Ecology of Gaur (*Bos gaurus*) in North Bengal including population dynamics, distribution, habitat use pattern, protected area wise carrying capacity estimation and Human Gaur conflict

FINAL REPORT

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Executive Summary

The gaur population in India is restricted to a few states including the Northern part of West Bengal. As this landscape is contiguous with Bhutan, Bangladesh and Nepal, North Bengal forms a key conservation area for gaurs. The gaurs are predominantly forest-dwelling bovids, with preference for evergreen and moist deciduous forests; but also occurs in the dry deciduous forests. The forests of North Bengal support a healthy population of gaurs, but mostly confined to the protected areas. During a survey conducted by West Bengal Forest Department in 2002, a total of 1261gaurs were reported. However, ecological studies on gaurs are limited from the region.

The landscape is fragmented with little connectivity among the forested areas. This has considerably increased the straying of gaurs, and thus increased human-gaur confrontations around the fringe areas. We conducted this study from 2016 to 2020 to understand the ecology of the species with support from West Bengal Forest Department and Biodiversity Conservation Project.

To understand the distribution of the species across the landscape we conducted a grid-based survey using grid cells of 4km x 4km size. Based on the information of the survey, we attempted to estimate gaur population abundance using the standard Distance Sampling framework, which has been extensively used to estimate population density of herbivores across Asia. Within the Distance Sampling approach, we adopted line transect sampling protocol and estimated the gaur population abundance at 3962± 680, with the highest density at the Gorumara National Park. Further, we investigated the population structure of the gaurs in our study area. The estimated sex ratio of the population was 1:3.14 (male:female) and the age structure was recorded as 68.7:17.6:13.7 (Adult:Sub-adult:Juvenile/calf). The mean herd size was found to be 15.12 ± 2.36.

We investigated the habitat use pattern by gaurs at finer scale, wherein we categorised nine habitat types within the study area. We used Manly's preference index to describe the habitat preference of gaurs. In our study area the gaurs were found most abundantly in the semievergreen forests, with a strong preference for this habitat type. The semievergreen forests were used more than its availability. The other habitat typesused in proportion to its availability

are the mixed forests and grasslands. During the study, the gaurs were found to use the tea gardens, as the tea gardens occur at the edge of forests. Using direct observation technique, we identified 32 species of plants that are used by gaurs as their dietary item.

During our study period we recorded 90 human-gaurconflict incidents in the landscape which mostly included gaur stray-out to the nearby villages, and crop-raids. The Jalpaiguri District and the Gorumara National Park witnessed the maximum number of straying cases. There are very few incidents of human fatalities.

We attempted to estimate the gaur carrying capacity in the forested areas of northern West Bengal. Though we did not have any primary data for estimating the carrying capacity as it requires long-term data, which was beyond the capacity of the project; we “borrowed” data from available literature to get an estimate. We found that the study area can support approximately 5479 gaurs based on habitat and biomass availability, and assuming no human pressure. We also provide a set of recommendations that may be implemented for ensuring the survival of the species.

Chapter I: Introduction

1.1 Background

The gaur *Bos gaurus* is the largest bovid species in the world, with adults weighing up to 900 kg (Prater 1980). It is categorized as vulnerable by the IUCN Red List (Duckworth et al. 2016), with a decreasing population trend. Once distributed throughout South and Southeast Asia, but currently occurring in fragmented populations of the original distributional range in India, Nepal, Bhutan Cambodia, China, Lao PDR, Malaysia (Peninsular Malaysia), Myanmar, Thailand, and Viet Nam (Fig. 1). The species became extinct in Sri Lanka, and its presence in Bangladesh is questionable (Duckworth et al. 2016). Karanth et al. (2010), estimated approximately 60% range reduction of the species in the past 50 years. Nonetheless, India is the stronghold of gaur population, distributed in four major regions such as the Western Ghats, Eastern Ghats, Central India and the northeast India (Choudhury 2002).

Figure 1: Global distribution of gaur *Bos gaurus*, adopted from Duckworth et al. 2016 (IUCN Red list).

The northeast India population covers North Bengal as well as other states of the NE India. The habitat is contiguous with that of the transboundary landscapes of Bhutan, Bangladesh, Myanmar and Nepal (Choudhury 2002). In the north Bengal region, the gaur is found in the Himalayan foothills of the Darjeeling, Jalpaiguri and Alipurduar districts (Choudhury 2002).

The gaurs are predominantly forest-dwelling bovids, with preference for evergreen and moist deciduous forests; but also occurs in the dry deciduous forests (Schaller 1967). They are bulk feeders (Hofmann 1989), and their diet mostly consists of grasses, browse, and herbs (Chetri 2006, Sankar et al. 2013, Haleem &Ollyas 2018). The gaurs live in social groups and the group size may vary with sites (Ramesh et al. 2012).

Despite being a charismatic and large mammal species, there are very few studies on gaurs. Information on animal population abundance is crucial for scientific management of the wildlife (Huapeng et al. 1997). However, it requires a huge effort to estimate gaur population densities as the animals occur in dense forest habitats at low population density (Ahrestani&Karanth 2014). The population densities of gaurs varied from 0.6 to 11.3 per km^2 (Karanth& Nichols 2000, Karanth et al. 2001, 2008; Karanth& Kumar 2005). A study by Kumar (2010) in southern India has shown that the gaurs are known to be benefitted from higher level of protection and are also negatively impacted by anthropogenic activities.

1.2 Gaur in North Bengal

In North Bengal, the gaur population is mainly confined to the protected areas. Bhattacharyya, Choudhury & Biswas (1997) estimated a population size of 1000-1200 gaurs, mainly occurring in the Buxa Tiger Reserve, Jaldapara, Gorumara, Mahananda, Chapramari and Neora Valley protected areas. Subsequently, the gaur number was put at 1261 during the census conducted by the West Bengal Forest Department in 2002. In subsequent censuses by the Forest Department in 2010 and 2012, the gaur population was estimated to be 2,000 and 4,000, respectively across the North Bengal region*.

*(https://www.telegraphindia.com/west-bengal/food-chain-imbalance-swells-bison-count/cid/348792.

The gaur habitat in northern West Bengal is highly fragmented, with very little to no connectivity among the forested areas (Choudhury 2002). This has considerably increased the human-gaur conflict (HGC) around the fringe zones of the gaur-bearing areas.

Aaranyak conducted an ecological study on the species to gain an overall insight into the current status of the gaur population and to assess the ecological parameters, so as to come-up withinformed conservation recommendations. The study was commissioned by West Bengal Forest Department and Biodiversity Conservation Project with support from JICA and conducted from 2016 to 2020.

The straying of gaurs and the consequent conflicts with local people increased in recent years owing to loss of habitat, increase in both number and area of human settlements leading to habitat loss and fragmentation of the gaur habitat. Large number of tea estates, with their human population, in the adjacent areas of the forest land across the entire landscape is also a major reason for human-gaur interaction in the region. It has been noted that there has been a steady increase in gaur population in the protected areas of Northern districts of West Bengal, especially, in Gorumara NP, Chapramari WLS and Buxa Tiger Reserve. This may lead to more conflicts in the fringe areas. This final report presents the details of the three-year study, its findings and a set of management recommendations.

1.3 Objectives

The overall goal of the study was to investigate the ecology of gaur in North Bengal landscape and develop a management plan for the species. To achieve the goal the study has set the following objectives:

1. To study gaur ecology in North Bengal landscape.
    - To assess the population size
    - To assess the population structure
    - To assess the habitat use pattern
    - To study the feeding habit

2. To assess the gaur-carrying capacity in different protected areas of North Bengal.
3. To analyse the human-gaur conflict in the entire North Bengal landscape
    - To assess the present status of human gaur conflict
    - To develop plan for minimizing human-gaur conflict.
4. To develop the management plan of the species with suggestions from the Forest Department and other concerned authorities.

Chapter II: Study Area

2.1 Study Sites

The landscape of North Bengal encompasses a total geographical area of 12800 km^2 (Source – GIS Lab, Aaranyak) (Map 1). Of these, at least 3306 km^2 is forest area and approximately 1600 km^2 is considered to be gaur habitat (Source-GIS Lab, Aaranyak). The gaur habitat size is based on the total size of all the PAs and non-PA areas where gaur was previously reported. The landscape is divided into five administrative districts viz. Darjeeling, Kalimpong, Jalpaiguri, Alipurduar and Coochbehar (Map 2). There are nine forest divisions within the North Bengal landscape and five Protected areas (Table 1).

Table 1: Details of the Protected Areas of Northern West Bengal.

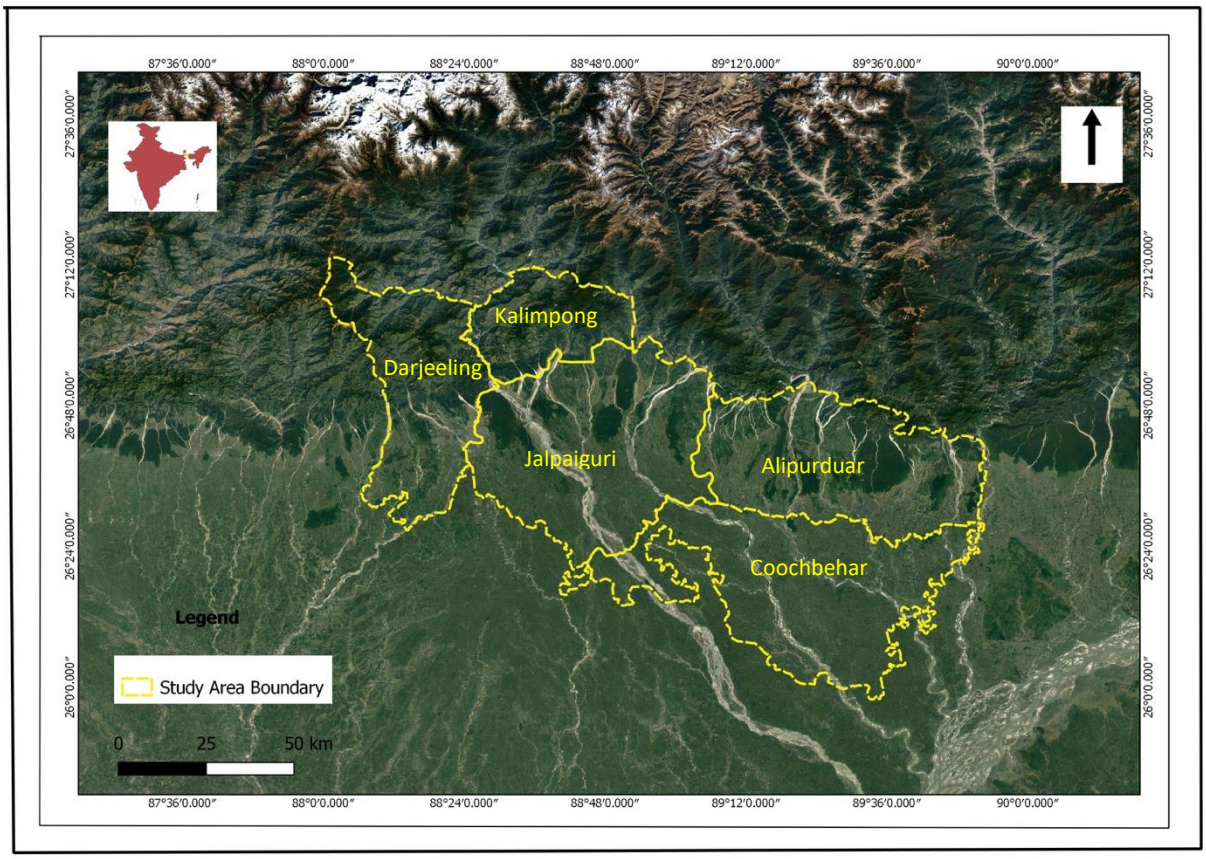
Sl. No.	Protected Area	Area (in km^2)	Key Biodiversity
1.	Buxa Tiger Reserve	760	Elephants, Gaur, Leopard
2.	Gorumara National Park	80	One-horned rhinoceros, Spotted Deer, Hog Deer, Gaurs
3.	Jaldapara National Park	216.5	One-horned rhinoceros, Hog Deer, Gaur
4.	Mahananda Wildlife Sanctuary	158	Rufous-necked hornbill, Gaur
5.	Chapramari Wildlife Sanctuary	9.6	Gaur, elephants
6.	Neora Valley	88	Rhododendron, Leopard, Asiatic Black Bear, Gaurs

The entire landscape is criss-crossed by numerous rivers like *Mechi, Teesta, Torsa, Raidak, Jainti, Dima, Basra, Diana, Murti, Jaldhaka, Neora, Leesh-Gheesh, Balaso* to name a few. Our study area covers all these administrative districts including the protected areas and non-protected territorial divisions. The region is included in the lower Ganga plain excluding the Darjeeling district, which falls under the Eastern Himalayas. The landscape can be broadly classified into three major geomorphic units as follows:

