

Patterns and determinants of elephant habitat use in a
mosaic landscape in Northern Chhattisgarh

A DISSERTATION SUBMITTED TO SAURASHTRA UNIVERSITY, RAJKOT, IN
PARTIAL FULFILMENT OF THE MASTERS DEGREE IN WILDLIFE SCIENCE

JUNE
2019

By

Kushagra Meshram



भारतीय वन्यजीव संस्थान
Wildlife Institute of India



भारतीय वन्यजीव संस्थान
Wildlife Institute of India

CERTIFICATE

This is to certify that **Mr. Kushagra Meshram** has carried out original research from the Wildlife Institute of India, titled "**Patterns and determinants of elephant habitat use in a mosaic landscape in Northern Chhattisgarh**", in partial fulfilment of a Master's Degree in Wildlife Science from Saurashtra University, Rajkot, India. The study was carried out under our supervision from December 2018 to June 2019. We hereby certify that this work has not been submitted for any other degree to any University.

Dr. Bivash Pandav
Scientist F

Dr. Parag Nigam
Scientist F

Dr. Bhai Habib
Scientist E

Date: 30th June 2019

Place: Dehradun

पत्रपेटी सं० 18, चन्द्रबनी, देहरादून - 248 001, उत्तराखण्ड, भारत
Post Box No. 18, Chandrabani, Dehradun - 248 001, Uttarakhand, INDIA
ई.पी.ए.बी.एक्स : +91-135-2640114, 2640115, 2646100 फ़ैक्स : 0135-2640117
EPABX : +91-135-2640114, 2640115, 2646100 Fax : 0135-2640117
ई-मेल/E-mail : wii@wii.gov.in वेब/Website : www.wii.gov.in

DECLARATION

I, **Kushagra Meshram** hereby declare that the research work entitled “**Patterns and determinants of elephant habitat use in a mosaic landscape in Northern Chhattisgarh**”, carried out in partial fulfilment of M.Sc. (Wildlife Science) degree of Saurashtra University, Rajkot is an original piece of research work. This research work was carried out under the supervision of **Dr. Bivash Pandav**, at the Wildlife Institute of India from November 2018 to June 2019. I hereby declare that this work has not been submitted for any other degree of any university.

Date: June 10, 2019

Place: Dehra Dun

Mr. Kushagra Meshram

(XVI M.Sc. Course)

Acknowledgements

I would like to thank the Director, Dean and Course Director Dr. Gopi G.V and Assistant Course Director Dr. Samrat Mondal, XVI M.Sc. at WII for facilitating our course and field work. I would like to express my sincere gratitude to my supervisors, Dr. Bivash Pandav, Dr. Parag Nigam and Dr. Bilal Habib for their suggestions, guidance and support. I am really thankful to Dr. Bivash Pandav for his fatherly support. He has encouraged me to do my work on time and ensured that responsibilities towards family were not compromised during my fieldwork. Dr. Parag has been instrumental in collaring of elephants without which I wouldn't have been able to finish my objectives. I would like to thank Dr. Bilal Habib for his inputs on study design and analytical methods. I am grateful to all the faculty members of Wildlife Institute of India for their valuable inputs throughout the entire course.

I am indebted to the support I got from N. LakshmiNarayanan, both in field and during analysis due to which I was able to submit my thesis on time. I would like to thank Rewat Lal, my field assistant and Researchers, Ankit Kumar and Jayjit for their company in field. I thank Shyam Lal and his family for how they ensured that I don't have to worry about food in the field. Constant support from all my classmates has been of great help. I would like to especially thank Coffee Friends, Abir, Bhavya, Doli, Sutirtha and Sakshi for always being there for me.

Here at WII, I would like to thank Keshab Gogoi, Nilanjan, Arun Kumar and UdhayRaj for their help in analysis and GIS. I would extend my sincere gratitude to Chhattisgarh Forest department for being helpful throughout the study. Shri Kishore Kumar Bishen, I.F.S. and Shri P. Arvind have provided support whenever it was required in field.

Words can not adequately express my gratitude towards my grand mother, mother and sister who have been a constant source of support. My friends Ajay, Raja and Ankur have been a source of laughter even in the toughest times of field. Finally, I would like to thank my Father, Late Shri Dhananjay Meshram who encouraged me to join this course and whose teachings will always be the guiding light of my life.

At last, To thee O' mother Nature I shall eternally be Grateful.

TABLE OF CONTENTS

SUMMARY	VII
INTRODUCTION	1
CONFLICT AND CROP RAIDING:	2
HOME RANGES AND SPATIO-TEMPORAL HABITAT USE OF RADIO COLLARED INDIVIDUALS.	3
OBJECTIVES:	5
STUDY AREA:	6
PHYSICAL FEATURES:	6
CLIMATE:	6
VEGETATION:	6
INTENSIVE STUDY AREA:	8
METHODOLOGY	9
FIELD METHODS:	9
VEGETATION SAMPLING:	9
ELEPHANT PRESENCE	10
SATELLITE COLLARED INDIVIDUALS:	10
GIS-BASED METHODS:	11
ANALYTICAL METHODS:	11
USE OF FOREST PATCH BY ELEPHANTS:	11
CROP RAIDS AND CONFLICT:	12
SPATIO-TEMPORAL DAY-NIGHT HABITAT USAGE:	12
HOME RANGE:	12
RESULTS:	13
VEGETATION	13
VEGETATION DENSITY:	13
CROP RAIDING AND CONFLICT:	15
HOME RANGE:	19
DISCUSSION:	20

FIGURES

FIGURE 1: DOTPLOT OF SPECIES RICHNESS FOR EACH PATCH, WITH CONFIDENCE INTERVALS	13
FIGURE 2: DOTPLOT OF TREE DENSITY PER HECTARE FOR EACH PATCH	14
FIGURE 3: BARCHART OF NUMBER OF RAIDS BY ELEPHANTS ON DIFFERENT CROP SPECIES.	16
FIGURE 4: BARCHART OF PERCENTAGE OF POINTS IN DIFFERENT HABITAT TYPES BY TIME, FOR PYARE.	17
FIGURE 5: BARCHART OF PERCENTAGE OF POINTS IN DIFFERENT HABITAT TYPES, BY TIME, FOR BEHRADEV	18
FIGURE 6: BARCHART OF PERCENTAGE OF PLOTS IN EACH HABITAT TYPE FOR DAY AND NIGHT FOR BOTH COLLARED INDIVIDUALS.	19

MAPS

MAP 1: MAP OF STUDY AREA.....	6
MAP 2: INTENSIVE STUDY AREA.....	9
MAP 3: MAP OF DAY/NIGHT LOCATIONS OF PYARE WITH ELEPHANT HERD.....	17
MAP 4: MAP OF DAY/NIGHT LOCATIONS OF BEHRADEV	18
MAP 5: MAP OF HOME RANGES OF BOTH COLLARED ELEPHANTS (PYARE IN RED, BEHRADEV IN BLUE).....	19

TABLES

TABLE 1: SUMMARY OF GLM OUTPUT FOR MODELLING USE OF FOREST PATCHES BY ELEPHANTS.....	15
--	----

Summary

Habitat use help us to understand the interaction between animals and different biotic and abiotic factors available to it. Habitat use is affected by a wide range of factors, like the amount of resources available, its distribution in space, quality of resource, presence and absence of limiting factors like roads and settlements. Increasing anthropogenic pressure has lead to the degradation of the habitat available to animals in the form fragmentation of forests, introduction of invasive species and reduction in the quality of the available forage. This in turns alters the composition and modify the natural systems. This modification of habitat may compel animals to alter the way they use it by adopting new strategies. On these lines, I did my study on assessing the factors that influence habitat use of elephants in a mosaic landscape in Northern Chhattisgarh.

The study was carried out in Surguja district of Chhattisgarh. This district is famous has been infamous for elephant conflict since 1900s. The problem has exacerbated due to rapid urbanisation, increasing population and alteration in land use. Today, it is one of the most human-elephant conflict affected area in country. This is a repercussion of wanton modification of natural habitat. How elephants are interacting with this modified habitat which is a matrix of remnant forest patches, agricultural areas and settlements is the crux of my study. In order to to study this, I selected a study area of 1200 square kilometres. As a part of the study I also followed two satellite Collared individuals(one living with a herd and the other, a solitary male) to understand spatio-temporal habitat use and ranging behaviour of elephants. I also collaborated with Indian Space and Research Organisation for my study. High resolution land-use maps were provided by ISRO for this study. The field work was carried out from 21st December 2018 to 15th April 2019. GIS based work was done in the GIS lab of the Wildlife Institute of India, Dehradun.

