Tiger Recovery Strategy and Long-term Monitoring in Sahyadri Tiger Reserve, Maharashtra

Feasibility Assessment and Strategic Action Plan

SAHYADRI TIGER RESERVE

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

National Tiger Conservation Authority
राष्ट्रीय व्याघ्र संरक्षण प्राधिकरण

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Chapter I:

General introduction and Overview

The Sahyadri Tiger Reserve, nestled in the northern Western Ghats in India, is the only tiger reserve in western Maharashtra. Sahyadri boasts a long and glorious history of the reign of Shivaji Maharaj and his successors. This history of empires also parallels with the history of wild tigers. Tigers have been known to be common in the Sahyadri mountain ranges; the hunting records of Shahu Maharaja (years 1894–1922) of Kolhapur prove that tigers were fairly common in the Sahyadri, in Western Ghats within the state of Maharashtra, in the early part of the last century. With the onset of the 21st century, tiger populations declined in the entire nation. The population decreased overtime with escalating human population and pressure. Though it has a low density of tigers, Sahyadri was declared as a tiger reserve in 2008. As per the census in 2014, seven tigers were estimated to be present through scat analyses in Sahyadri, but a robust estimate was still lacking.

The northern Sahyadri range or the northern Western Ghats extends from Dang in Gujarat to Dandeli in Karnataka. This range however is fragmented at many locations owing to human habitation and presence of huge megalopolis such as Nashik and Pune, hindering the movement of tigers and other such large mammals. However, these fragments do provide essential cover to extant species here. Tigers have also been reported previously to range and move around in this stretch, but camera trap records within the limits of Sahyadri Tiger Reserve dates back to 2011. After that there have been no concrete evidence of tiger presence, however, tiger presence based on scat analyses was confirmed by the Wildlife Institute of India in 2014.

Its status as a tiger reserve is often questioned due to low tiger density, and thus restoring its tiger population is imperative. With this background, tiger recovery program that has been initiated by the Sahyadri Tiger Reserve Conservation Foundation collaboratively with the Wildlife Institute of India and National Tiger Conservation Authority is underway. With an overall goal of enabling ecological integrity by establishing an optimal, free-ranging tiger population in Sahyadri Tiger Reserve by 2025, the first phase i. e., the feasibility assessment has been completed, as a part of Species Recovery Plan, endorsed by the National Tiger Conservation Authority and Sahyadri Tiger Reserve Conservation Foundation. We present the findings of the feasibility assessment in this report divided into different chapters in the following section of this report and also provide the strategic action plans that would be required towards tiger recovery in Sahyadri Tiger Reserve.

Following this introductory Chapter I, Chapter II deals with the habitat assessment undertaken in STR. We used GIS and RS to better understand the landscape. We also carried out field vegetation surveys to understand of the density of trees and look at the overall vegetation and forest cover of STR. Tree density was recorded to be 14.93 (±7.72 SD) per plot, canopy cover 54.31% (± 9.20 SD) per plot, cutting signs 0.13 (± 0.31 SD) per plot, lopping signs 0.32 (± 0.46 SD) per plot and livestock dung density 0.76 (± 0.73 SD) per plot. We found seven forest types in STR, of which barren land and dense forest were the dominant types. We found that contiguity was rightest in the dense forest type among all the forest types.

Chapter III deals with the status of tiger and carnivore prey present in STR. Wild ungulate density was estimated to be 9.5 (2.79 SE) per km^2, livestock density 10.81 (6.00 SE) per km^2 and primate density 11.18 (5.00 SE) per km^2. The major ungulate species recorded were the gaur, sambar, barking deer, wild boar, mouse deer and four horned antelope. Other preferable prey carnivores are primates and livestock. Among primates, during our field surveys, only two species were recorded from the core, the bonnet macaque *Macaca radiata* and the southwestern langur *Semnopithecus hypoleucos*. However, in this area rhesus macaques *Macaca rhesus* are also common. The encounter rate of the gaur (0.280) per km based on line transects was maximum, followed by livestock (0.304), primates (0.034), barking deer (0.085), sambar (0.0365), wild boar (0.0365) and mouse deer (0.036). Mean capture rates based on the camera trap capture rates was maximum for wild boar (0.162), primates (0.126), gaur (0.121), livestock (0.095), barking deer (0.054), sambar (0.045), mouse deer (0.035) and four horned antelope (0.001).

Chapter IV elaborates on the status of tigers and other carnivores in STR. Twelve carnivore species have been recorded so far from both sign survey and camera trapping effort. Sign surveys indicate the presence of four carnivore species leopards, sloth bear, civets and dholes. We found that leopards occupy 77% of the whole of STR, followed by sloth bears 75%, civets 57% and dholes 11%. The most encountered carnivore in camera traps was the leopard (0.0217), closely followed by sloth bear (0.0214), ruddy mongoose (0.0176), small Indian civet (0.0121), dhole (0.0104), common palm civet (0.0060), brown palm civet (0.0046), grey mongoose (0.0044), stripe necked mongoose (0.0024), jungle cat (0.0022), leopard cat (0.0016) and rusty spotted cat (0.0002). Recently tigers was captured in May 2018.

Chapter V discusses the social surveys carried out in and around the villages of STR. Seventy-nine villages are present in the five ranges of STR, of these 79, 18 villages are in core and 61 in buffer zone. Surveys reveal that the major forest product used by the locals is fuel wood (59.98%) followed by fruits (26.93%). A total of 3601 households exist in these 79 villages. Our questionnaire surveys show that 46.13% accept the tiger project and are willing to support it while 53.87% people are not. This means that almost half of the village residents are willing to support the recovery project.

Our results suggest that there is no resident tiger population in STR and even if few individuals had escaped from our sampling, it will be precariously low. Given the low number or local extinction of tigers, and the habitat suitability including moderate prey base, tiger augmentation would be required to ensure a viable population in STR.

Chapter VI discusses all the scientific management aspects required for tiger reintroduction in STR. It summarizes the outcome of all the field surveys, and suggests future tiger recovery strategies to be undertaken.

Chapter II:

Status of Habitat in Sahyadri Tiger Reserve

2.1. Introduction:

The changes in habitat and landscape characteristics due to land-use change can have significant effect on species presence, abundance and geographic distribution (Núñez et al 2010). These are required to be quantified for decision-making. In addition to field level habitat assessment, landscape metrics focusing on patch properties provide useful understanding of the compositional and spatial aspects of landscapes (Kupfer, 2012). The definition and identification of individual patches and their boundaries are important steps in characterizing the structure of landscape, and in planning in management of targeted species, especially large mammals such as tigers, elephants and leopards who occupy a large home range. The use of GIS and remote sensing techniques has become very popular in recent times in forestry and wildlife studies. Wildlife and biodiversity management has emphasized the need of having updated spatial information for purposes such as decision-making and implementation of plans. GIS can provide spatial information and with relevant conventional statistics may aid in changing the very approach of wildlife management based more on current information and location oriented. In this assessment, we focused on field level information based on plot sampling and landscape level analyses involving remote sensing and GIS analyses in Shyadri Tiger Reserve (STR), Maharashtra. This is primarily aimed at spatially explicit information gathering and visualization of the outcome. We deployed standard protocol for habitat mapping while integrating robust analytical tools for achieving the objectives of habitat assessment. This approach addressed the usual concerns of scale related habitat information incorporating local as well as landscape scales. Accordingly, the specific inputs could be drawn for decision making for this tiger recovery efforts and some of the landscape information has been used to map the potential habitat currently available in STR and this knowledge has been incorporated for estimating carrying capacity which provides basis for strategic action plan.

There are various techniques like the FRAGSTAT are used to derive landscape level and class level metrics to give the detailed idea about the structure and patterns within a particular landscape. One of the significant features of FRAGSTAT software is that it can provide metrics at the individual patch Level as well as class and landscape level. Class indices separately quantify the amount and spatial configuration of each patch type and thus provide a means to quantify the extent and fragmentation of each patch type in landscape. So, in our feasibility assessment of STR, we used some of the class level indices such as the number of patches, patch density, largest patch Index and contiguity index to reflect detailed understanding about the spatial pattern and functional characters of the area, including about fragmentation and the level of connectivity in the landscape patterns of STR.

2.1.1. Description of the area:

The Sahyadri Tiger Reserve (STR) is located in the state of Maharashtra and takes its name due to the geographical position in the Sahyadri range of the Western Ghats. Comprising an area of 1166 km^2, it is constituted by combining the Chandoli National Park and the Koyana Wildlife Sanctuary. In terms of political administration boundary, it spreads across four districts *viz.* satara (Mahabaleshwar, Jawali, Satara and Patan tehsils), Sangli (Shirala tehsil), Kolhapur (Shahuvadi tehsil) and Ratnagiri (Sangameshwar and Khed tehsils). Chandoli National Park is one of the important protected areas in the North-Western Ghats. It was declared as a Wildlife Sanctuary in 1985 by the Maharashtra State Government and later on upgraded to the status of a National park in 2004.