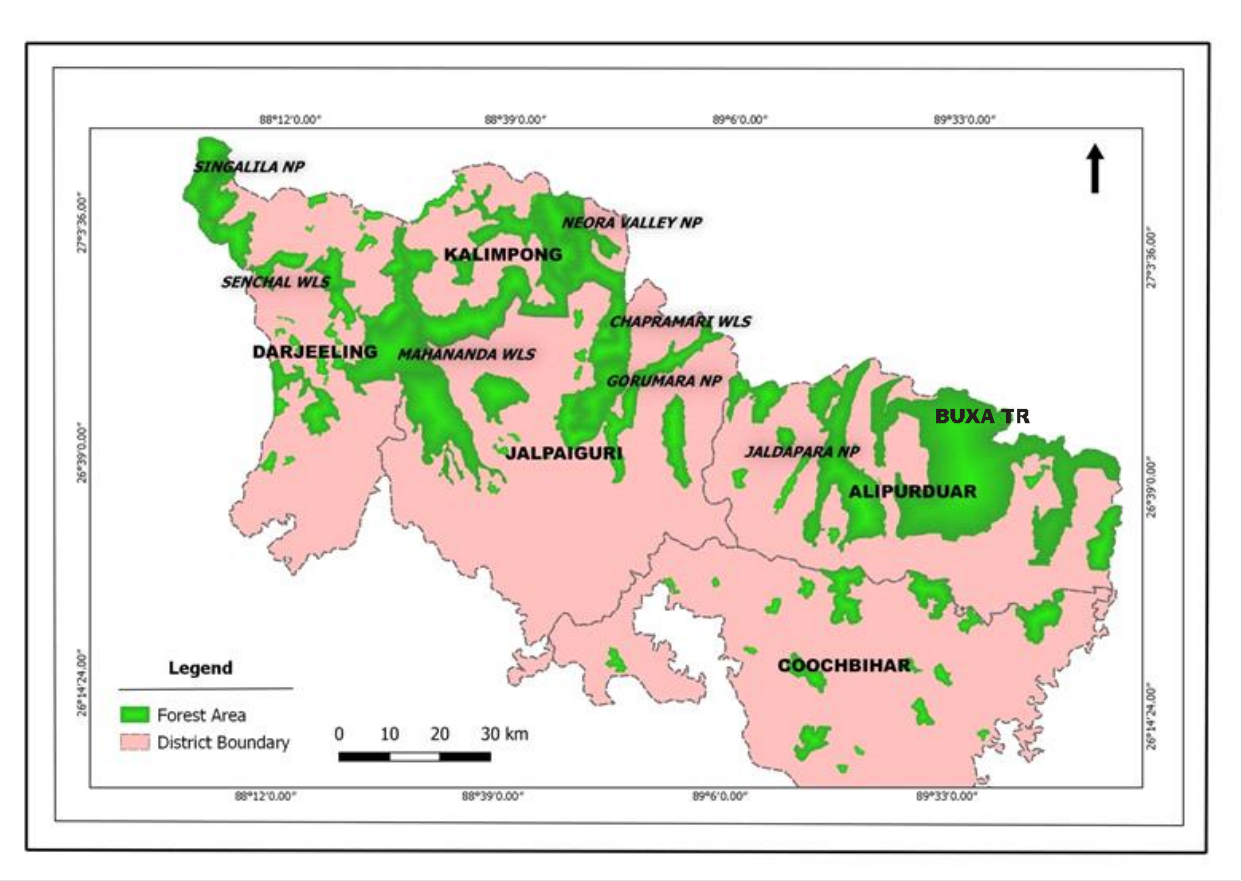
- The Hilly Region of North Bengal
- The Terai and the Dooars Region
- The Plains of the North Bengal

The altitude ranges within 600m to 3000 m. The Terai and Dooars region is covered by alluvium deposits, consisting of coarse gravels at the foot hills, sandy clay and sand along the course of the rivers, and fine sand consolidating into clay in the other parts of the river plain. The river Jaldhaka, Mechi and Rangit flows in the east, west and north portion of the region respectively, while in the middle, the river Balason, Mahananda, Teesta, Leesh-Ghees, Murti are known to flow. The average rainfall of the region is 250 cm to 300 cm. The forest types range from tropical evergreen in the foothills, through temperate evergreen in the middle ranges, to the coniferous in the higher elevations. The tropical evergreen forests are found below 1,000 m where *sal*, teak, *peepul*, *sishu*, bamboo are the dominant species.

The socio-economy of the region is based on agriculture while other activities are also noticeable. The region has witnessed a growth in manufacturing industries in recent years. Tea plantation is a major production hub in the region. The main crops cultivated are rice, wheat, mustard, jute and fruits.



Map 1: Map of the entire landscape with the district boundaries.



Map 2: Map of the entire landscape with the protected areas and district boundary classified.

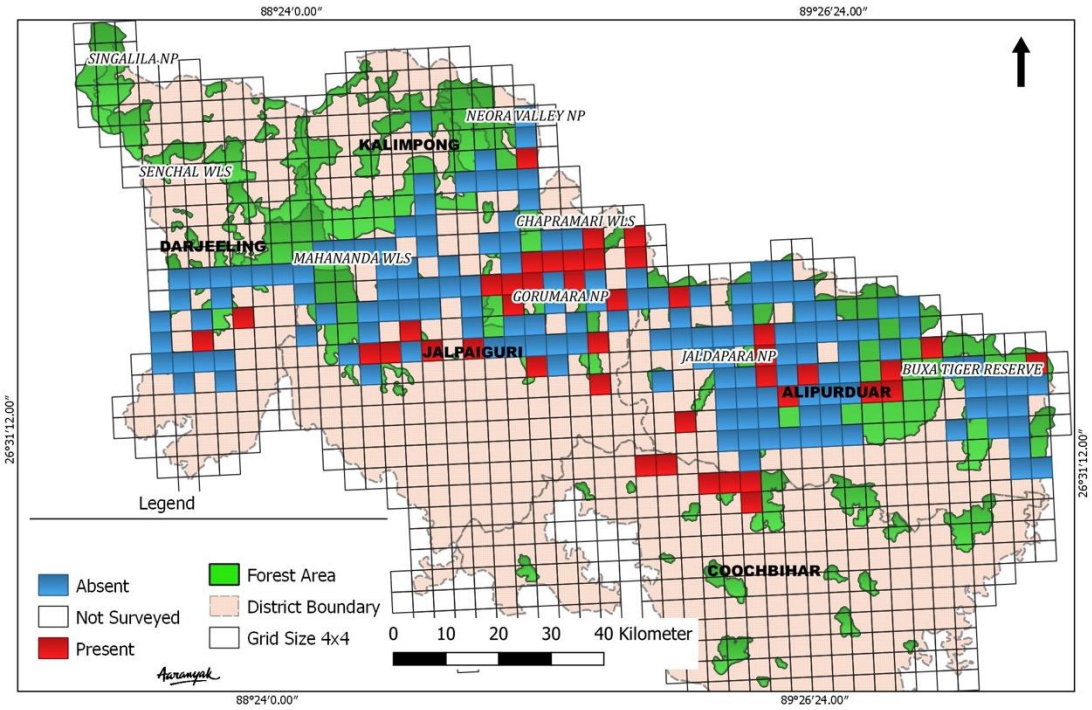
Chapter III: Population Status and Structure

3.1 Population status and structure

Preliminary reconnaissance survey

October 2016 – December 2016

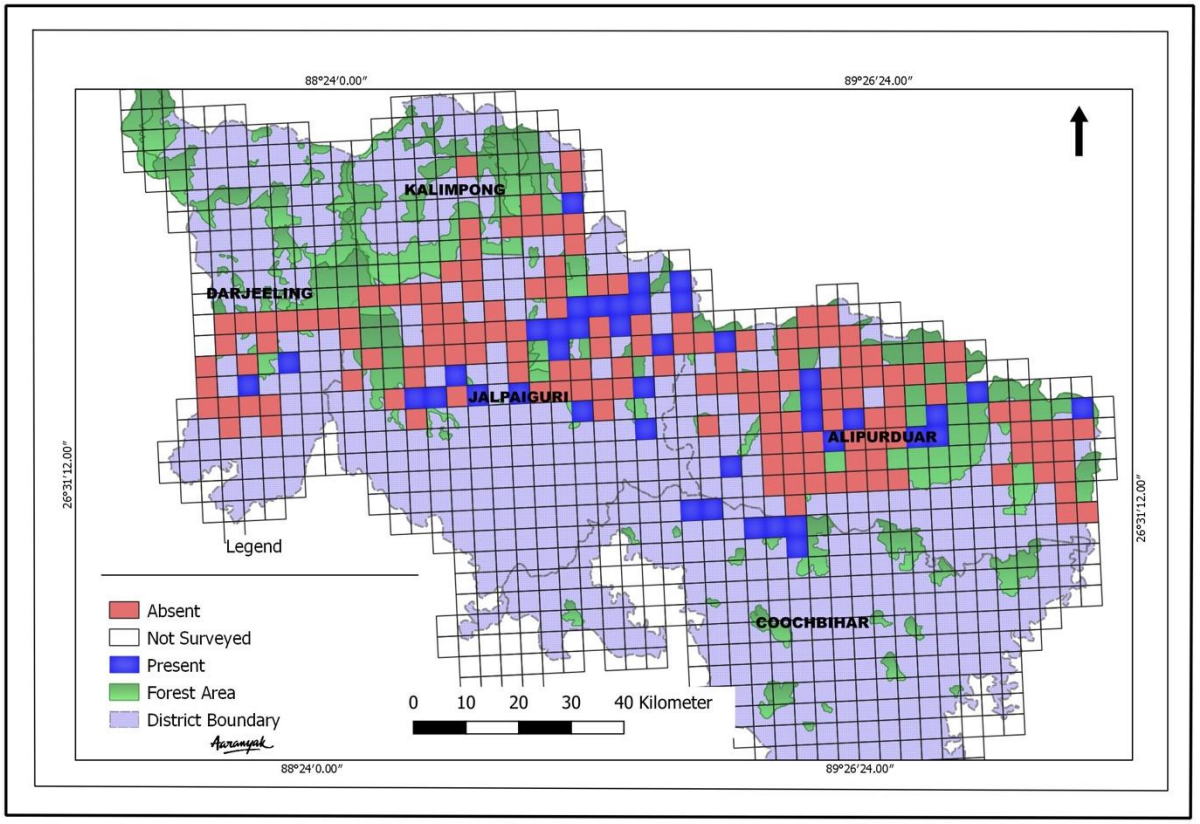
At the beginning of the study, we conducted rapid reconnaissance presence-absence survey of gaurs in the entire landscape of North Bengal. This also helped in selecting the sampling sites. Initially, the landscape was gridded into 16 km^2 (4 km x 4 km) blocks and the total number of blocks were 952 in the entire landscape. We surveyed 230 blocks to understand the occurrence pattern of gaur and reported the presence of gaur from only 36 grids (around 16% of the total surveyed grids) (Map 3).



Map 3. Map depicting the first grid- based presence-absence survey during October to December 2016.

December 2017 – February 2018

Another survey to document the gaur occurrence was carried out during December 2017 to February 2018, so that few more areas can be encompassed during this phase of the survey, besides noting any new areas where gaur has moved to in the current year. We sampled 186 blocks and found the presence of gaurs in 40 blocks (Map 4). We could not ascertain gaur presence in 146 blocks.



Map 4. Map depicting the second grid- based presence-absence survey of gaurs during December 2017- February 2018.

3.1.1 Population size

Assessing the population of any large mammal is always a challenge. To estimate the gaur population in the forests of north Bengal was a major challenge because of the dense vegetation and low density in certain areas. Additionally, the low sighting instances always pose a concern

in analysing the data. To overcome the limitation, we have conducted rigourous sampling with increased number of spatial replicates. During 2012, the population of gaur in the protected areas of North Bengal was around 4000 (Census, 2012) although it was not clear what methodology was followed to derive this estimate.