To understand the use of forest patches I identified 37 forest patches of different sizes in the study area. Vegetation sampling for species richness and density was carried out in order to assess the quality of vegetation. Crop raids by elephants were recorded inside the study area. Information about elephant presence was obtained from the satellite

collared individuals, direct sightings and an established elephant monitoring network run by Chhattisgarh Forest Dept. with the help of villagers. Unsupervised classification was done in order to delineate area under crop during the study period. Softwares “ArcGIS” and “R” were mainly used for doing the analysis. The study showed that the elephant use of forest patches was determined mainly by the distance to water from a forest patch. It showed an inverse relationship which means that elephants are staying in those forest patches for longer duration which have water sources at proximity. Elephants were found to be using the patches as “refuge” areas during day and were raiding crop fields during night. This strategy has been adopted by elephants in the area in response to the modification of its original habitat. Home ranges of both collared individuals were found to be similar in size. The incidences of crop raiding were found to be the repercussions of the modification of habitat. Frequency of raids on sugarcane were found to be highest. This is attributed more to the availability of the sugarcane in the area and not on the selection by elephants. Many anecdotal information, beautiful sightings and photographs also came out as the result of this study.

Introduction

Mega herbivores like elephants require large areas (Williams *et al.*, 2008; Alfred *et al.*, 2012) to meet their ecological requirements and to perform their life history strategies (Rood *et al.*, 2010; Steinheim *et al.*, 2005). However, elephants are facing challenges due to loss of habitat caused by expanding human populations and growing resource demands (Sukumar, 2003). Landscape fragmentation is a process that results in reduction of habitat into small bits, and/or increased isolation of habitats (André'n, 1994), creating a mosaic of forests, agricultural areas and human settlements (Levins, 1969). Habitat fragmentation has been recognized as one of the major threats affecting elephant habitats across their distributional range (Leimgruber *et al.*, 2004). Fragmentation leads to opening up of forest for human use. Often, human populations also reside near these fragments and their livelihoods are closely dependent on these remnant forests (Banerjee & Madhurima, 2013). Once occurring in large wilderness, today Asian elephants occur in isolated populations across much of their historical ranges (Sukumar, 1989; Riddle *et al.*, 2010). Elephants, being generalist species, can adapt themselves accordingly in these modified landscapes (Bal *et al.*, 2011). Further, the fragments may be highly degraded due to penetration of edge effects and thus, turn into sub-optimal habitats with inadequate food resources to support elephants (Sukumar, 1990). The selection of habitat by elephants is dependent upon many factors, which include extent of available resources and their quality. Further, factors such as the composition of habitat mosaics and the context of their spatial arrangement also influences elephants' use of habitat patches (Okello *et al.*, 2015). There is a plethora of elephant-habitat studies carried out across different ecological settings during the last 50 years or so. 'Habitat use' and 'habitat selection' are effective state variables, which are comparatively simple to assess. There are various approaches to assess habitat selection both in the field and analytically as well. One of the widely used approaches is to compare "use" with "availability". Habitat selection is a hierarchical process and can be assessed at different levels. Johnson (1980) provides an elegant framework to study habitat selection by ordering selection process in a hierarchical manner: First order selection pertains to selection of geographical range by a species in a larger landscape, second order selection pertains to selection of home ranges within a distributional range (the metric occupancy), third order selection pertains to usage of habitat components within home range (habitat use) and the fourth order

selection deals with fine-scale behavioral mechanisms involved in use of resource patches (Johnson, 1980). It presents an opportunity to us to study use of habitat by animals at different scales (Manly *et al.*, 2002). The interaction between humans and elephants are repercussions of elephants' use of habitat in response to modification done to it by humans. In order to advance conflict mitigation solutions, particularly in human-dominated landscapes, an understanding of how elephants use / select a mosaic landscape is fundamental.

Conflict and Crop Raiding:

While there could be several drivers of human–elephant conflict, there is an increased consensus that habitat-related threats like fragmentation, and degradation are usually the first trigger (Desai & Riddle, 2014, Desai, 1991; Madhusudan, 2003). According to IUCN/SSC African Elephant Specialist Group (AfESG), the broad definition of Human elephant conflict (HEC) is “*any human-elephant interaction which results in negative effects on human social, economic or cultural life, on elephant conservation or on the environment*”. Conflict is severe in areas that are witnessing increased land-use changes that are incompatible with elephant conservation and intensification of agriculture, thereby exerting enormous pressure on remnant natural habitats (Hoare & du Toit, 1999; Sitati *et al.*, 2003). Human-Elephant conflict includes depredation of cultivated crops, damage to property and also direct threats to lives of people as well as elephants involved in conflict (Sukumar, 2003). Communities living in close proximity to natural systems with wildlife are more susceptible to conflict (Karanth, 2005). Studies show that factors like rainfall, availability of surface water, extent of anthropogenic disturbance, availability of cultivated crops and vagaries of seasons influence habitat selection by elephants. Similarly, suite of ecological and anthropogenic factors could explain crop raiding patterns by elephants. For example, in the Western Ghats of South India, distance to water from village, crop variety and movement pattern were correlated with intensity of crop raiding by elephants (Sukumar,1990). While in Africa, Hoare (1999) did not identify any strong spatial correlates and suggested that individual behavioural idiosyncrasies may drive crop raiding patterns of elephants. Population density of humans and elephants may also influence conflict (Smith & Kasiki, 1999). Sitati *et al.*, (2003) found the occurrence of conflict and its intensity to be related

to areas of cultivation and proximity to towns and roads. Rainfall was the best predictor for elephant habitat use in African savannah (Hoare, 1990). However, in Western Ghats, rainfall was not playing a major role in determining the habitat use by elephants but elephant habitat use was higher near the riverine areas (Jathanna *et al.*, 2015).

Crop raiding by elephants may be influenced by the nutritional stress caused by a decline in the quality and nutritive value of natural forage. In this case, crop raiding maximises nutrient uptake during periods of scarcity (Osborn, 1998). High level of nutrition in crops (Sukumar, 1990), and lower levels of toxins and secondary metabolites (Osborn & Hill, 2005) may attract elephants to the crop fields. However, the availability of crops in certain periods acts as a pull factor for elephants and is independent of changes in the forage in natural systems (Sukumar, 1989). In land use with rotational cropping pattern, the availability of crop may change with seasons. Crop raiding is found to be seasonal, coinciding with the time of ripening of crops (Chiyo *et al.*, 2005; Balasubramaniam *et al.*, 1991; Sukumar, 2003). Elephants' life history traits and behavioral differences between individuals also influence crop raiding. A few males are known to indulge in crop raiding more than the family groups as a few individuals follow a "high risk-high gain" strategy. While females and herds take less risk as they move with their calves and resort to "low risk-low gain" strategy (Sukumar, 1990; Chiyo *et al.*, 2005). While raiding crops, elephants tend to be more vigilant near human habitations (Kumar, 2010). Crop raiding is also influenced by group type and age of the elephant. At the individual level, the observed variation could be explained only by the idiosyncratic behaviours of individuals (Srinivasaiah *et al.*, 2012). Crop raiding is also influenced by the light conditions. Night provides an excellent cover for elephants to sneak into fields. From the above studies, one can get a fair idea that the determinants of elephant habitat use and crop raiding are landscape specific and are dependent upon many features like the availability of crops, availability of forage inside forest, their life history strategies physiological factors and individual idiosyncratic behaviours.

Home Ranges and spatio-temporal habitat use of radio collared individuals.

The spatial scale of animal space use, measured as individual home range size, is an important metric with key implications for ecological and evolutionary processes as

well as management and conservation of elephants. Home range size has therefore gained great importance in ecological research. Home range is defined as '*that area traversed by the individual in its normal activities of food gathering, mating, and caring for the young*' (Burt, 1943). Loss of its natural habitat, fragmentation, degradation, conversion and resource exploitation due to anthropogenic activities has led to change in the available habitat for wild species. Large scale conversion of forests to croplands and developed areas alter the space use and also the temporal pattern of space use. In such mosaic landscape understanding the relationship between different land use categories like settlements, croplands and forested areas and the temporal habitat use is an important area of research (Hoare, 1999).

Studies suggest that elephants use different land use classes at different times of the day (Hoare, 1995; Osborn, 1998; Sitati *et al.*, 2003; Barnes *et al.*, 2006). There are studies that assess interactions between wildlife at the landscape scale from seasonal or annual aerial counts that give insights into the daytime distribution and relative abundance (e.g. Parker & Graham, 1989; Hoare & Du Toit, 1999). Ground transect data provides patterns of distribution in relation to different habitat characteristics. However, neither provides insights on the finer-scale spatio-temporal habitat use in mosaic landscapes. Recent technological developments have enabled high-resolution global positioning system (GPS) tracking, allowing researchers to establish over a 24-h period where tagged animals spend their time.

With this in mind, I chose a study area that has undergone modification of its natural habitat and is being used by elephants which is causing conflict. The study area chosen is a mosaic of different land-use types. This presents an opportunity to study elephants' habitat use in such mosaic landscapes which are becoming ubiquitous. This can help in having a better understanding of the use of such mosaic landscapes by elephants and may help in finding mitigation measures that may ameliorate human-elephant conflict.

Objectives:

Considering the fact that Surguja district is subjected to intense human elephant conflict and elephant habitats there occur in patches, I carried out this study with following objectives:

1. To assess the macro scale habitat use of elephants at landscape level:

Research Questions:

1.a. What factors determine the use of forest patches by elephants?

