

## Distribution, Abundance and Occupancy of Gaur (*Bos gaurus* Smith) in the Royal Manas National Park, Bhutan

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### Abstract

The Gaur, *Bos gaurus* Smith, plays an important role in the pyramidal food chain – being an important prey for large carnivores such as tiger, common leopard, and Asiatic wild dog. Presence of Gaur in an area indicates wild and healthy ecosystem. Reduction of global distribution of Gaur by over 80% in the past 100 years, scaling in the IUCN Red List of Vulnerable category shows the species is facing serious threats. The present study assessed the distribution, activity pattern, and abundance of Gaur in the Royal Manas National Park (RMNP) through a single season occupancy modeling. The study was conducted through camera trap survey for a period of three months. Gaur was the second most abundant species among targeted sympatric species (RAI = 6.35) and its distribution was restricted mostly in the southern sub-tropical forest belts. The highest elevation that Gaur was recorded was 2256 m asl. The mean detection probability of Gaur in RMNP was 33 %  $\pm$  0.04 (0.25-0.47) and naive occupancy rate was 51.5%. The estimated Gaur occupancy with inclusion of imperfect detection showed 62.4%  $\pm$  0.15 (0.296-0.864) of 659.6 km<sup>2</sup> of RMNP area occupied. Core zone in RMNP was observed as most preferred habitat as Gaur tended to avoid human disturbances. Distance to saltlick and settlement was the most significant habitat parameter for Gaur's existence. Evidences of poaching inside the park call for reinforcing Spatial Monitoring Assessment and Reporting Tool (SMART) in patrolling and management of Gaur conservation in RMNP.

**Keywords:** Bhutan, Gaur, habitat, occupancy modeling, predators, prey, saltlicks, waterholes

### Introduction

Bhutan is an important part of one of the 20 priority tiger conservation landscapes that supports breeding tiger population (Wikramanayake *et al.*, 2011). For a tiger and other higher profile predators to exist, a strong prey base such as the Gaur – the principal focus species for the present study, besides others is vital (Pabla *et al.*,

2011; Sankar *et al.*, 2013). The Gaur, scientifically known as *Bos gaurus* Smith, is one of the largest herbivores of Bovidae family (Choudhury, 2002) and they are mostly confined to the oriental biogeographic region (Ashokkumar *et al.*, 2011) of the world. Gaur has been recorded in Bangladesh, Bhutan, Cambodia, China, India, Laos, Malaysia, Myanmar, Nepal, Thailand, and Vietnam (Choudhury, 2002; Nguyen *et al.*, 2007), but its habitat is mostly confined to the protected areas. The global distribution of Gaur has reduced by over 80% in the past 100 years (Groves and Grubb, 2011) and its population status is poorly known

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in many countries (Duckworth *et al.*, 2016) which is why Gaur is listed in Vulnerable category in the Red List document of International Union for Conservation of Nature (IUCN). Habitat loss and fragmentation in general are among the most pervasive threats affecting the biological diversity (Wilcox and Murphy, 1985).

In Bhutan, Gaur is mostly confined in the southern belts consisting of sub-tropical forest tracks within the elevation range of 97 to 1500 metre above sea level (m asl) (Wangchuk *et al.*, 2004). While Gaur is listed under Schedule -I species of the Forest and Nature Conservation Act 1995 (RGOB, 1995) and is totally protected, limited research and policy documents without lined conservation strategy hinders conservation priority action plan for the species. The species owing to its elusive, large and convoluted nature is least studied group worldwide and Bhutan is no exception. The limited information about the distribution of Gaur comes from carnivore population monitoring activities worldwide (Ashokkumar *et al.*, 2011; Tempa *et al.*, 2011; Ahmed *et al.*, 2015) and there are only few instances of species specific research.