3.2 Methods

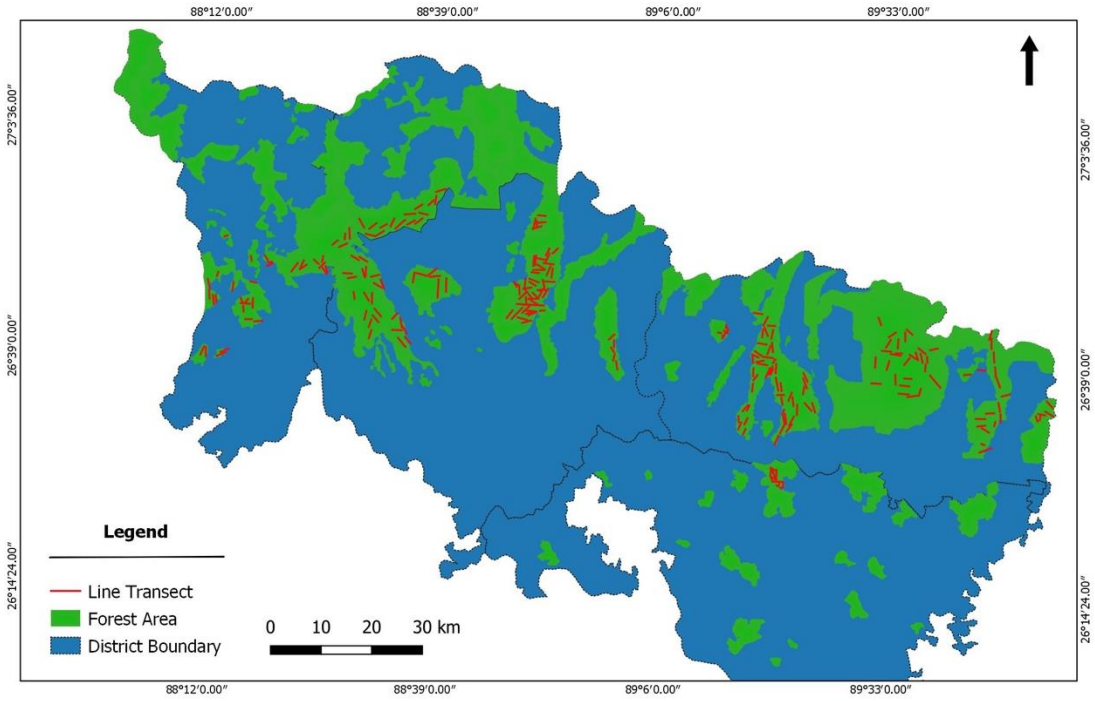
The line transect method following direct count, within the Distance Sampling framework is the most reliable and used method for gaur population estimation in the range countries (Jathanna et al. 2003). Hence, we adopteddistance sampling protocol using line transects to conduct the study. At first, the entire landscape was stratified on the basis of habitat type (in terms of vegetation) using GIS based map into (4 x 4) km^2 blocks.

3.2.1 Transect layout

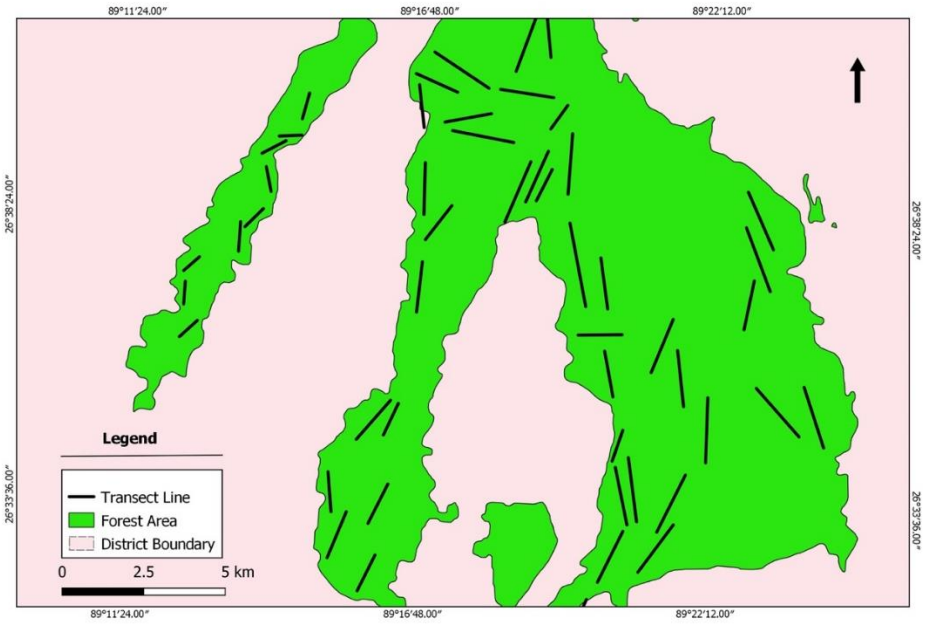
Layout of transects were systematically done (to maximise map coverage) using (4 x 4) km^2 grid in the study area (Map 5). The selection of the transect sites was done based on the reconnaissance survey. Maps 6, 7, 8, and 9 give the layout of transects in the various PAs in the study area. The transect length varied from 1 km to 2.5 km based on accessibility of the area. The team walked in a straight line along the transect, scanning both sides of the habitat for direct sighting of gaur. Once an individual or a group of gaurs was encountered, the radial distance and sighting angle were noted with the help of range finder and compass, from the first sighted location. The transects were one off transects and were spatial replicates. A total of 262 transects were laid covering a total distance of 352 km in the entire north Bengal landscape covering different habitat types. The details of the transects in different Forest Divisions are given in Table 2.

Table 2. Details of the line transect survey in the study area.

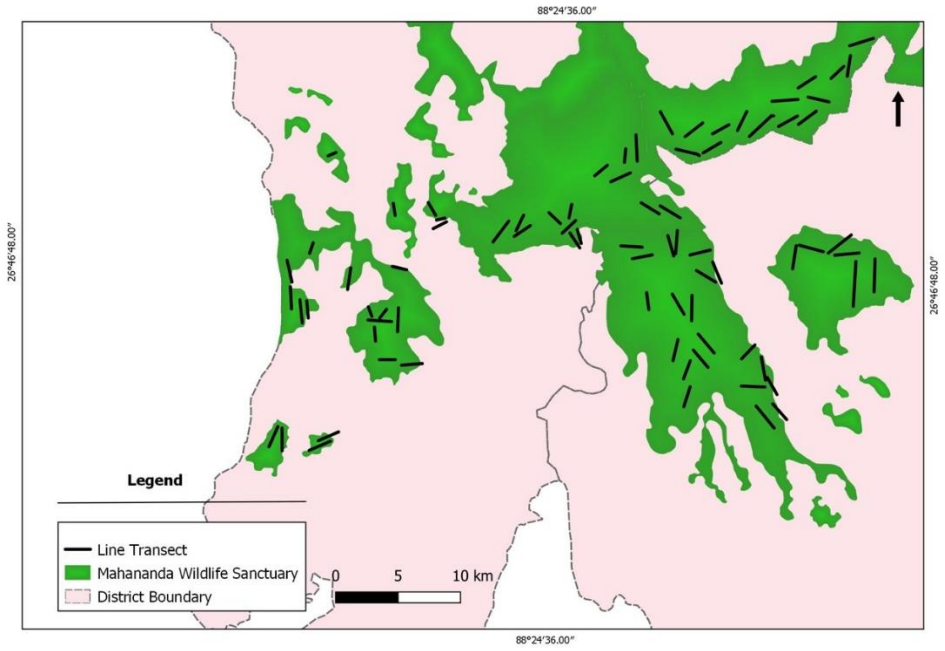
Division	No of transects	Average length	Max (km)	Min (km)	Effective Strip Width (m)	Total length of transects (km)
Buxa TR (East and West)	62	1.4	2.5	0.8	123.2	86.8
Jaldapara	52	1.3	2.3	0.7	88.6	67.6
Gorumara	53	1.3	2.4	0.8	129.04	68.9
Mahananda	21	1.2	2.3	1	98.5	25.2
Baikunthpur	42	1.4	2	1.1	76.4	58.8
Kurseong	32	1.4	1.8	0.8	65.3	44.8
Total	**262**	**1.33**				**352**



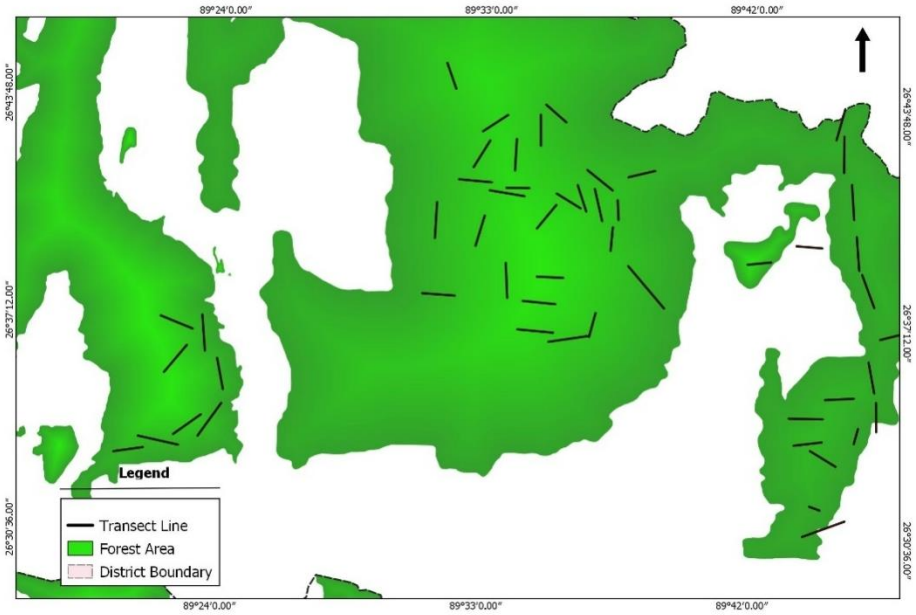
Map 5. The lay-out of transect across the landscape.



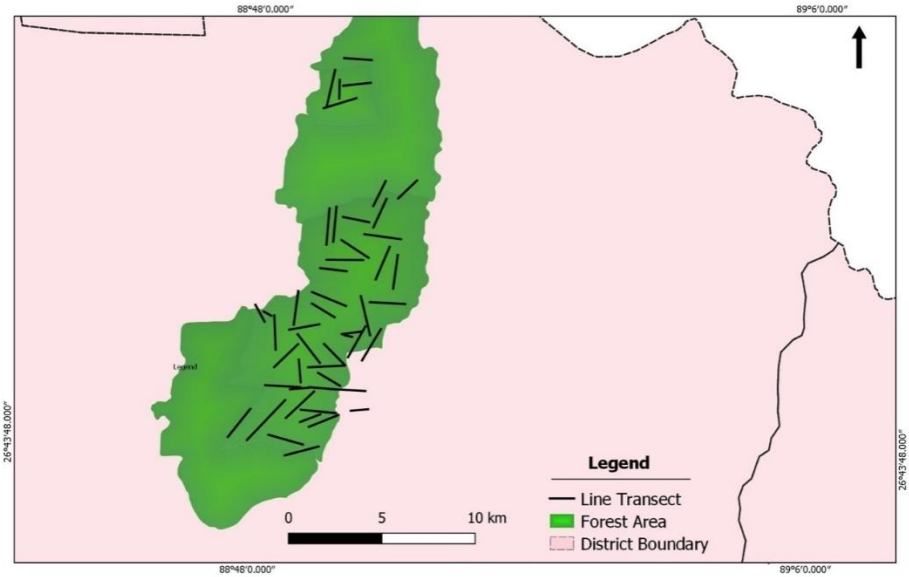
Map 6. The lay-out of transects in Jaldapara National Park.



Map 7. The lay-out of transects in Mahananda Wildlife Sanctuary.



Map 8. The lay-out of transects in Buxa Tiger Reserve.



Map 9. The lay-out of transects in Gorumara National Park.

3.2.2 Data analysis

We usedprogram DISTANCE v6.2 to analyse the data, which allows the selection of different models and also includes a range of different options (Burnham et al. 1980). The probability of detection was estimated using six models recommended by Buckland et al.(2001) combining probability density function (uniform, half normal and hazard-rate) with adjustments (cosines, simple and hermite polynomials). The model with the lowest Akaike's Information Criterion (AIC) was selected. The program automatically calculates the f(0) from the perpendicular distance data. This is an estimate of the reciprocal of the 'Effective Strip Width' (ESW).

The density of gaur, D is then calculated by the following formula:

$D = n.f(0)/2L$

where,

n = number of gaurs sighted during transect sampling

L = total length of the transects

Variance of D and the confidence limits were estimated following Burnham et al. (1980). F (0) is the probability density function of detected distances from the line, evaluated at zero distances (Alfred et al. 2010). Further, density (D) was estimated for each habitat types and the population size (N) were computed based on the size of the habitat area.

The data were stratified based on habitat types to detect separate detection function for each habitat and the overall density was estimated by using the mean of each habitats weighted by the habitat area. The model that generated the lowest AIC was considered as a reasonable density.

3.3 Results

A total of 1029 gaurs were recorded in 78 sighting occasions within and outside the transects. The overall estimated population density of gaur was found to be 2.64/km^2 (CV: 21.14%, 95% CI: 1.94-3.38). No gaurs were recorded beyond 165 meters from the centre-line of the transects. Extrapolating this density across the North Bengal landscape, the total population size was estimated to be 3962 ± 680. The total area of the landscape used is the total area of all the PAs (1312 km^2) and additional 288 km^2 for non-PAs (Baikunthpur and KurseongDivisions). The PA-wise density estimation is summarised in Table 3.