1.b. Which crops are being raided by elephants in the landscape?

2. To assess the spatio-temporal habitat use of satellite collared Individuals:

Research Questions:

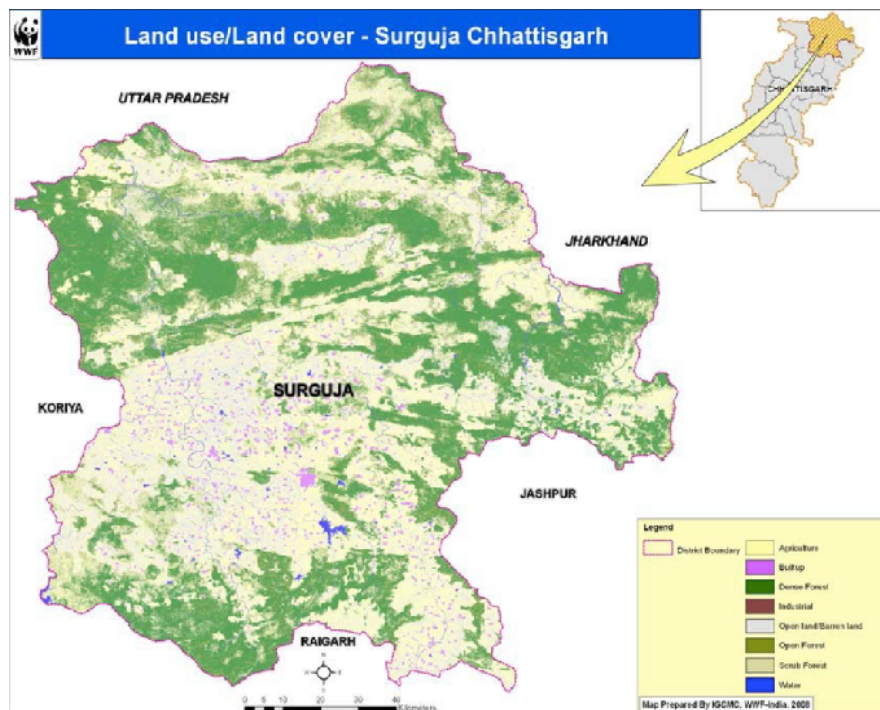
2.a. What are the home ranges of the satellite collared Individuals?

2.b. How does habitat use change temporally (Day/Night) ?

Study Area:

Physical Features:

Situated in the northern part of State of Chhattisgarh, Surguja and Surajpur district extends between south-eastern parts of Vindhyaachal- Baghelkhand region of peninsular India. Much of this landscape is an extension of Satpura hills. The highlands of Surguja District have a unique 'Pat formation' (Messa) and high land with small tablelands. Average altitude is around 600m above sea level. The region is hilly in the west and



Map 1: Land use map of study area, Surguja forest Circle, northern Chhattisgarh

comparatively undulating as we move eastwards. The district bears sandy soil in most parts; whereas, black soil is scarcely available.

There are four river basins in Surguja district

–Hasdeo, Rihand,

Mahaan and Kanhar. (Jadhav *et al.*, 2013)

Climate:

The climate of the district is hot in summer where mercury rises to 40°C and in winter temperature lowers down to 1.3° C. The area receives rainfall from South West Monsoon. Average rainfall is about 200-300cm. Humidity can range from 27% to 83%

Vegetation:

Surguja is rich in its forest resources. About 58% of the area in the district lies under the forest. Surguja is rich in its forest resources. The vegetation

consists of 32 families of plants and trees. Dry deciduous forest is the dominating forest type. Species like Teak (*Tectona grandis*), Sal (*Shorea robusta*), Bija (*Pterocarpus marsupium*), Saja (*Terminalia tomentosa*), Dhawarda (*Anogeissus latifolia*), Bamboo (*Dendrocalamus strictus*), Tendu (*Diospyrus melanoxylon*), Mahua (*Madhuca indica*) and Amla (*Embilica officinalis*) are dominant species (Shrivastav *et al.*, 2015).

Demography:

Surguja district has a population density of 150 inhabitants per square kilometre (390/sq mi). Its population growth rate over the decade 2001-2011 was 19.74%. Surguja has a sex ratio of 976 females for every 1000 males, and a literacy rate of 61.16%. About 90% of the working population depends on agriculture, in which 50.36% of working population are of cultivated and about 12.77% of the region are agriculture labourers. Major tribes of Surguja region are *Nagesiya, Baiga, Kanwar, Panika, Korwa and Uraon*. (Census Report, 2011)

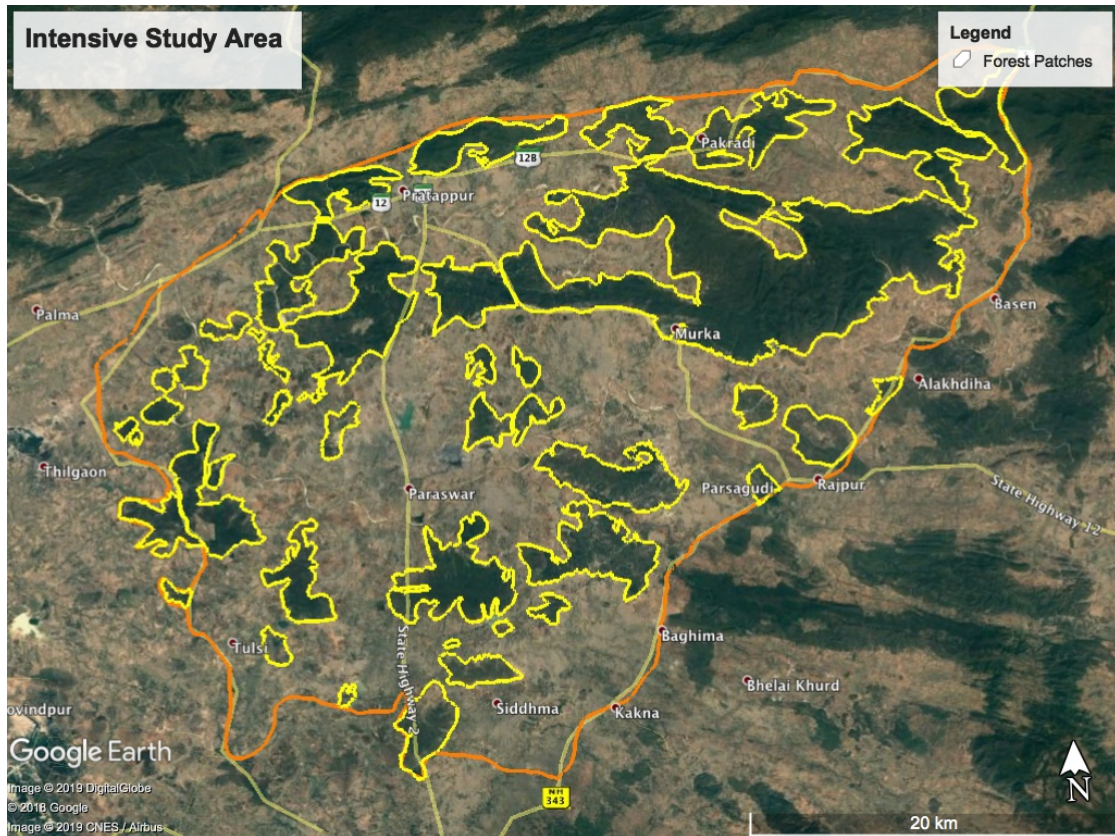
History:

The chapter on elephants in Arthashastra ranks eight forests on the basis of the quality of elephants found in them. The Elephants of central and eastern India were of middle and best quality given their size, accessibility and flexibility to be used as war elephants. The Mughal rulers' love for elephant has been documented in Abul-Fazl's *Ain-a-Akbari*. Historically, central Indian and South Indian forests have maintained high population of elephants given their large area and intactness. Mughal historians have marked 41 different elephant forests. One among them is of 'Bhatta and Surguja' princely states which were under the then Rajput kings. This region lies presently in the northern part of Chhattisgarh. It is spread in the administrative districts of Surguja, Korja, and Surajpur (Trautman, 2015). In the past, Surguja has had a history of supplying wild elephants to the Mughal armies. (Xalxo, 2016). In his book, *Highlands of Central India* (1872), Capt. James Forsyth has mentioned about Asian elephants distributed across the landscape in great numbers in a chapter titled "An exploration of far east". He had written in detail about conflict with elephants, causing havoc in the rural farms and terror

amongst the people. Post Independence, increase in the population and dependence on the forest had caused fragmentation and exacerbated the problem for elephants as well as humans. In view of this in 1980s Elephant Capture operations were done in order to capture wild and problem elephants and to use them as 'kumkis'. This has also been documented in Mike Pandey's Green Oscar winning documentary, *The Last Migration*. Elephants have started to recolonise their old distribution ranges. The conflict is aggravating due to the fragmenting forest, land use change, increase in area of crops and low level of traditional knowledge in the present tribal communities.