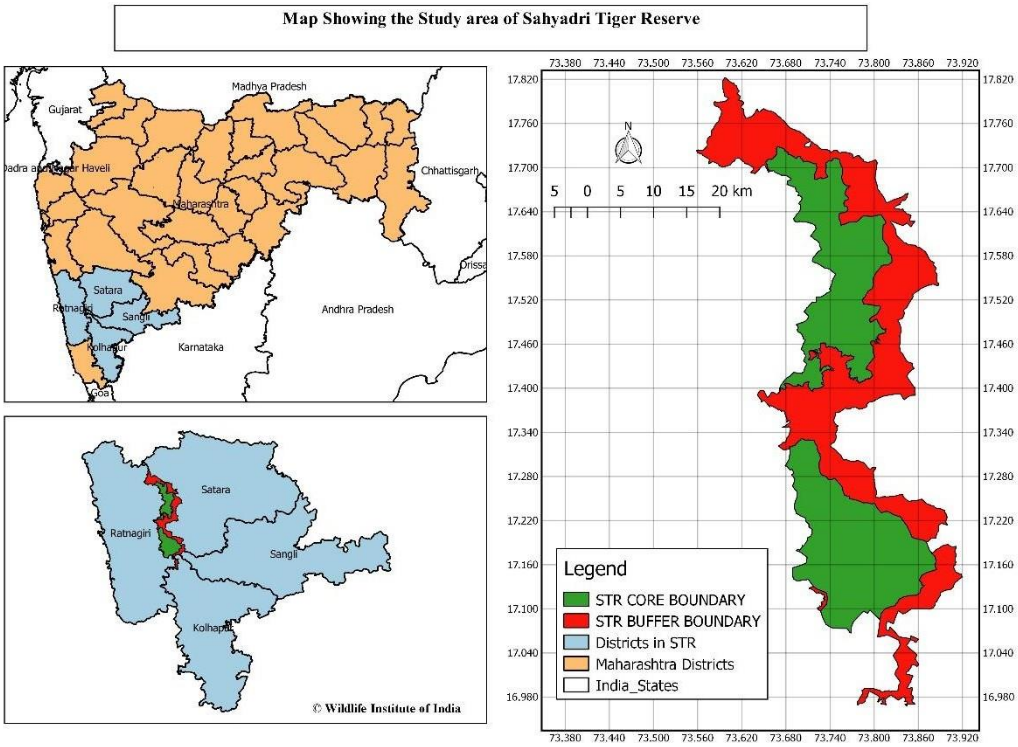

Figure 1: Map of Sahyadri Tiger Reserve showing core and buffer areas

The park is situated in the juncture of four districts Kolhapur, Sangli, Satara and Ratnagiri and also forms a corridor between Koyana Wildlife Sanctuary and Radhanagri Wildlife Sanctuary aiding in the much required animal movement. The park is spread the Vasantsagar reservoir of Chandoli dam. River Warana originates from Patarpunj, an area in Chandoli National Park. Semi-evergreen and moist deciduous forest patches, massive plateaus, huge grasslands, rich riverine systems make this area favourable for rich diversity of plants and animals. The vast plateaus of the park spring to life in the post monsoon season as they flourish with wide variety of ephemeral wild flowers during July to October. Indian Mugger can be commonly seen in the Vasantsagar reservoir, which is now a natural breeding ground of this species. The park is also abode to mammals like Sambar, Gaur, Barking deer, four-horned Antelope, Mouse deer, Bonnet Macaque, South-western langurs, leopards, sloth bears, pocucpines, mongooses, civets, wild dogs, etc. This area is not only rich in biodiversity but also has historical importance with a temple of Bhavimata on fort Prachitgadh.

Koyana Wildlife Sanctuary: Koyana Wildlife Sanctuary, the other half of the tiger reserve encompassing. The sanctuary spreads along the expanse of the Shivsagar reservoir of Koyana dam. Koyana was declared as a wildlife sanctuary in 1985. Koyana has two ranges, Koyana and Bamnoli and major part of this sanctuary is covered by the Koyana river that flows with dense forest on both sides. Sloth bears, sambars, mouse deers, pangolins, gaurs are commonly sighted animals here. The faunal and floral diversity of Koyana Wildlife Sanctuary is understudied except some preliminary work. Hence, this area presents enormous potential for research.

2.1.2. Topography and stream network:

The Sahyadri Tiger Reserve has a very rugged and undulating terrain. The altitudinal gradient ranges from 350 m to 1250 m. Because of such topography, small water flows, runoffs and flow lines get highly influenced making STR a better place for stream network and water availability.

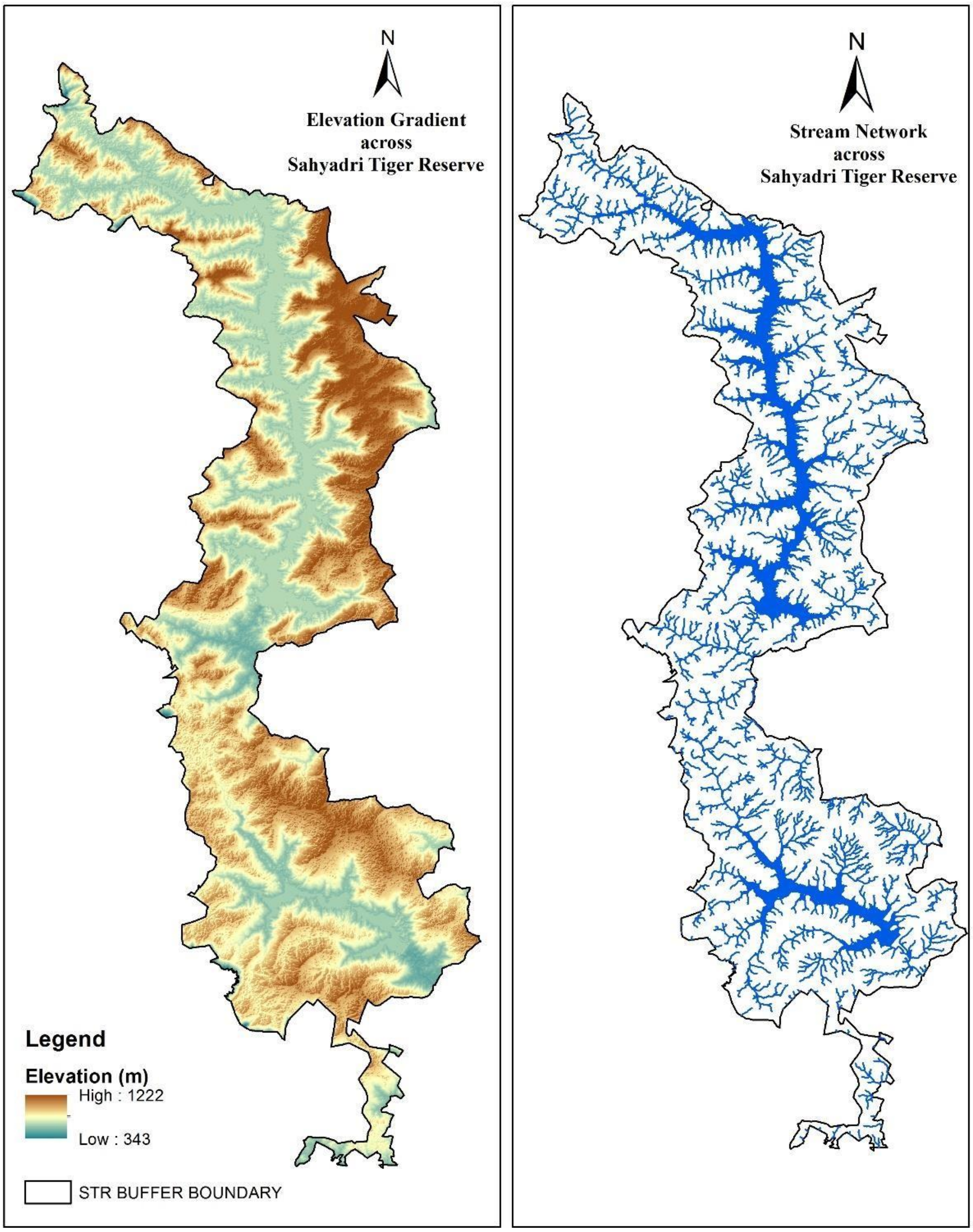

Figure 2: Map of STR showing the elevation gradient and stream network

2.1.3. Vegetation status:

The vegetation properties are easily found by using various mathematical indices such as NDVI, LAI etc. The NDVI index is widely used to find biomass or vegetative vigor as well as to obtain information about surface characteristics of region. The NDVI is a ratio of near-infrared (NIR) and red bands of a multispectral image which ranges from -1 to 1. Values which are ranges from 0.5 to 0.9 are Vegetation.

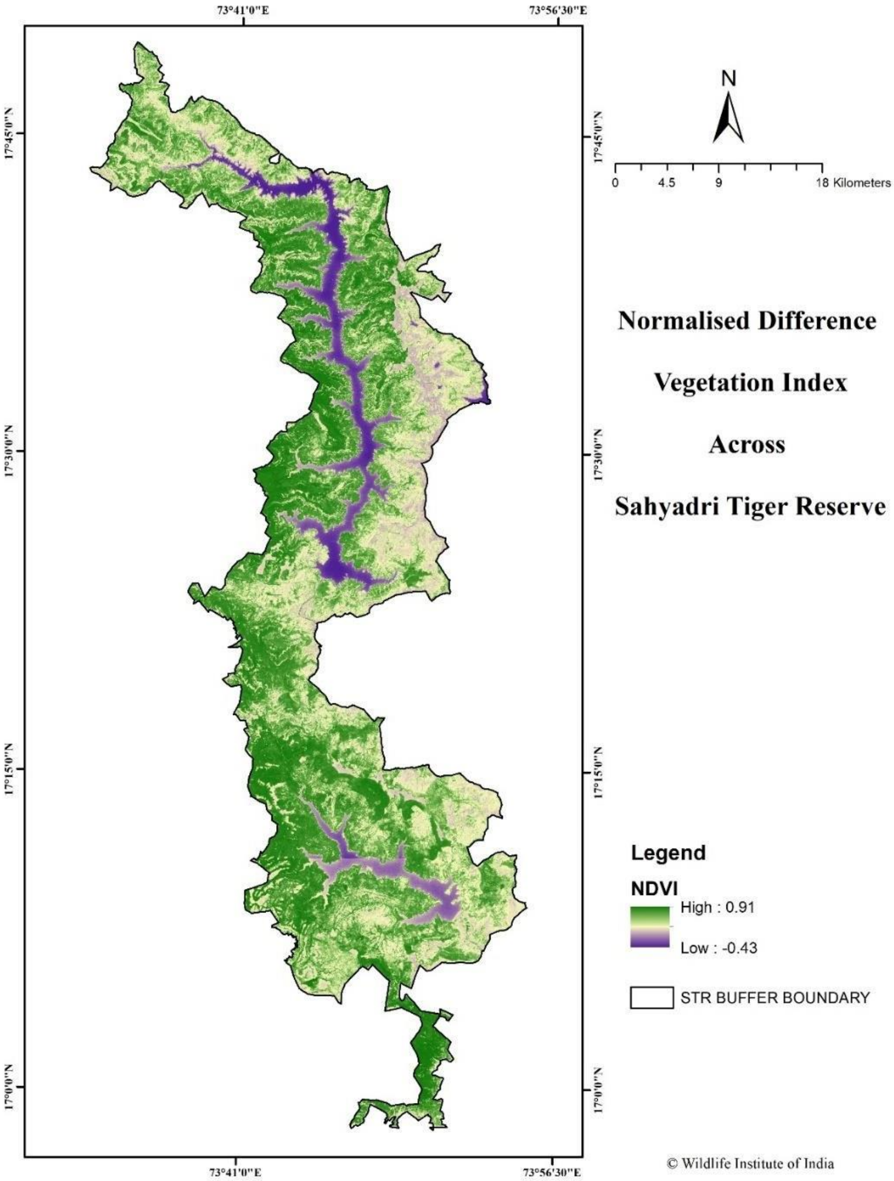

Figure 3: Showing NDVI across STR

2.2. Methods and Datasets:

For assessing the habitat characteristics and connectivity patterns, we used geospatial tools (ArcGIS10.5, ERDAS, Fragstat 2.4). Land-use land cover map (LULC Map) has been generated to get the whole idea about landscape features. We used the Landsat 8 satellite data for LULC classification from which we further classified the STR.