The potential habitats and thriving population of Gaur in the southern region (Choudhury, 2002) also face threats from increasing illegal wildlife trade, hunting for hu-

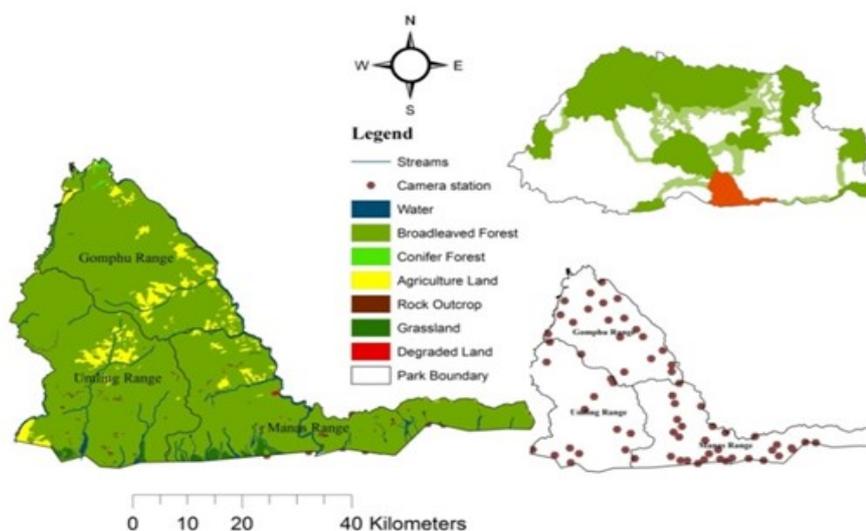
man consumption, and habitat fragmentation (RMNP, 2015). The recent adventure in the use of camera traps to study terrestrial animals (Tobler *et al.*, 2008) has enabled wildlife researchers to enter into the realm of cryptic animals (Nichols *et al.*, 2002) such as the Gaur, accelerate the discovery of habitat use and activity patterns, and pro-

vide essential information for their conservation. Camera traps and occurrence data provide useful information concerning habitat use, degree of habitat overlap, and activity patterns (Sanderson, 2010), which help to understand the ecological requirements of Gaur and in developing informed conservation interventions. In Bhutan, Thinley *et al.* (2015) used camera traps to understand the occupancy rate of mammalian carnivores in Jigme Dorji National Park. Therefore, the objectives of this study were to estimate Gaur distribution and abundance, determine the habitat use of Gaur and its interaction with other sympatric ungulates and major predators, and estimate occupancy and detection probability of Gaur using different habitat covariates in a single season time frame.

## Materials and Method

### Study area

The Royal Manas National Park (RMNP) is situated in the south central foothills of Bhutan (90°35'E to 91°13'E and 26°46'N to 27°08'N), which is the oldest park in Bhutan. Administratively, the park intersects three political districts of Bhutan: Zhemgang, Sarpang, and Pemagatshel. Spanning an area of 1,057 km<sup>2</sup> the park is the central thread connected by both national and international protected area



**Figure 1:** Study area map and camera trap locations

network (DOFPS, 2016) which is recognised globally (UNESCO World Heritage Centre, Paris) as a single transboundary entity and conservation complex (Ahmed *et al.*, 2015).

RMNP is connected with other protected areas of Bhutan by biological corridors such as the Phibsoo Wildlife Sanctuary and Jigme Singye Wangchuck National Park. It further adjoins with the World Heritage Site (Manas National Park) in India forming an integral part of the Transboundary Manas Conservation Area (TraMCA) and Manas Tiger Reserve (DOFPS, 2016).

The unique landscape of RMNP forms an important natural conservatory of the country representing outstanding habitat diversity ranging from tropical monsoon forests (< 500 m) and subtropical forests (500–1000 m) to warm broadleaved forests (1000–2000 m) and cool broadleaved forests (2000–2714 m). RMNP is known for harbouring one of the greatest populations of wildlife diversity. It is one of the few places in the world which harbour eight felid species of which three species are Threatened and two are Near Threatened category of IUCN Red List (RMNP, 2015). Geographically, RMNP covers elevation ranging from 97 m asl adjoining the Indian border to as high as 2714 m asl (DOFPS, 2016). The annual maximum temperature ranges from 20–34 °C and annual rainfall varies from 200–4400 mm; and the area is hot and humid in summer and dry and cool in winter months (RMNP, 2015). The RMNP is functionally divided into two management zones; the core zone covering 653 km<sup>2</sup> and the remaining under multiple-use zone. Core zones are set aside for strict wildlife conservation with the strict restriction for entry of people or resource extraction. Multiple-use zone on the other hand also harbours human settlements and resource extraction is allowed for subsistence use by the park residents.

The camera trapping in this study was carried out in Manas, Gomphu, and Umling ranges of RMNP which cover the prime habitat of Gaur located within tropical monsoon, sub-tropical, warm broadleaved and cool broadleaved forests.