Intensive Study Area

The intensive study area spreads over 1200 square km. and roughly constitutes the home range of a large herd of elephants that Wildlife Institute of India has been intensively monitoring in collaboration with Chhattisgarh Forest Department since the year 2017. Thus, in this study, I assessed 3rd order selection of habitats by elephants, wherein, their use of various elements of the landscape within an area that roughly falls within their home range was studied. The study site was chosen keeping in mind the research questions and the presence of elephants in the area. A suitable site was selected that represented a landscape with forest patches of different sizes. Crop pattern in the area was also taken into consideration. For highly mobile species like elephants with large home ranges, deciding extent of study area is a challenge. Keeping the accessibility in consideration, the study area was confined between 3 highways viz. NH-343 (Rajpur road), AH-12B (Balrampur road) and State Highway-2 (Banaras road). However, the forest patches that were being intersected by the roads were also kept as they form a part of a contiguous forest patch that are used by elephants.



Map 2: Intensive Study Area

Methodology

Field Methods:

Vegetation Sampling:

Random points were laid on each forest patch using ‘Random points’ tool in ArcGIS. This was done in order to randomise the sampling effort and to eliminate bias. A circular plot of 10 metre radius was laid at each random point. Vegetation sampling was done for trees and shrubs by counting the number of individuals of each species that occurred within each 10 metre plots. This was repeated until a species accumulation curve was reached for each patch. Species accumulation curve was made in Software R with the help of “Vegan” package.

Elephant Presence

An elephant conflict management group with staff and local village volunteers was actively patrolling the area to document the presence of elephants. Additionally, radio collared elephants were being monitored. Information on elephant presence from their reports was collated on a day-to-day basis to find out the presence of elephants in different patches. Real time information of raiding incidents by elephants was obtained from an established elephant monitoring network run by the Chhattisgarh Forest Department with the help of villagers, wherein the locations and sightings of elephants are reported immediately to a centralised server. This provides real time information of raiding incidences by elephants and also the forest patch being used. Once the information about raiding was received, the site was visited at the earliest and information like crop variety, number of elephants and time of raiding were recorded. In cases where direct sighting was not possible, validation through Forest Department personnel at the site and villagers was carried out in order to obtain an approximate number of elephants that were using a patch. Moreover, the villagers depend on the forests for fodder, firewood and others and they promptly report the presence of elephants to the forest department field formations. All these information were pooled and the sites were visited to validate the presence of elephants in forest patches.

Satellite Collared Individuals:

Wildlife Institute of India has collared three elephants in the landscape as part of their on-going long-term research project on elephants in Chhattisgarh. The collars had an inbuilt GPS device and a satellite transmitter to record location fixes. This technology allows locations to be transmitted through satellite and retrieved in a computer any time of the day. The satellite GPS collars were supplied by Savannah Tracking, Kenya. A counterweight on the collar ensured that the functioning parts of the unit stayed on top of the elephant's neck to allow a clear path of signal reception from the satellites. The entire collar weighed between 13–15 kg, a minimal weight to be carried by a three-ton (3,000 kg) elephant. Elephant locations of a herd and a solitary bull were recorded for a period

of 4 months starting from December 15th, 2018 to April 15th, 2019. Collars were programmed to provide 24 locations at every 1 hour interval.

GIS-based methods:

Indian Space and Research Organization has been working with WII and Chhattisgarh FD and developed a high-resolution Landuse landcover map for elephant ranging divisions in the state. The Land use land cover map of the study area has the following land use categories viz. cropland, forest, water bodies (rivers, ponds, lakes, canals), mining areas, and sandy areas mapped at 10 m resolution.

- 37 forest patches were identified on the basis of their contiguity, fragmentation and keeping in consideration the basic behaviour and biology of elephants.
- The extent of net sown area inside the study area was identified by doing an unsupervised classification in software Arc Map.
- Based on the results received from the ongoing elephant project, it was found that elephants on an average move up to 1 kilometre from the patch in order to raid crop (unpublished). They move farther distances too if they move between patches. Thus a 1-kilometre buffer from the forest patch boundary was made around each patch with the help of “Buffer” tool in ARC GIS. In each buffer, the area under crop was extracted. This was converted into proportion by dividing total area under crop inside buffer by the total area of the buffer).
- Similarly, NDVI, ruggedness, elevation for each patch and the distance to water, size of the forest patch was also calculated. These were kept as the predictor variables for the study.
- The response variables was number of days elephants spent in a patch – a count variable.

Analytical Methods:

Use of Forest Patch by Elephants:

In order to study the use of forest patch by elephants, All the explanatory variables were tested against each other and against the response variables in order to check for collinearity through Pearson Correlation Test. To assess the influence of independent variables on the response variables, I used Generalized Linear Regression with Poisson family to build ecological models. I used Information Theory approach and compared Akaike Information Criteria (AIC) to select the most suitable model that has the least AIC scores. The AIC values of different models were compared with AIC of null model.

Crop raids and Conflict:

Each incident was characterised by the variety of crop raided and a bar-plot was made in Software R for the crop raiding incidences.

Spatio-temporal Day-Night habitat Usage:

From the telemetry data, the elephant locations from 6:00 hrs to 18:00 hrs were taken as day time locations whereas from 19:00 hrs to 5:00 hrs were taken as night time locations. Based on this, the day and night locations were plotted over the land-use map in order to assess the location points against each land class. The total number of points against each land class were quantified. A bar plot was made in Software R to see the difference in day and night time habitat use. The location points were plotted on map in order to better visualise the spatio-temporal habitat use.

Home Range:

Total number of elephants locations at the rate of 24 per day were plotted over the Land use-land cover map. Home Range was obtained through the Minimum Convex Polygon(MCP) tool in Software ArcGIS. A 95% Minimum Convex Polygon was taken in order to remove the incidental errors due to technical issues. The home ranges of the two collared individuals were plotted on a map for better visualisation.

Results:

The total extent of study area is of 1200 square kilometres. I surveyed a total of 37 patches. The sum total of all the 37 patches is 483 square kilometres and the average patch size is 13.05 square kilometres.

Vegetation

Species richness inside each patch was calculated using Bootstrap species richness estimator. Bootstrap method has been found to be suitable for small sample sizes. The species richness was highest in Singhra_left patch (naïve count=13), Pakridih(12), Pandrinad(11), Nawki (10), Kewara (10), Bansipur (10), Bharda (10), large patch (10), Dhaura (10), while lowest in Chemi Patch (naïve count=5), Duppi left(5), Duppi right(5). (Fig. 1) shows the species richness value of each patch.

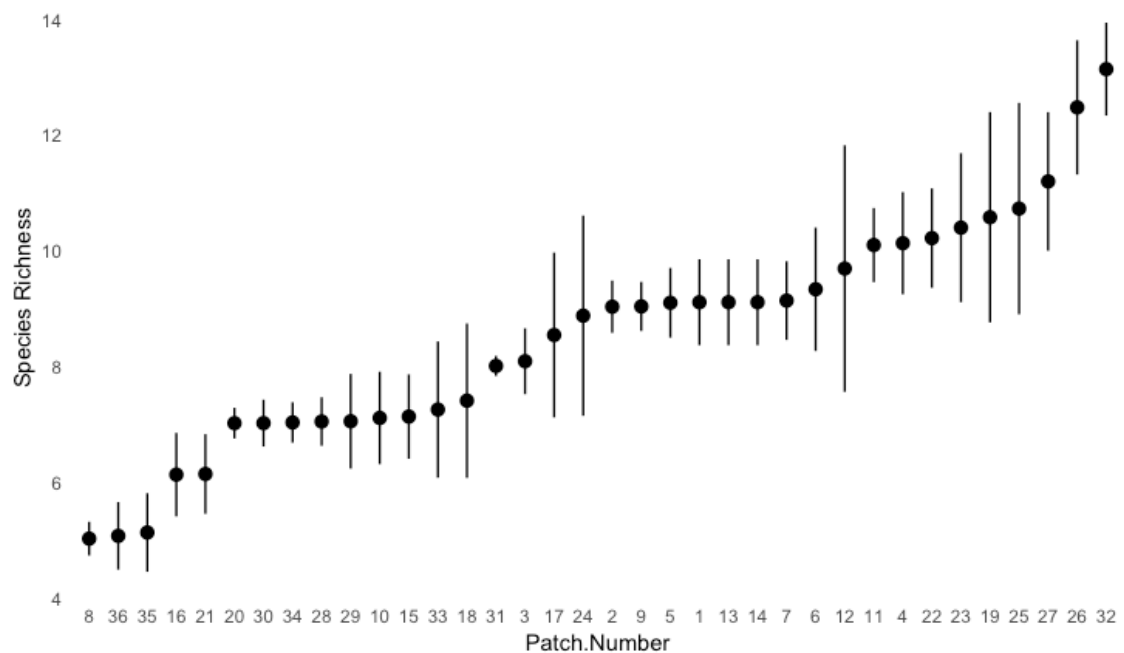


Figure 1: Dotplot of Species Richness for each Patch, with confidence intervals

Vegetation Density:

The vegetation density of trees and shrubs inside patches ranges from 50 to 400 trees per hectare. Vegetation density was highest in Khodro and Rewatpur patches while Dharampur and Durati Right patch had the lowest vegetation density.