Table 3. The density estimation of Gaur population in various protected areas.

Protected Area	Number of Transects	Density parameter (gaur/km^2)			Estimated Population Size		
		Point estimate	SE	% Coef. of Variation	Point estimate	SE	95 % CI
Buxa TR	62	1.87	0.53	15.97	1421	221.4	1202–1643
Jaldapara	52	3.24	0.71	19.87	701	164.32	539–868
Gorumara	53	7.86	0.67	15.83	629	112.5	201–358
Mahananda	21	2.31	0.87	21.24	365	145.24	218-514
Chapramari	8	3.2	0.65	25.54	31	18.7	17-49
Neora valley	18	1.25	0.21	18.09	111	21.4	87-134
Total Estimated Population Size in PAs					3258		

The population density of gaur was recorded the highest in Garumara National Park (7.86 km^2 ± 0.67) followed by population density of 3.24 km^2 ±0.71 in Jaldapara National Park. The Neora Valley had the lowest density (1.25 km^2 ±0.21) with an estimated population size of 111 individuals. The Buxa Tiger Reserve including East and West Divisions support 1421 (CI: 1202-1643) gaurs with a density of 1.87 km^2 ±0.53.

We also estimated gaur population density at 2.45km^2±0.79 in the non-protected areas of Baikunthapur and KurseongDivisions, with an estimated population size of 704±147.

3.3.1 Limitation of the exercise

Like any other studies, this exercise of population estimation has its own limitations. While estimating animal density, detection probability plays a crucial role.Line transect sampling is a robust method that takes into account the critical issue of estimations of detection probabilities within the surveyed areas (Jathanna et al. 2003). The detection probability for gaurs during this study was calculated by the DISTANCE software which showed that in this case the overall detection probability was 0.43 (43%) in the landscape. This implies that approximately 57% of the population could have been missed if the detection probability was not accounted for. The thick vegetation and tall grasses often restrict the visibility and detection. Besides, for logistic

reasons many of the transects counts were conducted during the noon time which limited the sighting possibilities of animals.

3.4. Population structure

To estimate the population structure of gaurs, besides gaur-sightings during the transect surveys, opportunistic sightings were recorded too. For each sighting, parameters such as age, sex, group size and other population information were recorded. It has been recorded that group size varies widely within and between species (Altmann 1974, Geist 1974,Jarman 1974, Rodman 1981). The age structure of a population gives an idea on the population growth and estimating life history parameters (Stearns 1992). Age structure of a population expressed as the distribution of the number of individuals in each age-group reflects fecundity, mortality, reproductive status and population change (Ramesh et al. 2012). It is an important measure of demographic change over time (Caughly 1977); while sex ratio is an indicator of the reproductive potentiality of a species (Ramesh et al.2012). A high percentage of young as compared to adults generally indicates a fast growing or thriving population in contrast to a relatively smaller percentage of young that usually indicates a sluggish rate of population increase (Ramesh et al. 2012).

3.5. Methods

We covered more than 90% of the gaur range on either foot or vehicle with regular and systematic surveys along the forest-roads, animal trails and waterbodies; besides, the transect surveys used for population estimation. During the surveys, all encounters with gaur herds were documented and required parameters were noted. This methodology for age-sex structure estimation can be termed as random and opportunistic approach. Whenever gaurs were sighted, data on age and sex were collected. Although in few instances age-sex classification was not possible because of dense vegetation and group movement. At every sighting information such as date of sighting, place, vegetation type, age-sex, group size was collected based on Schaller (1967) in a standard format. The sex identification was done based on morphological features as described by Schaller (1967) and Sankar et al. (2001). Table 4 shows how the sex and age class was identified in field based on Schaller (1967).

Table 4. The various age class category used to assess the gaur.

Age-Sex category	Morphological features
Adult ♂	Possess a shiny black coat with heavy horns protruding sideways and upwards and a large dewlap hanging below the chin, and gonad
Sub-adult ♂	Dark brown coat with a conspicuous dorsal ridge and a smaller dewlap, large drapes between the fore legs, gonad
Juvenile ♂	10–20 months old, 25–50% in size of sub-adult male with gonad
Adult ♀	Smaller than adult males, pelage is dark brown with more upright horns corrugated inwards than in adult males
Sub-adult ♀	50–75% in size of adult female lacking a conspicuous white stocking
Juvenile ♀	Light brown coat, 25 to 50% in size of sub-adult females without gonad
Small calf	Light brown coloured coat, approx. <3 months old of <30 kg, golden yellow pelage
Large calf	Light brown to dark brown coloured coat of approx. 30 to 100 kg and half the size of yearling females

3.6. Results

We sighted 1029 individuals of gaurs in 78 sighting instances (sightings and re-sightings) (Table 5 and Map 10). This includes sighting instances inside the protected area as well as near the forest boundary. Resighting instances could not be ascertained because of difficulties in identifying seen animals in dense forested landscape.

The sex ratio of the population was estimated to be 1: 3.14 (male: female), however, we discarded at least 11 % individuals (n=112) as we could not identify their sex because of group movement and thick vegetation (Fig. 2).

The age structure was found to be approximately 68.7:17.6:13.7 (in percentage) (n=1029) for Adult: Sub-adult: Juvenile/calf respectively (Fig. 3)

The mean herd size encountered was 15.12 ± 2.36 (95 % CI) in the entire landscape. The frequency of sighting smaller herd (1-5 gaur) was more as compared with the bigger herds (n=41) (Fig. 4).

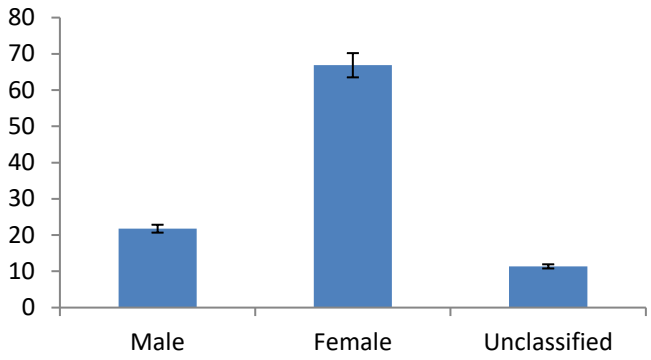


Figure 2. The percentage of male, female and unknown gaur individuals of the sighted groups during the study.

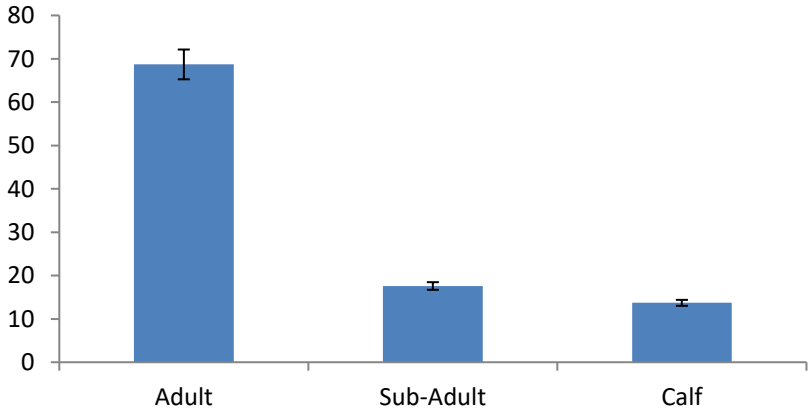


Figure 3. The age- class category of the observed gaur individuals in percentage in the study area.

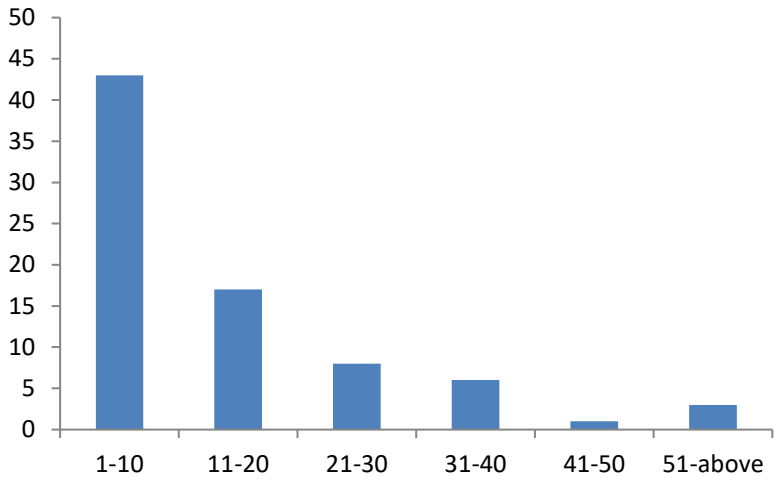


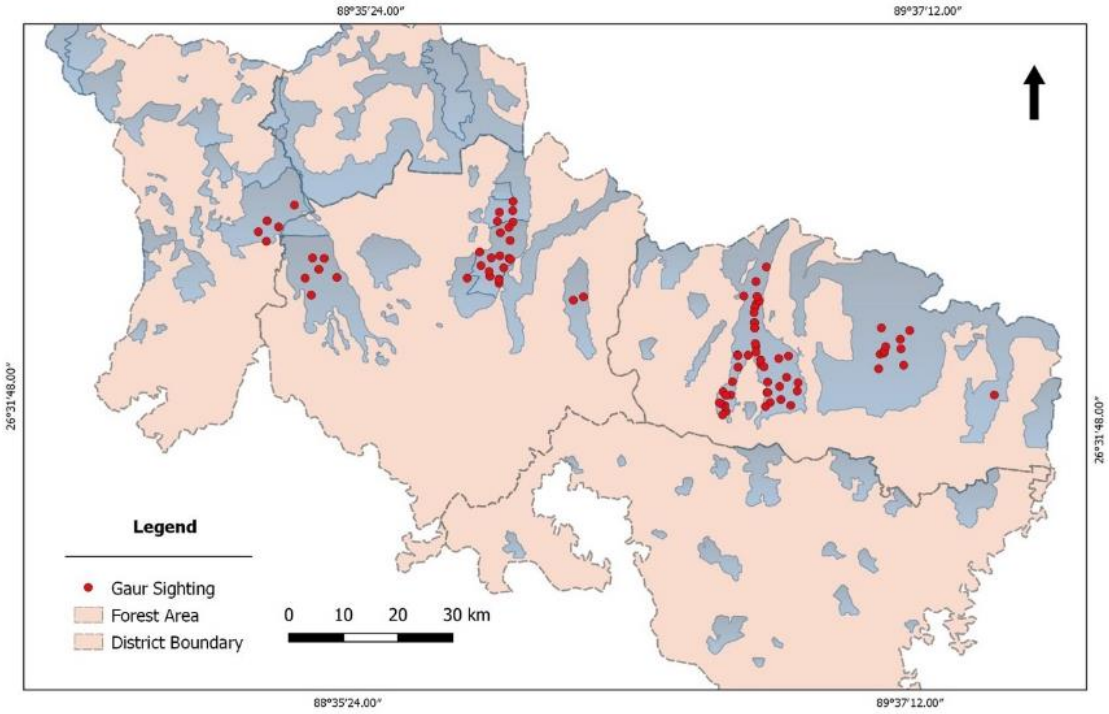
Figure 4. The group size frequency of the observed gaur individuals.

Table 5. Details of gaur sighted on 78 occasions during the study period.