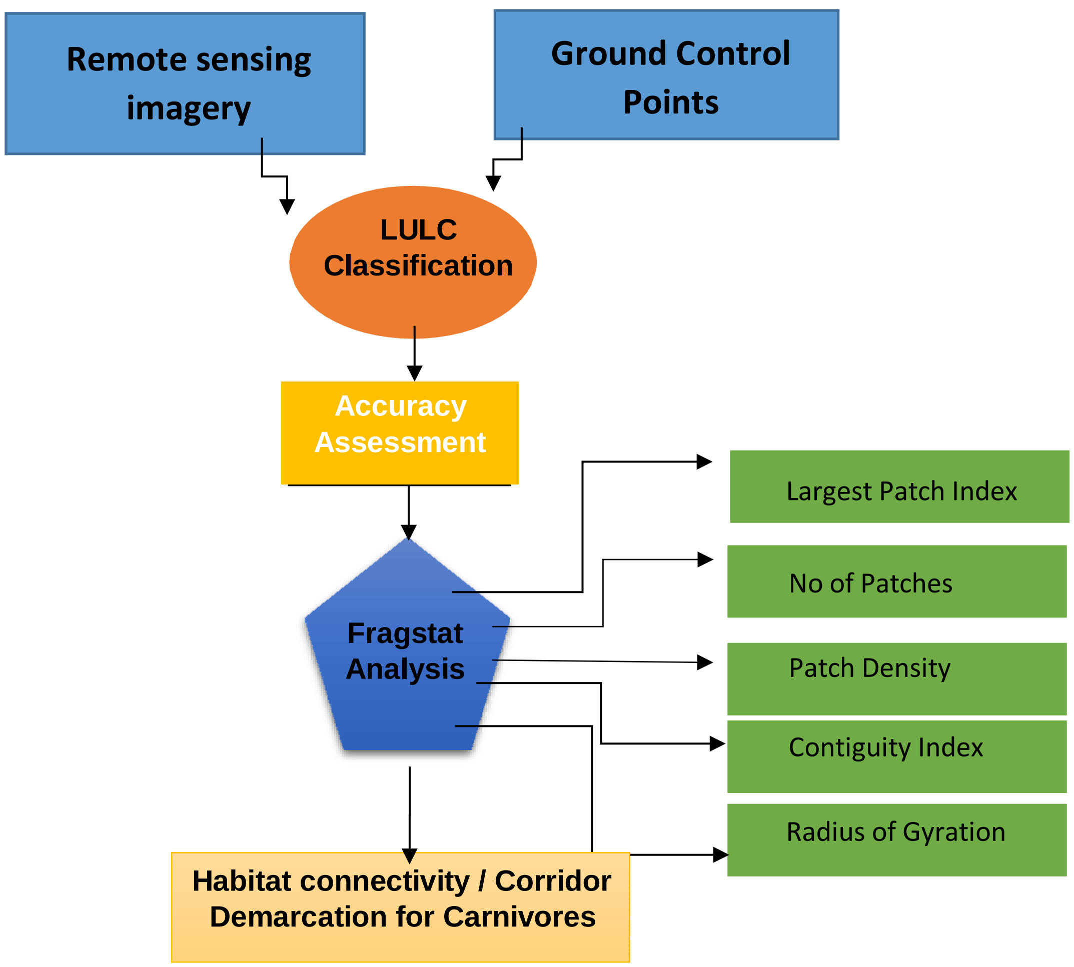

Figure 4: Flow-chart of the methodology followed in the GIS habitat analysis

2.2.1. Local scale habitat assessment:

We conducted vegetation sampling to quantify habitat parameters in 41 beats of the reserve. Sampling for trees and anthropogenic pressure were done in respective plot size in 250m interval on line transects and GPS coordinates of each plot were recorded. Trees (>2m height) were sampled in 10m radius circular plots. Name of the species, number, GBH, height and canopy cover were recorded. Cutting, lopping and livestock dung density were also noted for anthropogenic pressure estimate

2.2.2. Landscape characterization:

LULC classification is an important step for processing the satellite image of the area and categorizes it into various land use classes according to visual interpretation and ground information. For assessing the LULC analysis of STR, we used Landsat 8 imagery of March 2017. We then applied unsupervised classification with 32 numbers of classes. After this, we used recoding technique for merging the identical land use classes based on ground control points. For the accuracy assessment of our results we used both ground control points and Google Earth to cross check the results for better accuracy. After getting 92% accuracy, we proceeded further with the analysis.

2.2.3. Fragmentation analysis:

Fragmentation is the measure of forest and non-forest polygons per unit area. It is measured by calculating the amount of forest patches occurring in a landscape with respect to non-forest patches. To look at the fragmentation, the LULC map was generated, which has 7 land-use classes. After that we found the largest patch index, patch density and contiguity index using classified grid in FRAGSTAT.

2.2.4. Connectivity assessment:

Connectivity is needed to determine the management strategy of forest landscape as a wildlife habitat. It is important to find correlation between the connectivity and ecological indicators. This was done based on Contiguity Index and Radius of Gyration of forest patches using FRAGSTATS.

2.3. Results

2.3.1. Local scale habitat condition:

Tree density was found to be 14.93 (±7.72 SD) per plot, canopy cover 54.31% (± 9.20 SD) per plot, cutting signs 0.13 (± 0.31 SD) per plot, lopping signs 0.32 (± 0.46 SD) per plot and livestock dung density 0.76 (±0.73 SD) per plot.

2.3.2. Land-use and land-cover characteristics:

We found seven land use classes of our study area using supervised classification in ERDAS Imaging 2014. Land-use classes in STR are mainly dense forest, barren land, open forest, scrubland, water body, agricultural land and reservoir bed (Table 1). We collected ground truth records from various regions during our camera trapping and line transects field sessions, which have been useful to increase our accuracy of the supervised classification.

Land-use class	Area (km^2)
Dense forest	408.72
Open forest	220.94
Scrub land	134.29
Barren land	305.64
Agriculture land	20.76
Water body	75.86
Reservoir bed	11.79

Table 1: Showing the different forest classes with their respective areas

2.3.3. Fragmentation and connectivity:

Landscape matrices calculated in FRAGSTAT quantifies specific spatial characteristics of patches, classes of patches, or entire landscape which provides much clear reflection of patterns within the landscape. Following are the landscape matrices calculated in FRAGSTAT 4.2 using the image representing the quality and quantity of land use land cover distribution over STR;

a. Number of patches and patch density: Number of patches and patch density within the landscape for each class is demarcated as NP and PD respectively. NP often has limited interpretive value by itself because it conveys no information about, distribution, or density of patches but with patch density it is useful index to interpret. The more number of patches indicates more fragmentation in that class. PD represents the number of patches in the landscape, divided by total landscape area (m^2), multiplied by 10,000 and 100 and the output value is the density per 100 hectare. The following table shows the positive relationship between number of patches and patch density.

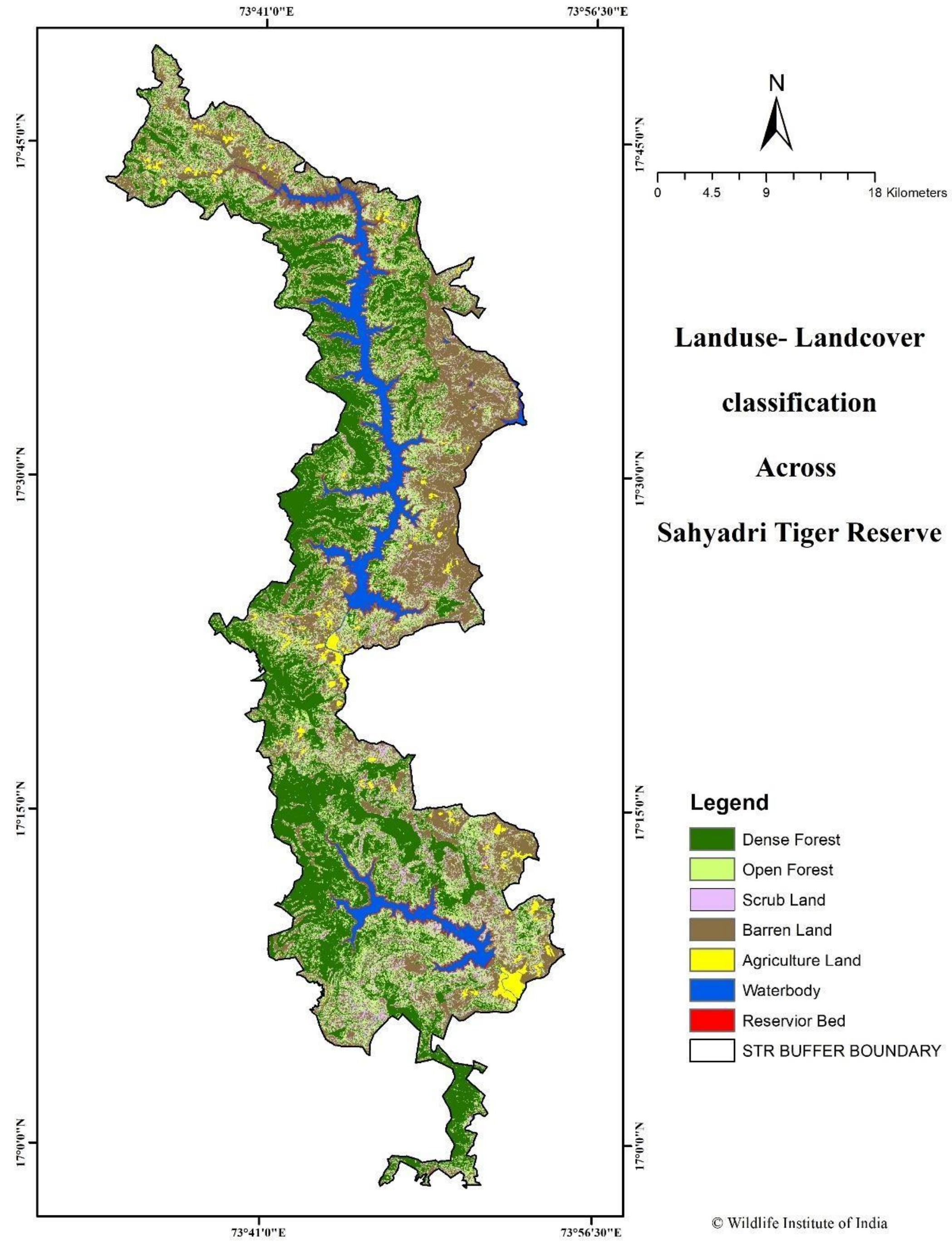

Figure 5: LULC map of STR representing all the forest types identified

Sl. No.	Class	No. of Patches	Patch Density
1	Dense Forest	66925	57
2	Open Forest	139345	118
3	Scrub Land	150931	128
4	Barren Land	62780	53
5	Agriculture Land	251	0.2
6	Water Body	427	0.4
7	Reservoir Bed	3886	3.3

Table 2: Showing the forest classes, number of patches and density of each class

b. Largest Patch Index: Largest Patch Index (LPI) is the percentage of the landscape comprised by the largest patch. LPI approaches 0 to 100% corresponding to the patch size. It is a simple measure of dominance of patch within the landscape. The following table shows highest largest patch index for barren land and dense forest respectively with very minor difference in values which is because of the dominance of rocky plateau and barren land in eastern part followed by forest dominance in western part of the reserve.

