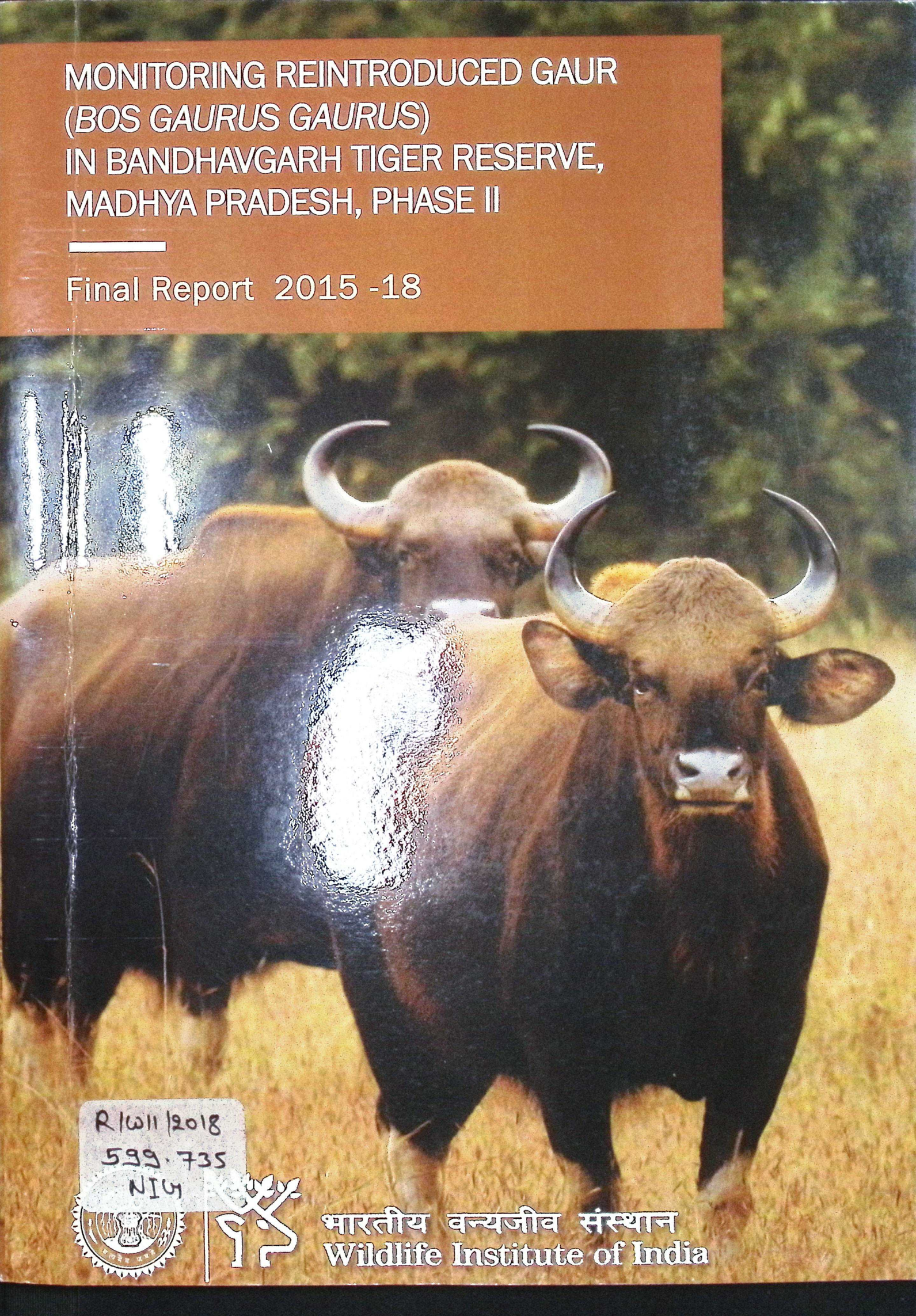
MONITORING REINTRODUCED GAUR (*BOS GAURUS GAURUS*) IN BANDHAVGARH TIGER RESERVE, MADHYA PRADESH, PHASE II

Final Report 2015 -18



भारतीय वन्यजीव संस्थान
Wildlife Institute of India

MONITORING REINTRODUCED GAUR (*BOS GAURUS GAURUS*) IN BANDHAVGARH TIGER RESERVE, MADHYA PRADESH, PHASE II

TECHNICAL REPORT

April 2015 to March 2018

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EXECUTIVE SUMMARY

Bandhavgarh Tiger Reserve (BTR), located between the Vindhyas and the Eastern flanks of Satpura hill ranges in the Central India, supported a small population of gaur (<40 individuals) till 1995. This population went locally extinct in 1998. Disruption of the migratory corridor between the forest of Bandhavgarh and Ghunghuti and Amarkantak was one of the factors attributed for the local extinction of gaur from Bandhavgarh. Even after the extinction of the gaur from the area, Bandhavgarh provided an excellent habitat for gaur. A proposal for reintroducing Gaur in BTR was initiated by the Madhya Pradesh Forest Department with support of the Wildlife Institute of India (WII) and & Beyond (previously known CC Africa).

Gaur were reintroduced in Bandhavgarh form Kanha Tiger Reserve (KTR) in two phases with first batch of 19 individuals during January 2011 and second batch of 31 individuals during March 2012. Of the total of 50 individuals, 27 individuals were fitted with radio collars and monitored continuously. Monitoring of the reintroduced population was facilitated by the WII through a collaborative project titled "Monitoring of Reintroduced Gaur in Bandhavgarh - Phase I (2011-15)" The objectives of Phase I included studying the ranging pattern, habitat use and feeding habits of reintroduced gaur in Bandhavgarh Tiger Reserve and provided newer insight into lesser known aspects of gaur biology, behavior and ecology.

The present study (Phase II) was carried out from April 2015 to March 2018, covering all the seasons in a year. The objective of the Phase II were to study the ranging pattern, habitat use, feeding habits, health considerations and competition of reintroduced gaur with other ungulates (Chital, Sambar and Nilgai) and camp elephants.

A total of four different gaur herds were identified based on the presence of radio collared individuals and physically identifiable attributes of select individuals to study the ranging pattern of reintroduced gaur. During the study period a total of 1277 locations were recorded from identified herds (n=4). During October and November 2017 six individuals (two males and four females) were fitted with collar (TELONICS VHF transmitters) and intensively monitored. The obtained radio-locations were plotted in ArcGIS 10.1. Minimum Convex Polygon (100% MCP) and Fixed Kernel Density (50% & 95% KFD) method were used to calculate home range of different gaur herds along different seasons (summer, monsoon and winter).

The estimated overall 100% MCP and 95% and 50% FKD home range of reintroduced gaur were 375.8 sq.km, 225.5 sq. km and 42.5 sq.km respectively. The overall annual

home range size of reintroduced gaur were 322.6 sq.km, 185.8 sq.km and 281. 4 sq.km , in 2015, 2016 and 2017 respectively.

The estimated 100% MCP for different herds (n=4) of reintroduced gaur in Bandhavgarh were 249.5%, 101.3%, 111.6% and 210.1% for H-I, H-II, H-III and H-VI respectively. The mean estimated seasonal home range for different gaur herds with 100 % MCP was 91.9 ± 12.8 (SE) sq.km during summer followed by 103.7 ± 10.8 (SE) sq.km during monsoon and 120.9 ± 8.4 (SE) sq.km during winters..

Group size between the four herds ranged from 7-58 individuals. The estimated annual home range (100% MCP) were 24%, 53.3%, 47.8% and 59.7% in 2015, 215.8%, 78%, 83.8% and 56,6% in 2016 and 249.2%, 101.3%, 111.6% and 210.2% in 2017 for the respective herds. The estimated average overall home range of gaur radio collared individuals (n=6) during winters was 24.5 ± 8.9 (SE) sq.km (range: 10.0 sq.km to 87.7 sq.km ; 95 % CI – 42.0 sq.km to 6.9 sq.km).

At the end of Phase II (March 2018), the gaur population in BTR was 127 comprising adult females (n= 32), calves (n=27), juveniles (n= 26), sub-adult males (n= 20), sub-adult females (n= 14) and adult males (n= 8). The estimated overall gaur sex ratio (adult male: adult female) was 1: 3.3, and adult female: calf ratio was 1: 1.4.

Both habitat use and habitat availability were assessed for the herd locations in the study area. The analysis of habitat use were limited to six different vegetation classes such as bamboo forest, grassland, open mixed forest, mixed forest, sal forest and riparian forest. Locations of individuals/identified herds obtained from April 2015 to March 2018 were used to assess the habitat use pattern. The collected gaur locations (n=1277) were plotted on the classified LISS-III imagery of Bandhavgarh. Second-order resource selection function was used to determine the habitat selection of reintroduced gaur. Resource selection program for windows was used to conduct the compositional analysis.

Though mixed forest were more available, the gaur largely used grassland followed by riparian and open mixed forests Sal and bamboo forests were used according to its availability within their entire home range though the gaur avoided mixed forest. The overall habitat preference of gaur using bonferroni analysis was in the following order as: grassland>reverine forest>bamboo forest>open mixed forest>sal forest>mixed forest. This result also support that gaur preferred grassland and avoided mixed forest and used rest of the forest as per their availability ($X^2 = 0.9917$, $df = 1$, $p = 0.05$).

The herd wise habitat use of gaur was estimated using the Ivlev's Index. The different herds used habitat differently. The herds mainly remain confined to their respective areas. Herd I and IV used reverine forest more than grassland whereas herd II and III used grassland more than reverine forest. All the other habitats such as, sal forest

and open mixed forest were used according to their availability except mixed forest, that were least preferred though it is dominant in gaur ranging area.

The data on the food plants and parts eaten by the gaur was obtained through scan sampling. The plant species and parts eaten by the individual were recorded.

During the study period, a total of 112 species of food plants belonging to 39 families were recorded. The food plants eaten by gaur were classified into five categories such as trees, shrubs, herbs, grasses and climbers. The 112 species of food plants recorded comprised of 41 tree species, 18 shrub species, 12 herb species, 34 grass species and 7 climber species. The different plant parts eaten by gaur were classified as leaf (for trees, shrubs and climbers), shoot (for grasses and herbs), floral bud, flower, barks and fruit. Major portion of gaur diet were comprised of leaves and shoots. A multispectral (LANDSAT 7 ETM+), high resolution (30m) satellite imagery from the Global Land Cover Facility (GLCF) was used to generate the landuse/landcover (LULC) map of the study area. For the quantification of vegetation (tree, shrub and ground layer), the digitized map of BTR was gridded (2 km* 2 km) in a GIS domain and systematic vegetation plots were laid in field for vegetation quantification. A ten meter radius plot was laid down to enumerate tree density, shrub density, was enumerated in five meter radius plot and the point intercept method was used to estimate the percentage of ground cover.

It was observed from the LULC map of BTR that the mixed forest was the dominant vegetation type and covered an area of 40.2%, whereas the area under plantation covered the lowest percent area (0.2%). In addition, bamboo forest covered an area of 12.6%, grassland 6.5%, whereas Sal Forest covered about 13.1% area in the entire Tiger Reserve. Between 2011 and 2015 three villages (Kallwah, Kumarwah, Magdhi and Milli) were relocated from the core area of BTR and the village relocated sites have been transformed into grasslands having mainly species like *Saccharum spontaneum* and *Vetiveria zizanoides*. The grasslands (on the relocated sites) have been observed to be used extensively by gaur and have become important feeding sites for the gaur in the study area.

The health condition of the reintroduced gaur population was evaluated on monthly basis from April 2015 to March 2018, using the body condition indices. A total 1,635 body scores were examined for BCI for both sexes including all the demographic classes of gaur during the study period. Of the observed individuals for body condition, 77.9 % were found to be in good body condition followed by 20.2 % in fair and 1.7 % in poor conditions. Thus it was concluded that overall, the health condition of the reintroduced gaur population in Bandhavgarh was good throughout the study period. However, three confirmed cases of tuberculosis based on post mortem reports of gaur mortality in BTR have occurred. This is an important challenge that needs to be appropriately addressed.

Food resource competition of reintroduced gaur with other wild ungulates and camp elephants was evaluated through direct observations. A check list of plant species eaten by identified wild ungulates and camp elephants was prepared. Based on this information, the percentage overlap of food plants eaten between gaur and ungulates and also with the camp elephants was calculated using Bernoulli (binary) distribution. Gaur utilized 112 food plants (41 trees, 18 shrubs, 12 herbs, 34 grasses and climbers) species. However, Chital utilized a total of 89 food plants (25 trees, 14 shrubs, 17 herbs, 7 climbers and 27 grasses. A total of 68 food plants (21 trees, 9 Shrubs, 10 herbs, 6 climbers and 22 grasses) species were recorded for sambar. For nilgai a total of 73 food plants (16 trees, 19 Shrubs, 16 herbs, 3 climbers and 19 grasses) species were recorded. Camp elephants utilized 72 food plants (37 trees, 7 shrubs, 11 herbs, 5 climbers and 14 grasses) species. The overlap for food resource of gaur with chital was found to be 100%. With camp elephant and nilgai, gaur shared 89% and 81% food resources respectively, whereas the overlap was found to be minimum (73%) with sambar.

Four villages namely Kallwah, Kumuruwah, Magdhi and Milli were successfully relocated during 2011-2015 from the core area. Gaur was found to use these vacated sites effectively. As the village reloation has provided additional space and forage availability for Gaur and other sympatric species, the relocation of the remaining 11 villages from the core area can play an important role in the long term conservation of this reintroduced population.

Continous scientific monitoring is recommended for the reintroduced population of gaur in Bandhavgarh Tiger reserve for future period.

CHAPTER 1

INTRODUCTION

Re-Introduction

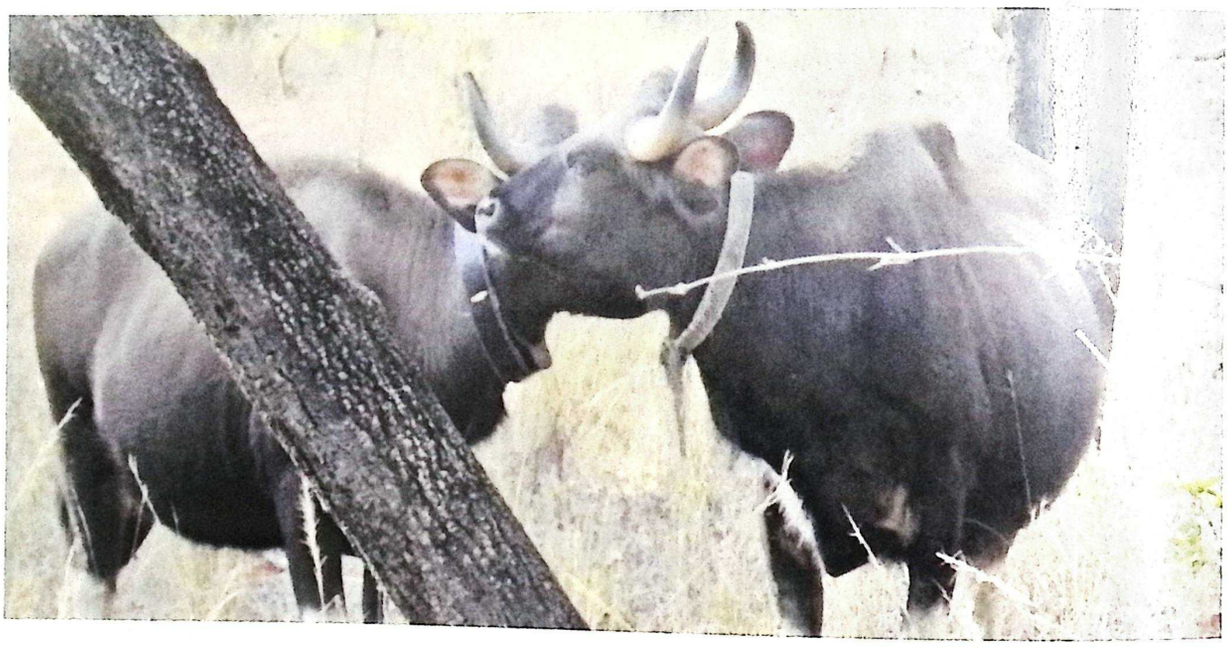
Reintroduction and translocation have become relevant in the present context with dwindling wildlife populations that essentially require support for their long term conservation. Successful wild animal reintroduction and restoration efforts have been attempted across the world. Campbell and Rosell (2010) described reintroduction as the returning of native species to localities where they have been lost.

These attempts involved introducing species from wild or from captivity to natural habitats (Rob Laidlaw 2001). Grey wolf (*Canis lupus*), Arabian oryx (*Oryx leucoryx*) and Black bear (*Ursus americanus*) in USA (Campbell and Rosell 2010), White Rhinoceros (*Ceratotherium simum*) in Botswana (Pitlagano 2007), Elk (*Cervus canadensis*) in America (Schneider et al. 2006), Reindeer (*Rangifer tarandus*) in Finland (Kojola et al. 1995), American bison (*Bison bison*) in Canada (Kay et al. 2001), Asiatic wild ass (*Equus hemionus*) in Israel (Saltz and Rubenstein 1995) and One Horned Rhinoceros (*Rhinoceros unicornis*) in Nepal (Jnawali 1991) are some of the successful programs. Successful programs in the Indian subcontinent include reintroduction of tigers (*Panthera tigress*) in Sariska Tiger Reserve, Western India (Sankar et al. 2010) and Panna Tiger Reserve, Central India (Ramesh et al. 2011), wild water buffalo (*Bubalus arnee*) in Dibru - Saikhowa National Park, Assam (Ashraf and Sarkar 2011), one horned rhinoceros (*Rhinoceros unicornis*) in Dudhwa Tiger Reserve, Uttar Pradesh (Sinha et al. 2001, Pitlagano 2007) and Manas National Park, Assam (Menon 2014). The IUCN/SSC (Duckworth et al., 2016) is an important document that has formed basis for recent reintroduction for variety of species across the world.

Further to local extinction of Gaur (*Bos gaurus gaurus*) from Bandhavgarh Tiger Reserve (BTR) in 1998, the Madhya

Pradesh Forest Department in collaboration with the Wildlife Institute of India and CC Africa (& Beyond) reintroduced 19 gaur in BTR in 2011. The details of the gaur translocation carried out in 2011 have been documented in Pabla *et al.* (2011). Subsequently, 31 gaur were supplemented to the BTR Gaur population in March 2012. Wildlife Instittue of India was bestowed with the responsibility for monitroing of the reintroduced gaur population since 2011 through a MPFD funded project titled " Monitoring of Reintroduced Gaur in Bandhavgarh Tiger Reserve-Phase I (2011-2015). The project envisaged studying the ranging pattern, habitat use, food habits and health condition of reintroduced gaur over the five year period (Sankar, 2015).

Besides the stated objectives, a need was felt to study the competition for resources between gaur and other ungulates including camp elephants. Accordingly the Phase II of the project "Monitoring of Reintroduced Gaur in Bandhavgarh Tiger Reserve" was initiated in March 2015 for a period of three years.



Objectives

- To study the ranging pattern of reindroduced gaur in BTR.
- To study the habitat use of reintroduced gaur in BTR.
- To study the food habits of reintroduced gaur in BTR.
- To study the health condition of reintroduced gaur in BTR.
- To study the food resource competititon of reintroduced gaur with other ungulates and camp elephants with BTR.

CHAPTER 2

STUDY SPECIES

Study Species

Taxonomic classification

The gaur (*Bos gaurus*) commonly known as the Indian Bison is the largest member of the family Bovidae of the Indian subcontinent confined to the Oriental bio-geographic region.

Kingdom	:	Animalia
Phylum	:	Chordata
Class	:	Mammalia
Order	:	Cetartiodactyla
Family	:	Bovidae
Scientific name	:	*Bos gaurus*
Species authority	:	C.H. Smith, 1827

Traditionally three subspecies of gaur (*Bos gaurus*) have been recognized *viz. Bos gaurus readei* (Myanmar and Cambodia), *Bos gaurus hubbacki* (Thailand south of the isthmus kra and west Malaysia) and *Bos gaurus gaurus* (India and Nepal). However, NRC (1983) recognizes only two subspecies, *Bos gaurus gaurus* of India and Nepal and *Bos gaurus laosiensis* of Myanmar, Thailand, Laos, Vietnam, Cambodia and Malaysia.

Evolution and Systematics

Ungulates are a diverse group of hoofed mammals spread across the globe and broadly classified as Artiodactlys and Perrisodactyls based on the whether they are even or odd toed. The even toed (Artiodactyl) ungulates belonging to the order Cetartiodactyla are the most successful group of large herbivores (Thenius 1990) and encompasses the family Bovidae with diverse group of the extant ungulates that are distributed mainly in the Old World with a few species being present in North America (Vairavel 1998). The family Bovidae includes cattles, buffaloes, antelopes, sheeps and goats. The present classification scheme for bovids recognizes eight subfamilies subdivided into two clades, the Boodontia which comprises of a single subfamily, Bovinae and Aegodontia comprising of all other bovid subfamilies

(Thomas 1984). The subfamily Bovinae represents an early offshoot of the family Bovidae and diverged from the Aegodontids approximately 25 million years ago. The modern Bovinae have attained large body sizes compared to any other bovid subfamilies which might have happened because of the cooler climates prevalent in Eurasia (Hernandez-Fernandez and Vrba 2005). Presently three tribes are recognized within the subfamily Bovinae *viz.* Bovini (cattle, buffalo, bison and saola), Boselaphini (nilgai and four-horned antelope), Tragelaphini (spiral-horned antelope). The Bovini tribe includes five genera containing ten species and 21 subspecies. The five genera include Asiatic buffalo (*Bubalus*), African buffalo (*Syncerus*), Bison (*Bison*), true cattle (*Bos*) and Saola (*Pseudoryx*).

General characteristics and ecology

Gaur is a large herbivore with the bulls weighing around 600-1000 kg and the cows about 300-700 kg. Bulls are taller compared to the cows with the shoulder height ranging between 1.6 to 1.9 m with the cows about 10 cm shorter (Sankar *et al.* 2001). Males can be identified by their larger horns, pronounced shoulder hump, two prominent dewlaps (at chin and a larger one hanging below the throat) and more swath (Sanderson 1968). Newly born calves are light golden yellow in color that darkens with age. Adult females are dark brown whereas adult males are black. Both hind legs and forelegs are white to tan below the knees. The animal reaches sexual maturity at three years of age and usually produce one and rarely two calves after a gestation period of 275 days. The mating season of gaur varies through the entire distributional range (Prater 1971), though in some areas, definitive peaks have been observed. Brander (1923) reported December-January as the peak mating season for gaur in central India. In south India, this may range from November to March (Morris 1937). An unsynchronized pattern in calving indicates that calves are born throughout the year and mating occurs across the year (Schaller 1967, Vairavel 1998, NRC 1983). The recorded life span for captive female gaur has been 24 years (Crandall 1964) and that for captive bull has been 23.6 years (Ahrestani *et al.* 2011).

They are group living though the group structure is quite fluid and dynamic. The group size in gaur may range from two individuals to more than 20 individuals. A typical group usually consists of adult cows, some calves, one or two adult bulls and a few sub adult animals. Sometimes gaur bulls also form bachelor herds (all male herds). Gaur bulls (mainly adult bulls) also roam solitary and may join different herds for short periods of time.

Gaur is known to be a mixed feeder (Schaller 1967). It mainly grazes in the monsoon but is known to browse in dry seasons. Their diet mainly consists of shoots and leaves of bamboo, grasses, herbs, trees and shrubs. Fruits of *Aegle marmelos*, *Bauhinia* spp., *Cassia fistula*, *Cordia myxa*, *Diospyros melanoxylon*, *Phyllanthus*

emblica, *Gmelina arborea*, *Terminalia bellerica* and *Randia dumetorum* are also eaten (Brander 1923, Schaller 1967, Krishnan 1972, Sankar *et al.* 2001).