Sl no	No. of gaur sighted in each occasion	Male	Female	Unclassified	Adult	Sub Adult	Calf/ Juvenile
1	32	8	21	3	22	6	4
2	4	0	3	1	3	1	0
3	1	0	1	0	1	0	0
4	3	0	3	0	3	0	0
5	2	2	0	0	2	0	0
6	1	0	1	0	1	0	0
7	1	1	0	0	1	0	0
8	2	0	1	1	1	0	1
9	4	1	3	0	4	0	0
10	4	1	2	1	3	0	1
11	7	1	4	2	4	1	2
12	8	1	5	2	6	0	2
13	7	1	5	1	5	2	0
14	57	13	35	9	42	9	6
15	1	0	1	0	1	0	0
16	1	1	0	0	1	0	0

Sl no	No. of gaur sighted in each occasion	Male	Female	Unclassified	Adult	Sub Adult	Calf/ Juvenile
17	12	3	6	3	7	2	3
18	15	3	8	4	5	6	4
19	3	0	3	0	2	1	0
20	36	7	26	3	22	7	7
21	5	1	4	0	3	2	0
22	1	1	0	0	1	0	0
23	4	1	3	0	3	1	0
24	8	2	5	1	5	1	2
25	33	7	24	2	21	7	5
26	22	5	13	4	10	9	3
27	1	1	0	0	1	0	0
28	1	1	0	0	1	0	0
29	2	0	2	0	2	0	0
30	13	2	11	0	9	1	3
31	14	3	9	2	9	3	2
32	3	0	3	0	3	0	0
33	1	1	0	0	1	0	0
34	2	0	2	0	2	0	0
35	3	1	2	0	2	1	0
36	7	1	6	0	5	2	0
37	25	4	17	4	18	4	3
38	6	1	5	0	5	0	1
39	22	3	16	3	19	1	2
40	4	1	3	0	4	0	0
41	4	2	2	0	4	0	0
42	13	1	10	2	9	2	2
43	3	1	2	0	3	0	0
44	1	1	0	0	1	0	0
45	20	3	14	3	14	2	4
46	1	1	0	0	1	0	0
47	15	1	13	1	12	1	2
48	26	5	19	2	20	2	4
49	13	3	10	0	9	1	3
50	8	3	5	0	6	2	0
51	1	1	0	0	1	0	0

Sl no	No. of gaur sighted in each occasion	Male	Female	Unclassified	Adult	Sub Adult	Calf/ Juvenile
52	2	0	2	0	2	0	0
53	3	0	3	0	2	1	0
54	8	2	5	1	6	2	0
55	55	9	42	4	42	5	8
56	37	4	28	5	26	8	3
57	63	8	51	4	49	6	8
58	1	1	0	0	1	0	0
59	45	5	38	2	39	2	4
60	19	3	14	2	10	5	4
61	4	1	3	0	4	0	0
62	19	5	11	3	12	4	3
63	2	0	2	0	2	0	0
64	17	3	12	2	12	3	2
65	11	1	9	1	8	3	0
66	28	6	17	5	19	4	5
67	12	6	4	2	9	3	0
68	20	4	12	4	12	6	2
69	15	5	8	2	8	5	2
70	12	3	6	3	6	3	3
71	39	11	23	5	20	10	9
72	17	9	5	3	11	4	2
73	5	1	2	2	2	1	2
74	25	9	12	4	15	6	4
75	27	7	17	3	17	5	5
76	23	6	13	4	13	6	4
77	34	13	19	2	19	11	4
78	3	1	2	0	1	1	1
Total	**1029**	**224**	**688**	**117**	**707**	**181**	**141**



Map 10. The location of the gaur sightings across the study area.

3.7. Discussion

Estimation of gaur population densities require a huge effort, as the species mostly occurs in low-density and in dense forested habitats (Ahrestani&Karanth 2014). Information on population status from North Bengal are limited. During this study a landscape-wide population estimation exercise was undertaken to understand the current population status. Presently, in the entire landscape approximately a population of 3258 gaurs were estimated based on the count-data using Distance Sampling technique. The Distance sampling technique is a robust sampling method that attempts to generate reliable population density estimates (Jathanna et al. 2003). Within the distance sampling framework, the population density is estimated using the count data (number of animals detected during the survey from line transect), detection probability and the proportion of area sampled. Based on these three parameters, the population density is computed using DISTANCE software. The information of population density and the total area is then used to extrapolate the data to compute the population abundance (population size).

This robust technique has been applied to derive the population abundance of gaur in entire northern West Bengal landscape, which is statistically and biologically a robust method of estimation (Jathanna et al. 2003). This forms a reliable estimate of gaur population in the study area. The estimated sex ratio in northern West Bengal indicated a female-biased population, which is true for most of the herbivore population across Asia. Our results indicated that the study area harbours a good gaur population. Reportedly, the gaurs in this region are known to occur along the Himalayan foothills and bhabar areas and move down to the plains regularly (Choudhury 2002).

Chapter IV: Habitat Use Pattern

4.1. Introduction

Habitat is the sum of specific resources that are needed by an organism and relates the presence of a species, population or individual to an area's physical and biological characteristics (Hall et al. 1997). Understanding the species-habitat relationship is of fundamental importance to implement conservation management. We studied the habitat utilisation pattern of gaurs in northern West Bengal so as to understand which habitats are selected over others. This provides vital information about the nature of the species, and how they meet their requirements for survival (Manly et al.2002), which in turn aids in making informed conservation decisions.

Broadly, the gaurs inhabit the forested habitats including the evergreen, semievergreen, moist deciduous and dry deciduous forests (Schaller 1967). In this study, we aimed at understanding the gaur habitat use pattern at finer scale of habitat categories. For this study we categorised the broad forested habitats and its surroundings into the following habitat categories based on land cover type – deciduous forest, riverine forest, mixed vegetation, Sal plantation, Teak plantation, Semi evergreen forest, grasslands, tea gardens and agriculture land.

4.2. Methods

To understand the habitat-use pattern by gaurs sampling was conducted in nine different habitat types in the study area (Table 6). Study design as described by Thomas & Taylor (1990) was used where surveys were conducted to record the relative number of animals into each habitat category by using line transects and the availability of these habitat categories was measured by sampling random plots along the line transects. In the transect line the habitat structure and quality was assessed by sampling vegetation plots of 10m x 10m for tress, and 5m x 5m quadrats for shrubs and herbs at regular interval of 500 m. A total of 728 plots were sampled along the 262 line transects across the study area. The habitat use was measured by the proportion of gaur in each habitat category.

Diagrammatic representation of a line transect of 2 km in length and vegetation sampling plots of 10m x 10m for trees and 5m x 5m for shrubs and herbs in every 500 m apart

4.2.1 Data analysis

A chi-squared test was performed to determine whether the habitat use by the gaurs was random and differ significantly among different habitat types. During the analysis, the habitat categories, where the expected frequencies were less than five, were dropped as these units were rarely selected (Manly et al. 2002). Since, the habitat-use by gaur differed significantly among the habitat types (χ^2= 519. 697, df=7, P<0.001), the habitat preference was calculated using Manly's standardised preference index, Bi (Manly et al. 2002). The index is based on the selection ratio $w_{i,s}$ which is the proportional use of each resource divided by the proportional availability.

$$w_{i,s} = o_{i,s} / \pi_i$$

Where, $o_{i,s}$ = Proportion of the numbers of individuals of species recorded in the habitat units in category i.

And π_i= Proportion of the habitats, i among all the habitats sampled.

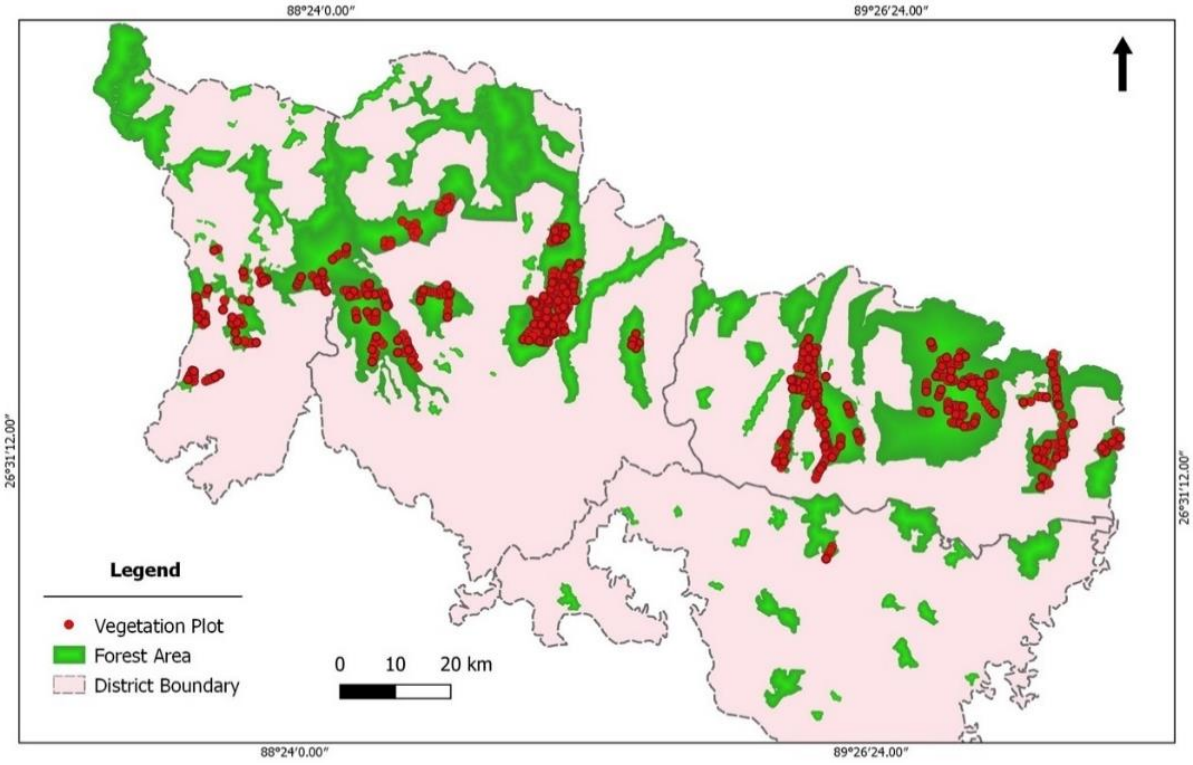
First, the $w_{i,s}$ was calculated and then the preference index was computed. The preference index was standardised using Manly's standardised equation:

$$\text{Bi} = \frac{w_{i,s}}{\sum_{i=1}^{H} w_{i,s}}$$

Where, H= number of resource habitats units.

In this preference index if the value is greater than 1, the habitat is considered to be preferred by the species, and if the value is less than 1 the habitat is not used by the species.

The value around 1 suggests that the habitat is used in proportion to its availability. The most preferred habitats are considered as the key habitats for the species. The data were analysed in program R (R Core Team 2019) using the package adehabitatHS (Calenge 2011).



Map 11. The location of the vegetation survey plots on the line transects.

4.3. Results

During the survey we recorded a total of 1029 gaurs across the study area. The gaurs were found most abundantly in the semievergreen forests, followed by mixed forests and deciduous forests respectively (Fig. 5). To determine the strength of habitat preference for gaurs, Manly's preference index was used. The most preferred habitats of gaurs in the study area were semievergreen forests, followed by tea gardens (Fig. 6). The semievergreen forest was used more than its availability, the mixed forests and grasslands were used in proportion to its availability, while the other habitat types were used less than its availability (Fig 7).

The tea gardens close to the forest lands are often used as refuge by the gaurs. We found that the gaurs use the relatively undisturbed areas of forest in the landscape.

Table 6. The sighting records of gaurs in different habitat types

Habitat type	Number of Sighting instances in each habitat	# of animals sighted	# of transects sampled in each habitat type	No. of vegetation plots surveyed in each habitat type
Deciduous Forest	10	145	51	134
Riverine forest	9	112	57	149
Mixed forest	12	155	43	118
Sal plantation	6	63	28	76
Teak Plantation	5	49	19	79
Semi Evergreen forest	15	243	29	58
Grasslands	9	112	31	87
Tea gardens	7	94	4	27
Agriculture land	5	56	0	0
Total	78	1029	262	728

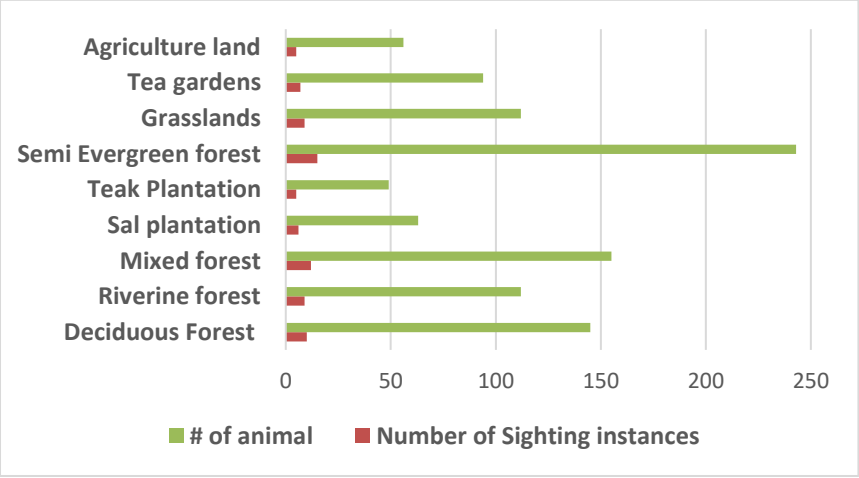


Figure 5. Number of direct sighting records of gaurs in different habitat types.