#### *Design of camera trap survey*

Camera-trap field data were collected from the study area of 1,057 km<sup>2</sup> covering three ranges (Umling, Manas, and Gomphu). The study area was divided into 2 x 2 km grid to increase the probability of Gaur detection (O'Brien, 2011) (Figure 1). Distance of 2–4 km was maintained between each camera stations. A total of 92 camera traps were set up along the sites having higher incidences of animal signs, game trails, river bed sides, and forest roads.

To deter and avoid damages from elephants, fresh elephant dung were placed on camera to blend with surrounding environment and each camera-trap was given unique number (e.g. RM\_004) and coordinates of all the locations were recorded by GPS. Data sheet used for data collections had provisions to collect habitat information such as the forest canopy. Cameras were operational for 90 trap nights with a camera trapping efforts of 5,386 trap days.

#### *Data management and analysis*

After retrieval of cameras, the images of mammals that were included in this study were sorted by survey sites and station grid numbers. A capture history of Gaur for single season was built using Camera Trap File Manager [CTFM] 2.1.8, (Kaplan, 2006). Date, capture time, survey site and grid IDs were stamped on captured images using CTFM software. The grassland shape files of RMNP were extracted from Land Cover Mapping Project (LCMP) (Ministry of Agriculture and Forests [MOAF], 2010) using clipping tool in ArcGIS. Meadows and shrubs were extracted from the land use type.

Saltlick points and waterhole shape files were obtained from RMNP office records. Major rivers and perennial streams of RMNP were laid on Google earth after consulting experienced field staff and converted into poly lines to be incorporated as habitat covariates. However, waterholes, rivers or streams were taken into habitat variables as water bodies in general. The settlement shape files were obtained from RMNP office record while presence of human disturbances in the study area were marked through

presence of human signs and evidences both from camera trap survey and field survey.

The distance between each camera station to settlements, water bodies, saltlicks and grasslands were measured using buffering tool of ArcGIS. The distance were taken as multiple of 100 m in order to reduce over or under estimation. For instance, the camera station measuring a distance of 20 m as well as 80 m from saltlick points were taken within 100 m. Elevation of the camera stations were recorded in camera trap data form while forest types were segregated based on elevation range as per Oshawa (1987) and RMNP (2015). Presence of carnivores was marked using camera trap data.

#### *Estimation of abundance and activity pattern*

The activity pattern was graphed as number of independent event obtained during a particular time period of 24 hour time scale. Each independent event, irrespective of animal species, was considered within the 30 minutes time frame (Kelly and Holub, 2008). The Photographic Capture Rate Index (PCRI) or Relative Abundance Index (RAI) was estimated for some of the mammal species besides Gaur in order to understand its sympatric species.

#### *Estimation of occupancy*

The data collected from motion-activated cameras were used to estimate detection and occu-

pancy estimates for Gaur by respecting closure assumption for the entire sampling period of 90 days (i.e., no changes in occupancy). Estimation for probability of detection and occupancy ( $\psi$ ) was done using programme PRESENCE Version 11.8 (Hines *et al.*, 2006).

For the purpose of this study, 90 days of survey period was divided into 7 sampling occasions consisting of 12 days in each occasion. Gaur detection histories were generated for each of the 92 cameras across the 90 sampling days. For a given species, detection histories provide a record of whether the species was detected (1) or not detected (0) and (-) for missing data on each survey day for each camera location. There were 92 detection histories for each camera station. Occupancy model (Mackenzie *et al.*, 2006) was used to analyse the proportion of area occupied by Gaur in RMNP.

## **Results and Discussion**

#### *Sampling efforts and sampling success*

The data here represent for 68 functional camera stations only. Gaur was captured only in 35 camera stations out of 68 functional cameras. In total, 5,763 images of Gaur were captured during the effective sampling period ranging from 97–2135 m asl. The highest photo capture was from Manas range with 1,387 photos and lowest was from Gomphu with only one picture from

**Table 1:** Relative abundance of major prey and predators of RMNP

Species	Total Station	Total Photo	Sampling Occasions	Sampling Efforts	Total IE	RAI-I	RAI-II
Common leopard	68	684	18	5,386	115	46.83	2.14
Tiger	68	221	18	5,386	57	94.49	1.06
Asiatic wild dog	68	455	18	5,386	90	59.84	1.67
Sambar	68	9,719	18	5,386	709	7.6	13.16
Water buffalo	68	208	18	5,386	21	256.48	0.39
Gaur	68	5,763	18	5,386	342	15.75	6.35

\* Relative Abundance Indices (RAI<sub>1</sub>: Number of days required to get single photo capture and RAI<sub>2</sub>: Number of photos per 100 trap-days) for major predators and co-prey species recorded in camera traps from RMNP

elevation of 2135 m asl. The highest elevation of Gaur recorded was at 2256 m asl and the highest elevation of camera set was at 2601 m asl.