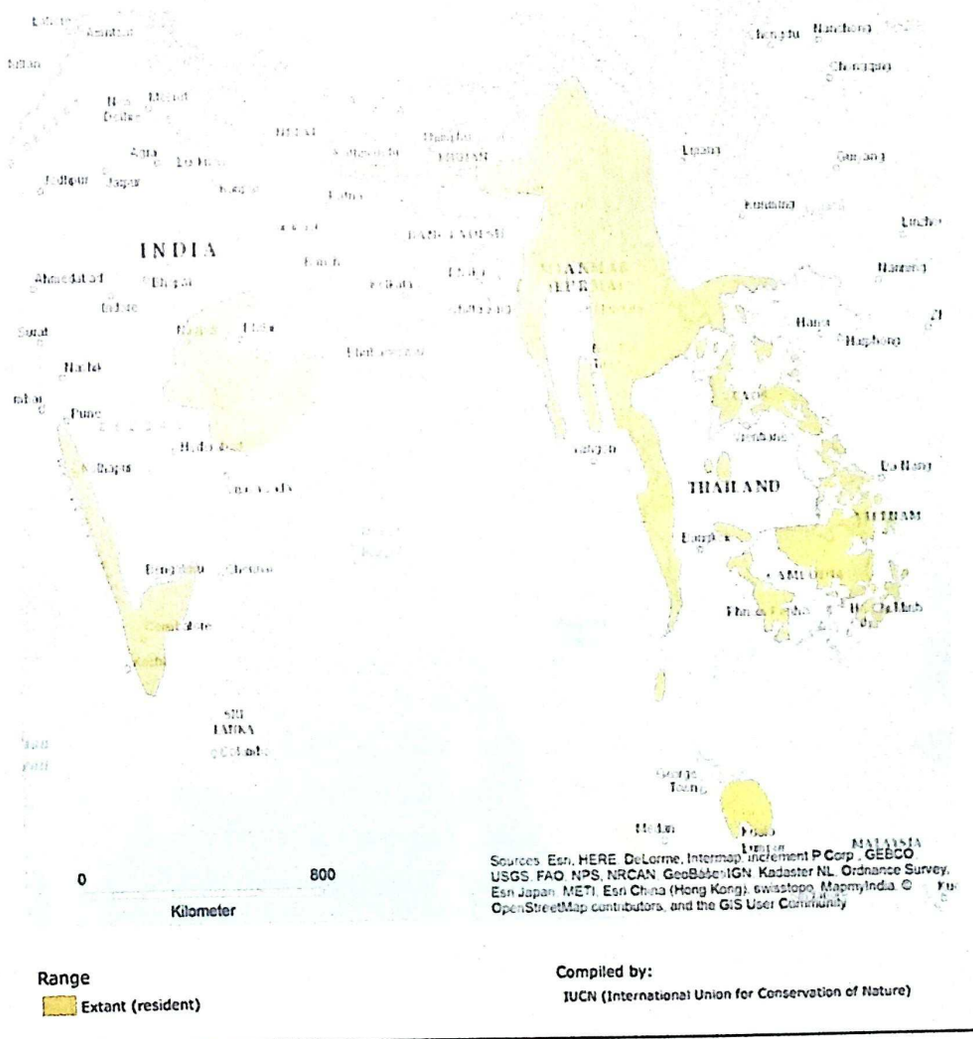
Global distribution of gaur

Historically, the distribution of the gaur covered the entire mainland of South and South-east Asia and Sri Lanka (Duckworth *et al.* 2016). The current distribution is restricted to scattered pockets in India, Nepal, Bhutan, Cambodia, China, the Lao PDR, peninsular Malaysia, Myanmar, Thailand and Vietnam (Figure 2.1).

Gaur distribution in India

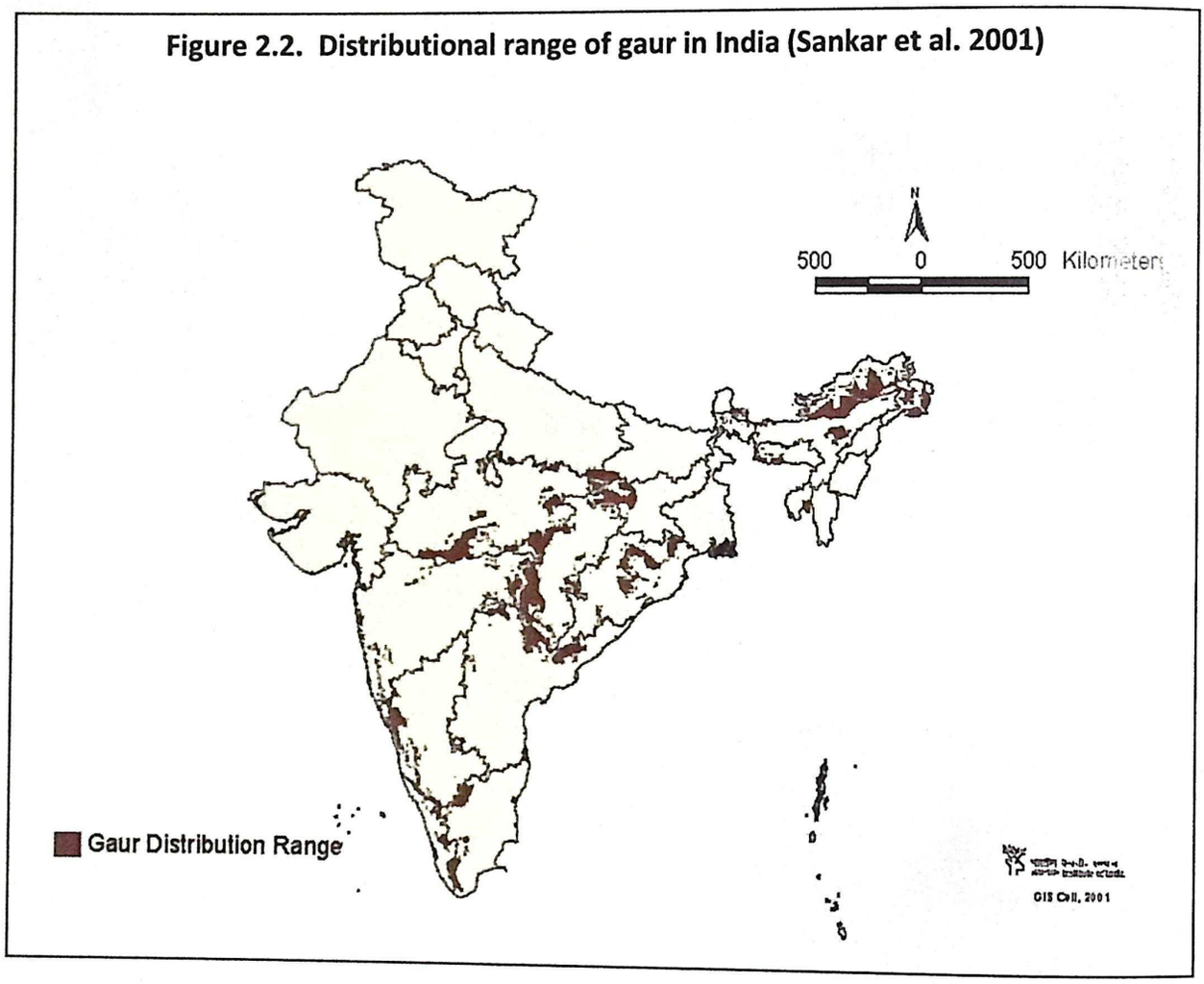
In Indian landscape, the gaur population is distributed mostly in isolated pockets largely corresponding to the major mountain systems of the Western Ghats, the Central Indian Highlands and the Northeastern Himalayas, including the hills south of Brahmaputra. Gaur is also found in the forests of Bihar, West Bengal and parts of the south-eastern peninsula. They occur in diverse habitats ranging from tropical wet,

Figure 2.1. Global distributional of gaur (IUCN)



semi-wet evergreen and bamboo forests in the North-east to Tropical Moist Deciduous forests in the Western Ghats to Tropical Dry Deciduous forests in Central India to Shola forests and Tropical Thorn forests on the eastern slopes in the Western Ghats. Sankar *et al.* (2001) reported that the Wayand-Nagarhole-Mudumalai-Bandipur complex in the Western-Ghats landscape is one of the most extensive extant strongholds of gaur. In the Central Indian landscape the most important units for gaur population are the Satpura-Melghat landscape and Achanakmar-Kanha-Pench landscape (Jhala *et al.* 2011). In the Terai-Arc landscape gaur has been reported only from the Valmiki Tiger Reserve in Bihar which shares connectivity with the Chitwan National Park in Nepal (Jhala *et al.* 2011).

Figure 2.2. Distributional range of gaur in India (Sankar et al. 2001)



The gaur habitat in North-east India is contiguous with the state of West Bengal in the west, Myanmar in the east, Bangladesh in the south and Bhutan in the north (Sankar *et al.* 2001). The Western Ghats and Central Indian Landscape hold about 75% of the present gaur population in India. The gaur range represents approximately 7.12% of the geographical area and 30% of the forested area of India (Sankar *et al.* 2001). The estimated population of gaur in India is between 12,000 and 22,000 (Ranjitsinh 1987). Sankar *et al.* (2001) estimated the gaur population in India to be approximately 23,500.

Threats

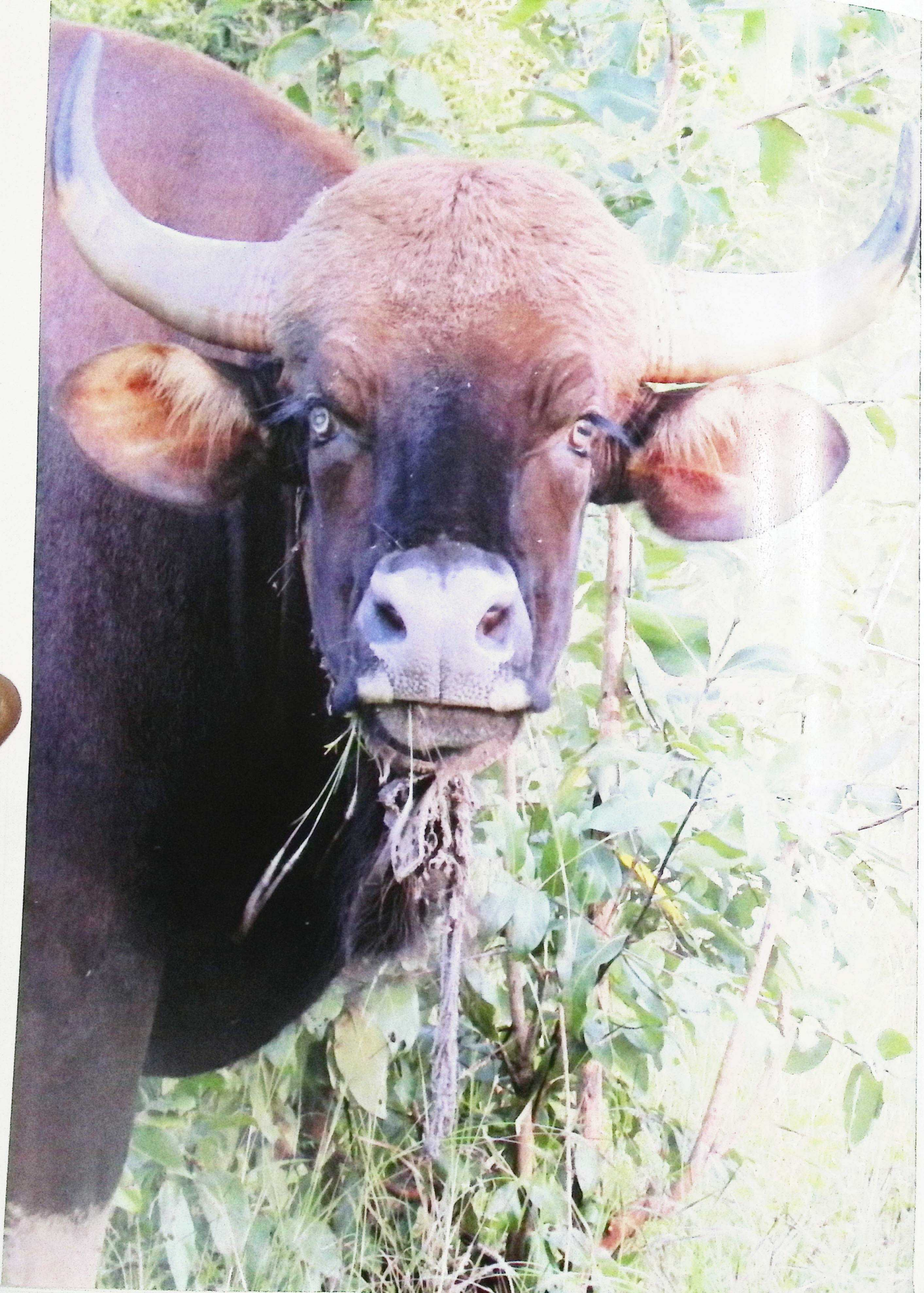
Gaur populations are prone to variety of threats that challenge their survival across their entire distributional range. Habitat degradation, loss and fragmentation together with poaching for consumption and diseases pose a major threat to their long term survival (Pasha *et al.* 2004).

The Central Indian landscape that harbors about one fourth of the gaur population in India (Sankar *et al.* 2001) has witnessed quite a few local extinctions of gaur population in the past couple of decades. The gaur population had gone extinct from Bandhavgarh Tiger Reserve in Madhya Pradesh and from Kanger Valley National Park in Chhattisgarh (Sankar *et al.* 2001). The species is also possibly extinct in Sanjay National Park, in eastern Madhya Pradesh, which earlier had a population of gaur connected to the populations in Chhattisgarh and Jharkhand.

The species is closely related to domestic livestock and is vulnerable to all the diseases that infect cattle. Past records indicate that populations of gaur have succumbed to epidemics of footand mouth disease (FMD), rinderpest and anthrax in many areas of distribution. Several subpopulations of gaur in Bandipur-Mudumalai area were nearly destroyed as a result of rinderpest in 1968 (Choudhury 2002). Among the diseases reported for gaur, FMD has been found to be the most prevalent disease in the gaur populations in India (Sankar *et al.* 2001).

Conservation Status

The global population of the gaur is estimated at 13,000-35,000 animals of which, only 6000- 21,000 are reproductively active individuals (Duckworth *et al.* 2016). The population has declined overall by at least 30% during the last three generations. Consequently, the gaur is categorized as Vulnerable (criteria A2cd+3cd+4cd ver. 3.1) in the IUCN Red List of Threatened Species (Duckworth *et al.* 2016). It is listed in Schedule I of the Indian Wildlife (Protection) Act of 1972 and is included in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).



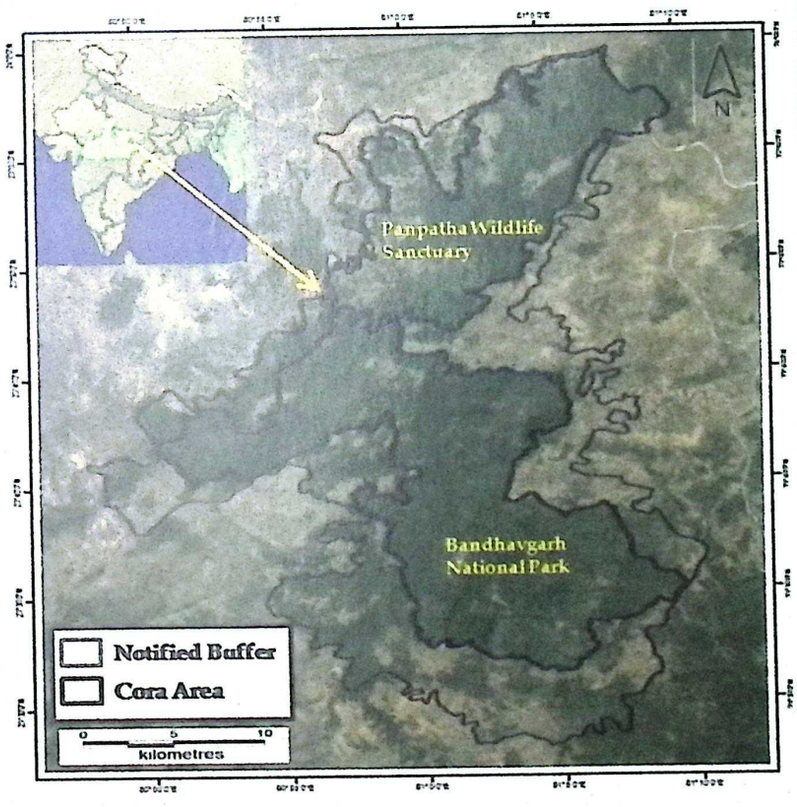
CHAPTER 3

STUDY AREA

Location and general information

The study was conducted in the Bandhavgarh Tiger Reserve (BTR), situated in the state of Madhya Pradesh in India (Figure 3.1). According to the Bio-geographic classification of India, Bandhavgarh Tiger Reserve falls in the zone 6E- Deccan plateau-Central highlands (Rodgers and Panwar 1988). It is located between the Vindhyan and the eastern flanks of Satpura hill ranges and the reserve lies between 23^0 30' 08" to 23^0 57' 01" North latitude and 80^0 47' 05" to 81^0 11' 43" East longitude. Bandhavgarh Tiger Reserve comprises of the core area (716.46 sq.km) and the buffer area (820.15 sq.km) and the total area of the reserve is 1536.7 sq.km.

Figure 3.1: Location of Bandhavgarh Tiger Reserve, Madhya Pradesh,Central India



The core area of the Tiger Reserve is further divided into two administrative units *viz.* Bandhavgarh National Park (448.84 sq.km) and Panpatha Wildlife Sanctuary (264.28 sq.km). The majority of the core area of BTR lies in the Umaria Forest Division (521.30 sq.km) and the remaining portion lies in the Katni Forest Division (Prakasam 2006).The reserve has a diverse assemblage of flora and fauna (Gopal 1991).

Historical and Legal Status

Bandhavgarh Tiger Reserve has an old history and ruins of the bygone era scattered all over the reserve. Monuments of historical significance are the Bandhavgarh fort, caves, rock paintings and carvings. The Bandhavgarh fort is considered to be approximately 2000 years old (Figure 3.2) (Sonakiya 1993).

Figure 3.2: Bandhavgarh fort – Testimony of old history

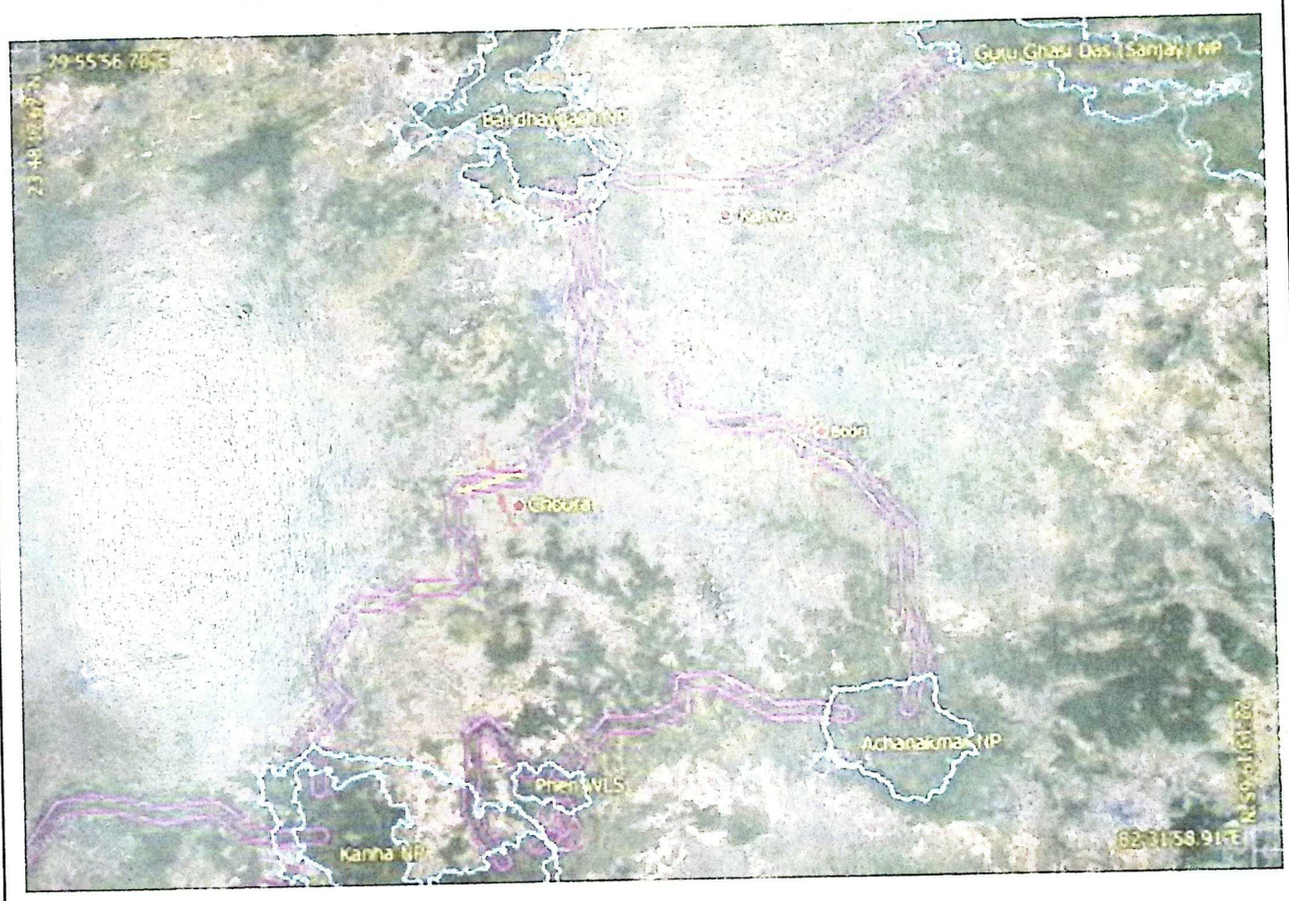
The Central Indian Landscape comprises of some of the most important and threatened habitats of tigers, co-predators and prey species in India (Jhala *et al.* 2011) and Bandhavgarh hold a good population of all the major species.

Topography and Geology

Topographically, Bandhavgarh is extremely rugged with small hillocks interspersed with grassy swamps (Gopal 1991). The highest part of this landscape is the Bandhavgarh fort, which lies at an altitude of 810 m above msl (mean sea level) while the lowest point is the village of Tala at an altitude of 440 m above msl (Nath 2000). The area of Panpatha Wildlife Sanctuary is mostly plain though some parts have undulating hillocks and the highest point of the Sanctuary is 500 m above msl (Sonakiya 1993). The reserve contains some of the oldest rocks in the world – the Gondwana rocks (Nath 2000). The rocks in the Bandhavgarh region belong to the

Gondwana Super group of the South Rewa Basin (Sonakiya 1993) and the rock formations in Bandhavgarh mainly comprise of sandstone.

Figure 3.3: Corridors connecting Bandhavgarh Tiger Reserve with Sanjay-Dubri, Achanakmar and Kanha Tiger Reserves (Jhala *et al.* 2011)



Physical features

The various rock formations and local topography have played an important role in the formation of soil in Bandhavgarh. The soil in the region is mainly sandy or sandy loam (Nath 2000). Richer clay and black cotton soils are also found in the park but their distribution is restricted to the areas of Badrehal and Pathari beats and the surrounding areas in the park (Sonakiya 1993). The composition of the chloride is 13 (Roy *et al.* 1992). The soil is usually poor in nitrogen and organic matter and fairly rich in potash.