Sl. No.	Class	Largest Patch Index
1	Dense Forest	6.40
2	Open Forest	0.10
3	Scrub Land	0.04
4	Barren Land	6.58
5	Agriculture Land	0.22
6	Water Body	4.61
7	Reservoir Bed	0.02

Table 3: Showing the largest patch index of the respective forest classes

c. Contiguity Index: Contiguity index assesses the spatial connectedness, or contiguity, of cells within a grid-cell patch and provides an index on patch boundary configuration and thus patch shape (LaGro 1991). The following table illustrates the highest contiguity score for agriculture land and reservoir bed, as both of the classes are regular or connected.

Sl. No.	Class	Contiguity Index
1	Dense Forest	0.19
2	Open Forest	0.24
3	Scrub Land	0.19
4	Barren Land	0.20
5	Agriculture Land	0.80
6	Water Body	0.27
7	Reservoir Bed	0.29

Table 4: Showing the contiguity index of all the forest classes

d. Area- weighted mean of Radius of Gyration (AM_GYRAT): The AM_GYRAT shows how far across the landscape a patch extends its reach. It can be considered as a measure of landscape continuity (also known as correlation length) that represents the average traversability of the landscape for an organism that is confined to remain within a single patch; specifically, it gives the average distance one can move from a random starting point and traveling in a random direction without leaving the patch. When summarized for the class or landscape as a whole using an area-weighted mean, this metric is also known as correlation length and gives the distance that one might expect to traverse the map while staying in a particular patch, from a random starting point and moving in a random direction (Keitt et al. 1997). The following map represents the AM_GYRAT or connectivity for the class 'forest'. The area shown in brown represents area having good connectivity among the forest patches followed by lesser values shown in different color gradient. This is important since tiger's dispersal or movement is a function of habitat connectivity and resistance in the landscape (Ramesh et al. 2016).

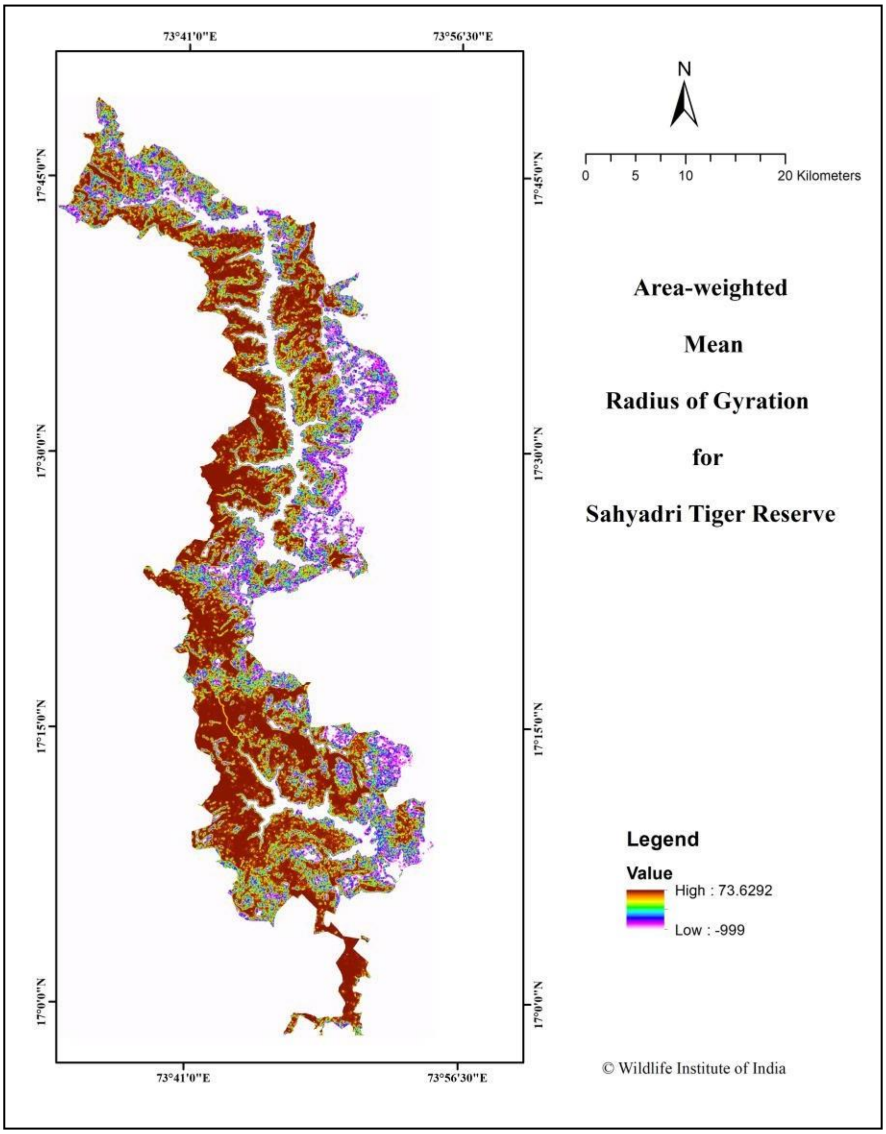

Figure 6: Map showing AM_GYRAT or the scale of connectivity in the landscape

2.4. Discussion:

Structurally, the buffer area connects the two parts of the tiger reserve, i.e. Chandoli National Park and Koyana Wildlife Sanctuary. While the shape of the STR is generally linear, it contains large patches that can support tiger presence if adequate monitoring and protections are ensured. STR has seven major types of forest in the reserve i.e. dense forest, open forest, scrubland, barren land, agricultural land, and water body and reservoir bed. Of these, two are dominant land-use types which are dense forest and barren lands (rocky land or plateaus). A major component is water body in the reserve. It is the third dominant feature type after barren land and dense forest. Hence, STR has a rich and strong stream network. The fact that dense forest is one the major forest type is also validated by our field vegetation samples. Our vegetation sampling data indicate a rich composition of trees in the reserve (15 trees) per plot (plot size = 10 m). Overall canopy cover was more than 50%. Cutting and lopping were low overall. However, the field data has been collected for just one season (April to July) and so represents the status only in one season.

The western side of STR has good connectivity of dense forests and the eastern side contains the rocky plateaus. FRAGSTAT results show that there is better connectivity in dense forest patches, which is mostly in the western side of STR, which is a positive point. The dense forest is already well connected; what we need from the management perspective is an active effort to manage and conserve this connectivity within the reserve is needed. In future, we plan to further analyze the decadal habitat changes (1995/2005/2015) with different seasons to get a more detailed picture of fragmentation.

Chapter III

Status of Prey in Sahyadri Tiger Reserve

3.1. Introduction:

Population distribution and behavior of prey influence the quality of a predator's habit and the health of predator populations. Studies on prey population estimation of carnivores have obvious, immediate important application in carnivore conservation and management. The greatest relevance of prey population studies is a resource base estimation of the species focusing to conservation (Jelil, 2015), in our case tigers. Large mammalian carnivore populations are mainly resource limited (Slobodkin et al. 1967), with the firmness of a predator population depending on the availability of its prey (Sunquist and Sunquist, 1989). The evolution and radiation of the *Panthera* stock in fact shows close correlation to that of the Cervid and Bovid species. All bovids and cervids are ruminants and have four-chambered stomachs comprising a reticulum, rumen, omassum and the true stomach (Menon, 2014). Most ungulates can be divided based on their type of herbivory into concentrate selectors, grass and roughage eaters, and intermediate feeders (Hoffman and Stewart, 1972). Smaller Indian ungulates are concentrate feeders such as muntjacs, chevrotains and musk deers, the larger ones are roughage and grass eaters, e. g., deer, antelope and cattle. Ungulates perform major ecological roles in tropical ecosystems influencing vegetation pattern, seed dispersal, forest structure, composition, productivity, nutrient cycling, soil structure and succession (McNaughton, 1979; Crawley, 1983; Adler et al. 2001; Jathanna et al. 2003; Prasad et al. 2006). Ungulates form bulk of the prey base and thereby, structure the large carnivore population (Jathanna et al. 2003; Karanth et al. 2004; Gray et al. 2012). From Tiger recovery perspective, having adequate prey population is vital to hold a viable tiger population as prey density functions as a determining factor of tiger population dynamics (Karanth et al. 2004; Gray et al. 2012). Beside wild ungulates, tiger diet reported to constitute a significant amount of livestock (mostly cattle and buffalos) and primates (macaque and langur) (Madhusudan, 2003; Bagchi et al. 2003; Wang and McDonald, 2006; Sangay and Vernes, 2008; Sarkar et al. 2017). Hence, primates and livestock present in the tiger landscapes are important for overall tiger diet and recovery, in case of recovery programs.

3.2. Methods and data collection:

Estimation of population density of a species is fundamental to understand the status, demography, conservation and effective management planning (Sahoo et al. 2015). Line transect on direct sightings is a widely used method for estimation of herbivore density (Kumara et al. 2012). Distance sampling by line transect considered to be one of the most accurate methods for herbivore density estimation as it takes into account the detectability issues (Buckland et al. 2001; Jathanna et al. 2003; Narasimmarajan et al. 2014).

3.2.1 Distance sampling:

Distance sampling by standard line transect methodology was used to estimate prey density (Thomas et al. 2010). Line transect methodology was carried out in 41 permanent transects, one in each beat, and minimum of 2 km in length. Each transect was walked on single occasion only, covering a total effort of 82 km. This data was collected between 6:30 to 8:30 in the morning or 16:00 to 18:30 in the evening by two observers from April to mid-July, 2017. Upon every animal sighting, species, cluster size, age-sex composition, sighting distance and sighting angle (along transect and to the centre of the cluster), forest and terrain type was recorded along with GPS coordinates. Sighting angle and sighting distance was measured using hand-held bearing compass and range finder, respectively.

The analysis was carried out for wild ungulates, primates and livestock, separately and for all prey combined (wild ungulates, primates and livestock) using DISTANCE software (version 7.0) (Thomas et al. 2010). Sighting distances were pooled into suitable intervals and farthest 5% observations were truncated. The fit of the model was judged using Akaike information criterion and goodness of fit tests generated in DISTANCE software (Buckland et al. 1993). The conventional distance-sampling (CDS) model was used and the half-normal was selected as the key function to run the analysis.