#### *Estimation of Relative Abundance Indices (RAI)*

Among the major ungulate sympatric species, sambar was the most abundant species ( $RAI = 13.16$ ) while water buffalo was the least ( $RAI = 0.39$ ). Gaur was relatively abundant ( $RAI = 6.35$ ). Common leopard was the most abundant ( $RAI = 2.14$ ) among the major predator species followed by Asiatic wild dog ( $RAI = 1.67$ ) and tiger ( $RAI = 1.06$ ). The findings of this study support the reports by Tempa *et al.* (2011) and Ahmed *et al.* (2015) who mentioned that sambar is the most abundant prey species and common leopard is the most abundant predator in similar habitats. Presence of abundant prey species such as the sambar could explain the abundance of predators such as the tiger in the RMNP.

#### *Gaur distribution along elevation*

RMNP in general holds a great potential habitat for Gaur. Its distribution is found in all three ranges (Manas, Umling, and Gomphu) at various elevation zones with varying density. Gaur distribution assessed through camera traps had higher abundance in lower elevations  $< 500$  m ( $n = 20$ ,  $IE = 292$ ) showing its preference towards tropical plains at lower elevations. The presence of Gaur decreased with increasing elevation. Only four of the seven camera traps ( $IE = 9$ ) set above the elevation of 2000 m asl captured Gaur. Highest elevation that captured Gaur picture was at 2256 m asl. Free transboundary movement and the availability of grounds interspersed by minerals in the tropical monsoon forests at elevation  $< 500$  m were the prime habitats of Gaur mostly in RMNP.

#### *Gaur distribution based on management zone*

A total of 41 functional cameras were located in core zone out of which 28 stations captured Gaur images. The management plan of RMNP (2015) reflects that the core zone constitutes major portion of the park with representation of

diverse ecosystem.

Contrary to this, multiple use zones are delineated based on the presence of settlements and other developmental activities such as roads. In accordance with the delineation functions, only 7 cameras out of 27 stations captured Gaur pictures in multiple use zones. Thus, based on the presence of the core zone spanning over an area of 653 km<sup>2</sup> and the capture of highest Gaur pictures inside this zone, it could be concluded that the zonation based on functions under RMNP is appropriate.

#### *Habitat use*

Presence of Gaur is largely determined by the availability of food and geographic range they dwell in (Imam and Kushwa, 2013). However, looking into field reality; scarce and season based resources, human encroachment due to increasing population, insurgent problem, and illegal felling of trees affecting prime habitats are some of the real habitat parameters which need to be considered in determining the habitat use patterns.

#### *Distance to water bodies*

Water is one of the fundamental requirements of life. Therefore, water requirement of species has implications for all aspects of its ecology and conservation (Hayward and Hayward, 2012). Of the 35 camera stations that recorded Gaur, 94% were found within a distance of 2,500 m from the nearest river/stream or waterhole with only two camera stations being located between 2,500 – 4,500 m. Majority of the cameras that captured Gaur were nearby water bodies or within the average walking range of 3.2 – 4.8 km/day of Gaur (Imam and Kushwa, 2013; Nayak and Patra, 2015). High incidences of short distances that the Gaurs traveled to water bodies reveal Gaur's dependency on water every day.

#### *Distance to saltlicks*

The present study found that Gaur inhabits habitats as far as 25,000 m from the saltlicks. However, majority of the camera stations ( $n = 25$ )

that captured Gaur were within the distance of 4,000 m from the nearest saltlick. The stations at the higher elevations were located furthest from the saltlicks. There was significant negative association between Gaur occurrence and distance to saltlicks ( $r = -.417, p < .01$ ). The number of camera stations increased from ( $n = 1$ ) at distance of 25,000 m to ( $n = 30$ ) at 5,500 m indicating high occurrence of Gaur near saltlicks.