The slope categories in BTR have been identified into eight classes viz. 330-390 degrees, 391-450 degrees, 451-520 degrees, 521- 580 degrees, 581- 640 degrees, 641-700 degrees, 701- 760 degrees and 761- 820 degrees (Figure 3.4). Most of the protected area falls into flat to gentle slope class (330- 640 degrees). Part of Tala range has a rugged terrain with steep slopes (701- 820 degrees).

Figure 3.4: Digital Elevation Model map of BTR

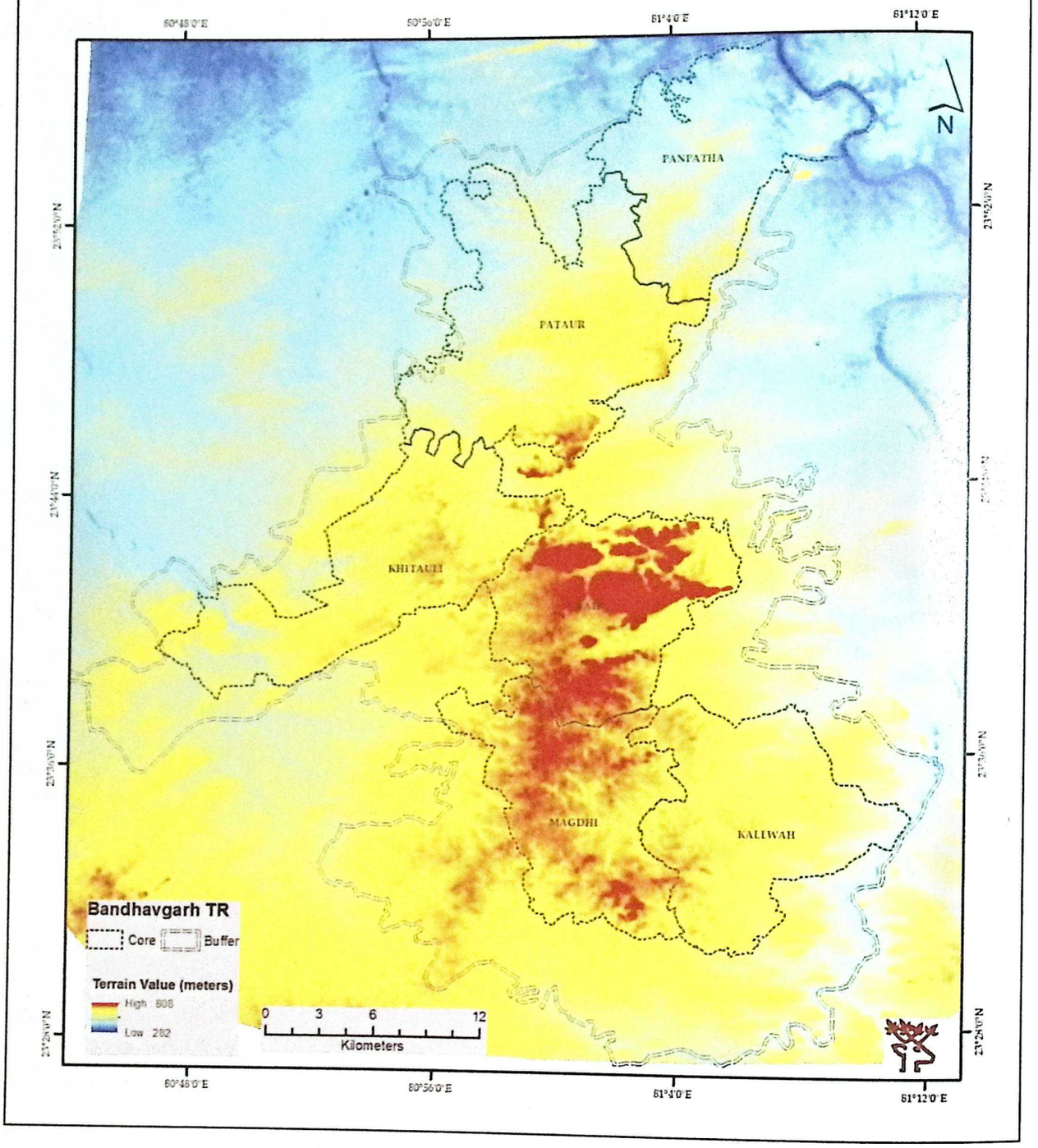
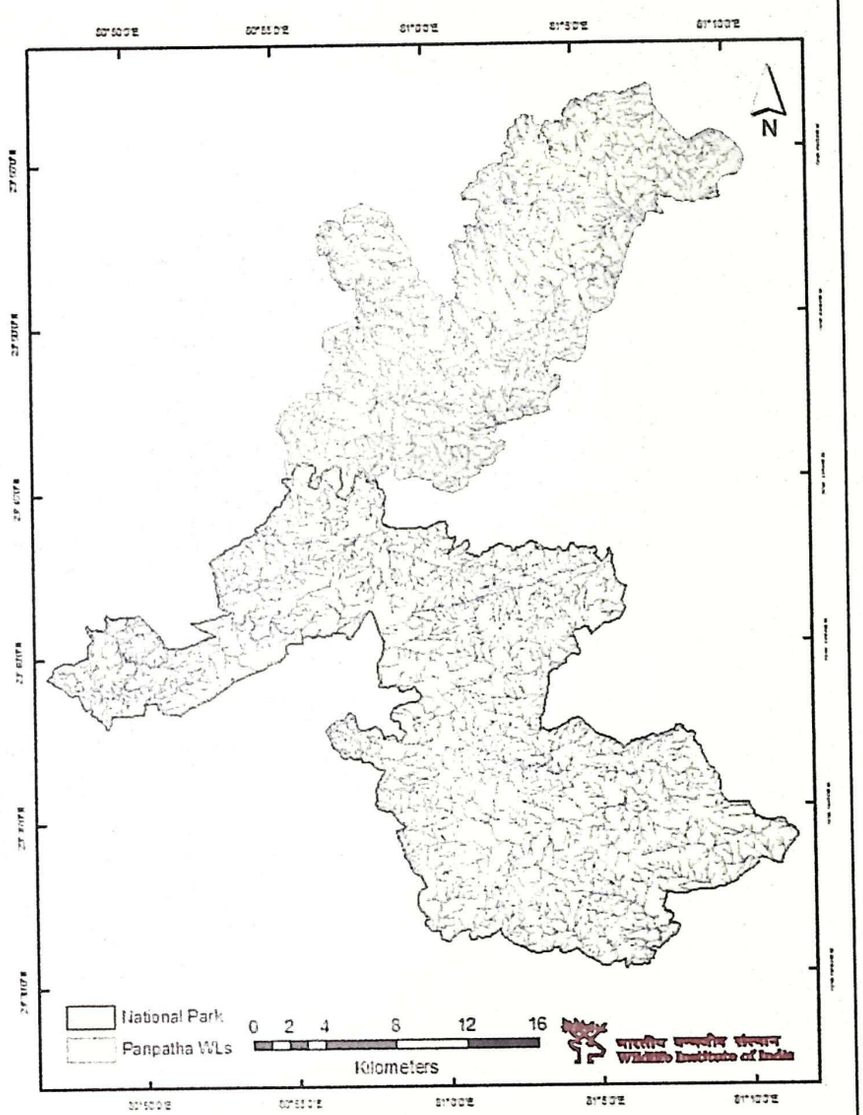


Figure 3.5: Drainage pattern of BTR



The rock formations comprise mainly of sandstone which is a well-known aquifer as it is characterized by porosity and permeability (Prakasam 2006). Being permeable, sandstone is capable of high recharge and discharge making it a storehouse of ground water which has resulted in some areas of the park having a very high water table. The Tiger Reserve has a number of seasonal and perennial streams and nullas (Lad and Gopal 1992). The major perennial rivers are Umarar, Damnar, Janad, Johila, Charanganga and seasonal nalas are Bhadar, Chachahi and Chamkuli (Prakasam 2006). A large number of perennial springs originate on the slope of Bandhavgarh fort, the most important being Charanganga which flows as a major river outside the park area (Pabla 1998). The river Janad runs year round and flows in North-East region of the park, which originates from Magdhi range and flows into Kallwah range and joins the Son river running along the buffer boundary. In Sanctuary area the main rivers are Halphal, Jaruwahi Nala and Bagaiha Nala. The major waterholes in the park are Rajbehra dam, Devkhanni talab, Andhri jeriya, Adhawal, Bamera dam, Damdama talab, Jhurjura dam, Mahaman dam, Bodha talab, Charakava talab and Sukha dam (Prakasam 2006). The drainage pattern of the Tiger Reserve is shown in figure 3.5.

Climate

The Tiger Reserve lies within the tropical zone, having three distinct seasons *viz.* summer (March-June), monsoon (July-October) and winter (November-February).

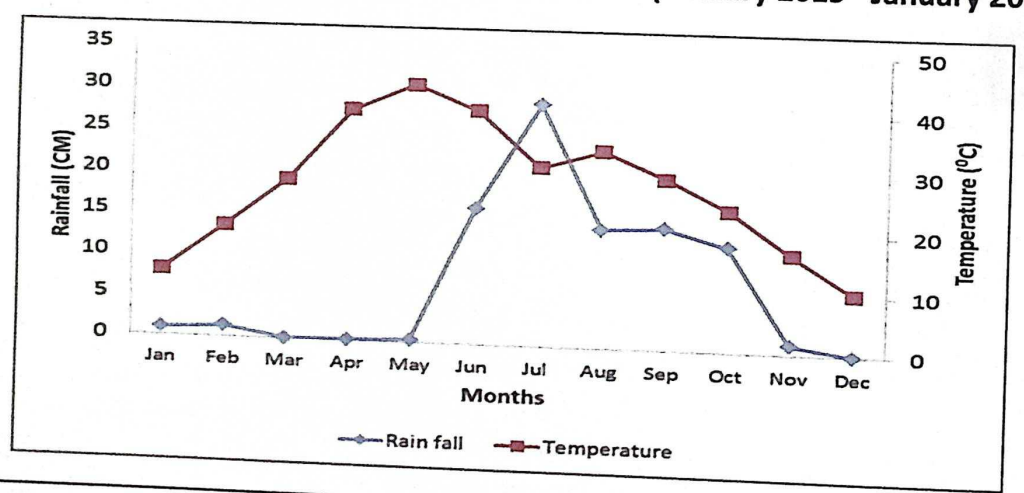
Summer

The summer sets in the month of March and lasts till around mid June when the area receives the first showers of the Southwest monsoon. Generally, the months of May and June are the hottest, with the temperature rising up to 46°C (Prakasam 2006). During the study period the highest mean monthly temperature was recorded in the month of May at 43.8 ^{0}C (Figure 3.6). Summer is usually dry, but instances of rains, hailstorms and thunder do occur in the month of March and April. The relative humidity in the early afternoon is as low as 15-20%. During this period many water holes dry up and the park area is prone to fires.

Monsoon

The area receives pre-monsoon showers by the mid of June and the regular southwest monsoon starts in the first week of July. More than 80% of the total precipitation in the year is received during July to September (Sonakiya 1993). Occasional winter rains occur during December to February from northeast monsoon constituting 5% of annual rainfall in this area (Prakasam 2006). During the study period the highest mean monthly rainfall was recorded in July at 28.7 centimeters (Figure 3.6).

Figure 3.6: Mean rainfall and temperature in BTR (January 2015 –January 2018)



Winter

The winter begins in November and lasts till February. However, December and January being the coldest months. In severe winters, the night temperature comes down very low, mercury dropping even to sub-zerotemperatures and severe ground

frost occurs in the meadows and valleys (Prakasam 2006). During the study period the lowest mean monthly temperature was recorded in December at 10.2 ^{0}C (Figure 3.6). Occurrence of fog in the early morning hours is common in winter. The relative humidity reaches 100% during the night, and the incidence of dew is heavy.

Flora

Vegetation of Bandhavgarh Tiger Reserve falls under five categories (Champion and Seth 1968) namely Moist peninsular low-level Sal forest (3C/C2e), Northern dry mixed deciduous forest (5B/C2), Dry deciduous scrub (DS1), Dry grassland (5/DS4) and West Gangetic moist mixed deciduous forest (3C/C3a) (table 3.1). The land use and land cover map of Bandhavgarh Tiger Reserve is given in figure 3.7.

Figure 3.7: Vegetation and land cover map of BTR

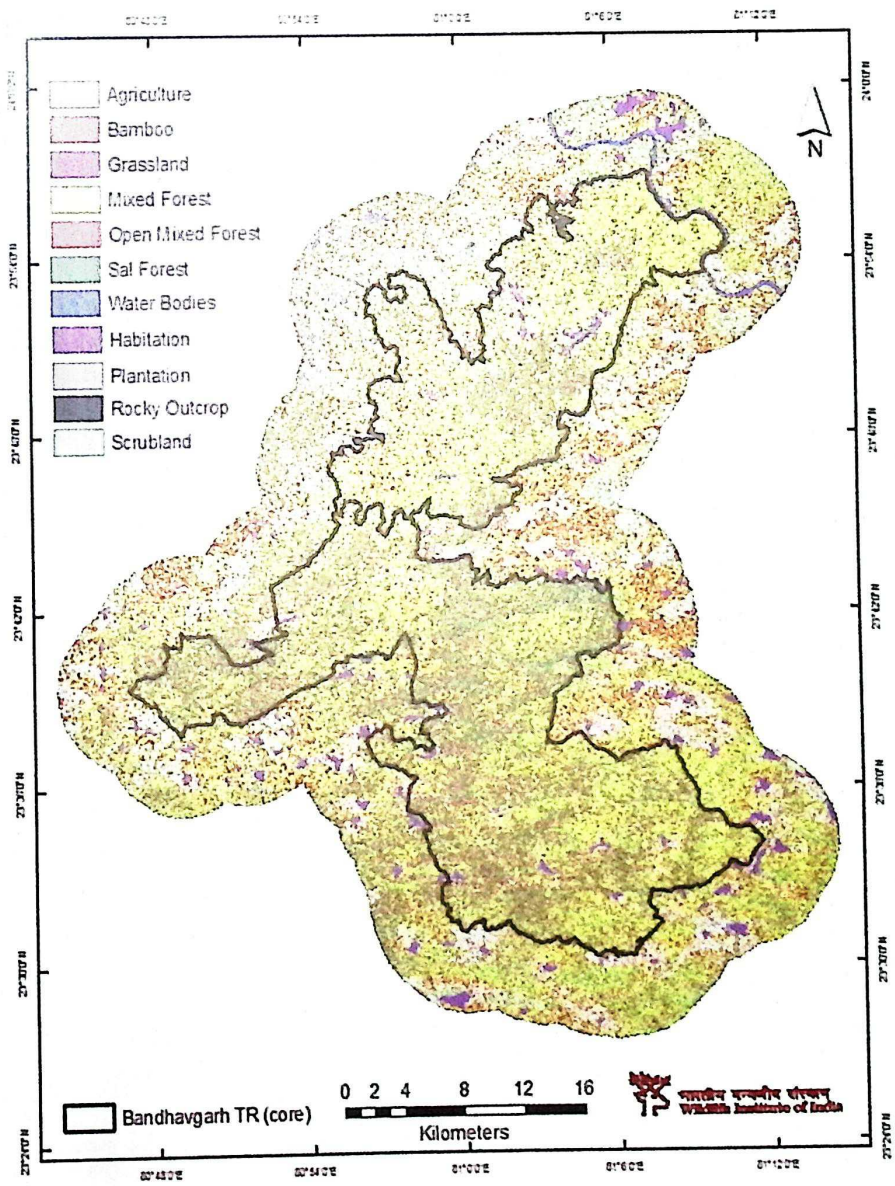


Table 3.1 : Forest type of BTR

S. No.	Forest Type	Description	
A.	Moist peninsular low level Sal forest (3C/C2e)	Sal typically forms a high forest in which it constitutes about 60 - 80% of the top canopy, which is 20–30 m high. The undergrowth is abundant with the presence of climbers. The main associates are *Terminalia tomentosa, Pterocarpus marsupium, Anogeissus latifolia, Madhuca indica, Phyllanthus emblica, Buchanania lanzan, Diospyros melanoxylan, Terminalia chebula, Kydia calycina, Ougeinia oojeinensis, Bridelia retusa, Bauhinia retusa* and *Phoenix acaulis*	
B.	Northern dry mixed deciduous forest (5B/C2)	The upper canopy in this forest type is usually light, open and irregular, the trees having relatively short bole and poor form and a height rarely over 10 m. The canopy is made entirely of deciduous trees. The main species found are *Anogeissus latifolia, Acacia catechu, Butea monosperma, Buchanania lanzan, Acacia leucophloea,* etc.	
C.	Dry deciduous scrub (DS1)	This forest type represents a degradation stage of the dry deciduous forest and has been brought into existence by adverse biotic factors like cattle grazing, lopping and forest fires. In spite of sufficient rains, moisture retention is poor and the type has now become a stable edaphic climax. The main species found are *Butea monosperma, Diospyros melanoxylon, Cassia fistula, Anogeissus latifolia* and the undergrowth mainly comprises of *Woodfordia floribunda* and *Flacourtia indica.*	
D.	Dry grassland (5/DS4)	Grasslands, locally called as *bah*, are a common feature of the valleys in the park. Most of the large grasslands in the park have been created at the areas from where villages have been relocated outside of the park. The grassland communities are complex. Tall, coarse grasses are found in the marshy areas. Species which commonly occur in these grasslands include *Themeda quadrivalvis.*	

E.	West Gangetic moist mixed deciduous forest (3C/C3a)	In this type of forest the canopy is comparatively open allowing good percentage of grass and herb to grow. The main species found in this type are *Lagerstroemia parviflora, Anogeissus latifolia, Adina cordifolia, Terminalia chebula, T. Bellerica, T. arjuna, Diospyros melanoxylon, Bauhinia retusa, Lannea coromandelica, Mitragyna parvifolia, Cassia fistula,* etc.	

Fauna

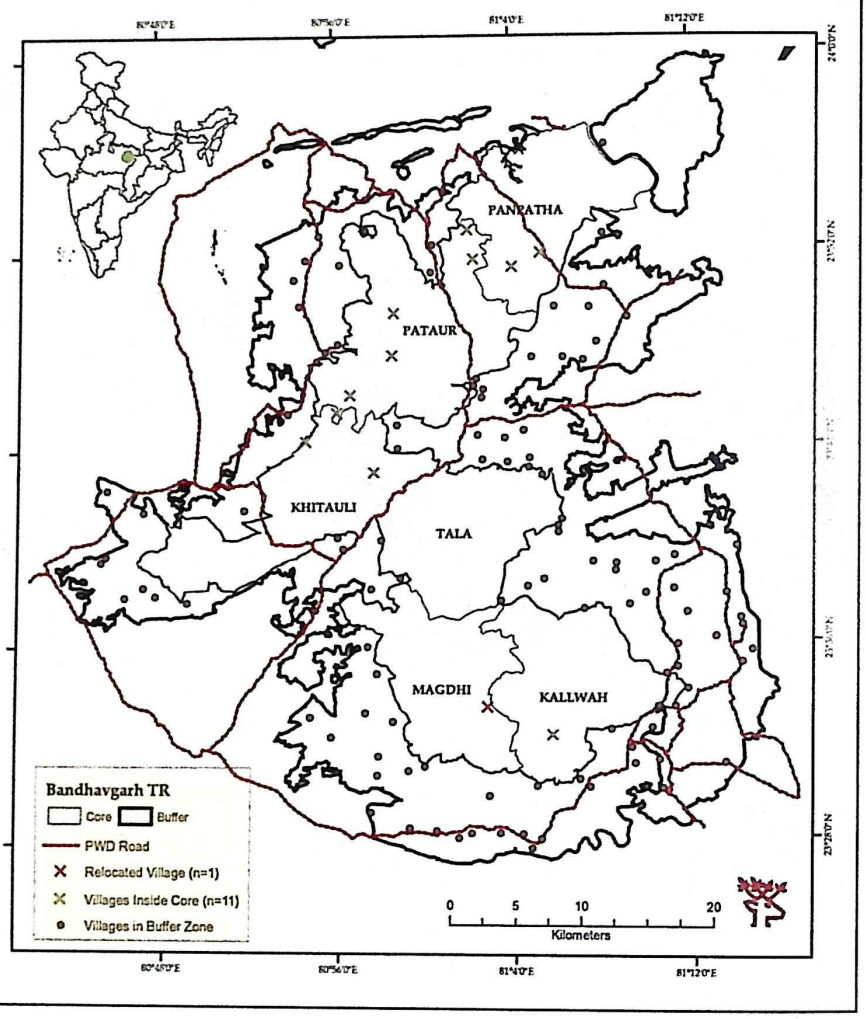
The Tiger Reserve supports a diverse assemblage of herbivores such as chital (*Axis axis),* sambar (*Rusa unicolor*) nilgai (*Boselaphus tragocamelus*), wild pig (*Susscrofa*), barking deer (*Muntiacus muntjac*), four-horned antelope (*Tetracerus quadricornis*) and chinkara (*Gazella bennettii*). Primates such as Rhesus macaque (*Macaca mulatta)* and common langur (*Semnopithecus entellus)* are found in the park. The area supports a wide variety of large, medium and small sized carnivores such as tiger (*Panthera tigris*), leopard (*Panthera pardus*), dhole (*Cuon alpinus*), sloth bear (*Melursus ursinus*), jackal (*Canis aureus*), jungle cat (*Felis chaus*), rusty spotted cat (*Prionailurus rubiginosus*), common palm civet (*Paradoxurus hermaphroditus*), small Indian civet (*Viverricula indica*), grey mongoose (*Herpestes edwardsii*), ruddy mongoose (*Herpestes smithii*) and stripe necked mongoose (*Herpestes vitticollis*). The presence of wolf (*Canis lupus*), striped hyena (*Hyaena hyaena*), and Indian fox (*Vulpes bengalensis*) has also been recorded from the fringes of the park. The Indian porcupine (*Hystrix indica)*, blacknaped hare (*Lepus nigricollis*), three stripped squirrel (*Funambulus palmarum*) and Indian pangolin (*Manis crassicaudata*) also occur in Bandhavgarh Tiger Reserve. Domestic livestock (cattle, buffalo and goat) occur in the village areas present inside the National Park and Sanctuary (Prakasam 2006).

Around 250 species of birds have been identified in the Reserve (Prakasam 2006). The prominent birds of Bandhavgarh are the Indian peafowl (*Pavo cristatus*), red jungle fowl (*Gallus gallus*), Indian grey hornbill (*Ocyceros birostris*), Malabar pied hornbill (*Anthracoceros coronatus*), common teal (*Anas crecca*), lesser whistling teal (*Dendrocygna javanica*), crested serpent eagle (*Spilornis cheela*), lesser adjutant stork (*Leptoptilos javanicus*), long billed vulture (*Gyps indicus*), red headed vulture (*Sarcogyps calvus*), white-rumped vulture (*Gyps bengalensis*) and Egyptian vulture (*Neophron percnopterus*) (Sonakiya 1993).

Human settlements

At the start of 2011, there were 15 villages located inside the Tiger Reserve, of which seven were located in the notified Bandhavgarh National Park and eight in the Panpatha Wildlife Sanctuary (Choudhary 2013). The villages inside the core area are due for relocation in a phase-wise manner and during 2011 to 2013 three villages, Kallwah, Kumarwah and Magdhi were relocated from the core area of BTR. During the study period, one village from Magdhi was relocated (Figure 3.8). Soon after relocation many herbivore species like chital, nilgai, chinkara, wild pig and gaur have been observed to use these relocated sites intensively (Sankar *et al.* 2013, Choudhary 2013). Also there are 96 villages within a five kilometer radius of the outer boundary of the core area of BTR. The total human population of these villages is estimated to be around 45,000 heads (Choudhary 2013). Agriculture is the main occupation in these villages and the major crops are wheat, ragi, cauliflower, cabbage and beans. Some villagers also work with the forest department as fire watchers, chowkidars, elephant caretakers and mahout, grass cutters and as a part of anti-poaching team. The livestock mainly includes a large number of buffaloes and a few cows along with some goats (Prakasam 2006).