3.2.2 Camera trapping:

We also carried out standard camera trapping in STR simultaneously, which also provided a clear picture of prey present in STR. We have used infrared and white flash cameras with motion sensor. We have divided our study area into 2km×2km grids and single camera was deployed in each grid. A total of 142 cameras were deployed, among which 11 cameras were stolen or damaged in the process. Cameras operated for a minimum of 5-camera trap nights to the maximum 39, totaling 2219 camera trap nights. Camera trapping was done from April to mid-July, 2017. Minimum distances between any 2 cameras were 1 km. Cameras were set to function 24h per day and delay between 2 consecutive captures kept fast as possible (FAP). For Helwak range, we used the forest department camera trap data of that range for our analysis. This was due to the inaccessible conditions during monsoon. This data was collected from November, 2016 to March, 2017; 1417 camera trap nights cumulatively, ranging from 17 to 113 camera trap nights for a single camera.

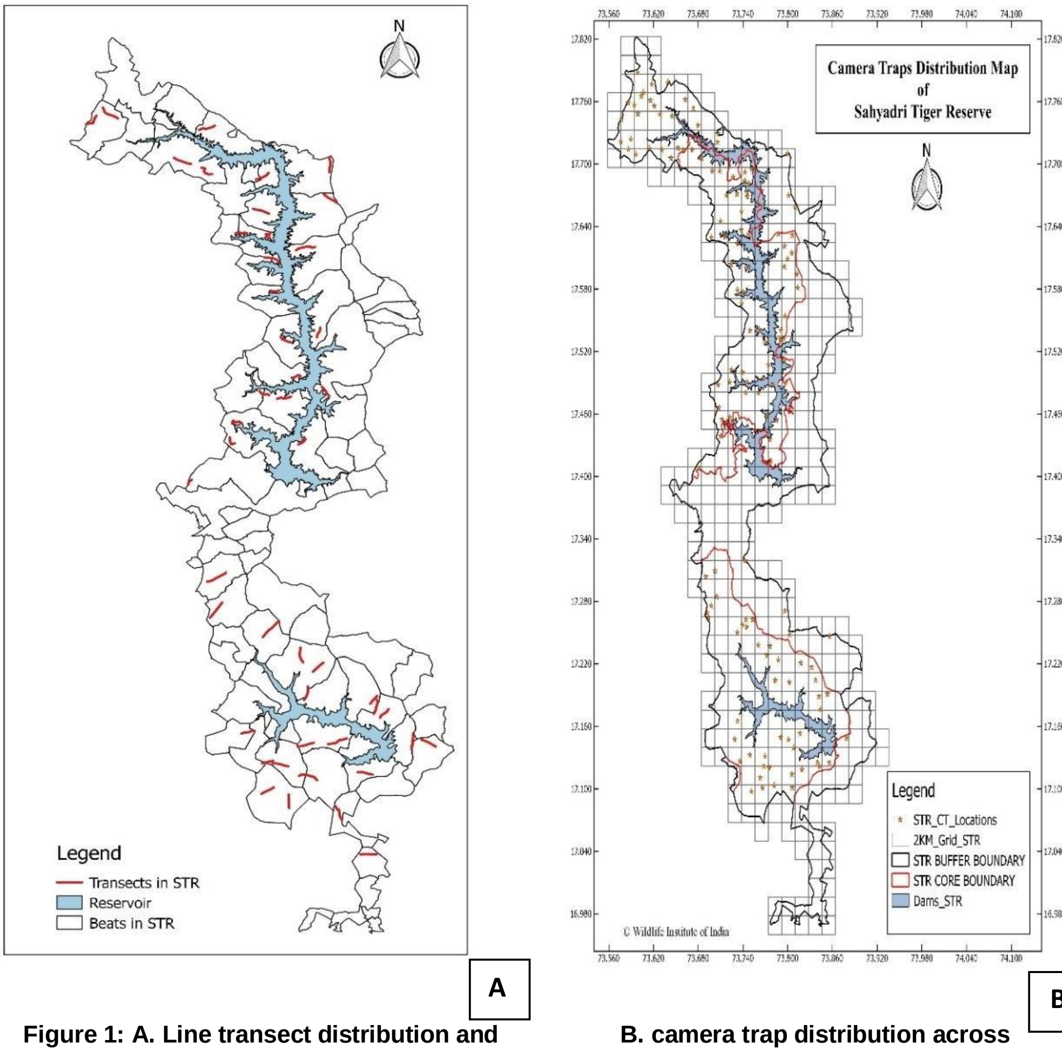

Figure 1: A. Line transect distribution and B. camera trap distribution across the STR landscape

3.2.3. Photographic capture rate:

Photographic capture rates of wild ungulate species, primates and livestock were calculated using the formula

Photographic capture rate = Number of photographic captures of individuals of prey species/days of operation

Photographic capture rates were used to prepare heat map of the distribution of individual prey species in STR and habitat suitability analysis. This will also help in identifying landscapes suitable for tiger reintroduction.

3.2.4. Encounter Rate:

Encounter rate of the detected prey species in the 41 line transects were calculated by number of objects detected per unit effort. (Buckland, 2001; Fewster, 2009)

Encounter rate = Total number of encountered individuals of a species (N)/ total distance walked in transect

Encounter rates are expressed in number per km. We have also compared encounter rate with photographic capture rate to crosscheck the effectiveness of line transect surveys in estimating prey density in STR.

3.3. Results

3.3.1. Prey Density:

Sahyadri Tiger Reserve hosts 6 species of wild ungulates, *viz.* gaur *Bos gaurus*, sambar *Rusa unicolor*, wild boar *Sus scrofa*, barking deer *Muntiacus muntjak*, four horned antelope *Tetracerus quadricornis* and Indian spotted chevrotain *Moschiola indica*. Primate species in this area includes bonnet macaque *Macacca radiata* and south western langur *Semnopithecus hypeleucos*. Among them gaur, sambar and four horned antelope are listed as "vulnerable" in IUCN Red List categories and present important conservation values. Estimated wild ungulate density in STR is 9.5 (2.79 SE) km^2 while primates and livestock density found to be 11.18 (5.00 SE) km^2 and 10.81 (6.00 SE) km^2, respectively (Figure 2).

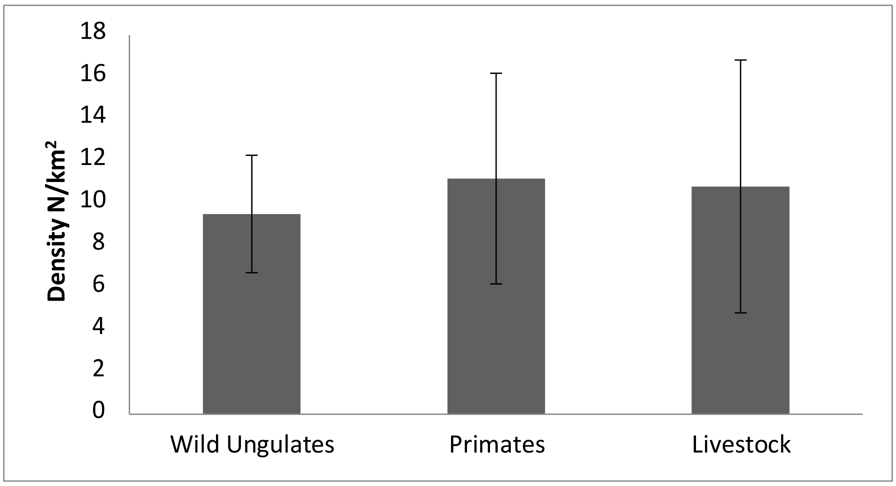

Figure 2: Prey density in STR (bars indicate density values, with standard error indicated by error bars).

3.3.2. Encounter rate and capture rates: Encounter rate data is based on line transect surveys conducted from April, 2017 to July, 2017 by our team. We found that encounter rate was highest for gaur (0.28), followed by livestock (0.304) and primates (0.304), barking deer (0.085). Encounter was least for mouse deer (0.036), sambar (0.036) and wild boar (0.036) (Table 1). The four horned antelope was not encountered in line transects.

We used our camera trap data as well to get a picture of the prey in STR. Mean capture rates were calculated from the data collected by our team (April, 2017 to July, 2017), as well as Maharashtra Forest Department (for Helwak Range; November, 2016 to March, 2017). Capture rates was highest for primates (0.126) closely followed by gaur (0.121), followed by wild boar (0.162), livestock (0.948), barking deer (0.054), sambar (0.045) and mouse deer (0.035). It was least for the four horned antelope (0.001) (Table 1).

Species	Encounter rate	Mean capture rate
Gaur	0.28	0.12
Sambar	0.04	0.04
Barking deer	0.08	0.05
Wild boar	0.04	0.16
Four horned antelope	0	0.001
Mouse deer	0.04	0.03
Livestock	0.3	0.95
Primates	0.3	0.13

Table 1: Encounter Rates and Photographic capture rate of prey species in Sahyadri Tiger Reserve.

We examined the relationship of the encounter rate data and camera capture rate. The results seemed to align well (Figure 3). We also used GIS tools to map the data camera trap data. Interpolated surfaces were based on location specific photographic capture rates. Species wise distribution had been color coded in decreasing order of encounter rates, with red representing the highest and blue being the lowest (Figure 4). We mapped data for four dominant prey i. e., gaur, sambar, wild boar and barking deer.

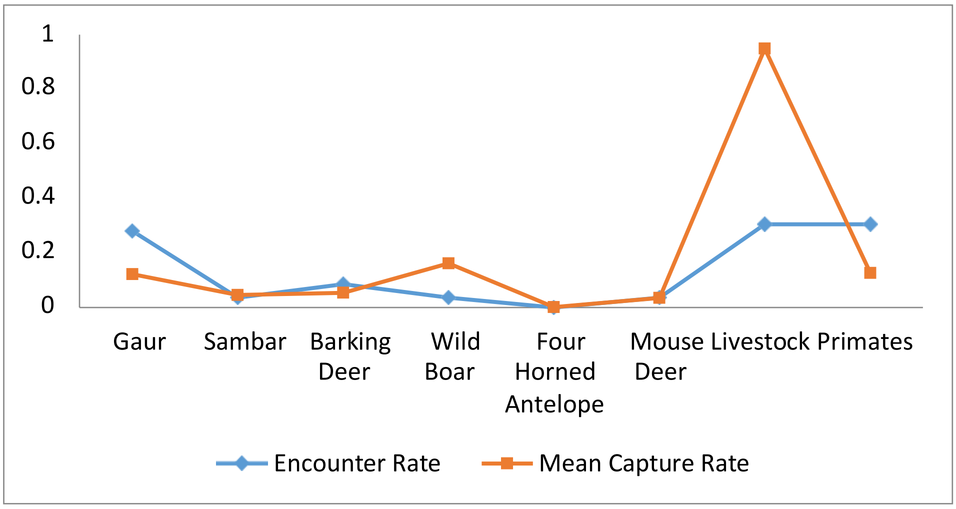

Figure 3: Species specific encounter rate and Photographic capture rate values based on line transect and camera trapping in STR.