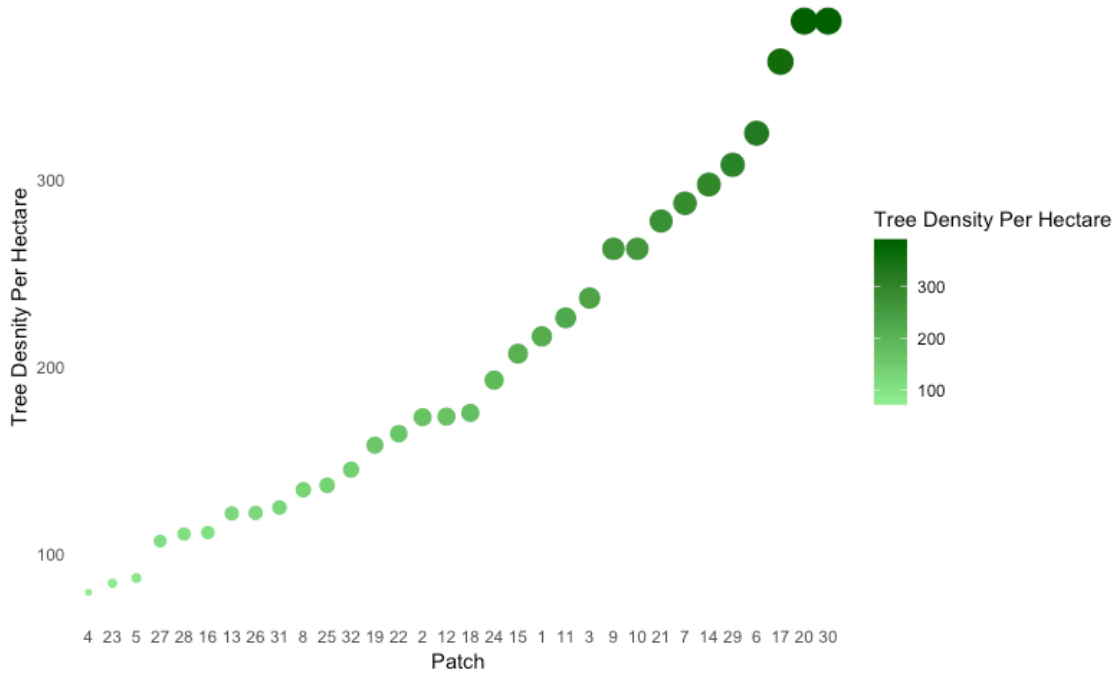


Figure 2: Dotplot of Tree Density per Hectare for each Patch

Determinants of Elephant use of forest patches in a mosaic landscape

Model with distance to water as a predictor turned out to be the most significant in predicting the observed patterns of habitat use by elephants in mosaic landscape (Delta AIC = 0, R2 = 0.20) (TABLE-2). The slope parameter of the best-fit model was as per the expected directions wherein the probability of habitat use by elephants increased with decreasing distance from the water body (Slope = -0.54, SE 0.04). The other predictors that I used to fit models, elevation of the patch, NDVI, Area of patch, vegetation diversity and distance to nearest patch did not turn out to be significant (Table 2). For the best model, the dispersion factor (null deviance divided by residual deviance) is 0.79 suggesting no evidence for overdispersion.

TABLE 1: SUMMARY OF GLM OUTPUT FOR MODELLING USE OF FOREST PATCHES BY ELEPHANTS

Model	Response Variable	Explanatory Variables	Null deviance	Residual deviance	AIC	Pseudo R²
p3	Days Elephant Spent	dswater	506.36	402	463	0.2060
p12	Days Elephant Spent	PatchArea	506.36	447.41	508	0.1172
p2	Days Elephant Spent	NDVI	506.36	463.15	524	0.0853
p4	Days Elephant Spent	CropProp	506.36	473.15	534	0.0655
p13	Days Elephant Spent	elevation	506.36	497.39	558	0.0177
p1	Days Elephant Spent	1	506.36	506.36	565	1
p14	Days Elephant Spent	patchdist	506.36	504	565.74	0.0046

Crop Raiding and Conflict:

A total of 392 incidents of crop raids were recorded during the study. All the major crops found in the area were raided by elephants. The area of the field did not play any role in making a crop more or less vulnerable. The crops raided were sugarcane, Pigeon pea, banana, potato, pea, mustard, paddy, and wheat. It was found during the study that elephants were not targeting a particular crop but were attracted by the croplands and foraging any crop that they can feed upon. There have also been incidences of elephants breaking houses and feeding on stored grains and salt. This behaviour by males has been reported from many places. However, cases of large herds surrounding a house and breaking is unique. It is not based on the availability of different crop. Incidences of

sugarcane raid were highest as the major crop in the study area was sugarcane. The reason for such pattern may also be attributed to the placement of sugarcane fields which were in areas near to forest patches and also away from settlements.

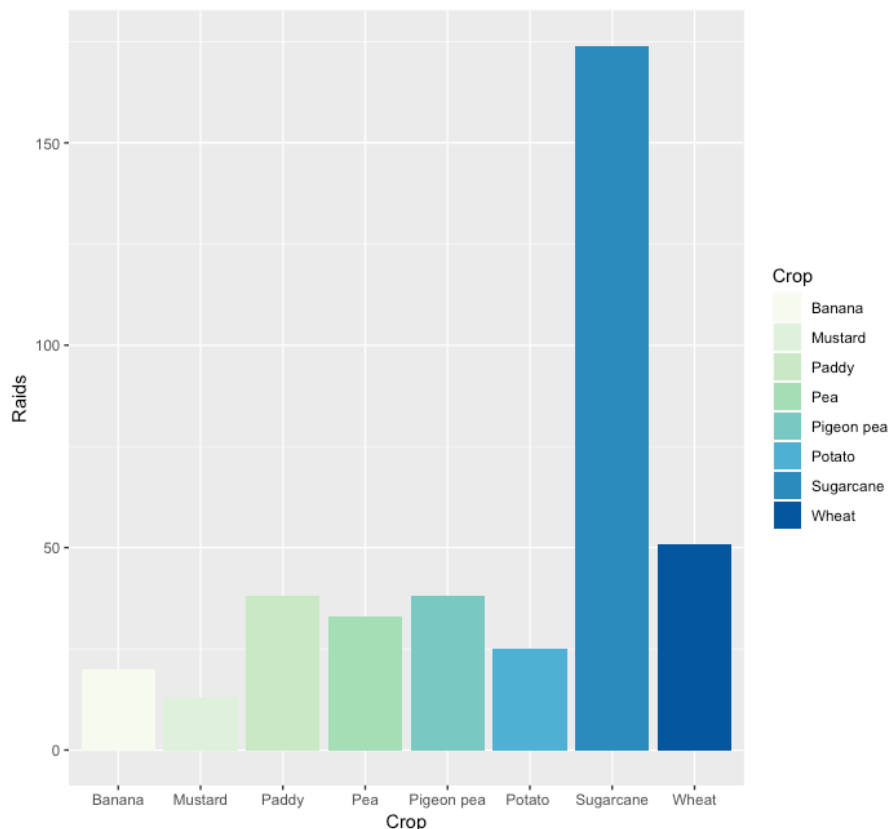


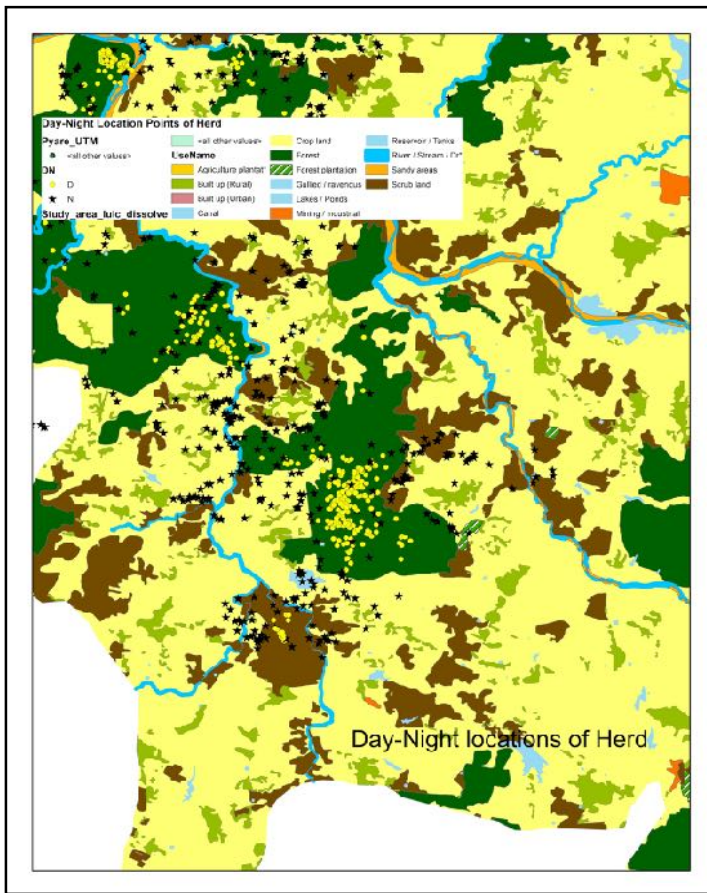
Figure 3: Bar chart of number of raids by elephants on different crop species.