Figure 3.8: Location of villages in the core and buffer area of BTR



CHAPTER 4

RANGING PATTERN OF REINTRODUCED GAUR

Introduction

Social mechanism may influence home range size in addition to metabolic requirement (Tufto *et al.* 1966). Home range is the result of animal's energy requirements and habitat heterogeneity (Tufto *et al.* 1966).

Burt (1943) described home range as the area traversed by an individual in its normal activities, including protection, feeding, mating, caring for young and other life history requisites. The social structures and behavioral patterns of the animal species also have some effects on the home range size (Gittleman and Harvey 1982, Lindstedt *et al.* 1986).

In the mid-1900's most of the source population of gaur were secure because of the remote and isolated nature of their habitat (Hubback 1937, Foenander 1952). Few studies reported the trend in population of gaur based on long-term and systematic monitoring. Weigum (1972) reported gaur home range as 13 sq. km in Taman Nagara National Park, Malaysia. Conry (1989) estimated home range of gaur yearling males, yearling females and adult males in Malaysia to be as 29.9 sq. km and 52.1 sq. km and 137.3 sq. km respectively. The estimated composite (one adult male, one adult female and one sub adult male) home range of gaur in Pench Tiger Reserve was 175 sq. km (Sankar et al. 2001). Physiographical features, temperature and rainfall fluctuations played important roles in determining the home range sizes of gaur in Pench Tiger Reserve, Madhya Pradesh (Sankar et al. 2001). Prayurasiddhi (1997) attempted a comparative study on gaur and banteng (Bos javanicus) in Thailand in which the population, feeding ecology of these species were investigated. Among the wild bovids, gaur is one of the most wide-ranging species showing seasonal and local movements between foraging sites (Schaller 1967). The ranging pattern of reintroduced gaur was first studied in Bandhavgarh (Sankar et al. 2015). Ranging pattern of distinct demography classes and different seasons was first reported in reintroduced gaur population in Bandhavgarh (Sankar *et al.* 2015).

The current study was carried out to understand the ranging pattern, annual and seasonal home ranges and intra-specific competition between gaur herds.

Methods

During phase I (2011-2015), 27 gaur (males 6 and females 21) were radio collared and monitored throughout the period. The functional collars of animals collared during Phase I were monitored through radio-tracking during 2015. Radio locations of each collared animal were determined by "Homing in" and "Triangulation" techniques from three to four known reference points (White and Garrot, 1990). Coordinates of these reference points were taken with the help of Global Positioning System (GPS). The gaur individuals with nonfunctional collars were identified in field based on their body size, structure of horn (length, shape, spread, colour and curve), permanent marking (scar/injury on the body) and size of *bos* as described by Ahrestani and Prins (2011). A total of four different gaur herds were identified during the study period (2015-2018). Individual gaur herds were identified based on characteristics of the identified animals.

Home range, daily and seasonal movement of the reintroduced gaur was studied by monitoring the identified individuals between January 2011 and March 2018.

Since, gaur are herd living (Schaller 1967), the home range size of different herds were estimated using 100% Minimum convex polygon (MCP) method between 2011 and 2018. For the identified herds minimum of one location per day was collected. Adult males were not considered in herd home range estimation, due to their being solitary and moving between herds (Schaller 1967).

During the study period a total of 1277 locations were recorded for all the gaur individuals from identified herds (n=4). During October and November 2017 six individuals (two males and four females) were radio collared (Table 4.1) using TELONICS VHF transmitters.

Table 4.1: Details of the radio collared individuals in BTR

Gaur Id	Range	Herd ID	Demography	Deployment of collar	Total number of locations*
GMN1	Magdhi	Tala	Sub adult male	15-Oct-17	33
GFN1	Magdhi	Magdhi	Adult female	24-Nov-17	18
GFN2	Kallwah	Kallwah	Sub adult female	25-Nov-17	15
GFN3	Kallwah	Kallwah	Sub adult female	25-Nov-17	16
GFN4	Kallwah	Kallwah	Adult female	26-Nov-17	9
GMN2	Kallwah	Kallwah	Sub adult male	26-Nov-17	16

GMN-gaur male new; GFN gaur female new; * Number of locations collected till March 2018.

Data collection

Minimum one location, per identified herds per day with independent locations at six hourly interval between consecutive locations of the same animal as defined by Dolev *et al.* (2002) were collected on foot and from vehicle between April 2015 to March 2018. The locations were obtained during 0600-1800 hrs in all seasons (summer, monsoon and winter). Two to four locations of collared individuals (Table 4.1) were recorded weekly.

Data analysis

Home range estimation was carried out based on information collected from the identified herds having identified individuals. Each herd (n=4) was monitored periodically through ground tracking "homing in" and "triangulation". Program ArcGIS 10.1 (ESRI 2006) was used to estimate home ranges. Two different methods *viz.* Minimum Convex Polygon (100% MCP) (Mohr 1947) and Fixed Kernel Density (FKD, 95% and 50%) method (Katajisto and Moilanen 2006) were used to calculate home range of different gaur herds along different seasons. The fixed kernel density estimator is rated as one of the most robust and least biased estimator of home range considering its performance with small sample sizes, auto-correlated data, and shape of underlying utilization distribution, outlier data and comparability between different studies (Jaremovic and Croft 1987, Kernohan *et al.* 2001, Worton 1995).

Results

Overall home range size of gaur

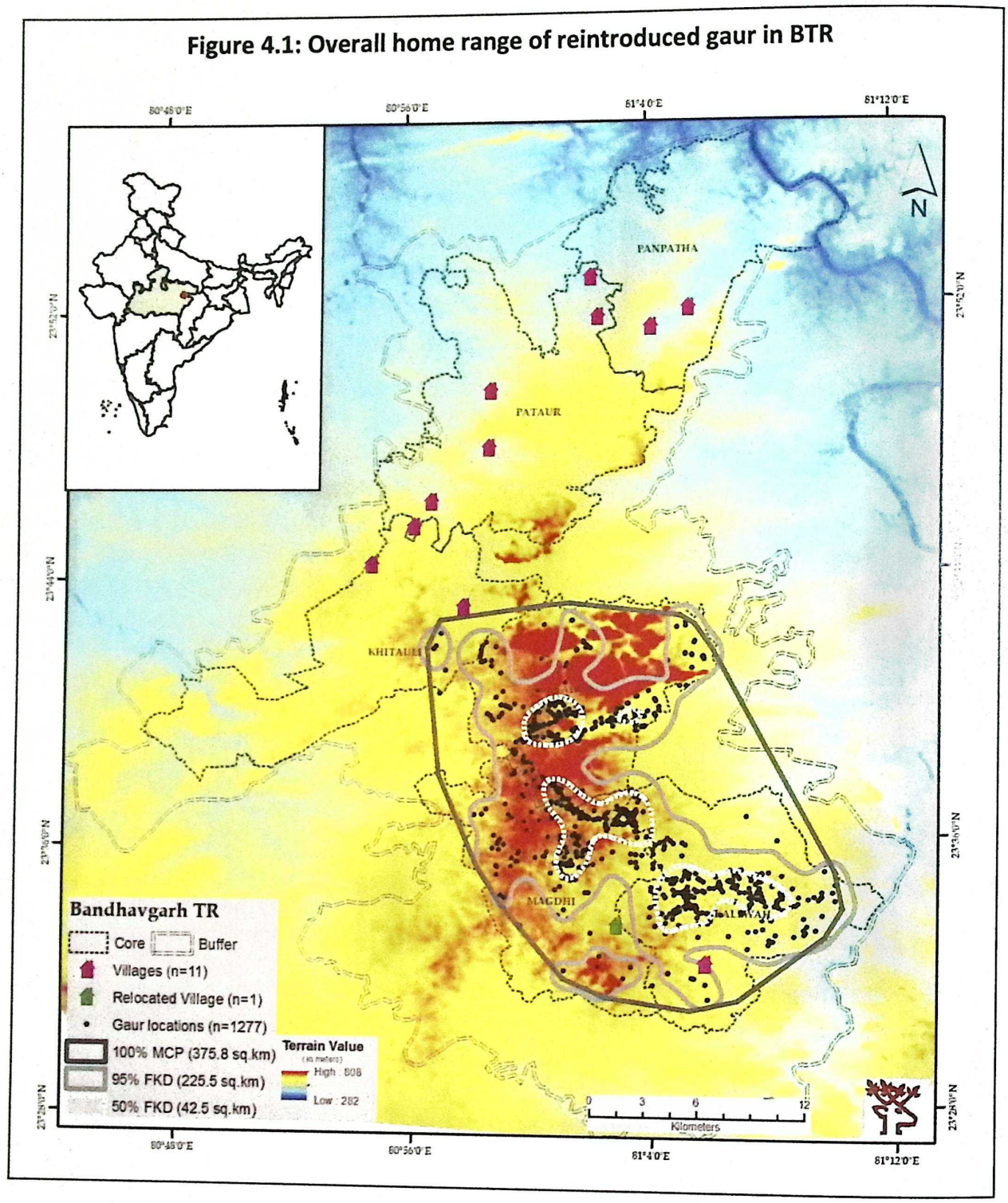
The estimated home range with 100% MCP was 375.8 sq.km whereas it was 225.5 sq.km at 95% FKD and 42.5 sq. km with 50% (core area) FKD (figure 4.1) during the project period.

Table 4.2: Overall home range size of gaur herds in BTR

Home range estimation	Herd 1	Herd 2	Herd 3	Herd 4
100 % MCP *	249.5	101.3	111.6	210.1
95 % FKD *	147.2	82.9	94.3	121.2
50 % FKD *	23.5	16.3	17.9	18.7

MCP-minimum convex polygon; FKD-fixed kernel density; * area in sq.km

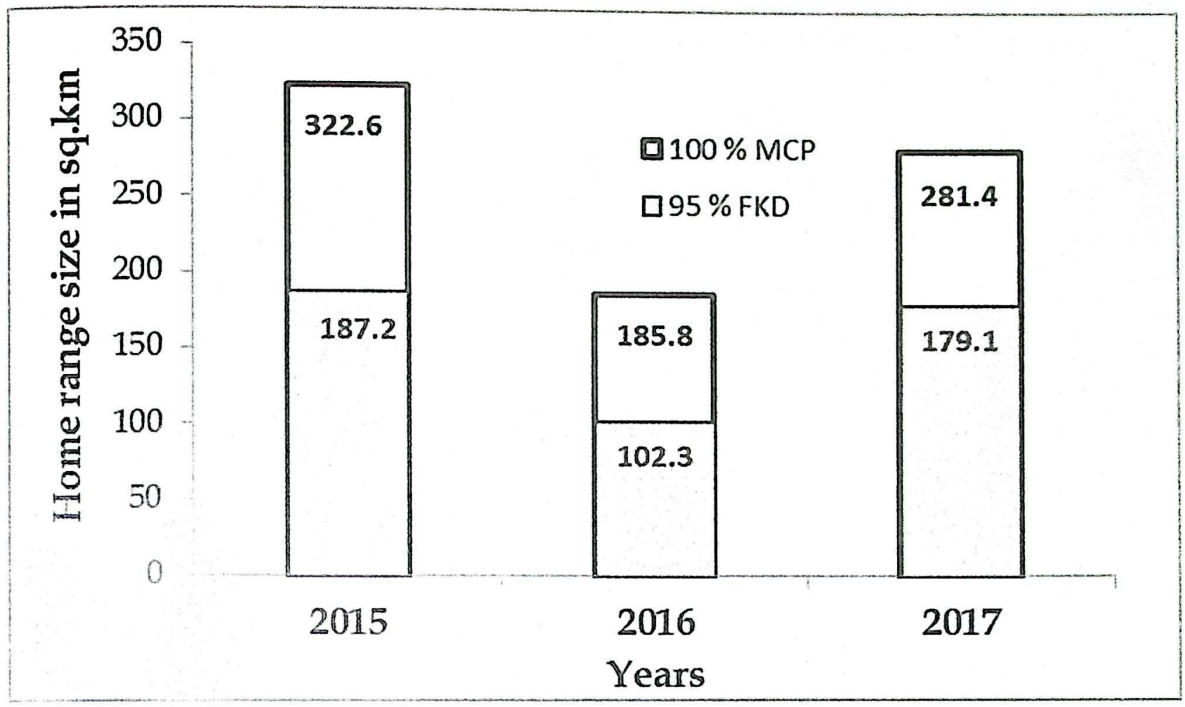
Figure 4.1: Overall home range of reintroduced gaur in BTR



Annual home range size of gaur

The annual home range of the reintroduced gaur varied across the years. In 2015 the 100% MCP was 322.6 sq.km, followed by 185.8 sq.km and 281.4 sq.km respectively . The 95 % FKD in 2015 was 187.2 sq.km followed by 102.3 sq.km and 179.1 sq.km in 2016 and 2017 respectively (Figure 4.2).

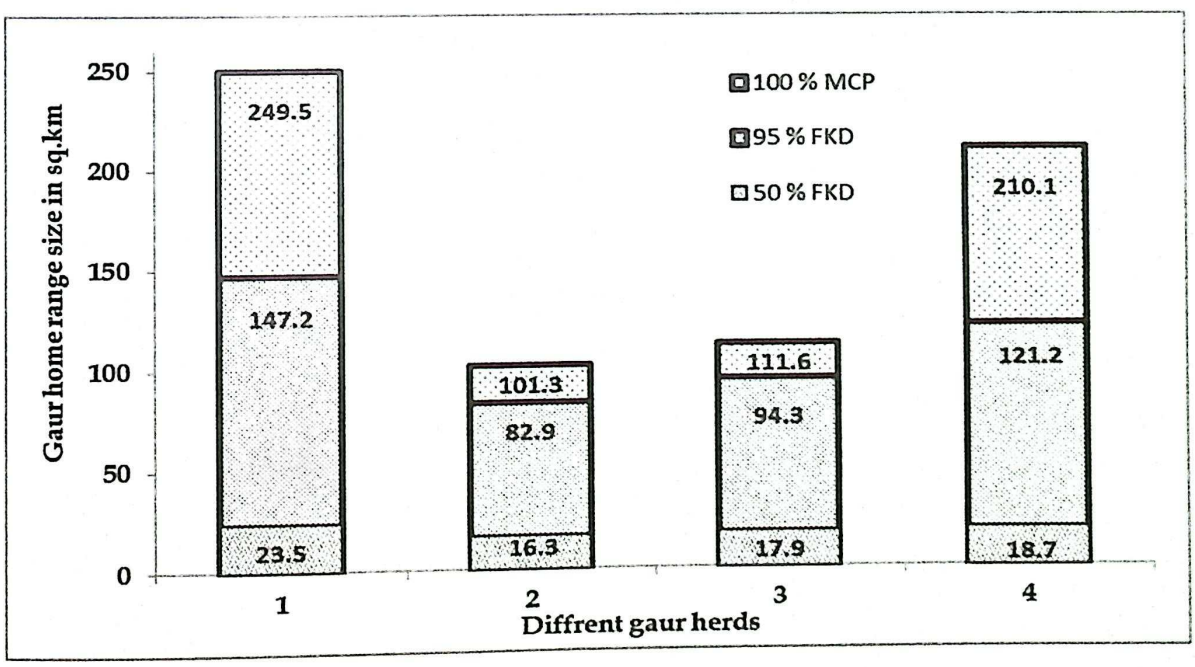
Figure 4.2: Annual home range size of gaur across different years in BTR



Home range size of different gaur herds

Four different herds were observed during the study period. The estimated home ranges for different gaur herds with different estimators are represented in table 4.4 and figure 4.3.

Figure 4.3: Overall home range size of gaur herds in BTR



Season wise home range of different gaur herds

The mean estimated seasonal home range for different gaur herds with 100% MCP is 91.9 ± 12.8 (SE) sq.km in summer followed by 103.7 ± 10.8 (SE) sq.km in monsoon 120.9 ± 8.4 (SE) sq.km in winter respectively (Table 4.3).

Table 4.3: Seasonal home range size of different gaur herds in BTR

Different gaur herd	100 % MCP (sq.km)		
	Summer	Monsoon	Winter
Herd 1	142.4	142.4	176.5
Herd 2	34.2	42.1	93.1
Herd 3	98.1	74.8	84.2
Herd 4	93.1	155.5	130.1
Mean	91.9	103.7	120.9
SD	44.4	54.1	42.0
SE	12.8	10.8	8.4
UCL	117.0	124.9	137.4
LCL	66.8	82.4	104.5

SD-standerd devation; SE-standerd error; UCL-upper confident intervel; LCL-lower confident intervel; MCP-Minimum convex polygon.

Group size and home range of different gaur herds (2011-2018)

The reintroduced gaur population was largly found in four diffrent herds (table 3.5) over the years (2011-2017). The group size between gaur herd varied between 7-58 (table 3.4). The home range of different gaur herds varied over the years (table 4.4 and figure 4.4-4.7)

Table 4.4: Annual home range size (100% MCP) and group size of gaur (2011-2017) in BTR

Herds	2011		2012		2013		2014		2015		2016		2017	
	GS	100 % MCP *	GS	100 % MCP *	GS	100 % MCP *	GS	100 % MCP *	GS	100 % MCP *	GS	100 % MCP *	GS	100 % MCP *
1	7	169.4	10	98.5	14	26.3	16	81	21	24	20	215.8	29	249.2
2	12	173.4	24	58.6	27	21.9	30	35.4	45	53.3	48	78.7	58	101.3
3	--	--	19	42.3	20	37.3	23	13.8	23	47.8	19	83.8	25	111.6
4	--	--	7	279.2	9	37.9	10	23.4	11	59.7	13	56.6	15	210.2