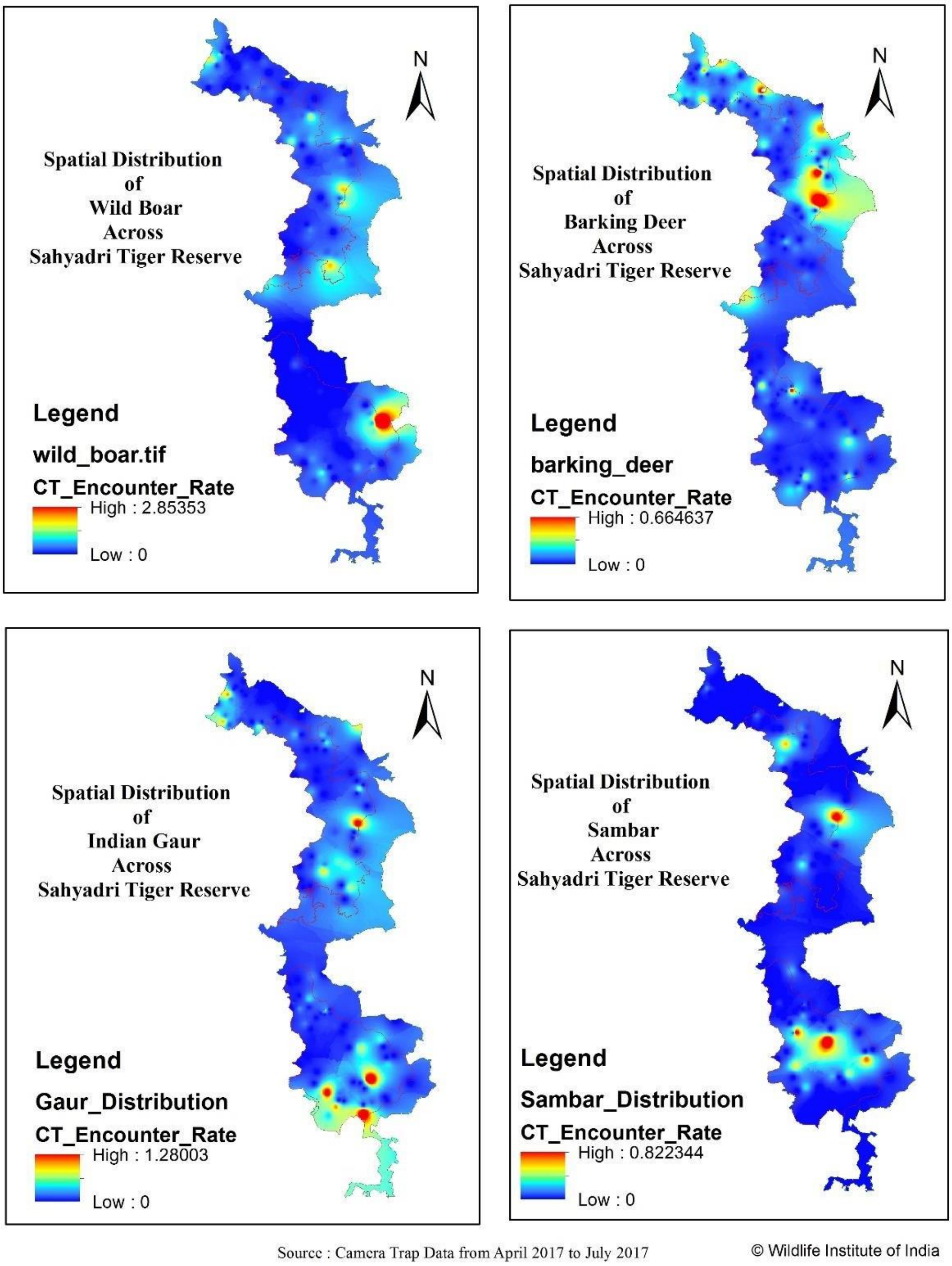

Figure 4: Spatial distribution of four dominant ungulate species in STR.

Gaur

Wild Boar

Barking Deer

Fouur-horned antelope

Mouse deer

Sambar

3.4. Discussion:

Despite being included in Western Ghats World Heritage Serial Sites and its diverse habitat and species assemblage, STR is one of the understudied areas in India. Only few literatures are available on wild prey base in STR. John et al. (2010) mentioned this place as low in wild prey abundance. He mentioned poaching, management issues and habitat connectivity as primary reasons for low prey base. Beside good habitat, prey base has been pointed out as a deciding factor for tiger presence in Chandoli National Park (Imam et al. 2009). Although, 55% of the forest of Chandoli National Park indicated as highly suitable for herbivores, our camera trap capture rates show comparatively less area is actually utilized by herbivores (Table 1, Figure 8).

Although, we have estimated 9.5 (2.79 SE) wild ungulates km^2 in STR, number of detections in line transect surveys were notably low from recommended 40 for useful analysis (Barking Deer 7, Gaur 23, Indian spotted chevrotain, Wild Boar and Sambar 3 each, livestocks 25 and Primates 25) (Burnham et al., 1980; Buckland et al., 1993). Absence of spatial replicates in our study could also lead to inappropriate estimation of prey. However, we compared the transect survey encounter rates and camera trap capture rates for the same beat (Figure 5). Even though there are evidences of an ungulate species in a specific location in camera trap images, there were no encounters of that species in the line transect. This could state the need of more rigorous sampling and possibly, and a finer methodology to avoid underestimation of prey density in landscapes like STR.

Ungulate density in STR is significantly low compared to other tiger reserves such as Ranthambore (97 ungulates km^2) in areas free from anthropogenic pressure (Johnsingh et al., 2010), Kanha TR (>50 ungulates km^2) (Karanth and Nichols, 2000; Gray et al., 2017) and Panna TR (32 ungulates km^2) (Ramesh et al. 2013). Wild ungulates available in STR ranges from gaur, weighing 650 kg to Indian spotted chevrotain of 3kg body mass, approximately (Hayward et al. 2012; Sidhu et al. 2015). With an estimated density of 9.5 wild ungulates km^2, STR holds 5700 ungulate preys of different body mass in its core; which supports 12 tigers following Karanth et al. (2004). Habitat recovery by relocation of villages and prey augmentation is possibly the imminent requirement to carry a viable source population in STR. Further habitat suitability analysis and Population Viability Analysis (PVA) have been performed based on prey population availability (refer to Chapter VI).

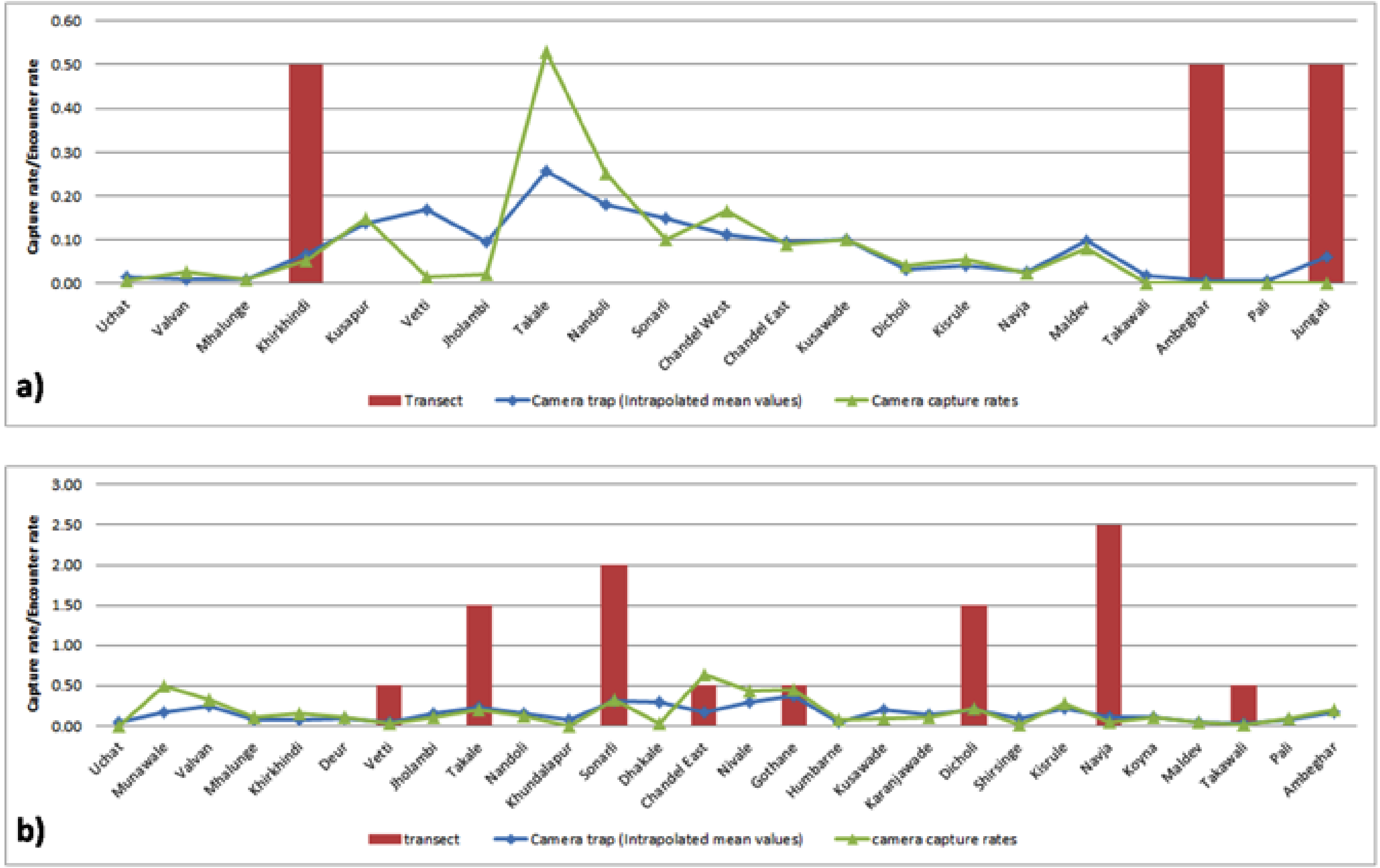

Figure 5: Beat-wise comparison of line transect encounter rate and camera trap capture rates of a) Sambar and b) Gaur.