Spatio-temporal habitat use

Total number of GPS locations of the solitary bull, “Behradev” during the study period of 4 months (from 15th November 2018 to 15th April 2019) were 2800 out of which 48.18 % of points fall within forest areas (patches), whereas only 19.82% points fall within forest in the night time. 1.37 % of points fall within cropland during the day whereas 26.65% of points time locations fall in cropland (Crop Area) during night time.

Total number of GPS location points of Pyare (the elephant with herd) during the study period (4 months from 15th November 2018 to 15th April 2019) were 3500 out of which 32.17% of day time locations fall within forest areas (patches) whereas 42.79% night time locations are within forest areas at night time. 0.36% of points are within the cropland in the day time whereas 18.52% of the points fall within the cropland at night.

This indicates that there is an increase in the proportion of locations in cropland during night time.



Map 3: Map of day/night locations of Pyare with elephant herd

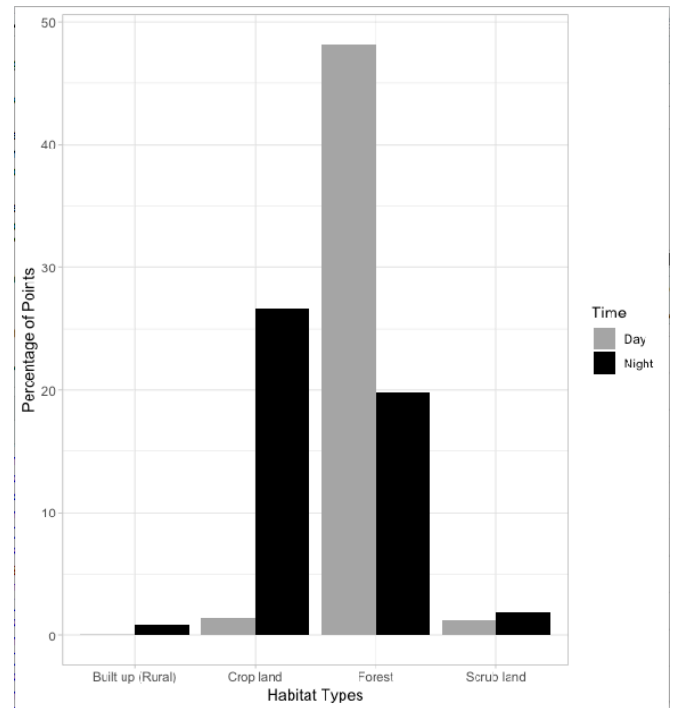
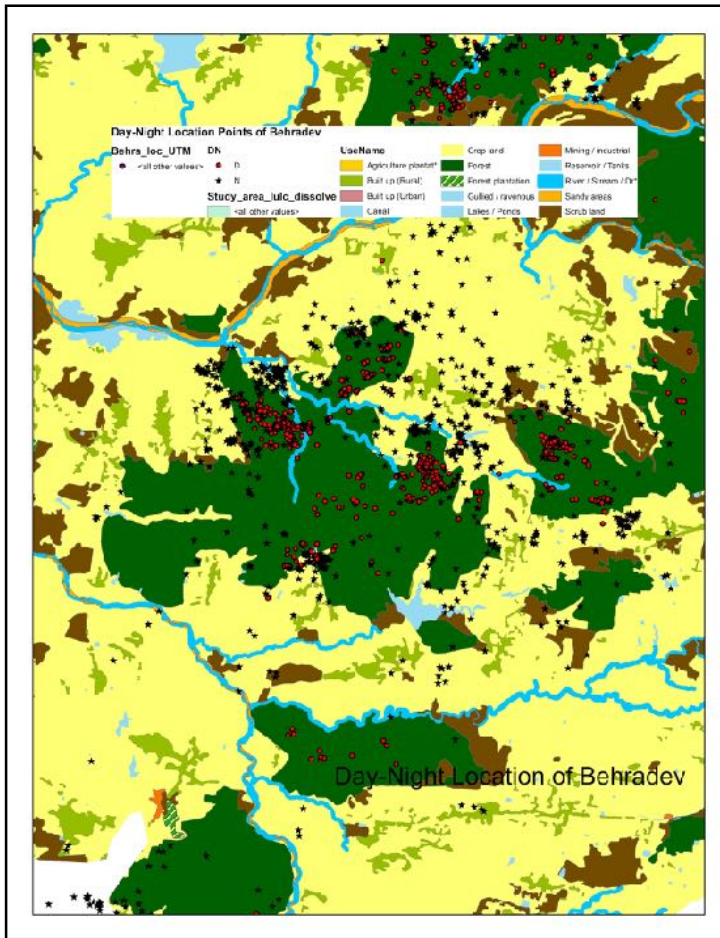


Figure 4: Bar chart of percentage of points in different habitat types by time, for Pyare.



Map 4: Map of day/night locations of Behradev

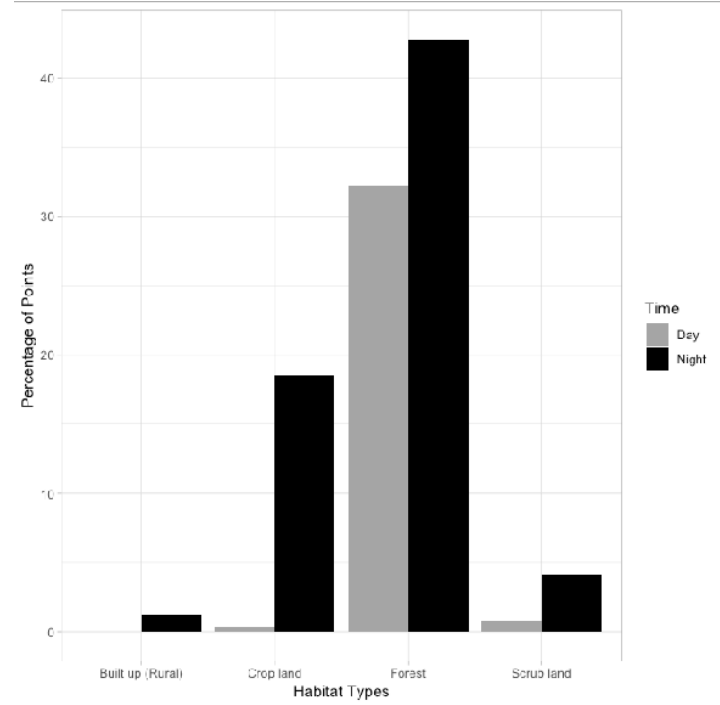
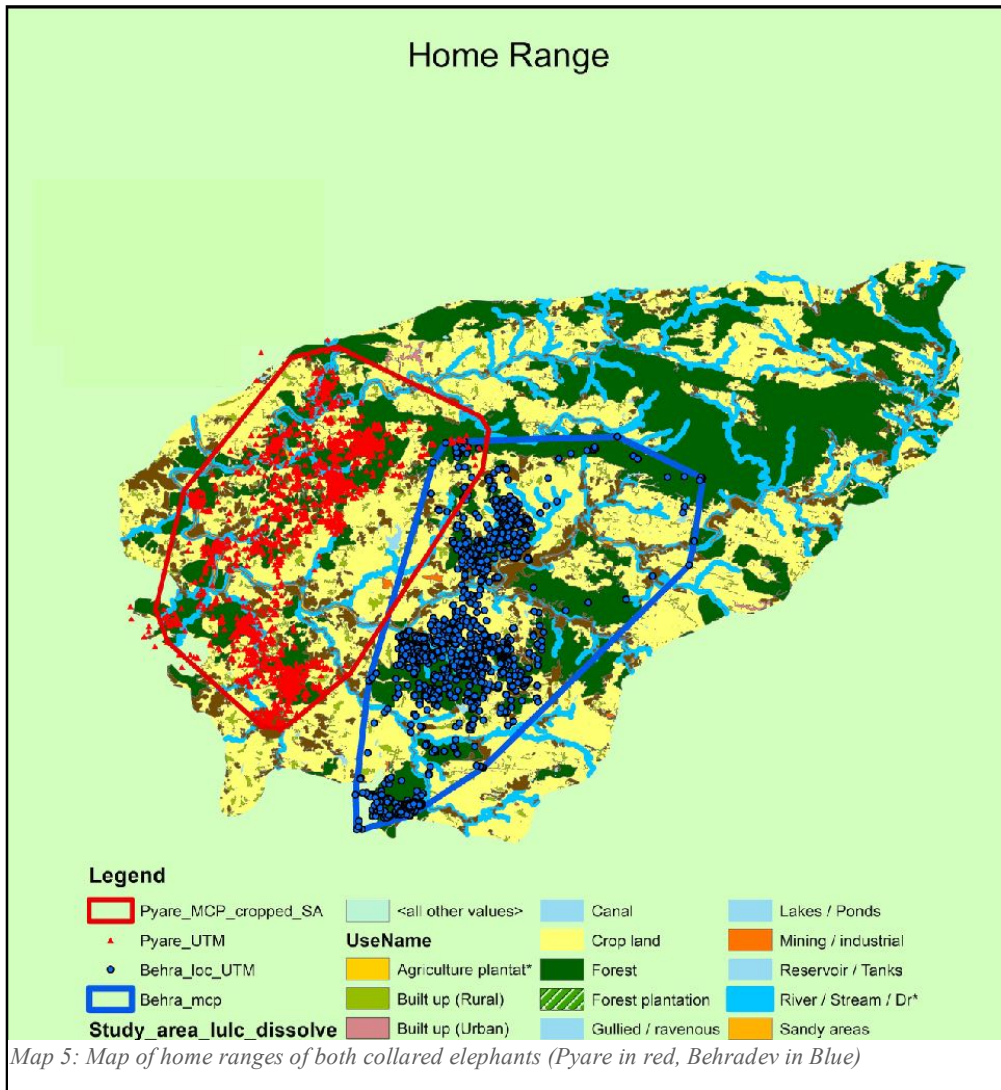