GS-group size; MCP-minimum convex polygon; * area in sq.km

Figure 4.4: Home ranges of Gaur Herd I (2011-2017) in BTR

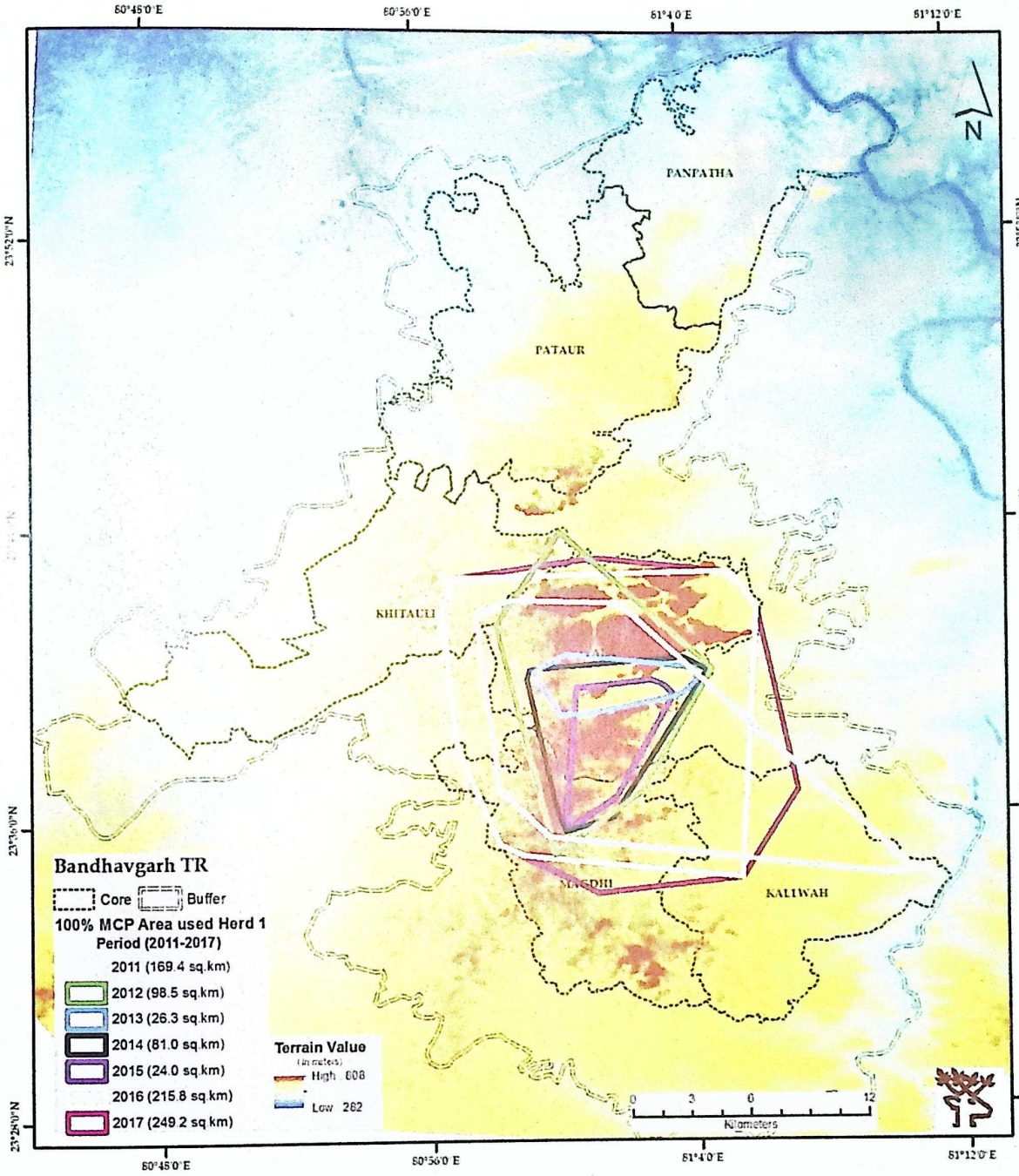


Figure 4.5: Home ranges of Gaur Herd II (2011-2017) in BTR

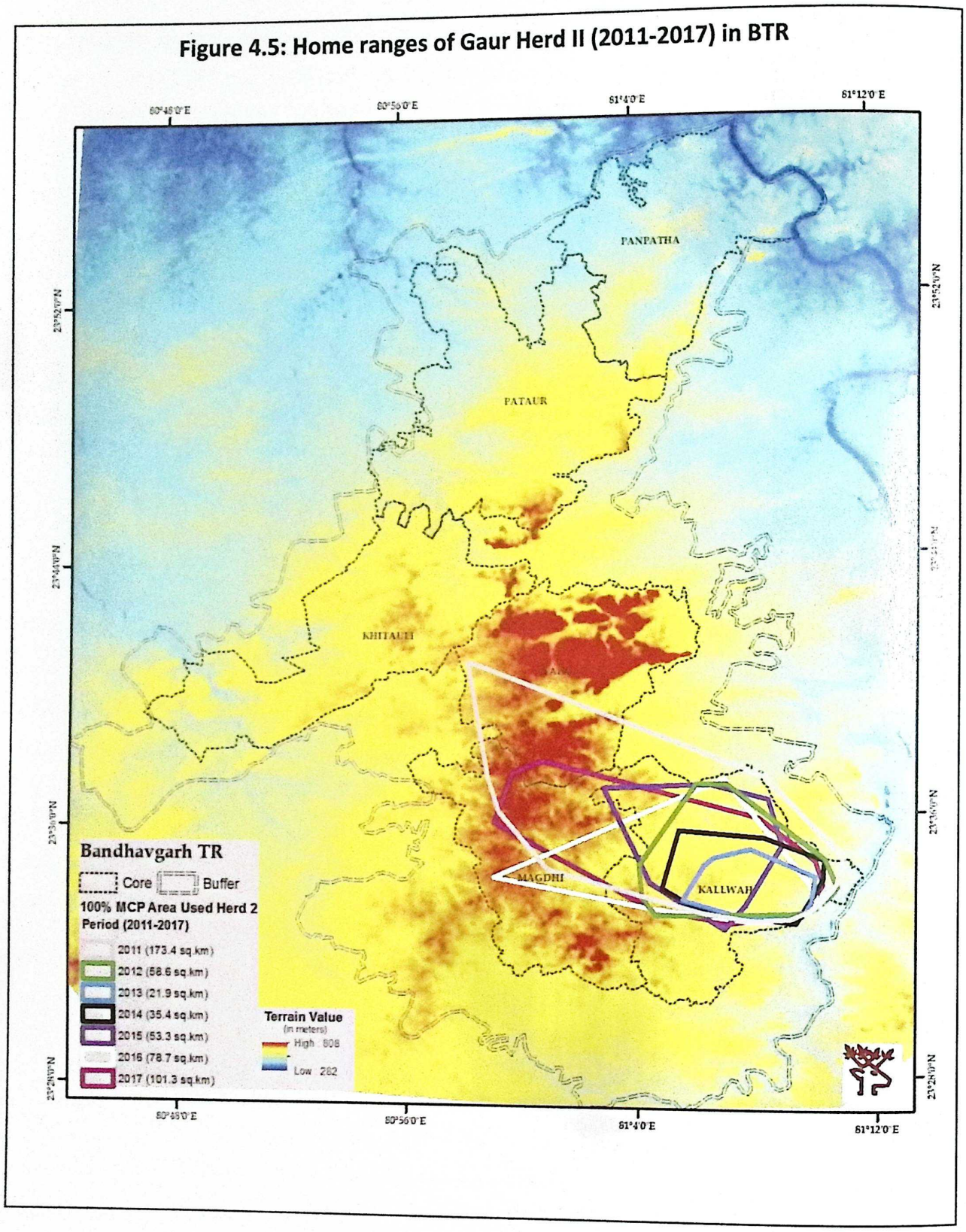


Figure 4.6: Home ranges of Gaur Herd III (2011-17) in BTR

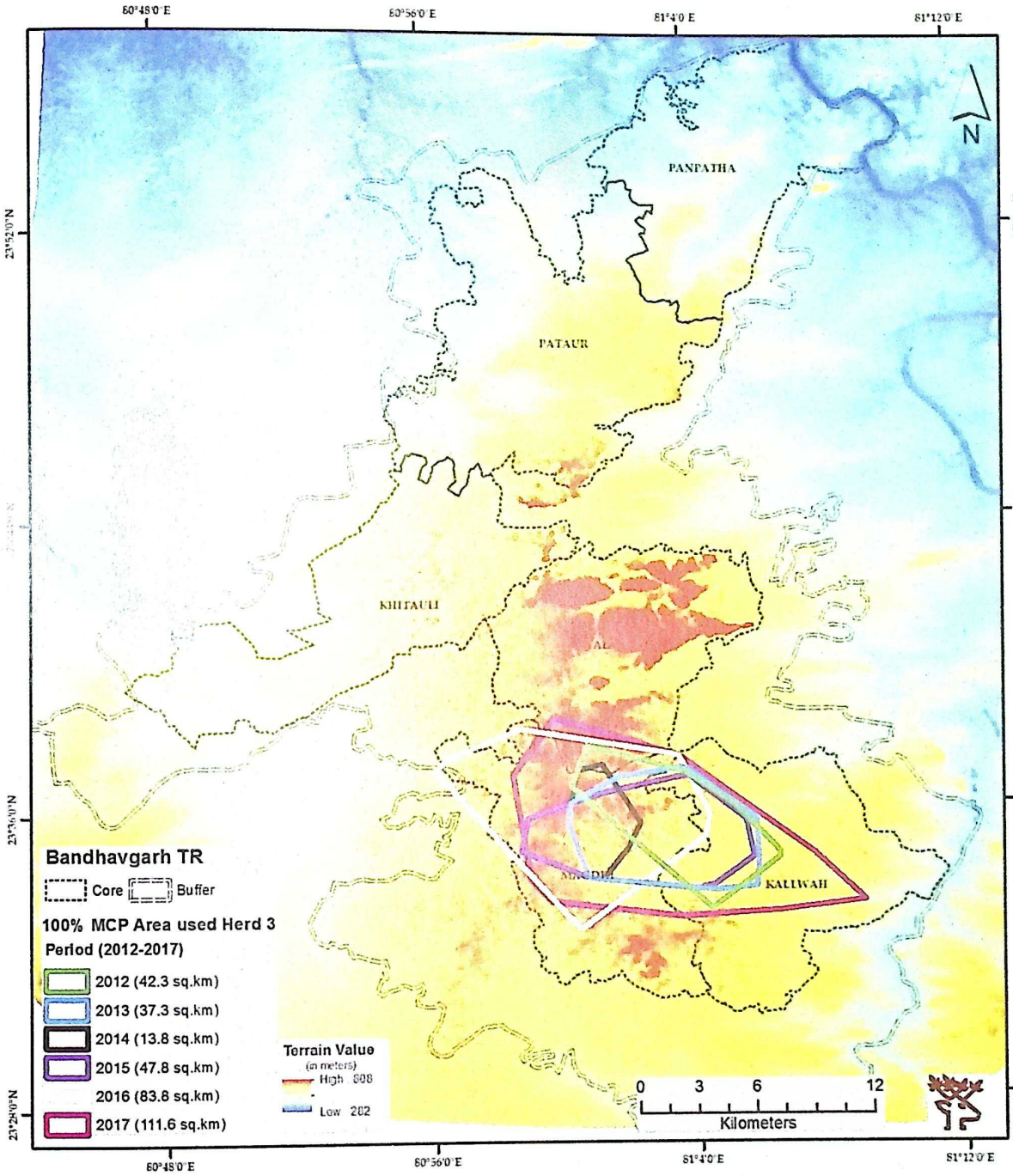
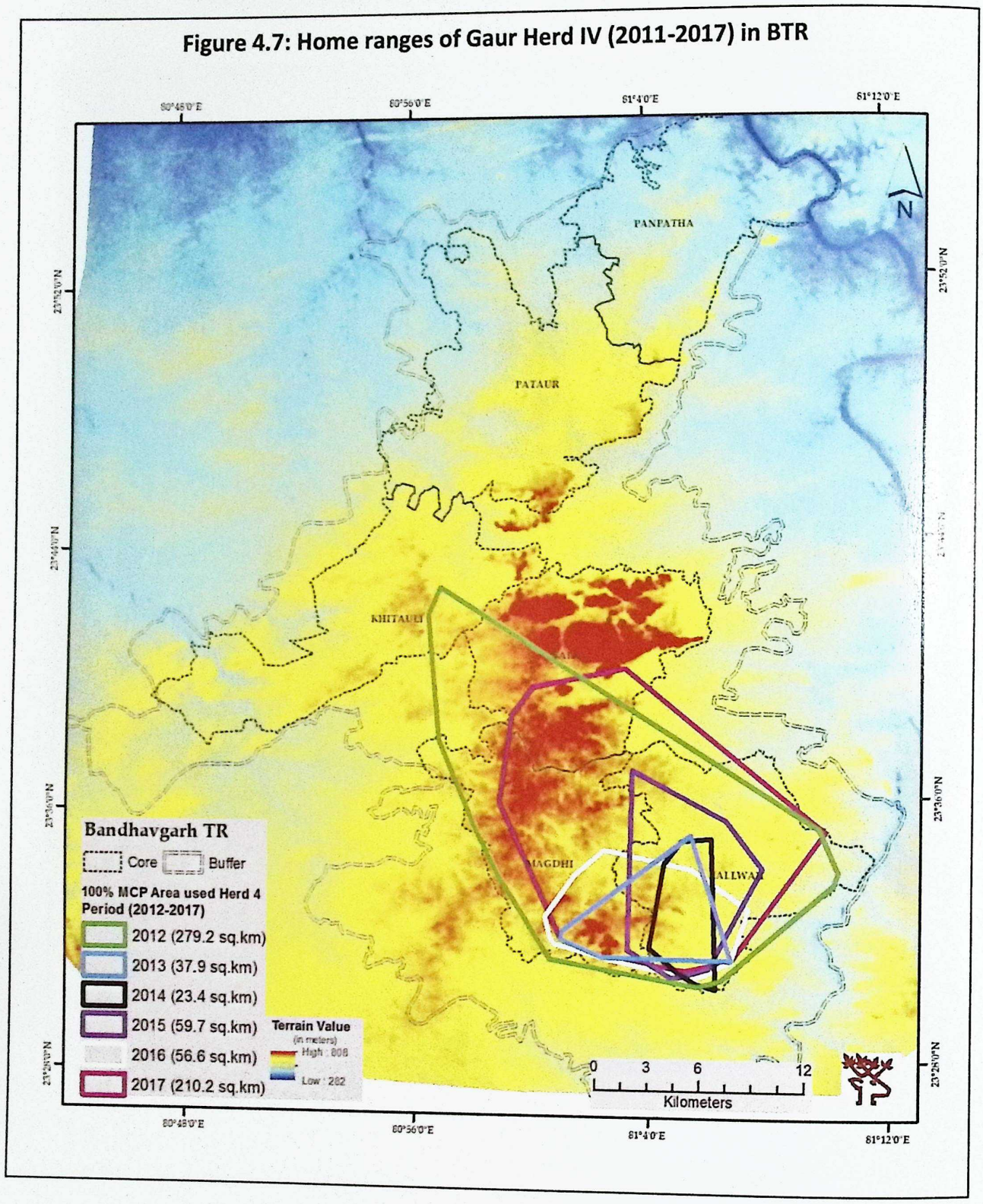


Figure 4.7: Home ranges of Gaur Herd IV (2011-2017) in BTR



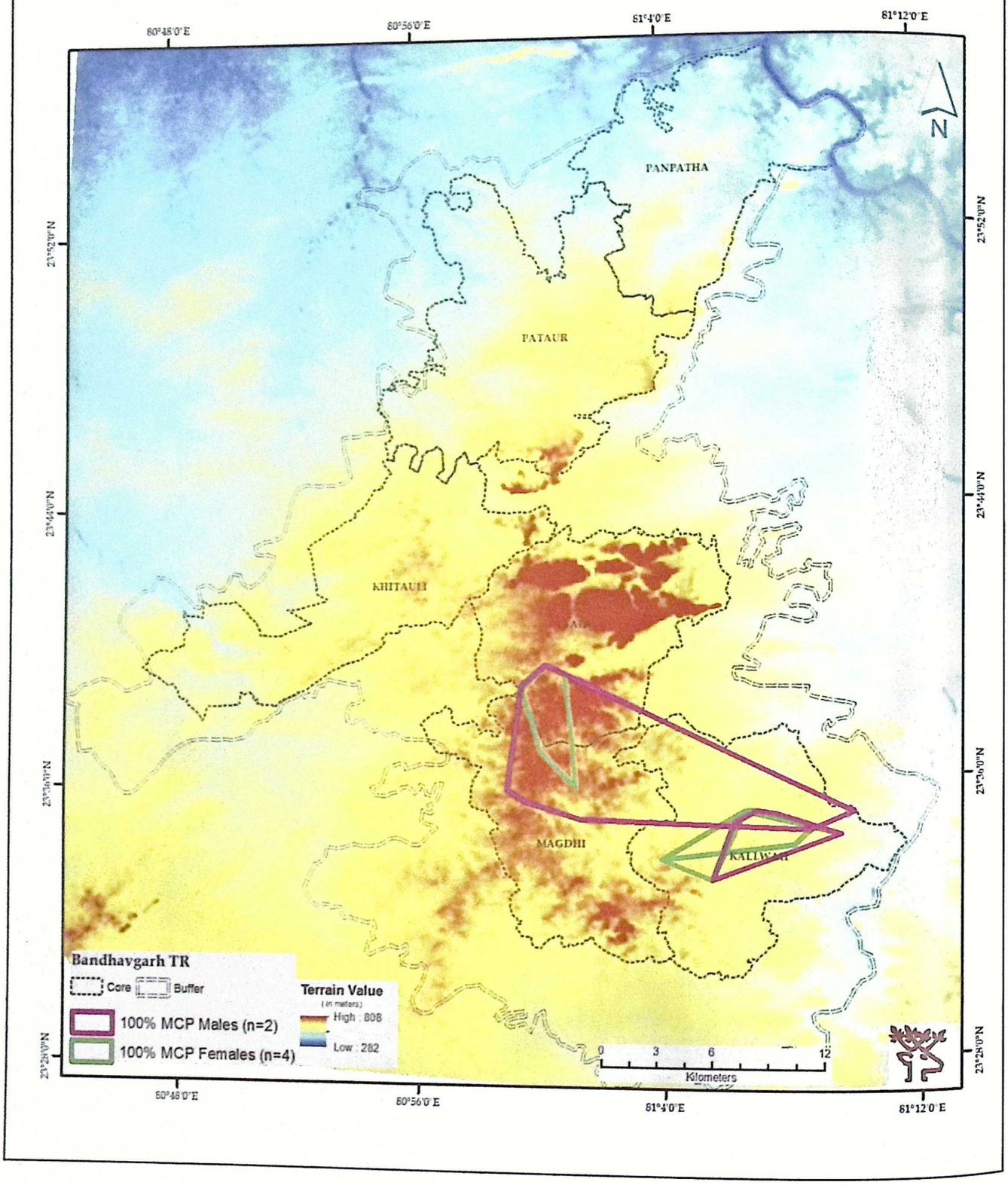
Home range size of radio collared gaur individuals

Using all locations of the different radio collared individuals (n=6) collared during 2017 at 100% MCP, the estimated average home range of gaur was 24.5 ± 8.9 (SE) sq.km (range: 10.0 sq.km to 87.7 sq.km; 95 % CI – 42.0 sq.km to 6.9 sq.km) (Table 4.5 and Figure 4.8) for the period of monitoring (October –March 2018).

Table 4.5: Home range size of radio collared gaur individuals in BTR from October 15th - March 20th 2018

Radio collared individuals (n=6)	Locations	Overall 100 % MCP (sq.km)
G[illegible]	18	10.7
G[illegible]	15	10.5
G[illegible]	16	10.0
G[illegible]	9	16.6
GM[illegible]	33	87.7
GM[illegible]2	16	11.6
Mean		24.5
Standerd devation		31.0
Standerd error		8.9
Upper confident intervel		42.0
lower confident intervel		6.9

Figure 4.8: Home range size of radio collared gaur individuals in BTR



Status and demography of gaur herds in Bandhavgarh

Group size of gaur in BTR

Four different gaur herds were observed during 2011-18 with herd size varying between 15 to 58 individuals (Table 4.6). The observed overall gaur mean group size (MGS) was 31.7± 9.2 (SE). Each herd comprised of mixed age and class individuals. Twenty one percent of the observed adult males were solitary.

Table 4.6: Herd composition and group size of gaur in BTR

S No	Age and sex classes	Herd 1* (tala)	Herd 2* (kallwah)	Herd 3* (magdhi)	Herd 4* (mehnwah)
1	Adult Male	1	3	2	2
2	Sub Adult Male	6	3	7	4
3	Adult Female	8	13	8	3
4	Sub Adult Female	2	6	4	2
5	Juveniles	5	17	2	2
6	Calf	7	16	2	2
	Total	29	58	25	15

* Group composition and group size of gaur up to March 2018

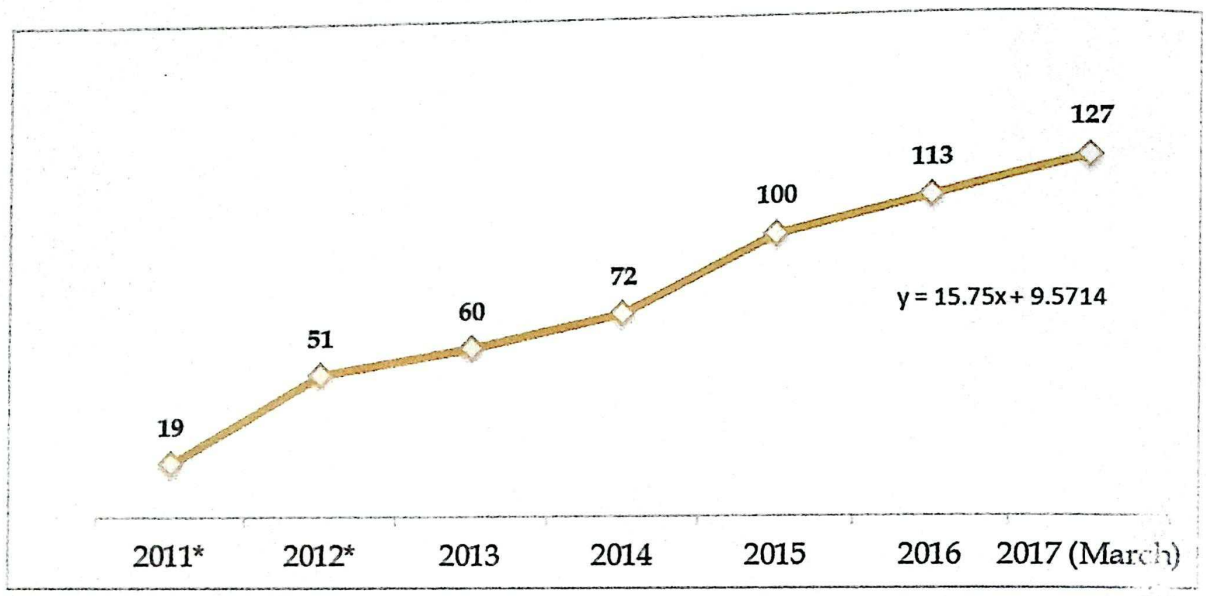
Overall gaur composition and sex ratio in BTR

The present gaur population (n= 127) comprises of adult females (n= 32), calves (n=27) juveniles (n= 26), sub-adult males (n= 20), sub-adult females (n= 14) and adult males (n= 8) (table 4.7). The estimated overall gaur sex ratio (adult male: adult female) was 1: 3.3, and adult female: calf ratio was 1: 1.4.

Table 4.7: Age and sex classes of reintroduced gaur 2011-12 and at the end of study period (March 2018)

Age and sex classes	Number of reintroduced gaur from Kanha (2011-2012)	Gaur population in 2015 (March)	Present gaur Population (March 2018)
Adult Male	3	5	8
Sub Adult Male	11	10	20
Adult Female	13	22	32
Sub Adult Female	21	14	14
Juveniles	2	13	26
Calves	--	15	27
Total	50	79	127

Figure 4.9: Gaur population over the years in BTR



* reintroduced population (19 in 2011 and 31 in 2012)

In total, 37 mortalities were reported between 2011-2017 of which 18 were recorded during April 2015 – March 2018. A total of 114 calves were born in Bandhavgarh during the period 2011-18.

Table 4.8: Details of births and mortalities (2011-2018) in BTR

Duration	Number of Births	Number of animal Mortalities	Cause of mortality
Phase I	47	19	Tiger Preadation (15), Disease (3)
Phase II	67	18	Tiger predation (14), Natural (3), Missing (2)
Total	114	37	

Discussion

A measure of the success of reintroduction is the establishment of self-sustaining wild populations (Scott and Carpenter 1987). The estimated overall home range (375.8 sq.km April 2015-March 2018) of the reintroduced gaur population in Bandhavgarh was similar to the previously reported home ranges (Navaneethan 2014, Sankar et al. 2015). Being influenced by the outlying fixes, the MCP area and shape included large unused areas causing an overestimation of home range size (Harris et al. 1990). The estimated home range with 95% FKD was however, much larger as compared to the previous study (Navaneethan 2014, Sankar *et al.* 2015) and is attributed to the increase in the population and change in age classes.

The difference in gaur home range across different years during the study period (2015-2018) varied on similar lines as reported from Bandhavgarh from previous

studies carried out by Navaneethan (2014) and Sankar *et al.* (2015). The variations in the home ranges during the study period 2015-18 is attributed to the inter-related aspects such as body size and ecological requirements (food habits, mating system, quality and abundance of forage and predation pressures) as these influence the social organisation and herd formation in animals (Jarman 1974, Giraldeau 1988, Fritz and Wichatitsky 1996). This study (phase II) especially demonstrates the importance of a long-term and a detailed post release monitoring program. Monitoring of the source population with more information generated through collared identified individuals can provide understanding on the establishment of gaur population along with the range expansion.

The overall home range (100 % MCP) of identified gaur herds (n=4) varied significantly (X^2 = 95.43, df = 3, p-value < 0.05) and is mainly attributed to the increase in group size across years and due to movment of animals in search of resource. The core area (50 % FKD) home range size did not show any significant difference (X^2= 1.5079, df = 3, p-value > 0.05).

This study demonstrates the importance of monitoring different herds across years as home range of these identified herds were estimated from 2011 onwards. Detailed home range of demography classes were not estimated in phase II due to limited choices for collaring specific age classes.

The estimated mean home range of gaur across different seasons (n=3) did not vary significantly (X^2= 4.0318, df = 2, p-value > 0.05), though the home range of gaur was found to be less during summer (table 3.3) as compared to monsoon and winter. The variation may be attributed to the restricted availability of resources and habitat for gaur in summers. The same has been reported on gaur in Bandhavgarh (Sankar *et al.* 2013, Navaneethan 2014: Sankar *et al.* 2015) and in Pench Tiger Reserve (Sankar *et al* 2001).

Species mean group size is influenced by variety of ecological factors as well as the association within and between the groups (Jarman 1974; Raman 1997). Gaur a social animal has been reported to have a fluid group structure (Brander 1923; Schaller 1967). The overall group size and mean group size of gaur in the present study were observed to be higher as compared to other available studies in India (Table 4.9). Among the different age and sex classes of gaur, cows (adult and calves) formed the highest proportion (45.6%) of the reintroduced gaur population as compared to the other age and sex classes in Bandhavgarh. More breeding individuals in the reintroducing population are vital for maintaining the long term reproductive success (Saltz and Rubenstein 1995). More solitary individuals were observed in males (21 %) during the present study. In mega herbivores males have the tendency to range larger from one herd to another herd as part of their mating strategy (McHugh 1972; Clutton-Brock 1982) and their nature of dominance over other individuals in the population may result in their solitary nature. Similar findings on gaur were reported

in India (Sankar *et.al* 2015, Schaller 1967; Vairavel 1998), Malaysia (Conry 1989) and also in American and European bison's (McHugh 1972; Green and Rothstein 1993). During the study period of seven years (January 2011 - March 2018) in Bandhavgarh, the growth rate of reintroduced gaur was 15.7%. The success of a species reintroduction cannot be assessed until the growth rate has reached a level that is sustainable (Riney 1964; Phillips 1997). Overall mortalities of reintroduced population over the years (2011-2018) were 37 individuals with 29 resulting from predation by tigers (78.3%).

Table 4.9: Gaur mean group size (MGS ± SE) and their group size reported from different Protected Areas in India.

Protected Areas	Overall MGS ± SE	Group size (range)	Authors
Bandhavgarh	31.7± 9.2	1-58	Present Study
Bandhavgarh	13.6 ± 1.9	1-31	Sankar *et al.* 2015, Navaneethan 2014
Mudumalai	7.5 ± 0.4	1-42	Ramesh *et al.* 2012
Mudumalai	9.8 ± 7.6	1-26	Ashokkumar *et al.* 2010
Trishna	5.9 ± 2.9	2-14	Dasgupta *et al.* 2008
Mudumalai	8.1 ± 0.6	1-47	Kumar *et al.* 2004
Bhadra	2.3 ± --	--	Jathanna *et al.* 2003
Pench	4.2 ± 0.1	1-19	Sankar *et al.* 2001
Jaldapara	--	1-70	Bhattacharya *et al.* 1997
Parambikulam	6 ± --	1-19	Vairavel 1998
Nagarahole	6.9 ± --	1-47	Karanth and Sunquist 1992
Bandipur	--	1-60	Johnsingh 1983
Palamu	5 to 7	2-27	Sahai 1972
Kanha	8.8 ± 0.7	1-40	Schaller 1967

MSG-mean group size; SE-standard error.

Gaur is one of the major prey species for tigers (Biswas and Sankar 2002). Long term monitoring is imperative for the reintroduced gaur population in Bandhavgarh Tiger Reserve to determine whether the current growth rates would continue and result in stabilizing the population.