Chapter IV:

Status of Carnivores: Tiger and Co-predators

4.1. Introduction:

Generally, felids, canids, hyaenids and ursines form the large carnivore group, while viverrids, herpestids, prionodontids, mustelids and ailurids represent the small carnivore assemblage. As a group, carnivores, big and small, exert a profound influence on biological communities via predation and interspecific competition. They play important and unique roles in the natural functioning of ecosystems by virtue of their apex trophic position (Estes, 1996; Crooks and Soulé 1999; Terborgh et al. 1999, 2001). They have the ability to structure and drive the dynamics of entire ecosystems and these effects are disproportionate to their abundance on the landscape. Carnivores control prey by direct and indirect methods. Through predatory activities, carnivores directly reduce numbers of prey (Terborgh, 1998; Terborgh et al. 1997; Estes et al, 1998; Schoener and Spiller, 1999). Indirectly, carnivores cause prey to alter their behaviour so that they become less vulnerable (Kotler et al. 1993; Brown et al. 1994; FitzGibbon and Lazarus, 1995; Palomares and Delibes, 1997; Schmitz, 1998; Brown, 1999). They choose different habitats, different food sources, different group sizes, different time of activity, or they reduce the amount of time spent feeding (Miller et al. 2001). By reducing the numerical abundance of a competitively dominant prey species (or by changing its behaviour), carnivores erect and enforce ecological boundaries that allow weaker competitors to persist (Estes et al. 2001). Large carnivores also directly and indirectly impact smaller predators, and therefore the community structure of small prey (Soulé et al 1988, Bolger et al. 1991; Vickery et al, 1992; Palomares et al. 1995; Sovada et al. 1995; Crooks and Soulé 1999; Henke and Bryant 1999; Schoener and Spiller, 1999). Scientific data increasingly indicate that carnivores play an important role in ecological health. Carnivores often regulate or limit the numbers of their prey, thereby altering theh structure and function of entire ecosystems (Schaller, 1972). As a result, carnivore management is of central concern to carnivore biologists. There is increasing concern about the status and distribution of terrestrial carnivore populations throughout the world (Schaller, 1996). Changes in land-use practices, habitat loss and fragmentation, sanctioned human persecution, declines in natural prey, disease, illegal poaching and increased competition within carnivore guilds have brought about a general decline in several carnivore populations with some species now occupying a fragment of their former range. Paramount to carnivore recovery, reintroduction, or development of management plans and policies, is having reliable and accurate information regarding the status, health, and well-being of the carnivore population of concern (Gese, 2001).

Tiger conservation is the cornerstone of Indian Wildlife conservation efforts. Although initially it was conceptualized as a flagship to protect key ecosystems, today a tiger's share of the resources, public attention and political will and policy thrust is aimed at protecting the tiger and its habitat. In this sense, carnivore conservation is the most advance of conservation sciences and activities being undertaken in the country today (Menon, 2014). To a lesser extent, the same attention has been endowed on other charismatic carnivores such as the lion, the bears, the snow leopard, the wolf, the leopard and the Dhole. Meanwhile lesser known carnivores such as the linsang or weasels, or even large carnivores such as Honey Badger or Clouded leopard have had very little research and targeted conservation actions. The conversion of large tracts of forest land and their degradation affect large carnivores as do poaching for their parts and derivatives. Other key threats to large carnivores are loss of prey and man-animal conflict, especially with leopards, bears and tigers that cause retaliatory killings and public ill-will. In contrast, smaller carnivores suffer from fragmentation, loss of suitable aquatic habitat (in case of otters, for instance), effect of insecticides and pesticides ad a general apathy to their existence.

4.1.1. An overview of tiger ecology and conservation status:

One of the largest living felids, the tiger has played a significant role as a cultural icon in many Asian societies. Despite this importance, three of the eight tiger subspecies have gone extinct in the last 60 years. Today, shrinking tiger numbers and habitat are major conservation issues globally and occupy most of the conservation space in India. Tigers are found mainly in the forests of tropical Asia, although they historically occurred more widely in drier and colder climes. One subspecies, the Amur Tiger, persists in the Russian Far East (Goodrich et al, 2015). Tigers have been reported up to 4500 m in Bhutan (Wang, 2008). Tigers are generally solitary, with adults maintaining exclusive territories, or home ranges. However, tiger home ranges are small where prey is abundant for example in Chitwan, female home ranges averaged 20 km^2, while in the Russian Far East they are as large as 400 km^2 (Goodrich et al. 2015; Goodrich et al. 2010; Sunquist and Sunquist, 2002). Asia is a densely populated and rapidly developing region, bringing huge pressures to bear on the large wild areas required for viable tiger populations. Conversion of forest land to agriculture and silviculture, commercial logging, and human settlement are the main drivers of tiger habitat loss. With their substantial dietary requirements, tigers require a healthy large ungulate prey base, but these species are also under heavy human subsistence, hunting pressure and competition from domestic livestock (Goodrich et al. 2015). In India, the tiger is distributed along the Terai foothills of the Himalayas, in north-east India, in central India (especially around the central highlands and Satpura-Maikal landscape including Vidarbha), the Eastern Ghats and Western Ghats including the Nilgiri plateau. The states of Madhya Pradesh, Maharashtra, Odisha, Bihar, West Bengal, Arunachal Pradesh and Andhra Pradesh have large tiger habitats left while tose in Assam, Karnataka, Uttarakhand and Rajasthan support large numbers in protected areas (Karanth, 2013). Tigers are widely distributed within their range in tropical dry and moist deciduous forests, evergreen forests and riverine forests. In the Sunderbans, it is adapted to a mangrove habitat, in the Terai it frequents a moist deciduous-grassland-riverine habitat complex (Karanth, 2013), and in higher altitudes such as Sikkim and Arunachal Pradesh, it inhabits coniferous, oak and rhododendron forests. Tigers can exist in dry scrub and semi-arid areas of Rajasthan just as well as above the treeline in Arunachal Pradesh, but these constitute suboptimal habitats (Menon, 2014).

It is estimated that India holds 2226 (1945–2491) odd tigers (>1.5 years of age) (Jhala et al. 2015). In 2014 tiger estimation, a total of 3, 78,118 km^2 of forests in 18 tiger states were surveyed, which resulted in 1540 unique tiger photo-captures, accounting for 70% of the total estimated population.

Since tigers have direct and indirect relationships with various other carnivores or meso-carnivores, hence it is also pertinent to detect and understand the presence/distribution of all the carnivores in a particular landscape. Hence, from the tiger recovery perspective, we intended to understand the present occurrence dynamics of all the carnivores in STR.

4.2. Methods and data collection:

Carnivores are inherently difficult to survey based on their secretive nature, often nocturnal habitats, and low densities (Gros et al. 1996). We carried out both remote camera trapping and carnivore sign surveys, both efficient to estimate presence of elusive carnivores. Our surveys started with a brief reconnaissance survey carried out in all the ranges of STR from January to March, 2017. Camera trapping and sign surveys were carried out from April to July.

4.2.1. Sign surveys:

Sign surveys are a non-invasive technique; which have commonly been used to determine distribution of many carnivores worldwide (Long et al. 2008). These methods are based on the detection of tracks, scats and other signs left by the focal species such as burrows, scats, digging marks, etc. Among them, scat counts are particularly profitable in terms of both species detection and the economic and logistics costs associated with surveys (Barea-Azcón et al. 2007). In STR, sign surveys were carried out in a total of 36 beats in all the five ranges of STR. In every beat, two forest trails were followed and carnivore signs were looked for. Total trail lengths in the beats varied from 8.5 to 14 km, with a total of 384.5 km of walk.

The sign surveys conducted beat-wise were put to basic descriptive analysis, such as encounter rate per km, and total beats where each species sign was found. We also performed occupancy analyses using PRESENCE (12.6) of all the carnivores identified through sign surveys. Signs of carnivores were identified and recorded by the field team. Only unambiguously identified signs were recorded. Two spatial replicates in a beat were carried out. Each type of sign detection was assigned only once each 250 m trail segment, thus yielding the standard '1' (detection) or '0' (non-detection) histories required for occupancy analyses. We used the simple single-season occupancy model for all the carnivores identified through signs. We ran four pre-defined and two custom models to analyse the occupancy of all the carnivores separately. We compared the models of MacKenzie et al. (2002) without additional covariates. All model comparisons were based on the Akaike information criterion (AIC) values (Burnham and Anderson, 2002). We estimated the overall occupancy rate, Ψ, and the probability of detection p, for all the carnivore species separately.

4.2.2. Camera trapping:

Camera trapping has long been used to survey for and monitor the occurrence of wildlife species around the world. Much attention has been focussed on using camera-trapping to detect otherwise elusive species, including charismatic species such as tigers, snow leopards, etc. In STR, camera traps were deployed from 1 April to 15 July in STR (142 stations). Camera traps were separated by at least 2 km with some exceptions because of constraints posed by terrain. At each site single motion-triggered digital camera was deployed by affixing it at a height of c. 60-70 cm to suitable trees. Camera traps were set to take consecutive images (FAP (fast as possible) mode was used) when triggered and were typically kept active at a given location between 10 and 39 days. The memory cards acquired from the installed cameras were arranged systematically correlating every memory card with its geographical location. These were then put to analyse capture rates for every carnivore species. Due to weather constraints during July, in one range (Helwak), we could only survey three beats and the other beats were inaccessible to due to heavy rains. For this, we incorporated the forest department data for this range. The forest department camera traps were deployed in the beats we could not survey. The camera traps by the forest department were installed from November, 2106 to March, 2017. The total cameras installed in this range were 18, and were kept active at a given location between 17 to 113 days. From the 142 cameras installed by our team, data from only 130 cameras could be retrieved (while 11 cameras were lost or damaged) and accounted for 2219 trap nights. We incorporated the data from forest department for one range. Here 18 cameras were installed for overall 1417 nights. Hence the total number of cameras from which we could retrieve data were 148 cameras and our total effort was calculated be 3636 nights. We calculated the capture rates for all species of carnivores using the following equation:

Capture rate = Number of photo captures of individuals of carnivores divided by the total number of days of operation.