#### *Elevation and forest type*

Over 57% ( $n = 20$ ) of the camera stations that captured Gaur were between the elevation of 97 to 500 m, especially in the southern part of the national park. As elevation increased, the number of camera traps capturing images of Gaur decreased. Choudhury (2002) mentioned the low-lying plains as the optimal habitats for Gaur which occupies areas mostly below 381 m asl. Following the subtropical monsoon forests, the warm broadleaved forest (500–1000 m) saw more camera traps capturing Gaur ( $n = 9$ ). Only two cameras captured Gaur in cool broadleaved forest (2000–2714 m) and both of them were solitary. The presence of Gaur showed negative association with elevation ( $r = -.270, p < .05$ ). These findings indicate that the Gaur prefers low lying subtropical and warm broadleaved forests in the southern foothills of Bhutan.

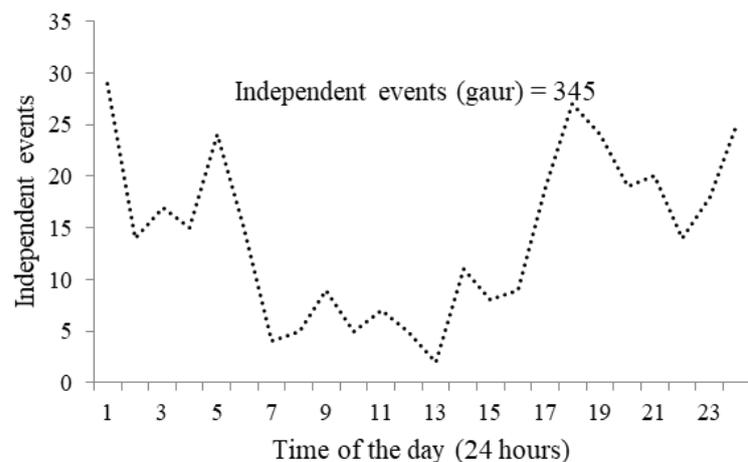
#### *Distance to grassland*

The distance to grassland and Gaur occurrence showed significant negative association ( $r = -.317, p < .01$ ) indicating Gaurs preference for open areas. Twenty four camera stations that recorded Gaur were within 4,500 m and 11 were away from 6,500 m from nearest grassland. Sankar *et al.* (2001), in his study on ecology of Gaur in Pench Tiger Reserve (PTR), Madhya Pradesh, found that Gaur does not prefer dense forest. Similarly,

Paliwal and Mathur (2012) using GIS based modeling in Tadoba Andhari Tiger Reserve in central India found habitat with lower canopy cover as suitable habitat. All these findings confirm the use of open grasslands by Gaurs as prime habitats.

#### *Distance to settlement and human presence*

Out of 35 camera station that captured Gaur, only five camera stations were located within the distance of 1,500 m from the nearest settlement. Twenty five camera stations were located 3,000 m away from settlements which indicate Gaur's avoid human settlements. There was positive association ( $r = .523, p < .01$ ) between Gaur occurrence and distance to settlement. The number of Gaur captured images increased as the distance increased from settlements. Also, there was significant negative association between human occurrence and presence of Gaur ( $r = -.335, p < .01$ ). Choudhury (2002) and Duckworth *et al.* (2008) defined habitat loss due to increase in human population as the large scale decline of Gaur range indicating it as a major threat to Gaur conservation in Asia. Imam and Kushwaha (2013) also pointed the anthropogenic pressure negatively affecting the Gaur population in CTR. Paliwal and Mathur (2012) also reported about Gaur avoiding areas where there are human presences in Tadoba Andhari Tiger Reserve in central India.



**Figure 2:** Temporal activity of Gaur in 24 hours

### Temporal activity of Gaur

Gaurs in general were active throughout the days and nights as their activity curve never dropped to zero (Figure 2). However, the Gaurs were highly active during the dusk (19:00 to 20:00 hours) and early morning (04:00 to 07:00 hours). Also, they remained active in the midnight hours (22:00 to 01:00 hours) making them crepuscular; and their movements were less during the days (07:00 to 16:00 hours). This finding supports the finding of Nayak and Patra (2015) from KWS, India where they reported highest feeding activity of Gaur in the early morning hours and in the evening hours. A study by King *et al.* (2016) on patterns of saltlicks usage by mammals in Cambodia found Gaurs' saltlick activities prominent at midnight, thus showing their nocturnal behavior.