CHAPTER 5

HABITAT USE OF REINTRODUCED GAUR

Introduction

The information on habitat use and resource selection leads to a better understanding of the species in its environment (Anderson et al. 2005). Selection of seasonal habitat in mega herbivores between different habitat types to fulfill their needs has been well documented in bison and European bison (Fuller 1960, Krasinska et al. 1987).

Among large herbivores, the habitat selection depends upon various factors, such as availability and quality of forage sites (Klein 1970, Skogland 1980, Bowyer 1986, Albon and Langvatn 1992, Cameron *et al.* 1929), mineral requirements (Belovsky and Jordan 1981), climatic factors (Ion and Kershaw 1989), parasite avoidance (Duncan 1975), predation (Bleich et al. 1997), inter-specific competition (Caro and Stoner 2003, Vanak and Gomper 2009) and food supply (Sinclair 1975, White 1978, Duncan 1983, McNaughton 1984 and 1988, Murden and Risenhoover 1993).

Schaller (1967) evaluated the vegetation maps of India with regard to distribution of gaur and concluded that the species is largely confined to evergreen, semi-evergreen, and moist deciduous forests but it also occurred in dry deciduous forests and thorn forests. Information on habitat use and resource selection of gaur was reported in a few Protected Areas in its entire distribution range. In Malaysia, Weigum (1972) observed that the abundance of grass, forbs and several browse species in agricultural lands are the most important factors influencing gaur distribution. Conry (1989) reported that gaur mostly preferred agricultural patches in Malaysia. In Western Ghats Landscape, India, Vairavel (1998) reported that gaur mostly preferred grassland. Imam and Kushwaha (2012) reported that gaur was largely found in mixed forests in Maharashtra. In Central Indian landscape (Pench Tiger Reserve), Sankar et al. (2001) reported that gaur largely used teak forest and miscellaneous forest, whereas Paliwal and Mathur (2012) reported that gaur in Tadoba-Andhari Tiger Reserve showed positive association with open forest. Conry (1983) and Sankar *et al.* (2001) reported the habitat use of gaur based on radio-telemetry studies. WII (2015) reported that gaur preferred bamboo forest because of

the nutritional value, availability and better cover as compared to other habitats in BTR.

In order to understand the pattern of habitat use in reintroduced gaur, quantitative data of habitat and were collected from April 2015- March 2018.

Methods

Data obtained from continuous monitoring was used to determine the habitat use. On each radio location, the macro and micro level habitat type data were recorded along with the GPS location. The GPS locations were plotted on a satellite imagery map (1:50,000) for better representation (Figure 5.1). Locations taken for each animal was classified to the habitat type in which they occurred to obtain habitat use. On each radio location, following parameters were recorded:

1. Major vegetation type
2. Major terrain type
3. Distances to the nearest Water hole (in meters), Road (in meters), Human habitation (in kilometers).
4. Density of trees (in 10 m radius).
5. Density of shrubs (in 5 m radius).
6. Percentage of ground cover (1m radius) plot by line intercept method (LI) (Canfield 1941)
7. Wood cutting and lopping signs (10 m radius)in percentage.
8. Grazing and Grass cutting signs (10 m radius) in percentage and
9. Weed abundance (10 m radius) in percentage.

Data analysis

The gaur habitat use data was limited to six different vegetation classes such as bamboo forest, grassland, open mixed forest, mixed forest, sal forest and riparian forest within the study area comprising 1545.8 sq.km (table 5.1). The vegetation classes such as habitation, plantation, agriculture, rocky outcrop and scrubland were dropped from the habitat use analysis since they are found in buffer area of the Tiger Reserve and falls outside the intensive area, used by gaur during the study period.

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dropped from the habitat use analysis since they are found in buffer area of the Tiger Reserve and falls outside the intensive area, used by gaur during the study period.

To evaluate habitat use pattern of reintroduced gaur, locations of major herds (n=4) were obtained from April 2015 to March 2018. The collected herd locations (1277) were plotted on the classified LISS-III imagery of Bandhavgarh. Habitat use was estimated as the percent number of locations recorded in each habitat type (Aebischer *et al.* 1993, White and Garrot 1990). The habitat availability in each gaur MCP home range, and the proportion of radio locations from radio collared gaur within each habitat type were calculated using the program Arc GIS 10.1 (ESRI 2006).

Second-order resource selection function (Aebischer *et al.* 1993) was used to determine the habitat selection of gaur by plotting a minimum convex polygon around the 100% MCP home range of all the radio collared gaur. Compositional analysis (Aebischer *et al.* 1993) was followed to determine the habitat selection, but with modification that assigned values based on the utilization distribution (UD) as described by Millspaugh *et al.* (2006). Habitat use of each radio collared gaur individual was defined as the number of locations obtained in each land cover types (Millspaugh *et al.* 2006). Third-order resource selection was determined by using discrete-choice analysis (Cooper and Millspaugh 1999, 2001) at the home range level. Resource Selection program for Windows (RSW; Leban 1999) was used to conduct the compositional analysis. We also estimated the season wise habitat use by reintroduced gaur, using compositional analysis (Aebischer *et al.* 1993), to understand whether any significant difference was observed in habitat use across seasons.

Results

Overall habitat use by reintroduced gaur

Gaur largely used grassland followed by riparian and open mixed whereas sal and bamboo forests were used according to its availability within their entire home range and gaur avoided mixed forest (figure 5.2). The overall habitat preference of gaur by using bonferroni analysis was in the following order as: grassland>reverine forest>bamboo forest>open mixed forest>sal forest>mixed forest. This result also supports the hypotheses that gaur preferred grassland and avoided mixed forest and used rest of the forest as per their availability (X^2 = 0.9917, df = 1, p = 0.05)(table 5.2). The habitat use of four herds (Chapter III) was shown using Ivlev's selectivity Index (figure 5.3, table 5.3).

Figure 5.1: Land use and land cover (LULC) map of BTR with 5 km buffer

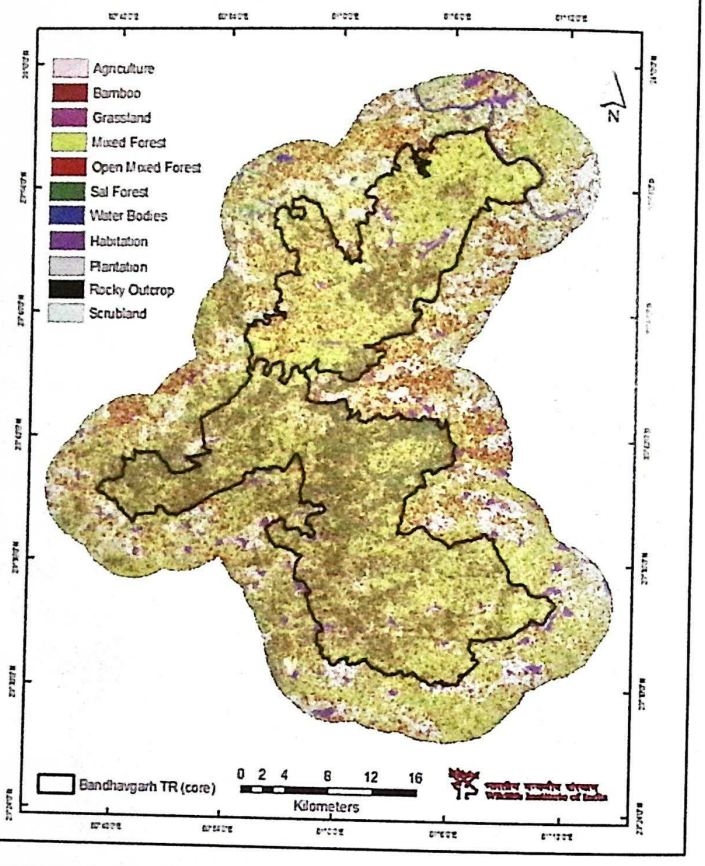


Figure 5.2: Use and availability of different vegetation types by gaur in BTR

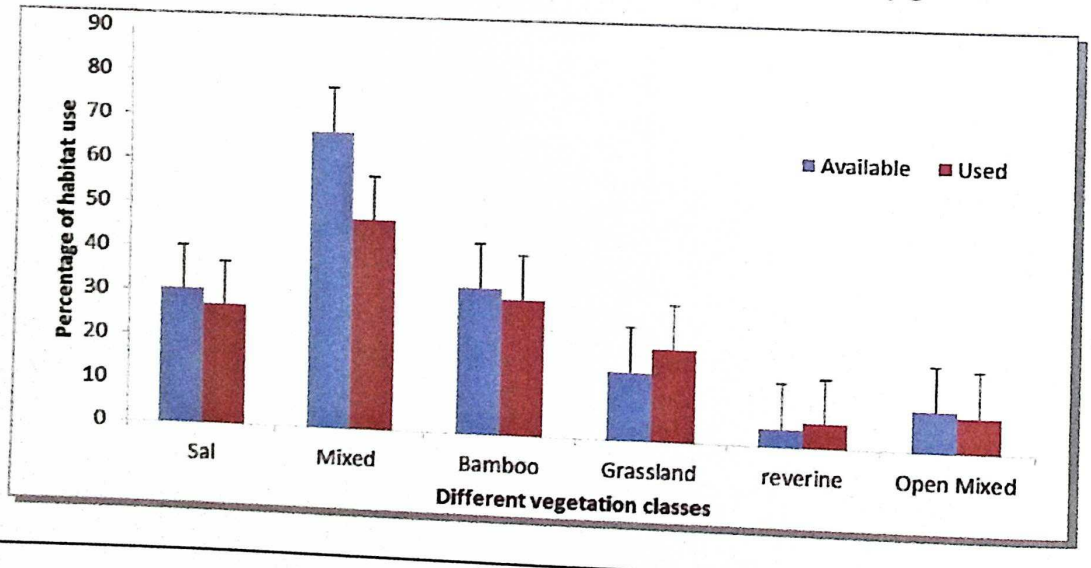


Table 5.1: Available vegetation and land cover classes in Bandhavgarh Tiger Reserve

Vegetation/Land cover type	Area (sq.km)	Percentage
Bamboo Forest (Bam)	221.9	14.36
Grassland (Gra)	115.3	7.46
Mixed Forest (Mix)	706.9	45.75
Open Mixed Forest (OMF)	196.4	12.71
Sal Forest (Sal)	231.1	14.96
Water Body (Riv)	73.2	4.74
Total	1544.8	100.0

Table 5.2: Preference of different vegetation types by gaur in BTR as shown by Bonferroni simultaneous confidence interval analysis

S. No.	Habitat Types	Proportion Use		Proportion Available	Preference	Significance
		Lower limit	Upper limit			
1	Sal	0.1501	0.2389	0.1911	Use as available	
2	Mixed	0.2877	0.3939	0.4220	Avoid	
3	Bamboo	0.1735	0.2664	0.2077	Use as available	
4	Grassland	0.1086	0.1884	0.0968	Prefer	($P < 0.05$)
5	Reverine	0.0172	0.0606	0.0256	Use as available	
6	Open Mixed	0.0313	0.0834	0.0568	Use as available	

Figure 5.3: Preference of different habitat types by gaur herds in BTR as shown by Ivlev's Selectivity Index

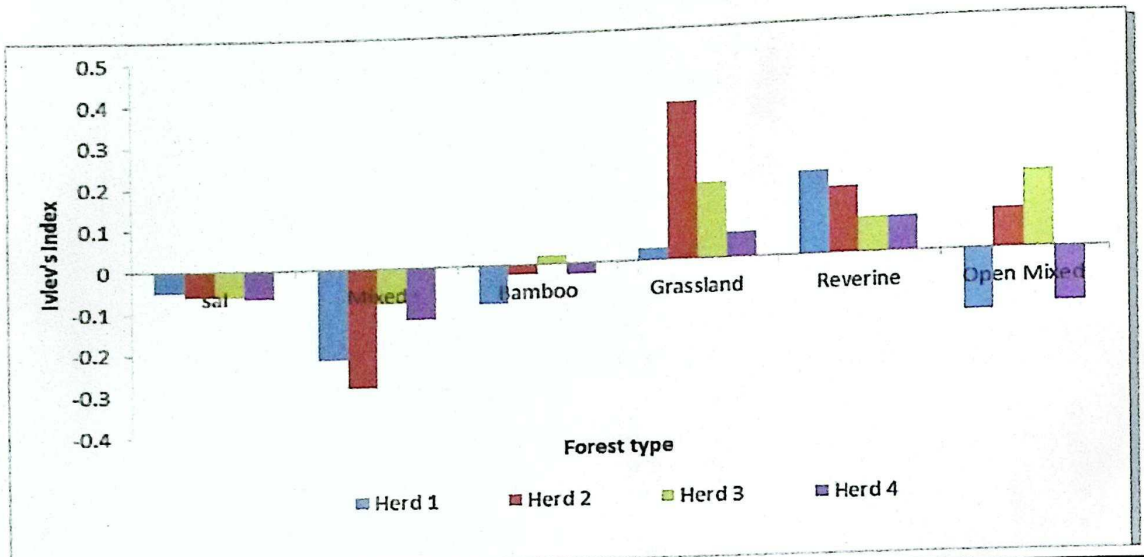


Table 5.3: Preference of different habitat types by gaur herds in BTR as shown by Ivlev's Selectivity Index analysis. (April 2015 - March 2018)

Habitat type	Herd 1			Herd 2			Herd 3			Herd 4		
	Ava	Use	Ivlev's	Ava	Use	Ivlev's	Ava	Use	Ivlev's	Ava	Use	Ivlev's
Sal	50.02	45.22	-0.0504	15.94	14.13	-0.0601	20.11	17.78	-0.0615	35.00	30.57	-0.0674
Mixed	93.16	60.02	-0.2163	44.44	24.73	-0.2849	43.91	37.00	-0.0854	85.80	66.95	-0.1234
Bamboo	47.47	39.55	-0.0909	19.65	18.73	-0.0241	24.30	25.33	0.0207	40.18	38.16	-0.0258
Grassland	20.91	22.18	0.0295	10.10	22.26	0.3760	11.25	16.22	0.1811	19.07	21.56	0.0611
Reverine	6.40	9.57	0.1984	2.33	3.19	0.1572	2.13	2.51	0.0829	5.33	6.28	0.0818
Open Mixed	16.70	12.45	-0.1456	4.09	4.95	0.0953	3.83	5.56	0.1836	11.36	8.79	-0.1276

Ava-habitat available; Use- habitat used

Discussion

The resource selection analysis was done by a second order Bonferroni analysis (Byers *et al.* 1984) and Ivlev's index (Ivlev, 1961). Though the habitat use of gaur was reported in a few Protected Areas (Weigum 1972, Conry 1989, Vairavel 1998, Sankar *et al.* 2001, 2013), this long term study provided a detailed account of their habitat use.

In BTR, though the mixed forest is the dominant vegetation type constituting 43.8% of the total area, the gaur primarily used grassland followed by reverine forest followed by bamboo forests . Grasslands provide much higher biomass of forbs and grasses (Song and Li 1994) and gaur is primarily a grazer (Haleem & Ilyas 2018) which might influence the animals to prefer grasslands. In general, herbivores select grassland where they can forage freely in large numbers (Treydte *et al.* 2014). Gaur used reverine forest as they are obligatory drinker (Sahai 1972). Bamboo leaves constitute a major food item of gaur and are available throughout the year in the study area (Sankar *et al.* 2015). Also the bamboo forest provides better shelter/resting areas as compared to other available habitat types in Bandhavgarh. In Pench Tiger Reserve the use of teak dominant forest and miscellaneous forest by gaur was significantly higher than other habitat types (Sankar *et al.* 2001). Gaur in Parambikulam National Park largely used grasslands as compared to other available habitats (Vairavel 1998). Free-ranging large herbivores have to make many foraging decisions at different resolution levels (Senft *et al.* 1987, Stuth 1991) resulting in a foraging strategy that meets specific nutrient and energy requirements of large herbivores that ultimately determines differential habitat selection by them.

The gaur in BTR were observed to use mixed forest least as the area has limited water and food resources (Sankar *et al.* 2015). In general, mega herbivores avoid habitats that do not have good forage with nutritional value (Roever *et al.* 2013).

In the present study, the use of different habitat types by four herds was mostly confined to their respective areas. Herd I & IV used reverine forest more than grassland whereas herd II & III used grassland more than reverine forest. This may be attributed to the availability of water resource and grassland in their ranging areas. All the other habitats such as sal forest and open mixed forest were used according to their availability except mixed forest that was least preferred though it is dominant in gaur ranging area.

CHAPTER 6

FOOD HABITS OF REINTRODUCED GAUR

Introduction

Diet assessment of herbivores provides insight into trophic relationships, the potential for competition, and the influences herbivores may have on an ecosystem (Bookhout 1996). Thus, the determination of their food requirements is imperative prior to the implementation of any management decisions, which must be based on reliable data (Bookhout 1996). Mega herbivores require more food and space than the smaller herbivores (Oven-Smith, 1988). The food resources of herbivores vary between different habitat types and also show marked seasonal variations within a given habitat in response to changes in rainfall patterns (Philipson 1975, Sinclair 1975). The feeding habits of ungulates are influenced by the seasonal and spatial differences between plant communities in species composition, production, food quality and quantity (Jarman and Sinclair 1979).

The 'Jarman-Bell Principle', as labelled by Geist (1974) states, large bodied ungulates are able to tolerate a lower quality diet as compared to smaller bodied species. For large herbivores, Owen-Smith (1988) has characterized the dietary intake in terms of (i) the plant species eaten, (ii) the plant parts ingested, or (iii) the nutrient contents of the ingested material.

Food habits of the members belonging to the wild cattle group (cattle, buffalo, bison and saola) have been studied for bison (Reynolds *et al.* 1982, Bergman *et al.* 2001, Fortin *et al.* 2002, Courant and Fortin 2012), African buffalo (Sinclair 1977, Prins 1996), Asiatic wild water buffalo (Chaiyarat 2002), anoa (Pujaningsih et al. 2009), wild yak (Harris and Miller 1995), banteng (Halder 1976, Prayurasiddhi 1997, Pudyatmoko 2005, Bhumpakphan and McShea 2011) and gaur (Schaller 1967, Krishnan 1972, Moorthy 1989, Prabhakar 1992, Vairavel 1998, Sankar et al. 2001, Gad and Shyama 2009, Gad 2011, Ahrestani *et al.* 2012, Sankar et al. 2013, Sankar *et al.* 2015 and Haleem and Ilyas 2018).

In the present study food habits of the reintroduced gaur population in Bandhavgarh Tiger Reserve were studied from April 2015 to March 2018.

Methodology

The data on the food plants and parts eaten by gaur was obtained mainly through scan sampling technique (Altman 1974) and through opportunistic sightings. Inspection of the sites, where gaur were seen feeding was also carried out so as to identify the eaten food plants. Samples of the eaten food plants were collected for each season (summer, monsoon, winter) for nutrient analysis. These samples were air dried and analyzed for nutrient contents, namely crude protein, minerals, ash, neutral detergent fiber, acid detergent fiber, crude lignin, tannins and alkaloids.

Fresh dung samples of gaur were collected for each season (at least 50 samples per season). These samples were air dried and stored in paper bags in the field. These samples are being analyzed in laboratory to estimate percentage frequency occurrence of fragments of various plant species and also the grass-browse ratio. The slides of plant fragments have been prepared for micro-histological examination following the method developed by Sparks and Malechek (1968) and later modified by Vavra and Holechek (1980); Jnawali (1991); Shrestha et al. (2005); and Wegge et al. (2006).

Results

During the study period a total of 112 species of food plants belonging to 39 families were recorded. The food plants eaten by gaur were classified into five categories such as trees, shrubs, herbs, grasses and climbers. The 112 species of food plants recorded comprised of 41 tree species, 18 shrub species, 12 herb species, 34 grass species and 7 climber species (Table 6.1). The different plant parts eaten by gaur were classified as leaf (for trees, shrubs and climbers), shoot (for grasses and herbs), floral bud, flower, barks and fruit. Major portion of gaur diet were comprised of leaves and shoots.

Table 6.1: Food plants of gaur in Bandhavgarh Tiger Reserve (April 2015 - March 2018).

S. No	Plant Species	Family	Plant Parts
	Trees		
1	*Anogeissus latifolia*	Combretaceae	Le
2	*Acacia catechu* *	Fabaceae	Le
3	*Acacia leucophloea* *	Mimosaceae	Le
4	*Adina cordifolia* *	Rubiaceae	Fl, Le
5	*Aegle marmelos*	Rutaceae	Fl, Le, Fr
6	*Albizzia odoratissima* *	Fabaceae	Le
7	*Albizzia procera*	Fabaceae	Le
8	*Buchanania lanzan*	Anacardiaceae	Le

S. No	Plant Species	Family	Plant Parts
9	*Bauhinia veriegata*	Fabaceae	Le
10	*Boswellia serrata*	Burseraceae	Le
11	*Bridelia hamiltoniana* *	Phyllanthaceae	Le
12	*Bridelia retusa*	Euphorbiaceae	Le
13	*Butea monosperma* *	Fabaceae	Le
14	*Careya arborea* *	Lecythidaceae	Le
15	*Cassia fistula*	Fabaceae	Le
16	*Chloroxylon swietenia*	Meliaceae	Le
17	*Dalbergia paniculata*	Fabaceae	Le
18	*Dalbergia sissoo* *	Fabaceae	Le
19	*Diospyros melanoxylon*	Ebenaceae	Br, Le
20	*Emblica officinalis*	Phyllanthaceae	Le
21	*Ficus benghalensis*	Moraceae	Le
22	*Ficus religiosa*	Moraceae	Fr, Le
23	*Flacourtia indica* *	Bixaceae	Le
24	*Lagerstroemia parviflora*	Lythraceae	Le
25	*Lannea grandis*	Anacardiaceae	Le
26	*Madhuca indica*	Sapotaceae	Le
27	*Miliusa tomentosa*	Annonaceae	Le
28	*Phyllanthus emblica*	Euphorbiaceae	Le
29	*Saccopetalum tomentosum* *	Annonaceae	Le
30	*Schleichera oleosa* *	Sapindaceae	Fl, Le
31	*Semecarpus anacardium*	Anacardiaceae	Le
32	*Shorea robusta*	Dipterocarpaceae	Fr, Le
33	*Soymida febrifuga* *	Meliaceae	Le
34	*Syzygium cumini*	Myrtaceae	Le
35	*Tectona grandis* *	Combretaceae	Le
36	*Terminalia bellirica*	Combretaceae	Le
37	*Terminalia chebula*	Combretaceae	Le
38	*Terminalia elleptica* *	Combretaceae	Fr, Le
39	*Terminalia tomentosa*	Combretaceae	Br, Le
40	*Wrightia tinctora* *	Apocynaceae	Le
41	*Zizyphus xylopyra*	Rhamnaceae	Le
	Shrubs		
1	*Asparagus racemosus* *	Asparagaceae	Le
2	*Euphorbia tirucalli* *	Euphorbiaceae	Le
3	*Flemingia bracteata* *	Fabaceae	Le
4	*Grewia hirsute* *	Tiliceae	Le
5	*Grewia hirta* *	Malvaceae	Le
6	*Helicteris isora* *	Malvaceae	Le