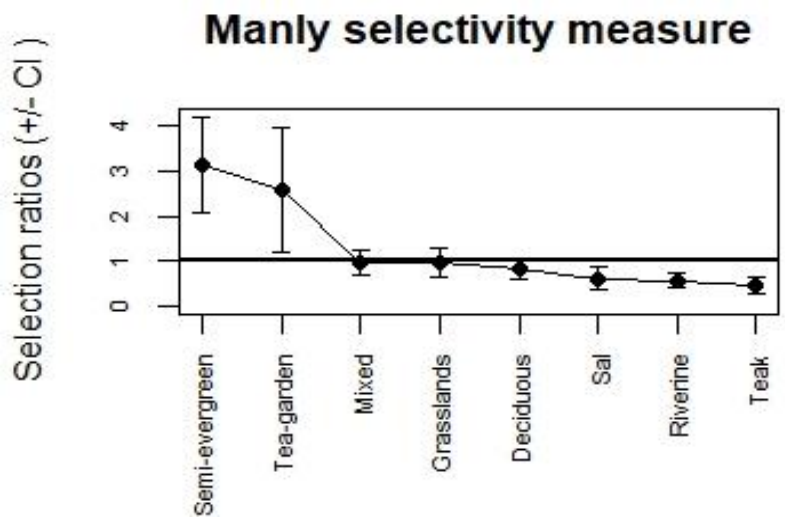


Figure 6. The gaurs have a preference for semi evergreen forests in the study area.

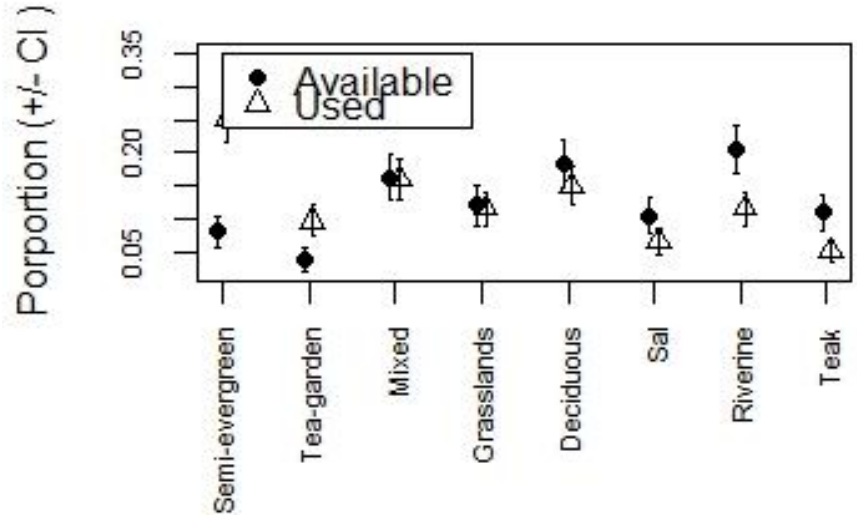


Figure 7. The proportion of habitat types used by gaurs versus the availability of each habitat type.

4.4. Discussion

Our study findings indicate that gaurs are forest dwelling species that are known to occur in a wide range of forest types. The habitat use study at finer scales of habitat categories in the study area indicated that the semievergreen forests, mixed forests and grasslands are important for survival of the gaurs in the landscape. The preference for these habitat types may be due to

availability of forage and less anthropogenic disturbances.

A study by Kumar (2010) inferred that the spatial abundance of gaurs is determined by factors such as protection effectiveness and site-level human disturbance.

During this study we found that tea gardens are also preferred by gaurs. This may be due to artefact of sampling. The research team sighted gaurs in the tea gardens quite often, and this may not reflect the true habitat preference. To this end, we suggest that while developing conservation management plan, this should be taken into account. The gaurs prefer forested areas, with availability of forage and minimum disturbances.

Chapter V: Feeding Habit

5.1. Introduction

The most important and consistent activity determining animal survival, health, and mobility is feeding (Haleem & Ilyas 2018). Understanding the feeding habit is a primary aspect of conserving any large mammals. The gaur is a major herbivore in Indian sub-continent. Despite being a mega herbivore ecological studies on gaurs are limited. A few studies undertaken on gaur feeding ecology infers that gaur are both grazers and browsers (Ahrestani et al. 2012, Sankar et al. 2013, Haleem & Ilyas2018). In the present study we identified the plant species that are consumed by gaurs in our study area and attempted to understand the preference of forage species based on direct observations.

5.2. Methods

We followed direct observation technique to identify the plant species eaten by gaur. Any opportunistic encounter with gaur in the forest was considered to be one sample. We observed gaurs through binoculars and recorded the forage items that the animals were feeding on during the observation bout. Once the gaur herd moved away from the feeding site, we tried to identify the plant species either in the field directly or took photographs for identifying them by plant taxonomists.

5.2.1. Data analysis

Most of the plant species were identified in field by our team as well as the accompanying staff from forest department. Most of the accompanying forest staff were familiar with the local name of the plants. The unidentified plants were later identified with the guidance from expert plant taxonomists at Aaranyak.

We adopted plot sampling method for abundance estimation of the fodder plants. We sampled 728 plots of 10m x 10m in 262 randomly placed transects across the study site (as mentioned in the Chapter-IV). We estimated the abundance of species based on the presence of the particular species in the surveyed plots.

5.3. Results

The gaurs in our study area were found to feed on 32 species of plants, belonging to 16 families (Table 7 and Fig. 9). Various plant parts such as fruits, leaves, bark and young shoots were recorded as dietary items of gaur during the study period. The most preferred dietary type was however leaves and grasses (70%). Based on their availability in our vegetation survey plots, we assessed their abundance. The most abundant fodder species recorded was *Gmelina arborea* (24%) followed by *Dillenia indica* (18%). Gaur tend to feed on any plants that are nutritious only during certain seasons.

Table 7. The list of identified fodder plants of gaur in the study area

Sl no	Species Name	Type	Family	Parts eaten	Abundance	Preference
1	*Bauhinia racemosa*	T	Fabaceae	L, F	18%	H
2	*Butea monosperma*	T	Fabaceae	L	8%	H
3	*Cassia fistula*	T	Fabaceae	L, F	4%	H
4	*Dilleniapentagyna*	T	Dilleniaceae	F	15%	H
5	*Gmelina arborea*	T	Lamiaceae	L	24%	H
6	*Grewia tiliaefolia*	T	Tiliaceae	L, F	4%	M
7	*Dillenia indica L.*	T	Dilleniaceae	F	18%	H
8	*Albizzia procera*	T	Mimosaceae	B	8%	M
9	*Sterculia villosa*	T	Sterculiaceae	B	16%	M
10	*Shorearobusta*	T	Dipterocarpaceae	L, B	43%	H
11	*Terminalia alata*	T	Combretaceae	L	8%	L
12	*Dalbergia latifolia*	T	Fabaceae	L, F	8%	L
13	*Calicarpalanata*	T	Lamiaceae	F, L	2%	L
14	*Strobilanthes sp.*	S	Acanthaceae	L, F	5%	L
15	*Grewia abutifolia*	S	Tiliaceae	L, F	Not found	M
16	*Helicteresisora*	S	Malvaceae	L, F	2%	M
17	*Spermacoce sp.*	H	Rubiaceae	L, F, S	5%	M
18	*Desmodiumtriflorum*	H	Fabaceae	L, F, S	4%	L
19	*Mimosa pudica L.*	H	Mimosaceae	E	14%	M

Sl no	Species Name	Type	Family	Parts eaten	Abundance	Preference
20	*Musa velutina*	H	Musaceae	E	4%	M
21	*Alpinia allughas*	H	Zingiberaceae	E	11%	H
22	*Urena lobata*	H	Malvaceae	L, F	8%	H
23	*Bambusaarundinacea*	G	Gramineae	E	17%	M
24	*Cynodondactylon*	G	Poaceae	E	5%	H
25	*Cyperus rotundus*	G	Cyperaceae	E	3%	H
26	*Digitaria sp.*	G	Poaceae	E	Not found	H
27	*Dendrocalamus strictus*	G	Poaceae	E	12%	H
28	*Phragmites karka*	G	Poaceae	E	21%	H
29	*Narenga porphyrocoma*	G	Poaceae	E	25%	M
30	*Thysanolaena maxima*	G	Poaceae	E	12%	H
31	*Saccharum procerum*	G	Poaceae	E	18%	H
32	*Saccharum spontaneum*	G	Poaceae	E	27%	H

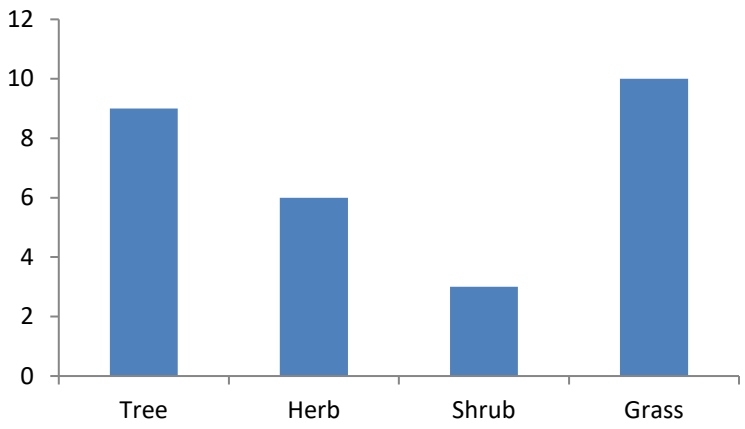


Figure 8. The number of fodder plant species of gaurs recorded in study area.

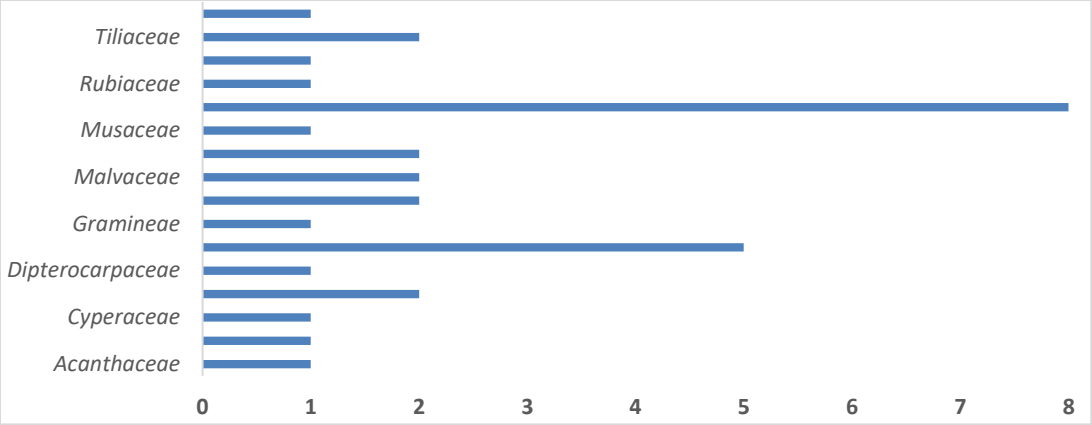


Figure 9. The number of species in each family.

5.4. Discussion

Our study has identified at least 32 species of plants that are eaten by gaurs in the study area. Our findings are in line with previous studies that reported gaurs to be generalist feeders, which are known to be both grazers and browsers (Sankar et al. 2013). The food preference of gaurs indicates the importance of natural forest habitats for their long-term conservation. Based on the preference level, management may consider planting of fodder plants in specific areas.

Chapter VI: Human-Gaur Conflict

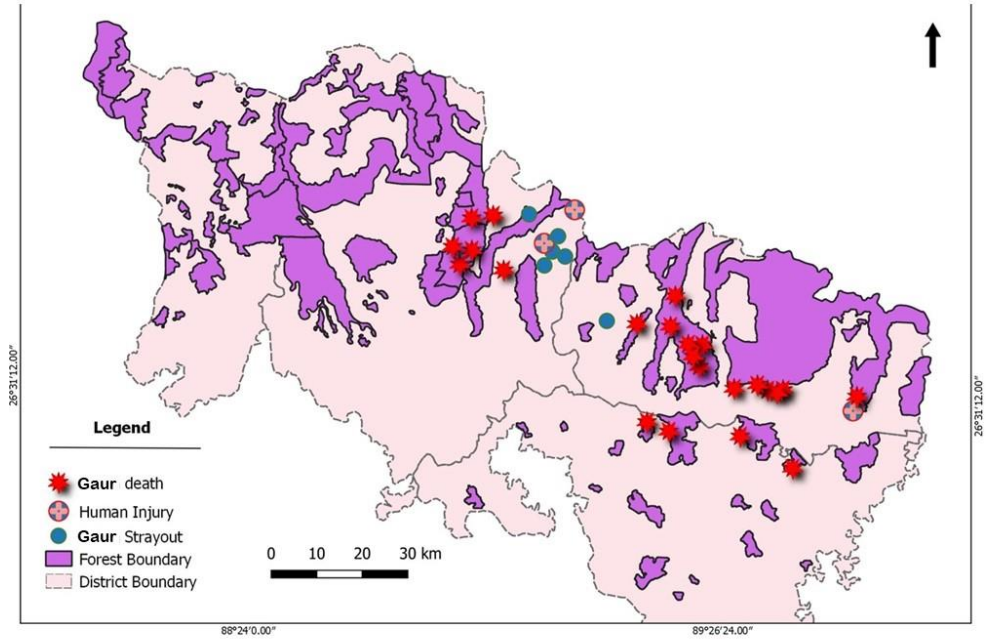
6.1. Introduction

Human-Gaur conflict (HGC) in the North Bengal landscape is on the rise. The reports of gaur raiding crops and straying out of the forest areas are becoming very common in recent times. As the gaur population is increasing in the forests of North Bengal, these interactions with human are to be effectively managed. The reason for the increase of gaur population is perhaps the absence (or low presence) of large predators like tigers. This can lead to sudden increase in the population but in the long run this effect may increase intra-species competition for food and shelter resulting in decline in population numbers. Forest department censuses estimated the gaur population at 2000 individuals in 2010 and 4000 Gaurs in 2012 (Chakraborty 2015). Our result also indicated a population of approximately 4000 gaurs in the entire landscape. Most of the gaur habitats in North Bengal is fragmented (Choudhury 2002), which often leads to confrontation with local people as they try to move between patches.

