among anthropogenic disturbances. It showed a strong correlation with a highly significant difference, which indicates that Sambar negatively responds to livestock. Therefore, livestock has a significant effect on Sambar occurrence in the study area. This could be attributed to the presence of more than 200 yaks and cattle accompanied by herders and shepherd dogs and consequent habitat degradation, which may be one of the causes of the low pellet group of Sambar in the livestock presence plots.

In Sambar used plot, 53 pellet groups were counted in the plots which had anthropogenic disturbances (36.84%, *n* =14). The pellet groups of 112 were observed in the plots with the most

natural disturbances (63.16%, $n = 24$). There is a significant difference in occurrence of Sambar in natural and anthropogenic disturbances (X^2 (2) = 9.733, p = .008). The highest natural disturbances were recorded in cool broadleaved forests, followed by mixed conifer and fir forests. However, the anthropogenic disturbances were recorded as the highest in the fir forest, followed by the mixed conifer and cool broadleaved forest. Likewise, Sambar occurred higher in the CBL than in the other two forest types (Table 1).

Table 1: Occurrence of disturbances in forest type in relation to pellet group count of Sambar

Forest Type	Natural disturbances (no. of plot)	Anthropogenic disturbances (no. of plot)	Pellet group (occurrence)
Fir	7	6	44
Cool Broadleaved Forest	9	3	109
Mixed Conifer Forest	8	5	61

This indicates that natural disturbances do not affect the Sambar occurrence. It showed that the more natural disturbances occurrence in the plot, the higher the pellet group counts. However, anthropogenic disturbances and Sambar occurrence showed an inversely proportional relationship, which indicates that anthropogenic disturbances have a negative impact on Sambar occurrence in the study area. Human disturbances influence wildlife behaviour and wildlife populations; therefore, wildlife are vigilant to human disturbance, which results in decreased forage intake and reduced reproductive success (Ciuti *et al*., 2012). Bhattacharya and Sathyakumar (2011) also reported that livestock and habitat destruction due to anthropogenic pressure found negative impacts on the population of mountain ungulates in the Nanda Devi Biosphere Reserve, India. Likewise, Schaller (1967) also reported that livestock grazing and other anthropogenic disturbances can cause competitive exclusion of wild animals from high-quality habitats because they may be forced to forage in poor habitats and spend more energy to move away from the disturbances that affect their nutritional balance.

A similar finding was also reported by Wani *et al*. (2011) in southern and central India, where much of the forest is deciduous; Sambar conspicuously avoids disturbed and open forests and is highly sensitive to any forest resource extractive activities. However, according to David and Leslie (2011), Sambar was found to be highly tolerant of forest degradation, and much higher numbers are found in encroached stands than in pristine forests if hunting is under control in Southeast Asian regions.

Conclusions and Recommendations

The study revealed that cool broadleaved forest was the habitat most preferred by Sambar deer, followed by mixed conifer and fir forest. In the study area, a total of 22 tree species, 14 shrub species, and 23 species of herbs were recorded. In the fir forest, *Abies densa* was the dominant species, followed by *Tsuga dumosa* and *Persea clarkeana* in the mixed conifer forest. Habitat parameter preference calculated by Ivlev's Electivity Index (*IEI*) showed that the Sambar deer mostly preferred the northeast-facing aspect, with an altitude range from 2356 - 2680 masl, a slope of 0 - 15°, a ground cover of 61 - 76%, canopy cover of 51 - 75% and a 101 to 200 m travel distance from water. Furthermore, the findings also showed that Sambar preferred tree species of *Taxus baccata* and *Betula utilis*, and from Shurb, they preferred shrub species of *Sarcococca hookeriana,* and from the herb category, their preferred choice species was *Stellaria vestita*.

The disturbances were found mostly in the fir forest and mixed conifer forest, with very few in the cool broadleaved forest. However, natural disturbances did not show any effect on the occurrence of Sambar. However, anthropogenic disturbances were found to have an effect on the occurrence of Sambar in the study area. The major anthropogenic disturbances to Sambar were from grazing competition by livestock and the extraction of natural resources by the park communities.

Therefore, the zonation of the park area based on ecological studies of the key wildlife species needs to be carried out to mitigate anthropogenic pressure on the habitat. Proper guidelines and regulations for livestock grazing inside the protected area and State Reserved Forest Land need to be reinforced for proper habitat management for the wild ungulates. Furthermore, a proper management plan for forest resource extraction and utilization should be drawn, at least for the communities living inside the protected areas.

This study was conducted in the winter months, which may not be enough information for generalizing habitat preference. Therefore, a similar study covering all seasons is crucial to support the statement adequately. Further dietary analysis of Sambar will be an essential source of information for understanding and identifying important plant species for the Sambar diet.