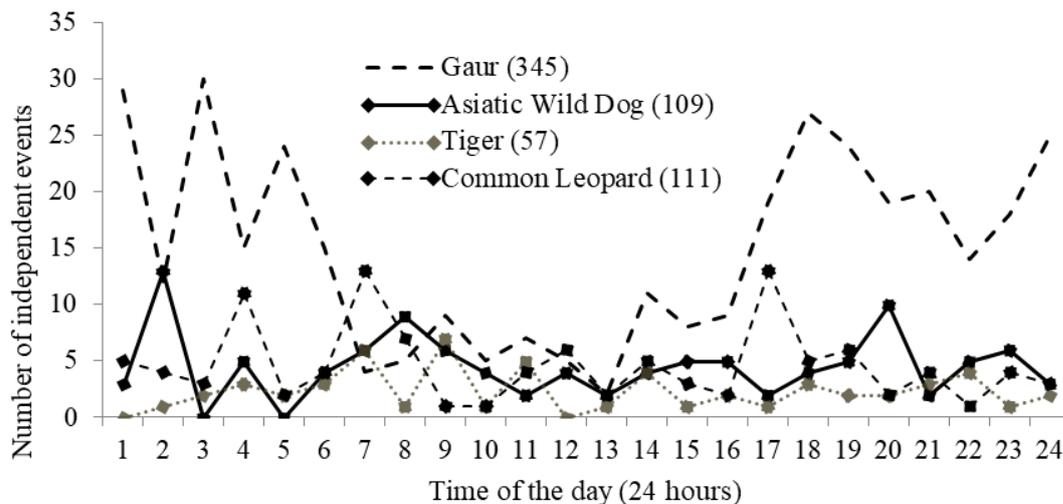
### Spatial and temporal habitat overlap of Gaur with its major predators

Gaur is considered as one of the major prey species of tiger and other large felids. The other prey species includes sambar and water buffalo. Tiger was found only in 20 stations out of 68 stations distributed spatially across the elevations in RMNP. The 18 stations out of 20 where tiger image captures were found overlapping with the Gaur captured stations indicate tiger as one of the major prey species of

Gaur. Asiatic wild dog was found in 17 stations mostly concentrated in the higher elevations and 10 of these stations were found to be overlapping with the presence of Gaur. Common leopard was found in 28 stations concentrated mostly in lower elevations and 20 of these stations overlapped with Gaur captured stations.

Predators' activity patterns were observed to be active throughout the days and nights. Gaur, common leopard, and Asiatic wild dog had similar activity patterns indicating high predator-based threat for Gaur. Tiger was seen active throughout the day though its activity peaked from dusk to noon.

Ashokkumar *et al.* (2011), while conducting large carnivore diet profile analysis, found Gaur in tiger's diet between 1.87 to 30.4%. Similarly, Gaur constituted around 10% in tiger's diet in Mudumalai (Bhumpakphan, 2008). Gaur diet percentage was higher in Nagarhole, Bandipur, and Indira Gandhi Wildlife Sanctuary of India with 17.4% (Karanth and Sunquist, 1995), 23.9% (Andheria *et al.*, 2007) and 30.4% (Kumaraguru, 2006) respectively. In leopard's diet Gaur constituted 10% whereas in wild dog's diet it constituted less than 1% in Mudumalai and Bandipur and 12% in Indira Gandhi Wildlife Sanctuary (Andheria *et al.*, 2007). The universal assumption of Gaur