During 2011-2012, a total of 11 gaur straying incidents occurred in North Bengal, of which seven gaurs were killed by local people (Bhattacharyya &Padhy 2013). During 2012, one gaur died because of a train hit in Chapramari Wildlife Sanctuary.

6.2. Methods

To assess the magnitude of human-gaur conflict, data were collected on all known conflict incidents which included crop-raiding, human deaths and injuries from October 2016 to June 2019. Our team visited each conflict incident site that was reported during the study period for ground truthing. For each conflict incident data on gaur age-sex class (as far as possible), time of incident, GPS location and type of conflict (e.g. crop-raid, human deaths/injuries etc) were recorded from complainants or secondary sources at the site of occurrence using a standardised reporting form (Hoare 1999). The UTM coordinates of each incident were imported into the Arc GIS 9.3 and ERDAS Imagine 9.1 software package for processing prior to analysis.



Map 12. Human-gaur conflict locations across the landscape.

6.3. Results

During the study period a total of 90 conflict incidents (n=90) were recorded (Fig 10). This included 57 incidents of crop-damage or straying, 21 incidents of physical injury, 8 incidents of gaur death and 4 human death incidents. Most of the incidents involved single male gaur.

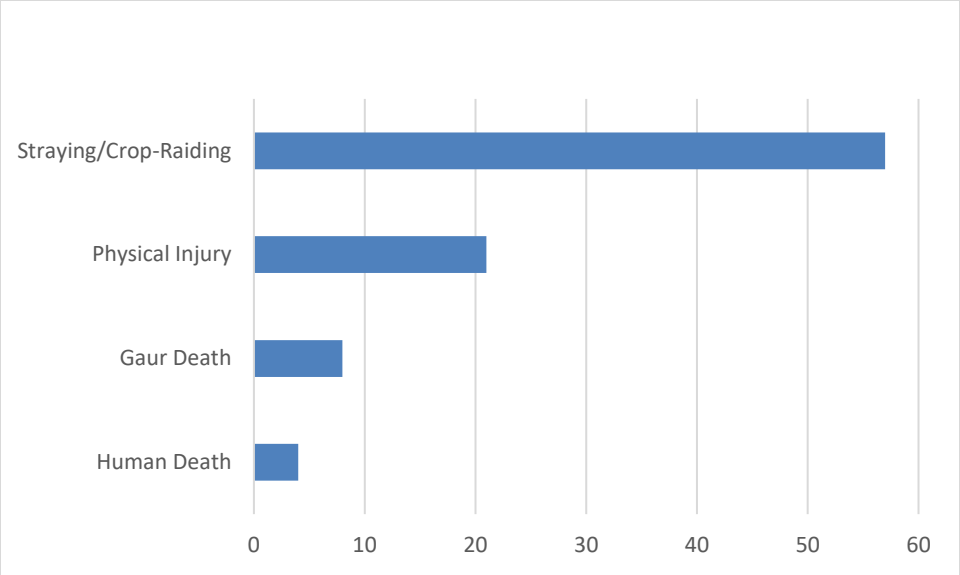


Figure 10. The number of human-gaur conflictincidents during the study period.

Besides, secondary information from the Forest Department were collected (Table 8 and Fig 10) from 2012 to 2018 for various Forest Divisions (Table 8 and Fig 10). While sorting andanalysing the data we realised that the department did not have a standard data collection format as it varied among different divisions. A standard format for collating human-gaur conflict incidents will be effective for later use.

Table 8. Human gaur conflict incidents collected across different Forest Divisions (Source: Forest Department)

Division	Straying	Gaur Death	Cases of Crop Damage	Human Death	Human injury
BTR West	7	8	-	-	3
BTR East	6	2	-	-	1
Jalpaiguri	21	15	4		3
Kurseong		0	-	-	
Baikunthapur	-	0	-	-	-
Gorumara	13	28	7	2	6
Jaldapara	9	32	6	4	13
Coachbehar	19	9	2	1	9
Darjeeling	-	-	-	-	-
Kalimpong	-	-	-	-	-
Total	75	94	19	7	35

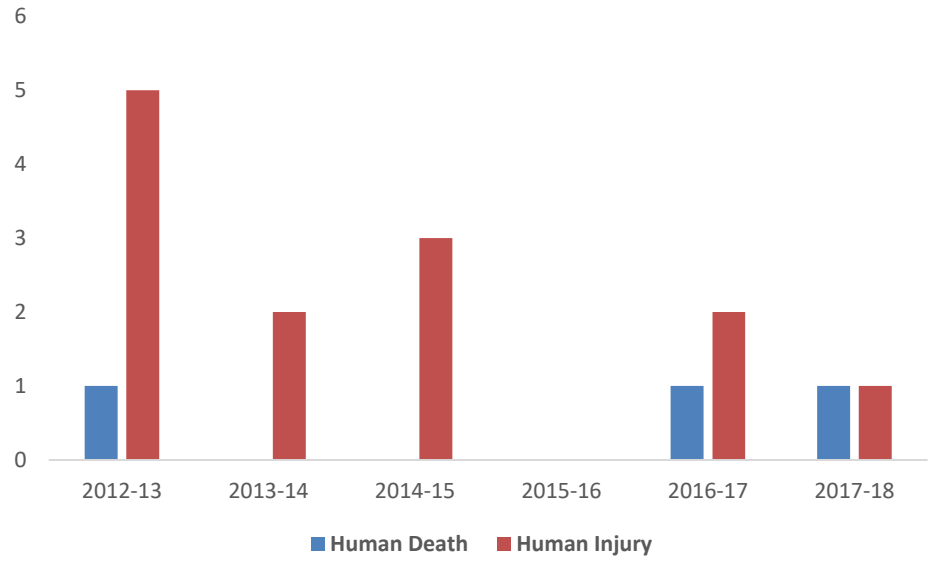
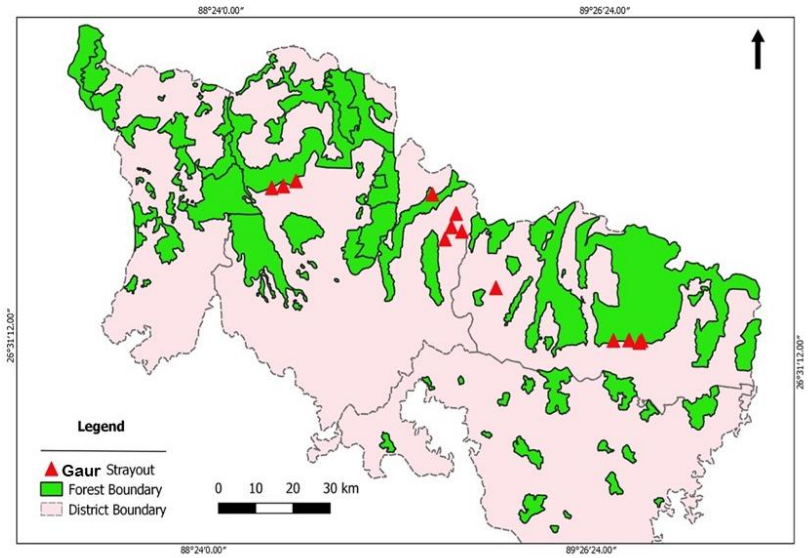


Figure 11. Status of human deaths and injuries by gaurs in Jaldapara during 2012-2018 (Source: Forest Department).

We recorded two train accidents resulting in the death of three gaurs since 2012 in Chapramari WLS. The secondary data and informal interviews with the villagers showed that the rate of gaur straying out of the forested area and direct encounter of gaurs with the humans were more common form of incidents as compared to crop raids.

6.4. Discussion

Investigation of patterns of human-gaur conflict indicated that most of the incidents comprise of gaur stray out. As evident from the Map (13), that gaur habitat is highly fragmented and the animals are confined in smaller habitat patches. From our study we infer that the gaurs,while moving between forest patches, use the human-use areas. This kind of confrontation can often lead to conflict.



Map 13. Stray-out areas of gaurs in the landscape during the study period.

Chapter VII: Carrying Capacity

7.1. Carrying capacity of North Bengal for Gaur

The carrying capacity of an area depends on factors such as availability of resources. Estimating carrying capacity of any wild species is theoretically possible, while it needs long-term data on species' population ecology, resource needs and other external factors. Carrying capacity is defined as "The maximum number of animals which can be sustained in a given ecosystem through the least favourable environmental conditions that occur within a stated interval of time without deterioration of the ecosystem and without impairing the quality of the animals" Edwards and Foyle (1955).

To study carrying capacity the first criteria considered is the ability of the habitat to provide food for the support of the inhabiting population. In case of herbivores this is determined by estimating the primary productivity of the vegetation. In this study, we could not estimate the productivity of fodder species for our study area. Here, we have attempted to provide an estimate of gaur carrying capacity in the landscape by "borrowing" information from available literature, which is ideally the mean productivity of forest and grasslands. We have considered the productivity to be 200 ton/km^2. Hence, for the total habitat area available for gaurs in our study area (approximately 1600 km^2, including protected and non-protected areas), the amount of mean productivity will be 3,20,000 tonnes of fodders. For calculating the carrying capacity, we have removed half of these amount for regeneration, which is equivalent to 160000 ton (Madugundu et al. 2008). Of these, we considered half of the amount is used by elephants (50%), and 25 % by other herbivores including deer and cattle. Therefore, the unused productivity for gaurs remained is 40,000 tonnes of fodder. The yearly requirement for gaur is considered to be 7.3 tonnes/gaur (Ramachandran et al. 1986). Hence, we can roughly calculate the carrying capacity of North Bengal landscape for Gaur as

$$\frac{\text{Unused biomass}}{\text{Yearly requirement of gaur}} = \text{Carrying capacity}$$

40000/7.3 = 5479 gaur individuals

This analysis is a complete theoretical analysis based on limited available literature on carrying capacity estimation of wild herbivores, and this may only be taken as a speculation.The result indicates that the present population of gaur in North Bengal is below the carrying capacity of the landscape. The reported sporadic straying of Gaurs in human use areas does not appear to be a result of the current population size.

Chapter VIII: Management Recommendations

The gaur management and conservation planning can be developed with the following key points of recommendations in North Bengal. For management of the gaur population in North Bengal, we recommend a few practical strategies to be implemented by the forest department.

Capacity building of JFMC and FPC members

- ⇒ All JFMCs and FPCs should be empowered to manage straying gaurs. Capacity building training should be organised for the members at a regular interval to train and create alert network for gaur stray.
- ⇒ The presently functional Wildlife squad in Buxa TR, KurseongDivision (Bagdogra, Sukna, Belacoba, Ramsai, Malbazar, Khunia, Madarihat) should be accompanied by an educational team to collect data and also assist in management local people during field patrolling.
- ⇒ These Wildlife squads should be more well equipped with modern tools like GPS and Walk-Talkie sets to be able to track any stray cases.

Building stewardship with Management of Tea gardens: The tea gardens are major refuge for gaurs as our results infer. We recommend that the management authorities should take tea garden authorities as part of conservation planning and may involve the managers of some of these tea gardens in regular meetings to garner their proactive support and create a sense of stewardship.

There are few small/medium sized tea gardens that not- functional in North Bengal. Government can take over those abandoned tea garden lands and can be used for restoration of gaur habitats with fodder plants.

Army cantonment

- ⇒ The army cantonments sometime overlap with gaur habitats and hence meetings with Army should be taken-up to discuss issues on fencing by army and the defence land at Rohini.

⇒ The department may regularly visit and monitor any gaur herds inside the army cantonments.

⇒ Regular meeting should be held with army officials (not below the rank of Commanding officer and CF from Forest Department)

Habitat management

⇒ The removal of alien invasive plants should be a priority in management for all the protected areas. If existing habitats in North Bengal (NP, WLS and Reserved Forests) are managed scientifically the same habitat may provide needed natural feed to gaurs.