S. No	Plant Species	Family	Plant Parts
7	*Holarrhena antidysentrica*	Apocynaceae	Le
8	*Ipomoea carnea* *	Convolvulaceae	Le
9	*Ixora parviflora* *	Rubiaceae	Le
10	*Lantana camara*	Verbinaceae	Le
11	*Ocimum tenuiflorum* *	Lamiaceae	Le
12	*Phoenix acaulis*	Arecaceae	Le
13	*Sida acuta* *	Malvaceae	Le
14	*Urginea indica* *	Liliaceae	Le
15	*Woodfordia fruticosa*	Lythraceae	Le
16	*Wrightia tinttoria*	Apocynaceae	Le
17	*Zizyphus oenobila* *	Rhamnaceae	Fr, Le
18	*Zizyphus mauritiana* *	Rhamnaceae	Fr, Le
	Herbs		
1	*Achyranthes aspera*	Amaranthaceae	Sh
2	*Bulbostylis barbata*	Cyperaceae	Sh
3	*Cassia tora*	Fabaceae	Sh
4	*Desmodium pulchelium*	Fabaceae	Sh
5	*Desmodium triflorum* *	Fabaceae	Sh
6	*Elephantopus scaber* *	Asteraceae	Sh
7	*Eranthemum purpureseens*	Acanthaceae	Sh
8	*Euphorbia hirta*	Euphorbiaceae	Sh
9	*Hemidesmum indicus* *	Asclepiadaceae	Sh
10	*Hyptis suaveolens* *	Lamiaceae	Sh
11	*Leucas aspera*	Lamiaceae	Sh
12	*Leucas biflora*	Lamiaceae	Sh
	Grasses		
1	*Andropogon pumillus*	Poaceae	Sh
2	*Apluda varia* *	Poaceae	Sh
3	*Aristida setacea*	Poaceae	Sh
4	*Arundinella pumila* *	Poaceae	Sh
5	*Chloris dolichostachya*	Poaceae	Sh
6	*Chrysopogon montanus* *	Gramineae	Sh
7	*Curculigo orchiodes* *	Amaryllidaceae	Sh
8	*Cynodon dactylon*	Poaceae	Sh
9	*Dactyloctenium aegyptium* *	Poaceae	Sh
10	*Dendrocalamus strictus* *	Poaceae	Sh
11	*Dicanthium annulatum*	Poaceae	Sh
12	*Dicanthium aristatum* *	Poaceae	Sh
13	*Digitaria setigera*	Poaceae	Sh
14	*Digitaria villosa* *	Poaceae	Sh

S. No	Plant Species	Family	Plant Parts
15	*Echinochloa colonum* *	Poaceae	Sh
16	*Elusine indica* *	Poaceae	Sh
17	*Eragaostis tenella*	Poaceae	Sh
18	*Eragrostis paniculatus* *	Poaceae	Sh
19	*Eragrostis intermedia* *	Poaceae	Sh
20	*Heteropogon contortus*	Poaceae	Sh
21	*Imperata cylindrica*	Poaceae	Sh
22	*Oplismenus burmannii* *	Poaceae	Sh
23	*Pasphalum flevidum*	Poaceae	Sh
24	*Rottbollia cochinchinensis* *	Poaceae	Sh
25	*Saccharum bengalense* *	Poaceae	Sh
26	*Saccharum spontanium*	Poaceae	Sh
27	*Setaria intermedia* *	Poaceae	Sh
28	*Setaria pumila*	Poaceae	Sh
29	*Sorghum controversum* *	Poaceae	Sh
30	*Themeda quadrivalvis* *	Gramineae	Sh
31	*Themeda triandra*	Poaceae	Sh
32	*Thysanolaena maxima*	Poaceae	Sh
33	*Urochloa ramosa* *	Poaceae	Sh
34	*Veteveria zizinoides*	Poaceae	Sh
	Climbers		
1	*Bauhinia Vahilii*	Fabaceae	Le
2	*Butea superb*	Fabaceae	Le
3	*Calycopteris floribunda* *	Combretaceae	Le
4	*Hemidesmus indicus**	Asclepiadaceae	Le
5	*Millettia extensa* *	Leguminosae	Le
6	*Ziziphus nummularia* *	Rhamnaceae	Le
7	*Ziziphus oenoplia*	Rhamnaceae	Le

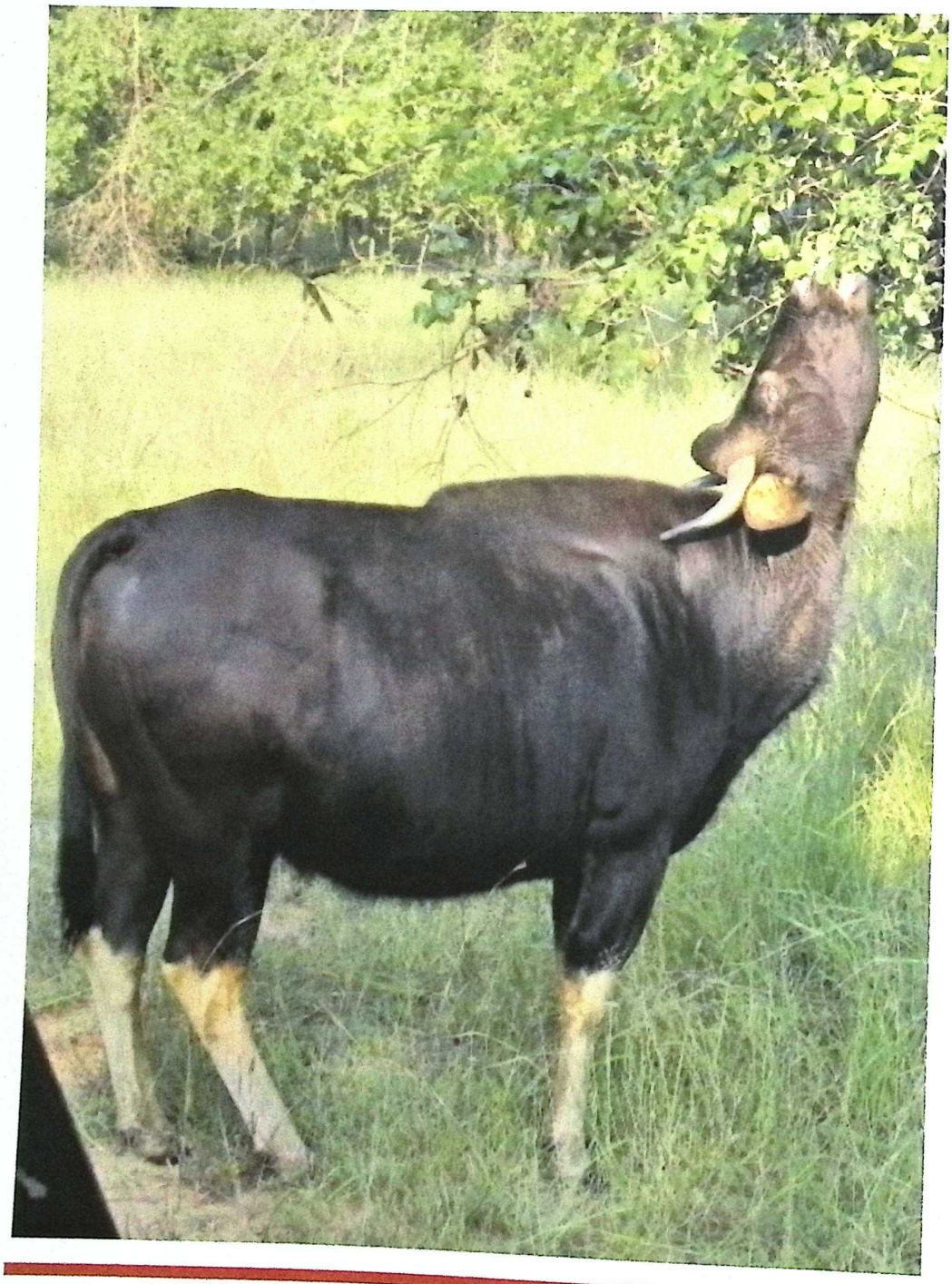
*New food plant species recorded during the study period Le- Leaves, Fl- Flower, Fr- Fruit, Sh- Shoot, Br- Bark.

Discussion

Gaur has been described as a generalist feeder (Sankar *et al.* 2001) and is known to feed on a large variety of food plants across many different forest types in India (Schaller 1967, Krishnan 1972, Vairavel 1998, Sankar *et al.* 2001, Gad 2011, Sankar *et al.* 2013, 2015, Manas 2016). In the present study gaur were observed to feed on 112 species of food plants (Table 5.1) which indicates the polyphagous feeding (Manas 2016) habit of this mega-herbivore. In phase I (2011-2015) a total of 82 food plant species were reported (Sankar *et al.* 2015, Manas 2016). Thirty more different food plant species were added to the list of food plants eaten by gaur in Bandhavgarh.

This may be attributed to the larger extent in population growth and use of resource in their ranging area. This also indicated the competition with other animals and extent use of resource available in entire gaur ranging area. Schaller (1967) reported that such a varied diet of gaur has enabled it to colonize a wide range of vegetation types across its distributional range in the country.

In total, 39 different plant families were recorded during the study period (table 4.1). Ten new plant species families (*Amaryllidaceae*, *Asclepiadaceae*, *Asteraceae*, *Convolvulaceae*, *Lecythidaceae*, *Leguminosae*, *Liliaceae*, *Mimosaceae*, *Phyllanthaceae* and *Sapindaceae*) were added to the gaur food plant list which was not reported in Bandhavgarh (Sankar *et al.* 2015 and Manas 2016). Similarly 55 different food plant species (trees 18, shrubs 15, herbs 4 grasses 19 and climber 4) were recorded newly, which is not reported earlier in Bandhavgarh (Sankar *et al.* 2015 and Manas 2016). Along with this 27 food plant species (trees 10, shrubs 3, herbs 6 and grasses 8) was not recorded during the study period which has been reported earlier (Sankar *et al.* 2015 and Manas 2016).



CHAPTER 7

HEALTH ASSESSMENT OF REINTRODUCED GAUR

Introduction

The health condition of an animal is primarily a reflection of its fat reserves which in turn are generally assumed to determine an individual's reproductive potential (Gerhart *et al.* 1996), food availability and/or presence or absence of diseases/disorders. Body condition scoring gives a reasonable idea of the health condition of an animal (Ramesh *et al.* 2011). It provides an index of the energy stored as fat and muscle and is a quick reliable means of identifying extremes in nutritional status (Riney 1960).

The average health condition among animals indicates the response of a population to the prevailing environmental conditions (Reuter and Adcock 1998) though behaviour and sex-based differences between individuals also affect body condition.

Proper health assessment provides an opportunity for Managers to take decisions for improving habitat quality through supplementation of nutrients to support overall health of free ranging animals. The body condition scores have been widely applied as measures of nutrition, reproductive potential and herd health or productivity in livestock (Russell *et al.* 1969, Wildman *et al.* 1982, Otto *et al.* 1991, Ruegg 1991) and the same has been found applicable in wild ungulates (Gerhart *et al.* 1996, Riney 1960, Singh *et al.* 2009), wild African elephants (Pinter-Wollman *et al.* 2009) and domestic and wild Asian elephants (Wemmer *et al.* 2006, Ramesh *et al.* 2011). Evaluating body condition of wild herbivores is therefore essential to monitor the population situation in relation to the environment and to be able to detect possible imbalances in the health condition of the population before serious problems arise (Ezenwa *et al.* 2009).

During phase I (2011-2015) the health condition of reintroduced gaur was studied in Bandhavgarh (Sankar *et al* 2015) and the objective was continued during Phase II carried out from April 2015-March 2018.

Methodology

The reintroduced gaur were tracked using radio telemetry and approached within the visible vicinity (<50 m) on a vehicle (four wheel) or using camp elephant. The body condition was examined and data were collected during morning (7.30 am to 9.30 am) and evening (3.30 pm to 5.30pm) hours. The reintroduced gaur age class was classified based on the criteria following Schaller (1967) and Krishnan (1972); adult male (>5 years), sub adult male (3-5 years), adult female (> 5 years), sub adult male (3-5 years), yearlings (> 1 years) and calf (< 1 year).

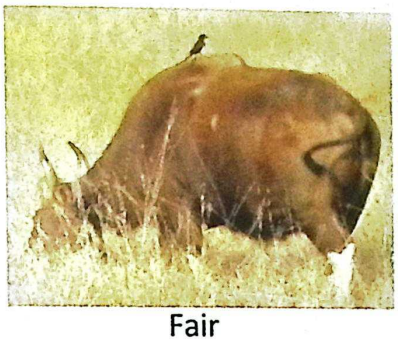
The Body Condition Index (BCI) consists of scoring different regions of the animal body, *i.e.* flank area, ribs, pelvic girdle, vertebral column, lumber shelf (Riney, 1960). A score between 0 and 2 was given to each measure for every region and all the scores were added to give a total score for assessing the overall body condition. Each region was given a score like 0 – good, 1- fair, 2 –poor (Riney, 1960) (Table 7.1). The total score was on a scale of 1-10. Scores ranging from 0-2 were considered as good; 3-5 were considered fair and above 6 were considered poor. Data was collected across different demography class and sex wise.

Table 7.1: Health Assessment of Gaur population in BTR. Generalized description and evaluation of different parts of ungulates (Riney *et al*, 1960).

Body part	*Point=0*	*Point-1*	*Point-2*
Flank area	Depression barely visible. Flank area outline is indistinct	Flank area slightly concave & outline visible	Depression concave and tucked in
Ribs	Thoracic surface is smooth and ribs are difficult to see	Ribs are visible but not all can be counted with ease	Ribs prominent with distince inter-costal depression
Pelvic girdle	Bony projections of pelvic girdle are barely visible	Pelvic girdle outline slightly visible	Bony projections of pelvic girdle are clearly visible
Vertebral column	When seen laterally, it runs smooth without any breaks. Lumbar process visible	Lateral processes of lumbar vertebrae are visible but not prominent	Lateral processes of lumbars very prominent. Dorsal processes of vertebrae seen
Lumbar shelf	No depression in shelf. Appears almost round from behind	Slight depression on either side	Depression deep and concave

Body Condition Index: Interpretation: 0-2= 'Good'; 3-5 = 'Fair'; > 6 = 'Poor'

Poor



Fair

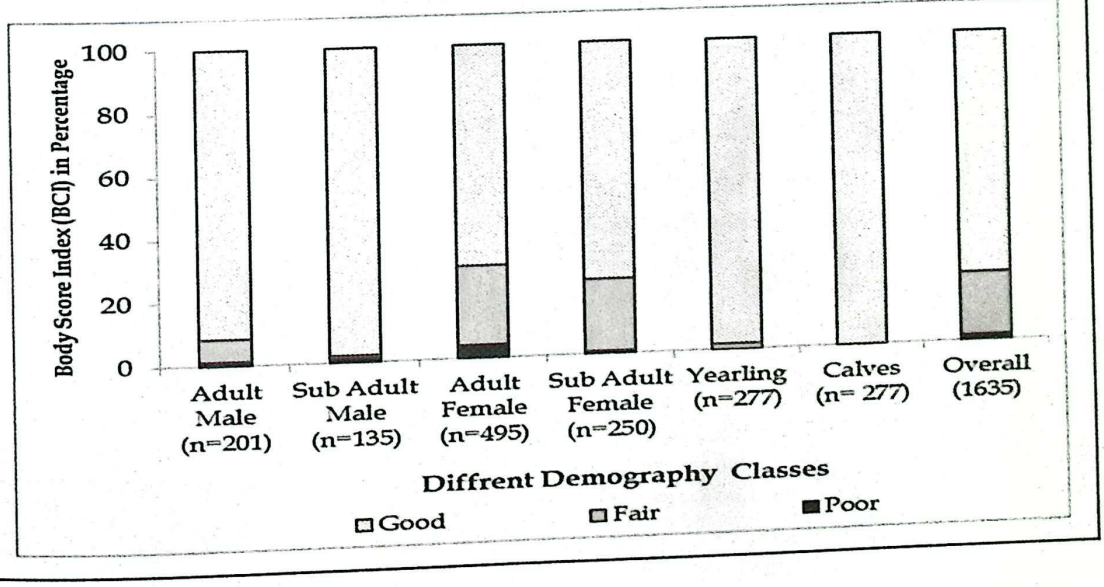
Good

Results

In total 1,635 body scores were examined for BCI for both sexes including all the demographic classes of gaur during the study period. Of the observed individuals for body condition, 77.9 % were found to be in good body condition followed by 20.2 % in fair and 1.7 % in poor conditions (Figure 7.1). Overall males (94.6 %) were observed in good body condition comparing to females (73.2 %). The BCS of different age classes in Bandhavgarh, calves were found in good body condition (99.6 %) followed by yearlings (97.8%), sub adult males (97.7%), adult males (91.5%), sub adult females (76%) and adult females (70.5%). During the study period, about 25.5% of the adult females were observed in fair body condition followed by sub adult females (23.2%) adult males 96.7% and yearling (1.8%). Mostly adult females (4.2%) were found in poor body condition followed by sub adult males and adult males 2.4 % and 1.2% respectively.

Post Mortem reports of three mortalities were attributed to Tuberculosis in the reintroduced population in Bandhavgarh Tiger Reserve. The mortalities included a yearling and two adult females.

Figure 7.1: BCI within each demographic classes of reintroduced gaur in BTR



Discussion

In the present study the health condition of the gaur population in Bandhavgarh was assessed using BCI method. During the entire study period majority of the gaur population were in good body condition as previously reported by Sankar *et al.* 2015. Adult females and sub adult females were in good to fair body condition. Nutrient depletion resulting from calving and lactation could be attributed to fair condition in adult females.

The present study shows that the BCI was a good indicator to assess the overall health condition of reintroduced gaur population and also it can be used in long-term health monitoring in Bandhavgarh.

Mortalities due to Tuberculosis calls for timely and appropriate actions, so as to contain the further spread of disease. Rodwell et al. (2001) reported, Tuberculosis in African Buffalo in Kruger wherein the disease was detected in a single animal in 1990 and was subsequently reported in 33/ 206 animals (16%) and 79/207 animals sampled (38.2%) from central and South Kruger respectively in 1998. TB is a chronic, progressive disease and time course of infection may last from weeks to months. For the majority of the course of infection, the animals appear clinically normal. The most common clinical sign of disease is weight loss and this only occurs in the advanced stage of the disease. Other signs of respiratory and other organ involvement have been variably reported (de Lisle, 2002).Based on the post-mortem findings, gross lesions and confirmatory diagnosis of tuberculosis, it is likely that other animals might have also been exposed

Prescription for managing Tuberculosis in BTR (Adapted from report provided to the Forest Department by the Wildlife Institute of India

1. Segregating animals that are showing physical signs of health deterioration from those looking apparently healthy. These animals can be shifted to the enclosure for close monitoring and testing for health and disease. This would also avoid spread of disease to other animals.
2. The apparently healthy looking animals may even harbor the infection and therefore it would be appropriate to have proper screening of these animals done as a part of disease surveillance program.
3. Scientific investigations may be requested from Indian Veterinary Research Institute including their expert advice on control and prevention of disease. Additionally, assistance may also be sought from CWFH, Jabalpur.
4. Investigation involving collection of biological samples from as many as animals possible is required to assess the level of Tuberculosis in the population and would help in understanding disease transmission risks, potential population effects, and the efficacy of disease management strategies
5. Detailed post-mortem examination of any mortality event both for ungulates as well as carnivores should be carried out.
6. Efforts need to be made to minimize interaction with livestock through appropriate interventions including putting efforts to check disease in livestock.
7. Any introduction or supplementation program of ungulates in or from BTR should include prior testing for diseases to check further spread of infection within and to other areas.

CHAPTER 8

FOOD RESOURCE COMPETITION OF REINTRODUCED GAUR WITH OTHER WILD UNGULATES AND CAMP ELEPHANTS

Introduction

Competition may arise where one species reduces the shared food resources below the level that can be exploited efficiently by another species (Illius and Gordon 1987, Murray and Illius2000, Prins and Olff 1998). Competition for the resource affects the population dynamics of the species involved (Hogstedt, 1980; Rusterholz, 1981). While knowledge on habitat requirements of sympatric animal species is essential for the conservation of animal communities, e.g., in protected areas (Whittaker et al. , 2005) only a few have addressed the species-habitat relationships of the assemblage of sympatric ungulate species (e.g., Bagchi et al., 2003; Bhattarai and Kindlmann, 2011).

Determining a species' resource requirements is important to understand the potential degree and consequences of competition (Broekhuis, 2017) as understanding herbivore selection and utilization of vegetation types is fundamental to conservation of multispecies communities (Bukombe et al. 2017). Interspecific competition theory predicts that different species should narrow their range of vegetation types in the dry season (Sinclair, 1985), resulting in a reduction in species overlap in resources. Resource availability influences food habits, which, in turn, may lead to interspecific competition for scarce key resources (de Boer & Prins, 1990).

Resource partitioning and high environmental heterogeneity facilitate coexistence between species (Godsoe *et al.* 2015). Furthermore, Sinclair (1979) concluded that interspecific competition was the dominant structuring process in the Serengeti community of Tanzania and Kenya, producing the presently observed separation and coexistence of herbivores.

Methods

The data on the food plants and parts eaten by gaur was obtained through direct observations. Gaur feeding sites inspection was made so as to identify the food plants eaten by gaur. Fresh dung samples of gaur were collected for each season (at least 50 samples per season). These samples were washed, air dried and stored in paper bags in the field. These were analyzed in WII laboratory to estimate percentage frequency occurrence of monocot and dicot plant fragments.

For the micro-histological analysis of dung samples the dried dung samples were ground using a grinder with a 1mm mesh to regulate the size of the material. These ground samples were stored in plastic vials and slides will be prepared for micro-histological examination following the method developed by Sparks and Malechek (1968) and later modified by Vavra and Holechek (1980); Jnawali (1995); Shrestha *et al.* (2005); and Wegge *et al.* (2006).

Data analysis

A check list of plant species eaten by all wild ungulates and camp elephants was prepared. Based on this information, the percentage overlap of food plants eaten between gaur and ungulates and also with the camp elephants was calculated by using Bernoulli (binary) distribution (Pledger and Gaene 2009) for the indicator, with species *i*, having probability *pi*, for "success" (value 1) and *qi* = 1-*pi* for "failure" (value 0). The proportion of individuals of species *i* with indicator 1 is the estimate of *pi*. Similarly *pj* for species *j* is estimated by the proportion of individuals of species *j* with indicator value 1.

The niche overlap between species *i* and *j* (on axis *t*) is defined as;
NO_{ijt}= min (*pi, pj*) + min (*qi, qj*)

Results

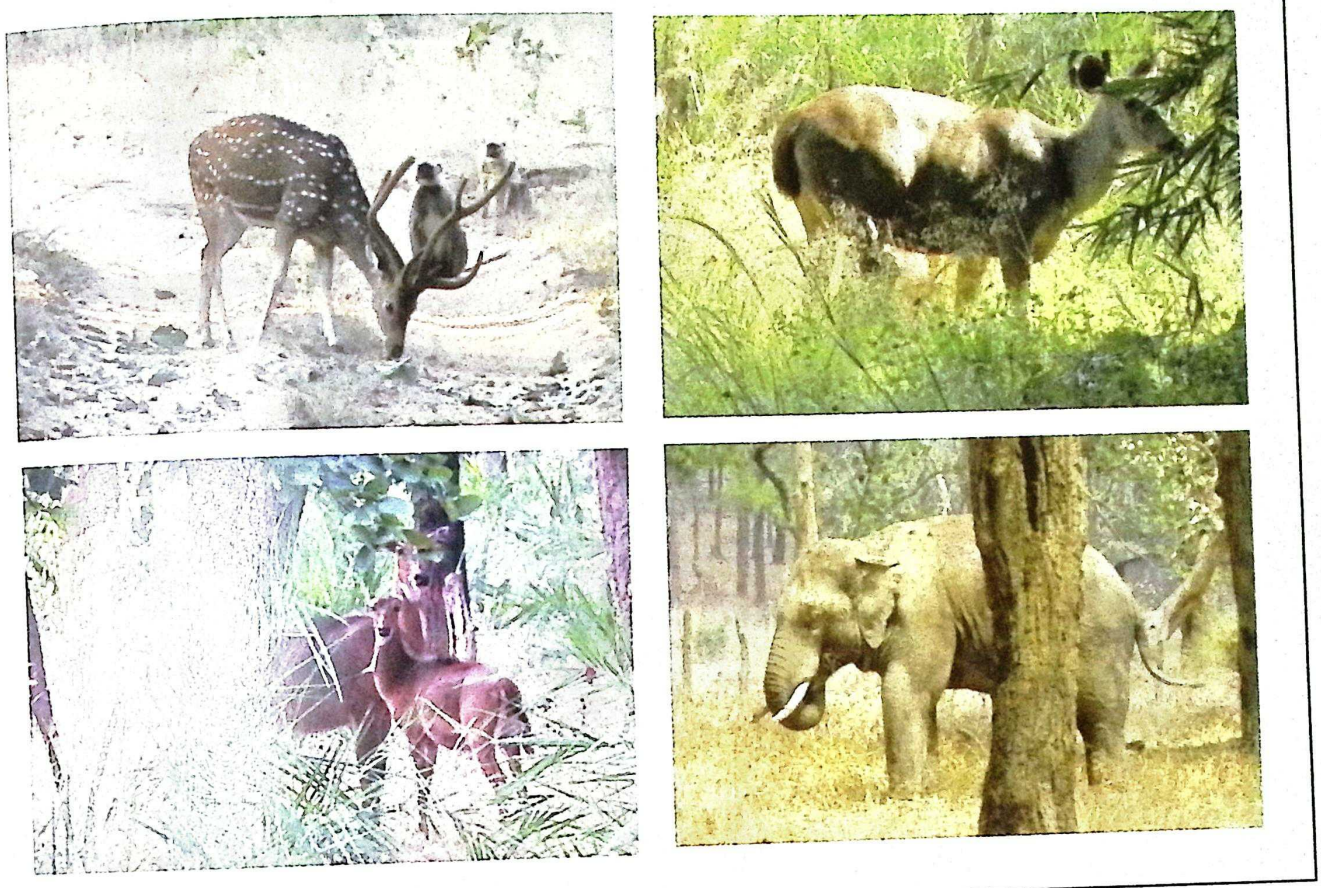
Gaur

Gaur utilized 112 food plants (41 trees, 18 shrubs, 12 herbs, 34 grasses and climbers) species were recorded from April 2015 to March 2018 (Table 8.1).