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References

Aryal, A. (2005). Status and distribution of Musk Deer '*Moschus chrysogaster'* in Annapurna Conservation Area of Manang district (Technical report) UK: ITNC.

Aryal, A. (2006). Himalayan Musk deer in Annapurana Conservation Area, Nepal, *Tiger paper*. 33(2): 11-18.

Aryal, A., Raubenheimer, D., Subedi, S. & Kattel, B. (2010). Spatial habitat overlap and habitat preference of Himalayan musk deer (*Moschus chrysogaster*), Sagarmatha *(Mt.Everest)* National Park, Nepal. *Journal of Biological Sciences,* 2: 217-225.

Bagchi, S., Goyal, S.P. & Sankar, K. (2003). Prey abundance and prey selection by tigers (*Panthera tigris*) in a semi-arid, dry deciduous forest in western India. *Journal of Zoology*, 260(3): 285-290. doi: 10.1017/S0952836903003765

Bentley, A. (1978). *An introduction to the deer of Australlia*. Melbourne: The Koeteong Trust.

Bhatnagar, Y. (1993). *Origin and distribution of Himalayan ungulates and the factors affecting their present distribution: High altitude of the Himalaya.* Nainital: Gyanodaya Prakashan.

Bhattacharya. T. & Sathyakumar, S. (2011). Natural Resource Use by Humans and Response of Wild. *International Mountain Society,* 31(3): 209-219. doi:10.1659/10-00069

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., Borchers, D.L. & Thomas, L. (2004). *Advanced Distance Sampling*. New York: Oxford University Press Inc.

Ciuti, S., Northrup, J.M., Muhly, T.B., Simi, S., Musiani, M., Pitt, J.A. & Boyce, M.S. (2012). Effects of humans on behaviour of wildlife exceed those of natural predators in a landscape of fear. *PloS one,* 7(11). doi:10.1371/journal.pone.0050611

Corbett, G.B. & Hill, J.E. (1992). *The Mammals of the Indomalayan Region. A Systematic Review*. USA: Oxford University Press.

David, M. & Leslie, J.R. (2011). Mammalian species. *American Society of Mammalogists*, 43(871): 1-30.

Dendup, P., Cheng, E., Lham, C. & Tenzin, U. (2016). Response of the Endangered red panda *Ailurus fulgens fulgens* to anthropogenic disturbances, and its distribution in Phrumsengla National Park, Bhutan. *Oryx*, 1-8. doi: 10.1017/S003060531000399

Dorji, S., Vernes, K. & Rajaratnam, R. (2011). Habitat Correlates of the Red Panda in the Temperate Forests of Bhutan. *PLoS ONE,* 6(10): doi:10.1371/journal.pone.0026483

Gill, R.M. (1992). A review of damage by mammals in North Temperate Forests, *Deer Forestry*. 65(2): 145-169.

Gormley, A.M., Forsyth, D.M., Griffioen, P., Lindeman, M., Ramsey, D.S., Scroggie, M.P. & Woodford, L. (2011). Using presence-only and presence-absence data to estimate the current and potential distributions of established invasive species. *The Journal of Applied Ecology*, 48(1), 25-34. doi:10.1111/j.1365-2664.2010.01911.x

Hofmann, R.R. & Stewart, D.R.M. (1972). Grazer or browser: A classification based on the stomach-structure and feeding habitats of east African ruminants, *Mammalia*, 36(2): 226-240.

Ivlev, V.S. (1961). *Experimental Ecology of the Feeding Fishes*. New Havens: Yale University Press.

Khan, J.A., Rodgers, W.A., Johnsingh , A.J.T. & Mathur, P.K. (1994). Tree and shrub mortality and debarking by Sambar *Cervus unicolor* (kerr) in Gir after a drought in Gujarat, India. *Biological Conservation,* 68 (2):149-152.

Kushwaha, S.P.S., Khan, A., Habib, B., Quadri, A. & Singh, A. (2004). Evaluation of Sambar and muntjak habitats Natural Resources, Gland: Switzerland. *Current science-bangalore,* 86(10): 1390-1400.

Leslie, D.M. (2011). *Rusa unicolor* (Artiodactyla: Cervidae). *Mammalian Species,* 43 (1): 1-30. doi:10.1644/871.1

Mani, M. S. (1974). *Ecology and biogeography in India.* Dr. W. Junk Publishers.

Md-Zain, B.M. & Chng, C.E. (2011). The activity patterns of a group of cantor dusky leaf monkeys (*Trachypithecus obsurus halonifer). International Journal of Zoological Research,* 7: 59-67.