Figure 6: Bar chart of percentage of points of Behradev in different habitat types, by time.

Home Range:

The findings from the study suggest that the herd was ranging in a total area of 311.2 square kilometres while the solitary male “Behradev” had a similar home range of 323.5 square kms. Herd showed high use in the western part of the study area and did not cross Pratappur road even once during the study period, whereas Behradev was ranging in the central region of the study area. There is also a slight overlap between the home ranges. However, no interaction was observed during the study period.

The following map (Map: 5) shows the distribution of elephant locations and the home ranges of both animals.



Discussion:

The state of Chhattisgarh reportedly supports a population of around 250 elephants (Sync. Elephant Census, PE, 2017). This population is contiguous to elephant populations in the state of Jharkhand, South West Bengal, Odisha and Madhya Pradesh. There is frequent movement of elephants across the state. This elephant population has been found to be residing in the fringes of forest and in mosaics of agriculture and human settlements. There is a dearth of literature available on the habitat use by elephants in such landscapes where there is no clear cut boundary of forest and human settlements unlike in South, North East and North India with large and intact protected areas.

Elephants are known to forage on a variety of plants, shrubs and grasses and eat selective parts of different plants. Sukumar, (1985) estimated that out of the 112 food species, 25 are considered important in elephant diet in a dry deciduous, thorn forest in South India. However, the species richness in the forest patches in the area of this study has been found to be very low. Also, the density of vegetation has been found to be very low in the study area. The results of elephant use of forest (Fig. 2) patches clearly shows that vegetation species richness and density are not significant factors that determine elephant habitat use. In a landscape which is already fragmented, there is a lot of pressure on forests for Non wood forest produce (NWFP) collection and due to grazing. *Madhuca indica* flower collection is an important source of livelihood for the people of this area. In order to collect the flowers, the forest floor is set on fire repeatedly in the months of March - May. Poverty levels of this region are high, this makes the communities dependent on the forest for their basic needs like firewood. The combination of all these factors have lead to the degradation of forest patches and their quality, making them sub-optimum for elephant use.

I evaluated all the possible factors that may affect the use of forest patches by elephants. To summarise, the size of the patch, vegetation density inside patch, vegetation species richness inside patch, distance to next nearest patch, amount of crop outside the patch, distance to water, mean elevation of patch and NDVI were taken as explanatory variables for understanding elephant use of patches. Results show that the use of forest patches by elephants is found to be determined by distance to water from the patch. The

availability of water plays an important role in determining the use of forest patches. Water is a fundamental necessity and an important determinant for elephant use. Results shown in (Table.1) explains that elephants were using patches from where distance to water(rivers, drains, canals, lakes, ponds) is less. That is, there is an inverse relationship between distance to water and the number of days elephants stay in a patch. This has also been highlighted by different studies,. Lakshminarayanan *et al.*, (2016), Jammes *et al.*, (2007), Shannon *et al.*, (2009) found that distance to river was the best predictor of elephant habitat use. It also affects the movement of elephants along with habitat use. In a landscape with relatively drier habitat and very low vegetation density, surface water becomes an important source of water. In the relatively drier season, pre-formed water in plants also decreases which in turn increases the dependency on surface water by elephants. The results were found to be consistent with the available literature.

The result obtained through the spatio-temporal habitat usage of collared individuals suggest that there is a peak in the use of forested areas in the day time while the use of cropland is negligible. There is decrease in the use of forest in the night time during which the use of cropland increases to a great extent. This has been highlighted by other studies like (Venkataraman *et al.*, 2005) . This suggests that elephants are using the forest patches as a “refuge” during the day time (Kinhan *et al.*, 2005) and come out during the night in crop fields in order to raid crops. This is explained by the graph shown in (Fig. 7). Generally, males are known to indulge in crop raiding but in this mosaic landscape even herds have shown similar pattern of spatial and temporal habitat use which involves raiding crop fields at night. This kind of social learning may exacerbate the problem as it may be transmitted to the offsprings and alter the typical elephant behaviour in such mosaic landscapes.

The ranging behaviour of elephants is affected by many factors like distribution of resources in the habitat, quality of habitat diet, and sex. Elephants being large body sized animals are known to range in larger areas (Williams *et al.*, 2008; Alfred *et al.*, 2012). This evolutionary trait is affected by the availability and nature of resource in the habitat, sex, diet, and mating system. Dispersed availability of resources lead to larger home ranges. Males are known to range extensively due to intra-specific competition and in order to maximise their fitness whereas herds with females and calves show relatively smaller ranges. However, this is dependent more upon the availability of resources in the

habitat as compared to their life history strategies. In natural elephant habitats females and herds have shown a smaller home range as compared to males (Sukumar, 1989). The home range size varies from habitat to habitat. In very productive moist grasslands, elephants can have very small home ranges as compared to dry deciduous forests (Sukumar, 1989). The findings from the study suggest that the herd had a home range of 311.2 square kilometres while the solitary male, “Behradev”, had a similar home range of 323.5 square kms. This may be attributed to the distribution of resource in the study area wherein majority of the study area is under cropland (605 km²), forest (438.177 km²), built up area (45.73 km²), and mining area (1.03km²). The solitary male Behradev and the herd show high fidelity to their respective home ranges. There is a small overlap between the home ranges. The reason for the greater home range of the herd may be attributed to anthropogenic causes. Tolerance towards wild animals declines with increasing negative interactions (Karanth, 2005). Villagers tend to drive elephants away as the damage due to raiding increases. This is done by throwing explosives and even setting the forest floor to fire. This may force elephants to move to the next nearest patch. Driving elephants away and setting the forest on fire were found to be temporary solutions as the elephants tend to come back to the same areas from where they have been driven. This may be attributed to the concentration of crops around some patches which make it valuable for humans as well as elephants. A few patches were repeatedly used by elephants even though there were cases of man-made fire and driving by villagers.

Large scale land use changes at the landscape level have altered the patterns and processes that used to exist in nature. Once unknown to the people of Northern Chhattisgarh, today elephants have permeated into the everyday life of the locals, causing terror and awe alike. The future of these elephants rest on the adaptability of the elephant population in a human-dominated landscape, and the tolerance of people to the presence of these mega-herbivores in their backyards and farms, coupled with better management by the forest department. Management of these elephants requires forward-looking and inclusive policies at a large scale, and greater collaboration between different departments of the government.