⇒ More research on scientific intervention to assist natural regeneration of gaur palatable growth to be conducted.

⇒ The preferred fodder plants (as per our results) should be promoted in infilling and supplement.

Compensation

⇒ One of the government initiatives to mitigate human-gaur conflict is providing compensation (ex-gratia) to the conflict victims. The compensation schemes are aimed to alleviate the losses suffered by the victims. However, the affected people opined that the amount received by them does not suffice and they are not satisfied by the process in many areas and also with the compensation amount.

⇒ The process of compensation or ex-gratia have to be expedited. We suggest of providing support to the local communities in form of livelihood diversification.

Awareness

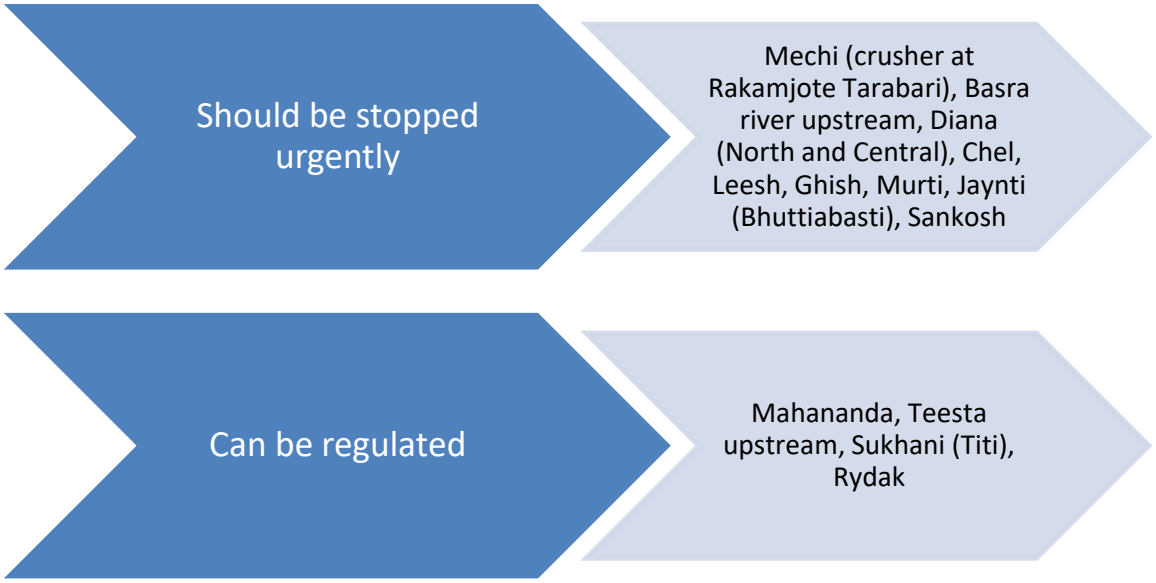
⇒ Village level awareness initiatives should be conducted regularly.

⇒ The department may engage local NGOs and panchayat members as these members have mass base which need to be used for positive outcome. Close relations with village headman are crucial to address emergency crisis in the villages that could arise from gaur straying cases.

Illegal mining

⇒ The illegal mining especially sand mining using crusher in the rivers should be either stopped or regulated.

⇒ The following chart shows which sites should be stopped immediately –



References

Altmann, J. (1974). Observational Study of Behavior: Sampling Methods. Behaviour. Vol. 49, No. 3/4 (1974), pp. 227-267.

Ahrestani, F.S., Heitkonig, I.M.A. &Prins, H.H.T. (2012). Diets & habitat-niche relationships with an assemblage of large herbivores in a seasonal tropical forest. Journal of Tropical Ecology, 8, 385-394.

Ahrestani, F. &Karanth, K. U. (2014). Gaur *Bos gaurus*. In: Melletti, M. & Burton, J. (ed.), Ecology, Evolution and Behavior of Wild Cattle: Implications for Conservation, Cambridge University Press.

Bhattacharyya, S., Choudhury, A.U. & Biswas, G.G. (1997) A Collaborative Study on Gaurs (Bos gaurus H. Smith) in North Bengal, West Bengal, India. WWF-India Eastern Region, Calcutta, India.

Bhattacharyya, M.K. &Padhy P.K. "Forest and Wildlife Scenarios of Northern West Bengal, India: A Review." International Research Journal of Biological Sciences 2, no.7 (July 2013): 2278-3202.

Caughley, G. (1977) Analysis of vertebrate populations. John Wiley and Sons, London

Chakraborty, S (2015). Human-Animal Conflicts in Northern West Bengal: Losses on both sides. International Journal of Pure Applied Bioscience3 (3): 35-44.

Choudhury, A. (2002). Distribution and conservation of the Gaur *Bos gaurus* in the Indian Subcontinent. Mammal Review, 32: 199-226.

Chetri, M. (2006). Diet Analysis of Gaur, *Bos gaurus gaurus* (Smith, 1827) by Micro-Histological Analysis of Fecal Samples in Parsa Wildlife Reserve, Nepal. Our Nature, 4: 20-28.

Duckworth, J.W., Sankar, K., Williams, A.C., Samba Kumar, N. & Timmins, R.J. 2016. *Bos gaurus*. *The IUCN Red List of Threatened Species* 2016: e.T2891A46363646. https://dx.doi.org/10.2305/IUCN.UK.2016-2.RLTS.T2891A46363646.en. Downloaded on 13 July 2020.

Geist, V (1974). On the Relationship of Social Evolution and Ecology in Ungulates. AMER. ZOOL., 14:205-220

Hallem, A. & Ilyas, O. (2018). Food and Feeding Habits of Gaur (*Bos gaurus*) in Highlands of Central India: A Case Study at Pench Tiger Reserve, Madhya Pradesh (India). Zoological Science, 35: 57-67.

Jarman, J. P. (1974). The social organisation of Antelopes in relation to their ecology. Behaviour, 48, pp- 212-267.

Jathanna, D., Karanth, K.U. &Johnsingh, A.J.T. (2003). Estimation of large herbivore densities in the tropical forests of southern India using distance sampling. Journal of Zoology261, 285–290. http://doi.org/10.1017/S0952836903004278.

Karanth, K. U. & Nichols, J. D. (2000). Ecological Status and Conservation of Tigers in India. Final Technical Report to US Fish and Wildlife Service - Division of International Conservation and Wildlife Conservation Society. Centre for Wildlife Studies, Bangalore, India.

Karanth, K. U., & Kumar, N.S. (2001). As good as it gets: Large herbivore densities in south Asian forests. Pages 489-492 in Ganeshaiah, K. N., R. Uma Shaanker, and K. S. Bawa (eds). Tropical Ecosystems: Structure, Diversity and Human Welfare. Proceedings of the International Conference on Tropical Ecosystems, Oxford-IBH, New Delhi, India.

Karanth, K. U., & Kumar, N.S. (2005). Distribution and dynamics of tiger and prey populations in Maharashtra, India. Final Technical Report. Centre for Wildlife Studies, Bangalore, India.

Karanth, K. U., Kumar, N. S., Gopalaswamy, A. M. & Srinivas, V. (2008). Distribution and dynamics of tiger and prey populations in Karnataka. Final Technical Report. Wildlife Conservation Society – India Program, Centre for Wildlife Studies, Bangalore, India.

Karanth, K. K., Nichols, J. D., Karanth, K. U., Hines, J. E. & Christensen, N. L. (2010). The shrinking Ark: Patterns of large mammal extinctions in India. Proceedings of the Royal Society-Biological Sciences, 227: 1971-1979.

Kumar, S.N. (2010). Assessment of distribution and abundance of ungulate prey using spatial models in Nagarahole and Bandipur Tiger Reserves of India. PhD Thesis submitted to Manipal University. 202 pp.

Madugundu, R., Khalid, A., Gaadi, A., Tola, E., Ahmed, G. & Jha, C. S. (2008). Estimation of gross primary production of irrigated maize using Landsat-8 imagery and Eddy Covariance data (DOI http://dx.doi.org/10.1016/j.sjbs.2016.10.003)

Ramchandran, K.K., Vijaykumaran Nair, P. &Easa, P.S. 1986. Ecology of larger mammmals of Periyar Wildlife Sanctuary. Journal of Bombay Natural History Society, 83(3): 505-524.

Ramesh, T., Shankar, K., Qureshi, Q., Kalle, R. (2012). Group Size and Population Structure of Megaherbivores (Gaur Bos gaurus and Asian Elephant Elephas maximus) in a Deciduous Habitat of Western Ghats, India. Mammal Study, 37(1):47–54

Rodman, P. S. (1981). Inclusive Fitness and Group Size with a Reconsideration of Group Sizes in Lions and Wolves. The American Naturalist. Vol. 118, No. 2 (Aug., 1981), pp. 275-283

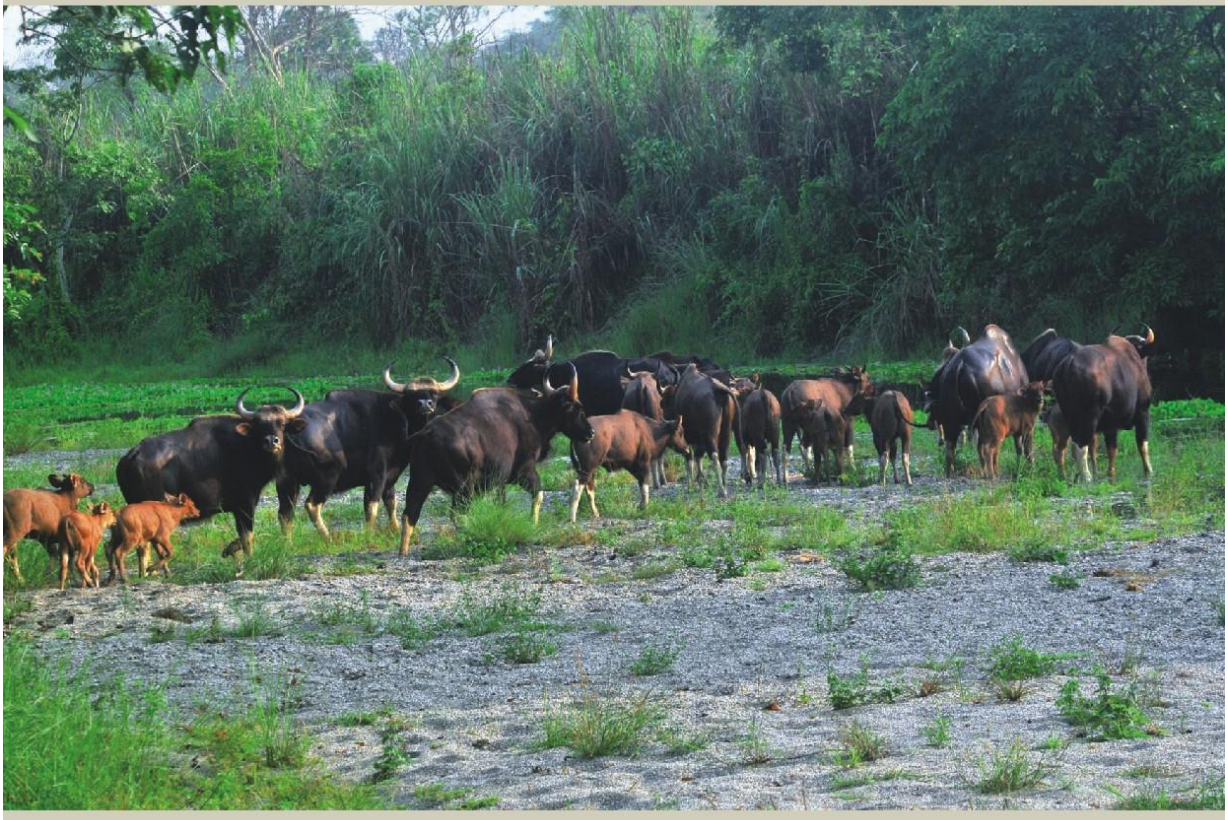
Sankar, K., Pabla, H. S. Patil, C. K., Nigam, P., Qureshi, Q., Navaneethan, B., Manjreakar, M., Virkar, P. S. & Mondal, K. (2013). Home range, habitat use and food habits of re-introduced gaur (*Bos gaurus gaurus*) in Bandhavgarh Tiger Reserve, Central India. Tropical Conservation Science, 6 :50-69.

Schaller, G.B. (1967). The Deer and the Tiger. A Study of Wildlife in India. University of Chicago Press, Chicago, USA and London, UK.

Stearns, C. S. (1992). The Evolution of Life Histories. Oxford University Press, London xii + 249 pp.

Thomas, D. & Taylor E. (1990). Study designs and tests for comparing resource use and availability. Journal of Wildlife Management, 54, 322-30.

PHOTOS FROM FIELD



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