Payne, J., Francis, C.M. & Phillipps, K. (1985). *Field guide to the mammals of Borneo*. Sabah Society; World Wildlife Fund Malaysia.

Thinley, P., Dorji, S., Tempa, T.,…Tandin (2015). Counting the Tigers in Bhutan: Report on the National Tiger Survey of Bhutan 2014-2015.

Rogers, G., Julander, O. & Robinette, W. L. (1958). Pellet-group counts for deer census and range-use index. *Journal of Wildlife Management*, 22: 193-199.

Royal Government of Bhutan. (n.d.). Phrumsengla National Park. Biodiversity Bhutan. https://biodiversity.bt/group/Phrumsengla_National_Park__

Sankar, K., Pabla, H.S., Patil, C.K., Nigam, P., Qureshi, Q. & Navaneethan, B. (2013). Home range, habitat use and food habits of re-introduced gaurin Bandhavgrah Tiger Reserve Central India. *Tropical Conservation Science*, 6: 50-69.

Schaller, G. B. (1967). *The Deer and the Tiger: A study of wildlife in India*. Chicago, Illinois: University of Chicago Press.

Schemnitz, S. D. (1980). *Wildlife Management Technique manual*. USA,Washington DC: Wildlife Society.

Simcharoen, A., Savini, T., Gale, G.A., Roche, E., Chimchome, V. & Smith, J.L. (2014). Ecological factors that influence Sambar (*Rusa unicolor*) distribution and abundance in western Thailand: Implications for tiger conservation. *The Raffles Bulletin of Zoology, 62*: 100-106.

Steinmetz, R., Chutipong, W., Seuaturien, N., Chirngsaard, E. & Khaengkhetkarn, M. (2009). Population recovery patterns of Southeast Asian ungulates after poaching. *Biological Conservation*, 143: 42-51.

Subedi, A., Aryal, A., Koirala, R.K., Timilsina, Y.P., Meng, X. & McKenzie, F. (2012). Habitat Ecology of Himalayan Musk Deer (*Moschus chrysogaster*) in Manaslu Conservation Area, Nepal. *International Journal of Zoological Research*, 8(2): 81. doi:10.3923/ijzr.2012.81.89.,

Thrumshingla National Park. (2008). *Thumshingla National Park: Management Plan (2008 - 2013)*. Ura: Bumthang, Department of Forests and Park Services, Ministry of Agriculture and Forests. Royal Government of Bhutan.

Timmins, R.J., Steinmetz, R., Sagar, B.H., Samba, K.N., Duckworth, J.W. & Anwarul, M. (2008). *Rusa unicolor. 2008 IUCN Red list of threatened species.* International Union for

Conservation of Nature and Natural Resources. <www.iucnredlist.org>. Accessed 3 March 2017.

Trisurat, Y., Alkemade, R. & Verburg, P.H. (2010). Projecting land-use change and its consequences for biodiversity in Northern Thailand. *Environmental Management*. 45(3): 626-639.

Tshering, U., Katel, O. & Nidup, T. (2017). Determining ungulate distribution and habitat utilization in royal Manas national park, Bhutan. *International Journal of Fauna and Bilogical studies,* 4(2): 91-96.

Wang, S. W. (2008). *Understanding ecological interactions among carnivores, ungulates and farmers in Bhutan's Jigme Singye Wangchuck National Park.* Cornell University.

Wang, X. & Ying, S. (1996). A preliminary study of Sambar winter habitat in Jinggangshan, Jiangxi Province. *Journal of Animal Science*, 18(3): 168-172.

Wangchuk, T., Thinley, P., Tshering, K., Tshering, C., Yonten, D. & Pema, B. (2004). *A Field Guide to the Mammals of Bhutan.* Thimphu: Royal Government of Bhutan

Wani, M.A., Telang, S., Bhat, S.A. & Sheikh, K.A. (2011). Fecal Pellets used for the Determination of Habitat Utilization of Sambar (*Rusa unicolor*) in Van Vihar National Park, Bhopal, Madhya Pradesh, India. *Biomedical & Pharmacology Journal*, 4(2): 353-356.

Whitehead, G.J. (1972). *Deer of the world*. London: Constable Publishing.

Yen, S., Lin, C., Hew, S.W., Yang, S. & Yeh, C. (2015). Taiwan Characterization of debarking behavior by Sambar deer (*Rusa unicolor*) in Taiwan. *Mammal Society of Japan*, 40(3): 167-179. doi: 10.3106/041.040.0304

Yen, S.C., Wang, Y & Ou, H.Y. (2013). Habitat of the Vulnerable Formosan Sambar deer Rusa unicolor swinhoii in Taiwan. *Oryx,* 48(2): 232-240. doi: 147.140.20.32