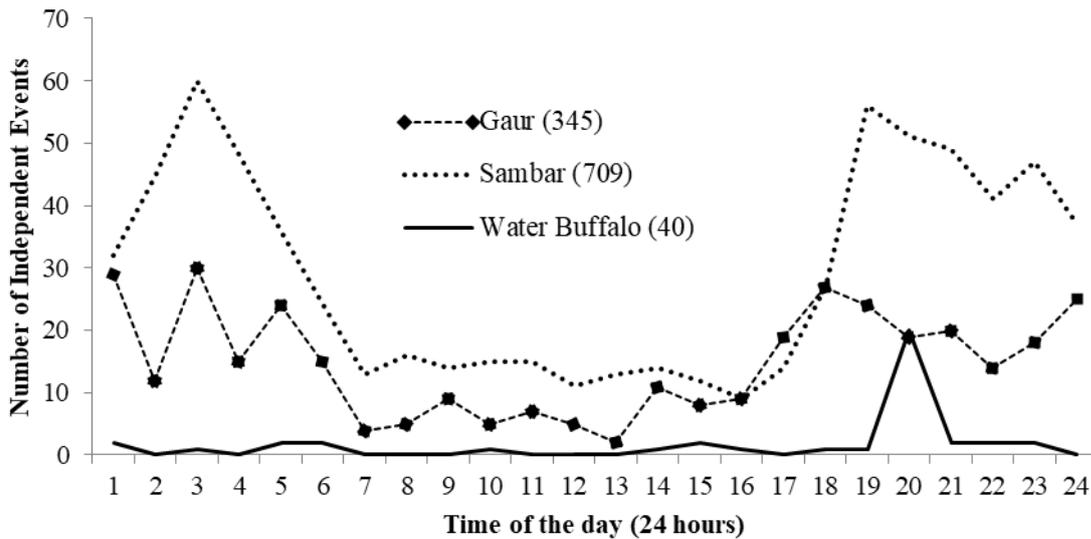
**Figure 3:** Temporal activity of Gaur and major predators in RMNP

as one of the important prey species for flagship species (tiger) can be agreed in case of RMNP as well, considering higher habitat sharing and similar activity pattern (Figure 3). Predation was also sighted during the camera trap survey which indicates tigers' preference for Gaur.

*Spatial and temporal habitat overlap of Gaur with its sympatric species*

Sambar and water buffalo were considered as Gaur's sympatric species because of their similarity in resource use pattern. Water buffalo was captured only in 4 camera stations out of 68 stations and Gaur was recorded in all these 4 camera stations indicating some degree of habitat overlap between the two mega herbivores. Sambar was found in 42 camera stations out of which 21 stations overlapped with Gaur's habitat.

Sambar had similar activity pattern with Gaur with its peak activity from dusk to early morning. However, water buffalo, because of its less detection ( $IE = 40$ ) were seen active only towards dusk. They remained inactive throughout the day and late night. Water buffalo, though less in number ( $IE = 40$ ) had similar activity pattern with Gaur and sambar (Figure 4). Similar feeding habit and timing showed resource competition between these herbivores especially in winter season when resources become scarce. Salt or mineral licks are must factors for Gaur, sambar and water buffalo that are mostly distributed in the lower areas. Such licks are regarded as spatially-limited resources (Klaus and Schmid, 1998). Matsubayashi *et al.* (2006) mentioned about having similar food-habit ratio among sambar, Gaur, and water buffalo.



**Figure 4:** Temporal activity pattern of Gaur and its sympatric species

*Probability of detection of Gaur in RMNP*

Psi ( $\psi$ ) is the probability a site is occupied by the target species. The  $p$  is the probability of detecting the species during the survey, given it is present. For detectability, the additive effects of sites and effort (number of sampling days) were taken in the top models (i.e., models where AIC difference [ $\Delta_i$ ] was  $< 2$ ). Model 4 (Table 2)

comprising of all the detectability parameters was found to be the most supporting model for Gaur detectability ( $\Delta I = 0.00$ ,  $w_i = 0.97$ ). Based on this model, both the site and effort were found important for the perfect detectability of Gaur in RMNP and the Gaur detection also varied among sites.

**Table 2:** Top ranked model influencing Gaur detectability

Model Code	Model	N.Par	AICc	$\Delta$ AICc	AICc Wt
g4	Psi (.) <i>p</i> (site + effort)	5	365.74	0.00	0.97
g3	Psi (.) <i>p</i> (effort)	4	372.74	7.00	0.03
g2	Psi (.) <i>p</i> (site)	3	377.35	11.60	0.00

\* $\Delta$ AICc is the absolute difference in AIC values relative to the model with the smallest AIC. AIC wt is the AIC model weight. N.Par is the number of parameters accounted in the model

Effort showed positive impact on Gaur detectability (0.348,  $SE = 0.16$ ). It indicates the increase in probability of Gaur detection with increase in effort not forgetting the closure assumption of sampling period (Rota *et al.*, 2009). Manas (site 1) was accounted as intercept ( $\beta_0$ ) as it had higher effect on Gaur detectability ( $-4.68$ ,  $SE = 1.97$ ) followed by Umling range ( $-2.183$ ,  $SE = 0.51$ ). Gomphu range had the least site effect on Gaur detectability ( $-0.289$ ,  $SE = 0.166$ ). Based on the 95% confidence interval of set models, the mean detection probability of Gaur in RMNP was found to be  $0.33 \pm 0.04 SE$ .