References:

- Alfred R, Ahmad AH, Payne J, Williams C, Ambu LN, How PM, Goossens B. (2012). Home Range and Ranging Behaviour of Bornean Elephant (*Elephas maximus borneensis*) Females 7.
- Alfred, R., Ahmad, A.H., Payne, J., Williams, C., Ambu, L.N., How, P.M. & Goossens, B. (2012). Home range and ranging behaviour of Bornean elephant (*Elephas maximus borneensis*) females. *PLoS ONE* 7, e31400.
- Andren, H., (1994). Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review. *Oikos*, pp.355-366. Elephant crop-raiding and human–elephant conflict in Cambodia: crop selection and seasonal timings of raids. (2019). 45:243–251.
- Anuradha JMPN, Fujimura M, Inaoka T, Sakai N. (2019). The Role of Agricultural Land Use Pattern Dynamics on Elephant Habitat Depletion and Human-Elephant Conflict in Sri Lanka:1–14.
- Bal, P., Nath, C.D., Nanaya, K.M., Kushalappa, C.G. and Garcia, C., (2011). Elephants also like coffee: trends and drivers of human–elephant conflicts in coffee agroforestry landscapes of Kodagu, Western Ghats, India. *Environmental management*, 47(5), pp.789-801.
- Balasubramanian M, Baskaran N, Swaminathan S, Desai AA. (1995). Crop raiding by Asian elephant (*Elephas maximus*) in the Nilgiri Biosphere Reserve, south India. In: Daniel JC, Datye HS, editors. A week with elephants. Bombay: Bombay Natural History Society; p. 350–367.
- Banerjee, A., & Madhurima, C. (2013). Forest degradation and livelihood of local communities in India: A human rights approach. *Journal of Horticulture and Forestry*, 5, 122–129.
- Barnes, R.F.W., Dubiure, U.F., Danquah, E., Boafo, Y., Nandjui, A., Hema, E.M. & Manford, M. (2006). Crop- raiding elephants and the moon. *Afr. J. Ecol.* 45, 112–115.
- Burt, W.H., (1943). Territoriality and home range concepts as applied to mammals. *Journal of mammalogy*, 24(3), pp.346-352.

- CHAMAILLÉ-JAMMES, S.I.M.O.N., Valeix, M. and Fritz, H., (2007). Managing heterogeneity in elephant distribution: interactions between elephant population density and surface-water availability. *Journal of Applied Ecology*, 44(3), pp.625-633.
- Chiyo, P.I., Cochrane, E.P., Naughton, L. and Basuta, G.I., (2005). Temporal patterns of crop raiding by elephants: a response to changes in forage quality or crop availability?. *African Journal of Ecology*, 43(1), pp.48-55.
- Desai, A.A. and Baskaran, N., (1996). Impact of human activities on the ranging behaviour of elephants in the Nilgiri Biosphere Reserve, South India. *Journal of the Bombay Natural History Society*, 93(3), pp.559-569.
- Foley, L. S. (2002). Influence of environmental factors and human activity on elephant distribution in Tarangire National Park, Tanzania. MSc thesis. International Institute for Geo Information Science and Earth Observation, Netherlands
- Hoare, R.E., (1999). Determinants of human-elephant conflict in a land-use mosaic 689–700.
- Jadhav SK KS. (2013). Traditional Herbal Medicines for the Treatment of Snake Bite and Scorpion Sting by the Tribes of South Surguja, Chhattisgarh, India. *Medicinal & Aromatic Plants* 02:2012–2014.
- Jathanna, D., Karanth, K.U., Kumar, N.S., Karanth, K.K. & Goswami, V.R. (2015). Patterns and determinants of habitat occupancy by the Asian elephant in the Western Ghats of Karnataka,
- Jathanna, D., Karanth, K.U., Kumar, N.S., Karanth, K.K., Goswami, V.R., 2015. Patterns and determinants of habitat occupancy by the Asian elephant in the western Ghats of Karnataka, India. *PLoS One* 10, 1–19.
<https://doi.org/10.1371/journal.pone.0133233>
- Kinahan, A.A., Pimm, S.L. and Van Aarde, R.J., (2007). Ambient temperature as a determinant of landscape use in the savanna elephant, *Loxodonta africana*. *Journal of Thermal Biology*, 32(1), pp.47-58.

- Koirala RK, Ji W, Aryal A, Rothman J. (2015). Dispersal and ranging patterns of the Asian Elephant (*Elephas maximus*) in relation to their interactions with humans in Nepal 9370.
- Kumar MA, Mudappa D, Raman TRS, Madhusudan MD. (2004). The elephant hills: Conservation of wild Asian elephants in a landscape of fragmented rainforests and plantations in the Anamalais, India. Available from http://www.ncf-india.org/publication/ncf_tr10.pdf.
- Kumar, M.A., Mudappa, D., Raman, T.R.S., (2010). Asian elephant *Elephas maximus* habitat use and ranging in fragmented rainforest and plantations in the Anamalai Hills , India 3, 143–158.
- Lakshminarayanan N, Karanth KK, Goswami VR, Vaidyanathan S, Karanth KU. (2016). Determinants of dry season habitat use by Asian elephants in the Western Ghats of India:169–177.
- Levins R. (1969). Some demographic and genetic consequences of environmental heterogeneity for biological control. *Bulletin of the Entomological Society of America* 15: 237–240.
- Madhusudan, M.D. (2003) Living amidst large wildlife: Livestock and crop deprecation by large mammals in the interior villages of Bhadra Tiger Reserve, South India. *Environmental Management*, 31(4), 466–475.
- Madhusudan, M.D., (2003). Living amidst large wildlife: livestock and crop deprecation by large mammals in the interior villages of Bhadra Tiger Reserve, South India. *Environmental Management*, 31(4), pp.0466-0475.
- Okello MM, Njumbi SJ, Kiringe JW, Isiiche J. (2015). Habitat use and preference by the African elephant outside of the protected area , and management implications in the Amboseli Landscape , Kenya 7:211–226.
- Osborn F V. (2004). Seasonal variation of feeding patterns and food selection by crop-raiding elephants in Zimbabwe. *African Journal of Ecology* 42:322–327.
- Osborn, F.V. and Hill, C.M., (2005). Techniques to reduce crop loss: human and technical dimensions in Africa. *CONSERVATION BIOLOGY SERIES-CAMBRIDGE-*, 9, p.72.

- Riddle, H. S., Schulte, B. A., Desai, A. A., & Meer, L. Van Der. (2010). Elephants - a conservation overview. *Journal of Threatened Taxa*, 2(1), 653–661. doi:10.202426i10653-661
- Rood, E., Ganie, A.A. and Nijman, V., (2010). Using presence-only modelling to predict Asian elephant habitat use in a tropical forest landscape: implications for conservation. *Diversity and Distributions*, 16(6), pp.975-984.
- Sala, O.E., Chapin, F.S., Armesto, J.J., Berlow, E., Bloomfield, J., Dirzo, R., Huber-Sanwald, E., Huenneke, L.F., Jackson, R.B., Kinzig, A. and Leemans, R., (2000). Global biodiversity scenarios for the year 2100. *science*, 287(5459), pp.1770-1774.
- Santiapillai, C., S. Wijeyamohan, G. Bandara, R. Athurupana, N. Dissanayake & B. Read (2010). An assessment of the human-elephant conflict in Sri Lanka. *Ceylon Journal of Science (Bio.Sci.)* 39: 21–33.
- Shannon, G., Matthews, W.S., Page, B.R., Parker, G.E. and Smith, R.J., (2009). The affects of artificial water availability on large herbivore ranging patterns in savanna habitats: a new approach based on modelling elephant path distributions. *Diversity and Distributions*, 15(5), pp.776-783.
- Sitati NW, Walpole MJ, Leader-Williams N. (2005). Factors affecting susceptibility of farms to crop raiding by African elephants: Using a predictive model to mitigate conflict. *Journal of Applied Ecology* 42:1175–1182.
- Sitompul AF, Griffin CR, Rayl ND, Fuller TK. (2013). Spatial and Temporal Habitat Use of an Asian Elephant in Sumatra:670–679.
- Smith, R. and Kasiki, S., (1999). A spatial analysis of human-elephant conflict in the Tsavo ecosystem. *Kenya IUCN African Elephant Specialist Group Report*.
- Srinivasaiah, N.M., Anand, V.D., Vaidyanathan, S., Sinha, A., (2012). Usual Populations , Unusual Individuals : Insights into the Behavior and Management of Asian Elephants in Fragmented Landscapes 7. <https://doi.org/10.1371/journal.pone.0042571>
- Steinheim G, Wegge P, Fjellstad JI, Jnawali SR, Weladji RB. (2005). Dry season diets and habitat use of sympatric Asian elephants (*Elephas maximus*)

and greater one-horned rhinoceros (*Rhinoceros unicornis*) in Nepal. *Journal of Zoology* 265:377–385.

- Sukumar R. (1989). Ecology of the asian elephant in southern india. i. movement and habitat utilization patterns. *Journal of Tropical Ecology* 5:1–18.
- Sukumar, R., (1990). Ecology of the Asian elephant in southern India. II. Feeding habits and crop raiding patterns. *J. Trop. Ecol.* 6, 33–53.
<https://doi.org/10.1017/S0266467400004004>
- Understanding spatial and temporal patterns of human–elephant conflict in Assam, India. (2019). 49:140–149.
- Venkataraman, A. (2002). What is an Asian elephant (*Elephas maximus*) corridor? pp. 24-31. In: V. Menon, S.K. Tiwari, P.S. Easa & R. Sukumar (eds.) *Right of Passage: Elephant Corridors of India*. Conservation Reference Series No. 3, Wildlife Trust of India, New Delhi.
- Williams, A.C., Johnsingh, A.J. and Krausman, P.R., (2001). Elephant-human conflicts in Rajaji National Park, northwestern India. *Wildlife Society Bulletin*, pp.1097-1104.