Chital

A total of 89 food plants (25 trees, 14 shrubs, 17 herbs, 7 climbers and 27 grasses) species were recorded (Table 8.1). Chital food habits varied from season to season, in which plants parts includes fallen leaves, flowers and fruits.

Figure 8.1 Food overlap of gaur with other ungulates and camp elephant in BTR
a . Cheetal, b. Sambar, c. Nilgai, d. Elephant



Nilgai

A total of 73 food plants (16 trees, 19 Shrubs, 16 herbs, 3 climbers and 19 grasses) species were recorded (Table 8.1).

Camp elephant

A total of 72 food plants (37 trees, 7 shrubs, 11 herbs, 5 climbers and 14 grasses) species were recorded (Table 8.1). The overlap for food resource of gaur with chital was found to be 100% (Figure 8.1, Table 8.1). With camp elephant and nilgai, gaur shared 89% and 81% food resources respectively, whereas the overlap was found to be minimum (73%) with sambar.

Table 8.1: List of plant species used by gaur and other ungulates and camp elephants in BTR (April 2015-March 2018).

S. No	Plant Species	Chital	Sambar	Gaur	Nilgai	Camp Elephant
		Trees				
1.	*Acacia nilotica*	*	*			
2.	*Anogeissus latifolia*	*		*		*
3.	*Annona squamosa*	*				
4.	*Buchanania lanzan*	*	*			*
5.	*Terminalia tomentosa*	*	*		*	*
6.	*Zizyphus xylopyra*	*	*	*		*
7.	*Acacia catechu*			*	*	
8.	*Acacia leucophloea*	*		*	*	
9.	*Adina cordifolia*	*		*		
10.	*Aegle marmelos*	*	*	*		*
11.	*Albizzia odoratissima*			*		*
12.	*Albizzia procera*			*		
13.	*Bauhinia variegata*	*	*	*	*	*
14.	*Bauhinia recemosa*					
15.	*Bombax ceiba*					*
16.	*Boswellia serrata*	*	*	*	*	*
17.	*Bridelia hamiltoniana*	*		*		*
18.	*Bridelia retusa*	*		*	*	*
19.	*Butea monosperma*		*	*		*
20.	*Careya arborea*			*		
21.	*Cassia fistula*	*		*		
22.	*Chloroxylon swietenia*		*	*	*	*
23.	*Dalbergia sissoo*			*		*
24.	*Dalbergia paniculata*			*		
25.	*Diospyros melanoxylon*	*	*	*	*	*
26.	*Emblica officinalis*	*	*	*	*	*
27.	*Erythrina indica*				*	
28.	*Ficus benghalensis*			*		*
29.	*Ficus religiosa*			*		*
30.	*Flacourtia indica*			*		
31.	*Ficus rumphii*					*
32.	*Grewia hirta*	*	*			
33.	*Helicteris isora*					*
34.	*Lagerstroemia parviflora*	*	*	*	*	*
35.	*Lannea grandis*	*	*	*		*
36.	*Madhuca indica*	*	*	*	*	*

S. No	Plant Species	Chital	Sambar	Gaur	Nilgai	Camp Elephant
37.	*Mangifera indica*	*				*
38.	*Mitragyna parviflora*					*
39.	*Miliusa tomentosa*			*		
40.	*Pterocarpus marsupium*	*	*			*
41.	*Phyllanthus emblica*		*	*		*
42.	*Saccopetalum tomentosum*			*		
43.	*Schleichera oleosa*			*		
44.	*Semecarpus anacardium*			*		*
45.	*Soymida febrifuga*			*		
46.	*Sterculia urens*					*
47.	*Syzygium cumini*	*	*	*	*	*
48.	*Shorea robusta*			*		*
49.	*Tamarindus indica*		*			*
50.	*Tectona grandis*	*	*	*	*	*
51.	*Terminalia arjuna*					*
52.	*Terminalia bellirica*		*	*	*	*
53.	*Terminalia chebula*	*	*	*		*
54.	*Terminalia elleptica*			*		
55.	*Wrightia tinctora*	*		*	*	*
56.	*Xylia xylocarpa*					*
		Shrubs				
1.	*Asparagus racemosus*	*	*	*	*	
2.	*Euphorbia tirucalli*	*		*	*	
3.	*Flemingia strobilifera*				*	
4.	*Grewia sps*	*		*	*	*
5.	*Grewia hirsuta*	*	*	*	*	*
6.	*Helicteris isora*	*	*	*	*	
7.	*Holarrhena antidysentrica*	*	*	*	*	*
8.	*Ixora parviflora*	*		*	*	*
9.	*Ipomoea carnea*			*		
10.	*Lantana camara*	*	*	*	*	
11.	*Mimosa hamata*	*			*	
12.	*Millettia extensa*				*	
13.	*Ocimum tenuiflorum*	*		*	*	*
14.	*Phoenix acaulis*	*	*	*	*	*
15.	*Randia dumetorum*				*	
16.	*Sida acuta*			*		
17.	*Urginea indica*				*	
18.	*Woodfordia fruticosa*	*	*	*	*	*
19.	*Wrightia tinttoria*			*	*	

S. No	Plant Species	Chital	Sambar	Gaur	Nilgai	Camp Elephant
20.	*Zizyphus oenobila*	*	*	*	*	
21.	*Zizyphus mauritiana*	*	*	*	*	
Herbs						
1.	*Sida cordifolia*		*		*	
2.	*Acacia pinnata*	*			*	*
3.	*Achyranthus aspera*	*	*	*		
4.	*Ageratum conzoindes*	*	*		*	
5.	*Argemone mexicana*	*				
6.	*Alternanthera sessile*					*
7.	*Atylosia scarabaeoides*	*				
8.	*Bulbostylis barbata*			*		
9.	*Calycopteris floribunda*					*
10.	*Cassia tora*	*		*	*	
11.	*Cleome Viscosa*		*			*
12.	*Commelina bengalensis*	*	*		*	
13.	*Crotolaria albida*	*			*	*
14.	*Desmodium pulchelium*		*	*		*
15.	*Desmodium triflorum*		*	*	*	
16.	*Dioscorea pentaphylla*	*	*		*	
17.	*Elephantopus scaber*			*		
18.	*Eranthemum purpureseens*			*		*
19.	*Euphorbia hirta*	*	*	*	*	
20.	*Hemidesmum indicus*	*		*	*	
21.	*Hygrophila Auriculata*	*			*	*
22.	*Hyptis sauvelens*	*		*	*	
23.	*Justicia quinquangularis*	*			*	*
24.	*Leucas aspera*	*		*		
25.	*Leucas biflora*			*	*	
26.	*Ocimum basilicum*				*	
27.	*Phyllanthus simplex*	*			*	
28.	*Tridax Procumbens*					*
29.	*Vernonia cinera*		*			*
	Grasses					
1.	*Andropogon pumillus*			*		
2.	*Arundinellia pumilla*			*		
3.	*Bothriochloa spp.*	*	*	*		
4.	*Dendrocalamus strictus*	*	*	*	*	*
5.	*Apluda varia*	*	*	*		
6.	*Aristida setacea*	*	*	*		*
7.	*Aristida funiculate*	*				

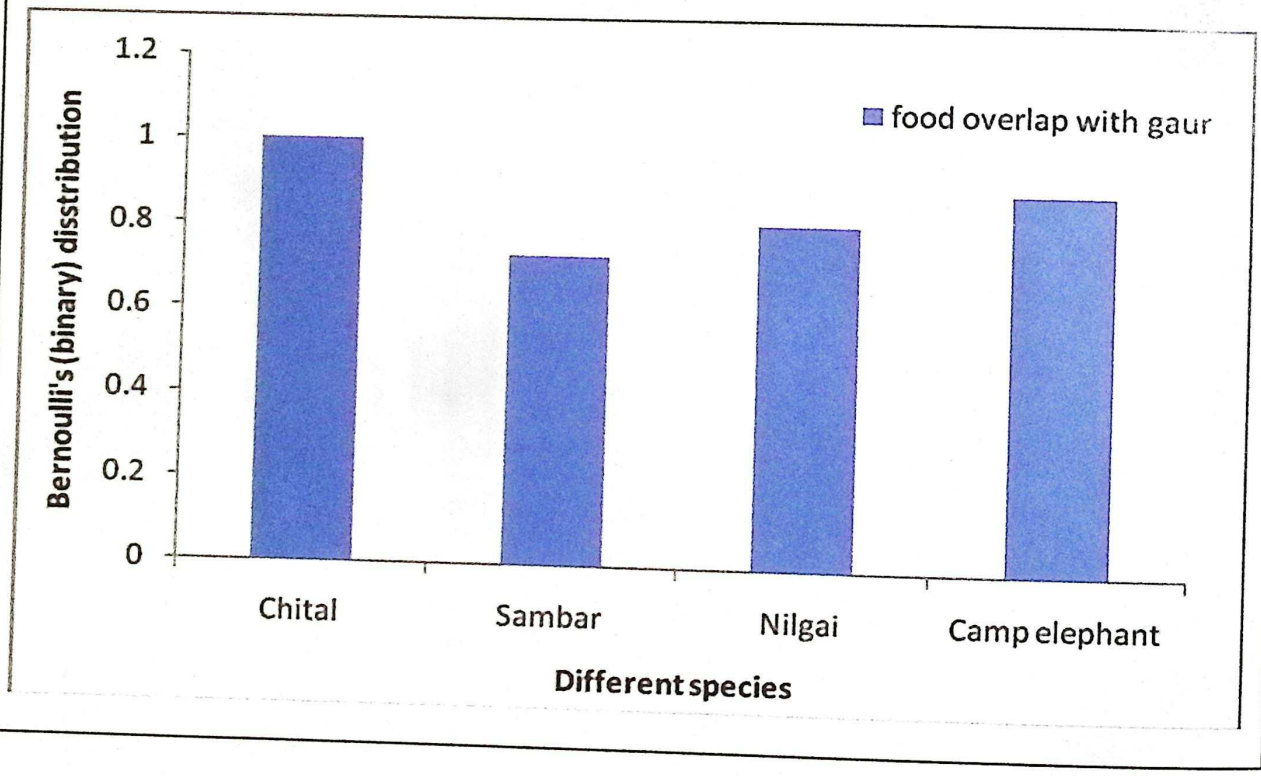
S. No	Plant Species	Chital	Sambar	Gaur	Nilgai	Camp Elephant
8.	*Thysanolaena maxima*					*
9.	*Curculigo orchiodes*			*		
10.	*Chionacnae sps*		*			
11.	*Chloris Barbata*	*	*			
12.	*Chloris dolicosticus*	*		*	*	
13.	*Chryzopogon fulvus*	*	*			
14.	*Chrysopogon montanus*			*		
15.	*Cynodon dactylon*	*	*	*		*
16.	*Dactylectum agepticum*		*	*	*	
17.	*Dicanthium annulatum*	*		*		*
18.	*Dicanthium aristatum*	*	*	*	*	
19.	*Digitaria setigera*	*	*	*		
20.	*Digiteria villosa*	*		*		*
21.	*Dimeria ornithopoda*	*			*	
22.	*Echinochloa colonum*		*	*	*	
23.	*Elusine indica*	*		*		
24.	*Eragrostis tenella*	*		*	*	
25.	*Eragrostis intermedia*		*	*		*
26.	*Eragrostis paniculatus*	*		*	*	
27.	*Heteropogon contortus*	*	*	*		*
28.	*Imperata cylendrica*	*		*	*	*
29.	*Ischaemum indicum*	*	*		*	
30.	*Iseilema laxum*	*				
31.	*Ischaemum rugosum*		*		*	
32.	*Oplismenus burmanii*	*	*	*	*	*
33.	*Pasphalum flevidum*	*	*	*		
34.	*Pennesetum Sps.*				*	
35.	*Saccharum spontaneum*	*	*	*	*	*
36.	*Saccharum bengalense*			*		
37.	*Setaria intermedia*		*	*	*	
38.	*Setaria pumila*	*	*	*	*	
39.	*Sorghum controversum*	*	*	*		
40.	*Themeda triandra*	*	*	*	*	*
41.	*Veteveria zizanioides*	*		*		*
42.	*Rottbolia cochinchinensis*			*	*	
43.	*Themeda quadrivalvis*			*	*	*
44.	*Thysanolaena maxima*			*		
45.	*Urochloa ramose*			*		

Climbers

S. No	Plant Species	Chital	Sambar	Gaur	Nilgai	Camp Elephant
1.	*Butea superb*	*	*	*		*
2.	*Bauhinia vahilii*	*	*	*		*
3.	*Ziziphus nummularia*	*	*	*	*	*
4.	*Calycopteris floribunda*	*	*	*	*	*
5.	*Ziziphus oenoplia*	*	*	*	*	
6.	*Clematis triloba*	*	*			*
7.	*Discorea daemona*	*				
8.	*Hemidesmus indicus*			*		
9.	*Millettia extensa*			*		

*- food plant species

Figure 8.1 Food overlap of gaur with other ungulates and camp elephant in BTR



Discussion

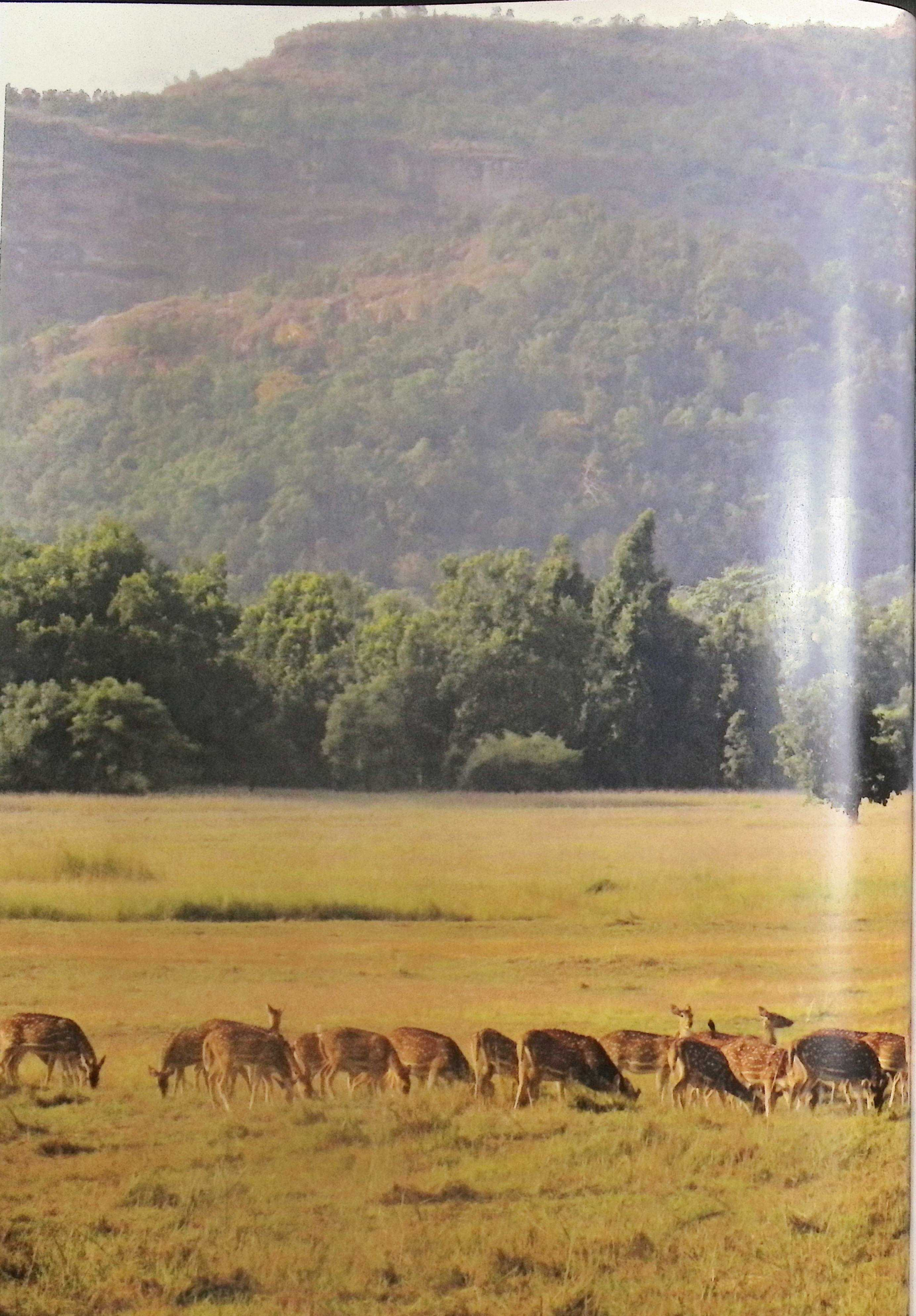
The plant species eaten by gaur and other ungulates (chital, sambar and nilgai) along with camp elephants (n=6) were recorded in gaur home range throughout the study period. Gaur and chital are primarily grazers in most of the protected areas of India as grass dominates in their diet during most of the seasons and the proportion of browse reduced to traces during monsoon (Krishnan 1972, , Reynolds and Hawley 1987, Sathyanarayana and Murthy 1995, Chetri 2006, Haleem and Ilyas 2018, Schaller 1967, Berwick 1974, Sharatchandra and Gadgil 1975, Dinerstein 1979, Johnsingh and Shankar 1991, Padmalal *et al.* 2003). The complete overlap of food resource of gaur with chital may be attributed to their similar feeding habit. The food resource overlap of gaur was observed to be minimum with sambar as compared to other ungulates (chital and nilgai) and camp elephants.

The least overlap with Sambar can be explained as Sambar is a browser (Schaller 1967, Berwick 1974) and grass comprised only a fraction of its diet and that too mostly during monsoon.

Nilgai exhibited a mixed feeding pattern. As the species can subsist on low quality food, survive in sub-optimal habitats and preferred to feed on large open areas interspersed with cover and water (Sheffield 1974), limited food resource overlap of gaur was seen with nilgai.

Gaur and camp elephant have high food resource overlap in Bandhavgarh; this may be attributed to both feeding on common trees, grasses and climber. Elephant has been reported to have impact on woody vegetation as in Kruger National Park, asserting that the woody plant fraction of elephant diets increases in areas with a high ratio of tree to grass leaves (Scholes *et al.* 2003). The study revealed that the area utilized by the elephants and their number was limited small to influence the food habits of reintroduced gaur.

In this study, no prominent food resource separation of gaur with other ungulates (chital, sambar and nilgai) and camp elephants was observed. The reintroduced gaur population is slowly increasing and expanding their ranging area in Bandhavgarh. The density of chital (58.5 ± 8.1 /sq.km), sambar (6.9 ± 1.1 /sq.km) and nilgai (5.8 ± 1.1/sq.km) are less (Krishnamurthy *et al.* 2016) and scattered across the study area. This existing population of gaur in BTR (n=127) is still not a potential competitor for other ungulates. The increasing population of gaur in Bandhavgarh may however influence the feeding habit of sympatric species and camp elephants in Bandhavgarh with time as they will reach carrying capicity. It is important that this aspect of resource competition with ungulates and camp elephants is further studied to ensure long term survival of gaur and sympatric ungulates in Bandhavgarh Tiger Reserve.



CHAPTER 9

CONSERVATION OF REINTRODUCED GAUR IN BTR

The known extinction of gaur from three protected areas in India (Thattakad Wildlife Sanctuary, Kerala; Bandhavgarh Tiger Reserve and Kangar Valley National Park, Madhya Pradesh) in the last two decades is a testimony to the fact that this species is losing ground rapidly and urgent measures are required to stem the process. Conservation of the species requires active programs like reintroduction and re-establishment of important species in the areas where they have been recently lost, with or without habitat related interventions. The reintroduction of gaur in Bandhavgarh Tiger Reserve was an important attempt in the efforts to to establish gaur populations in areas once part of its historical range. The present study highlights an important rather successful ecological step towards the conservation of this large bovid.

The past and present study has drawn the first time information on ranging pattern of reintroduced gaur and their degree of preferences towards different vegetation types in different seasons, which will be very useful for the park administration for effective conservation of this endangered species including habitat interventions, if needed.

The population of reintroduced gaur in BTR has grown over the period from 50 individuals reintroduced during 2011 & 2012 to the present population of 127 (excluding 37 mortalities over the seven year period). A total of 87 calves were born in BTR. Though the population has grown over the years, it calls for studying the genetic composition of the present population to understand their genetic fitness in the long term.

Between 2011-13, two villages namely Kumuruva and Kallwah and subsequently village Milli during 2015 from Kallwah and Magdhi Range were relocated outside the Protected Area. Gaurhave been observed to use these relocated village sites intensively. The study supports the need for having more such sites made available for gaur use through intensifying efforts towards village relocation. Efforts need to be made to relocate the remaining 11 proposed villages from the Tiger Reserve.

Since gaur share common pathogens with livestock, the chances of spillover of pathogens from livestock are high. There is a need to implement preventive health

strategies including vaccination and deworming programme for domestic livestock in and around Bandhavgarh Tiger Reserve. Additionally habitat improvement efforts that support better grassland along with mineral/ vitamin supplementation and better water availability would be beneficial is supporting overall health of Gaur in BTR. Efforts should be in place to minimize interactions between gaur and livestock through appropriate regulations.

Cutting and lopping of food plants species and collection of *Madhuca indica* flower and *Phyllanthus emblica* fruit, inside the buffer areas should be restricted to avoid resource depletion and consequent disturbance. Removal of weeds (*Cassia tora, Lantana camara, Parthenium hysterophorus and Xanthium strumarium*) from the gaur home range areas to improve the forage quality is recommended. It is important to explore possibility of improvement of the corridors between Bandhavgarh Tiger Reserve and Sanjay Tiger Reserve (STR) and Amarkantak Wildlife Sanctuary (AWS) to support movement of animals between PA's.

A long term study on the ecological aspects such as ranging pattern, habitat use, food habits and predation of the reintroduced gaur, genetic makeup and movement ecology in Bandhavgarh Tiger Reserve will be crucial for the conservation and management of this endangered bovid.

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