#### Occupancy models

Among univariate models,  $\Delta$ AICc ranking showed distance to settlement having the high-

est effect on Gaur occupancy ( $\Delta$ AICc < 2). A total of 64 multivariate models were conducted to check the additive effects of covariates on Gaur occupancy. Best performing occupancy models were selected based on  $\Delta$ AICc ranking which resulted in best 5 models i.e., within  $\Delta$ AICc < 2 (Table 3). Model selection at 95% confidence interval showed that distance to settlement has the highest impact on Gaur occupancy ( $SMW = 0.98$ ,  $CI = 0.364-2.475$ ). However, all *p*-covariates i.e., effort, site had highest impact on Gaur occupancy. As discussed in habitat use section, Gaur is known to avoid areas where there are settlement and human presence and the Gaur occurrence decreases with decrease in distance to settlement and vice versa.

**Table 3:** Top models influencing Gaur occupancy

Models	N.Par	logLik	AICc	$\Delta$ AICc	AICc Wt
$\hat{p}$ (effort + site) psi (set)	6	-172.04	357.46	0	0.27
$\hat{p}$ (effort + site) psi (ele + set + wat)	8	-169.78	358.01	0.54	0.2
$\hat{p}$ (effort + site) psi (ele + set)	7	-171.1	358.06	0.6	0.2
$\hat{p}$ (effort + site) psi (ele + fort + set + wat)	9	-168.48	358.06	0.6	0.2
$\hat{p}$ (effort + site) psi (ele + fort + set)	8	-170.27	358.97	1.51	0.13

\* $\Delta$ AICc = the absolute difference in AIC values relative to the model with the smallest AIC. AIC wt. = the AIC model weight. N.Par = the number of parameters accounted in the model. Loglik = maximum likelihood function of model, Effort = number of sampling days, Site = sampling site, Set = Distance from settlement, Wat = Distance from water bodies, Fort = Forest types

#### Overall predicted Gaur occupancy in RMNP

Overall occupancy of Gaur ( $\psi$ ) was estimated incorporating all the *p*-covariates and psi-covariates that were within the  $\Delta$ AICc < 2. Naive occupancy showed only 51.5% of RMNP area occupied by Gaur. However, the estimated occupancy showed  $62.4\% \pm 0.15 SE$  (0.296–

0.864) of RMNP area occupied by Gaur, which relates to 659.6 km<sup>2</sup>. The occupancy estimated was higher than the naive occupancy highlighting the importance of taking into account the imperfect detection and inclusion of habitat covariates. This prediction shows that site with higher probability of occupancy were

concentrated in lower elevations with relatively flat and moderate terrain area. Among sites, Manas range holds the highest probability of Gaur occupancy with least disturbed areas. Umiling range on other hand showed the least probability of detection and occupancy was least as there is threat from human presence.

### Conclusion and Recommendation

Gaur as one of the primary prey species for carnivores which have implications for conservation of many threatened predators including tiger as the reduction of large ungulate prey leads to declining population of the predators. A study on the distribution pattern, abundance and occupancy of Gaur in the RMNP was conducted with the primary goal of establishing baseline information for the important prey species – tiger, since RMNP forms an important tiger conservation landscape in the region. Besides this objective, occupancy modeling was also done to further assess the probability of Gaur occurrence based on detection data.

Model weighted through AICc found distance to settlement, elevation and distance to saltlick as the top ranked model,  $\Delta AICc < 2$ . Gaurs were widespread within three ranges of RMNP but tended to avoid disturbed areas, calling for conservation efforts to strengthen habitat protection. Gaur distribution within core and multi-

ple use zones also showed Gaur avoidance to human disturbances.

While the current distribution and occurrence of Gaur in RMNP is good with over 50% of the national park occupied by the species, the study also found certain threats for the conservation of the species. Habitat loss and degradation are found to be the emerging threats of higher risk and there were evidences of poachers inside the national park, which is even more alarming. This calls for reinforcing SMART patrolling frequently and regularly throughout the year. Since many important ungulate species and carnivores share same habitat, holistic conservation interventions will have wider impact in managing as the entire ecosystem level.

### Acknowledgement

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