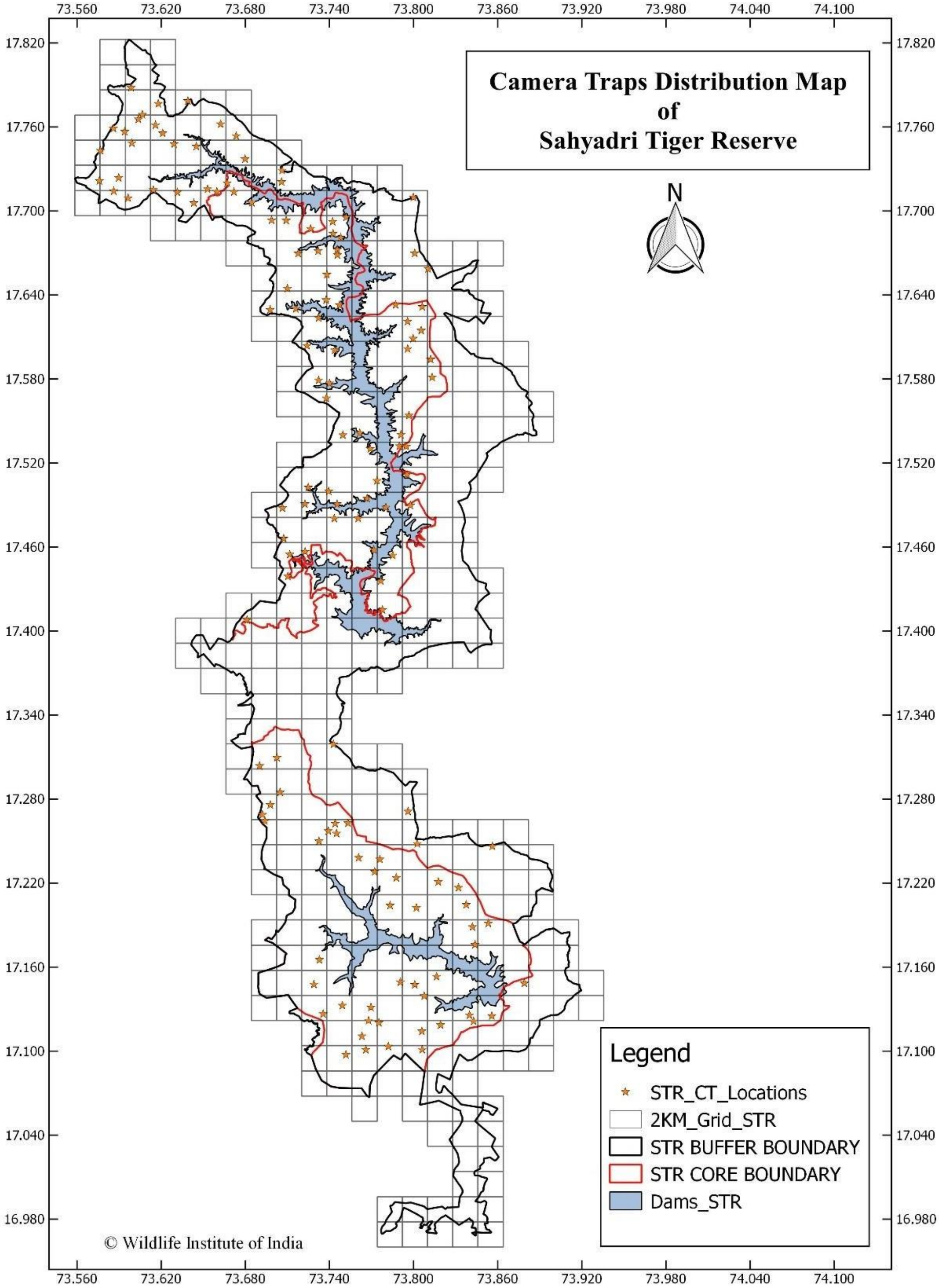

Figure 1: Map of camera trap locations in STR

4.3. Results

4.3.1. Occupancy and intensity of space use:

Field surveys identified four species of carnivores through sign; they were leopard, sloth bear, dhole and civet. A total of 132 signs of were recorded for all the carnivores. Sloth bear signs in the form of scat, digging marks and footprints were recorded in 25 beats, and the overall sloth bear sign encounter rate was 0.14 signs/ km (Figure 2, Table 2). Leopard signs were recorded from 25 beats; the overall sign encounter rate was 0.12 signs/ km. Civet signs were recorded from sixteen beats and the overall sign encounter rate was 0.06 signs/ km. Dhole sign were recorded from four beats, the overall sign encounter rate was found to be 0.013 signs/ km. No tiger signs were recorded.

Species	Effort (km walked)	Total number of signs sighted	Total number of beats signs recorded from	Encounter rate (= total number of signs/effort)
Sloth bear	384.5	55	25	0.14
Leopard	384.5	48	25	0.12
Civet	384.5	24	16	0.06
Dhole	384.5	5	4	0.01

Table 1: Representing species wise sign survey results

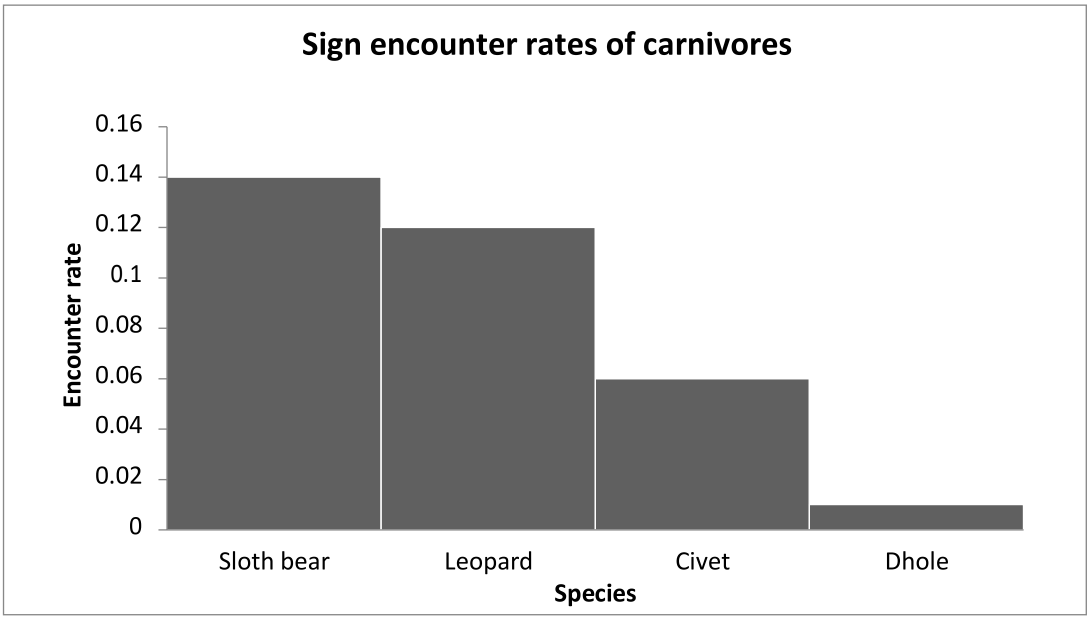

Figure 2: Encounter rate of signs of carnivore species

Leopard scat

Dhole scat

Civet scat

Sloth bear scat

The occupancy analyses for all four species of carnivores were carried out separately using the PRESENCE (12.6). We present the analyses separately for all species in the following part:

We ran two custom models; the first where we assume that the probability that a sampling unit is occupied is the same for all sampling units 'psi(.)'. This represents a model where detection probability is the same for all surveys 'p(.)'. Therefore, there is a single occupancy probability for all transects/trails and detection probability is constant both in time and across transects. In the second model, there are no factors influencing occupancy probability (it is the same for all transects) which is denoted as 'psi(.)' and detection probability is different for each survey hence 'p(survey)'. Models were selected on the basis of AIC values; models that showed the least AICs and hence the most parsimonious, were selected (refer to Table 2 to Table 4).

Leopard: We estimated that of the 1166 km^2 area of STR, leopards occupy 77%. The final parameter estimates for leopard habitat occupancy and sign detection probabilities from model averaging were psi (SE psi) = the total fraction of an area occupied by leopards in STR = 0.77 (0.09)

p (SE p)= the total probability of detecting a leopard sign on a replicate, given the presence of leopards on the replicate = 0.68 (0.08) (Table 2)

Model type	Model	AIC	Δ AIC	AIC wqt	Model likelihood	No. of Par	Log Like
Pre-defined	1 group, Survey-specific P	98.43	0.00	0.3070	1.0000	3	92.43
	1 group, Constant P	99.57	1.14	0.1736	0.565	2	95.57
	2 groups, Constant P	103.57	5.14	0.0235	0.0765	4	95.57
	2 groups, Survey-specific P	104.43	6.00	0.0153	0.0498	6	92.43
Custom	psi(.),p(.)	99.57	1.14	0.1736	0.565	2	95.57
	psi(.),p(survey)	98.43	0.00	0.3070	1.0000	3	92.43

Table 2: Model selection results for probability of leopards

Sloth bear: Sloth bears occupy 75% of the whole area of STR. The final parameter estimates for sloth bear habitat occupancy and sign detection probabilities from model averaging were:

psi (SE psi) = the total fraction of an area occupied by sloth bears in STR = 0.75 (0.09)

p (SE p) = the total probability of detecting a sloth bear sign on a replicate, given the presence of sloth bears on the replicate = 0.71 (0.08) (Table 3).

Model type	Model	AIC	Δ AIC	AIC wqt	Model likelihood	No. of Par	Log Like
Pre-defined	1 group, Survey-specific P	97.50	0.00	0.2609	1.0000	3	91.50
	1 group, Constant P	97.86	0.36	0.2179	0.8353	2	93.86
	2 groups, Constant P	101.86	4.36	0.295	0.1130	4	93.86
	2 groups, Survey-specific P	103.50	6.00	0.0130	0.0498	6	91.50
Custom	psi(.),p(.)	97.86	0.36	0.2179	0.8353	2	93.86
	psi(.),p(survey)	97.50	0.00	0.2609	1.0000	3	91.50

Table 3: Model selection results for probability of sloth bears

Dhole: Dholes occupy 11% of the whole area of STR. The final parameter estimates for dhole habitat occupancy and sign detection probabilities from model averaging were:

psi (SE psi) = the total fraction of an area occupied by dholes in STR = 0.11 (0.07)

p (SE p) = the total probability of detecting a dhole sign on a replicate, given the presence of sloth bears on the replicate =0.50 (0.30) (Table 4).

Model type	Model	AIC	Δ AIC	AIC wqt	Model likelihood	No. of Par	LogLike
Pre-defined	1 group, Survey-specific P	30.47	0.00	0.2855	1.0000	3	24.47
	1 group, Constant P	31.24	0.77	0.1943	0.6805	2	27.24
	2 groups, Constant P	35.24	4.77	0.0263	0.0921	4	27.24
	2 groups, Survey-specific P	36.47	6.00	0.0142	0.0498	6	24.47
Custom	psi(.),p(.)	31.24	0.77	0.1943	0.6805	2	27.24
	psi(.), p(survey)	30.47	0.00	0.2855	1.0000	3	24.47

Table 4: Model selection results for probability of dholes

Civet: Civets occupy 57% of the whole area of STR. The final parameter estimates for civet habitat occupancy and sign detection probabilities from model averaging were:

psi (SE psi) = the total fraction of an area occupied by civets in STR = 0.57 (0.12)

p (SE p) = the total probability of detecting a civet sign on a replicate, given the presence of civet on the replicate = 0.58 (0.11) (Table 5).

Model type	Model	AIC	Δ AIC	AIC wqt	Model likelihood	No. of Par	Log Like
Pre-defined	1 group, Survey-specific P	92.29	1.60	0.1470	0.4493	3	86.29
	1 group, Constant P	90.69	0.00	0.3272	1.0000	2	86.29
	2 groups, Constant P	94.69	4.00	0.0443	0.1353	4	86.69
	2 groups, Survey-specific P	98.29	7.60	0.0073	0.0224	6	86.29
Custom	psi(.),p(.)	90.69	0.00	0.3272	1.0000	2	86.69
	psi(.),p(survey)	92.29	1.60	0.1470	0.4493	3	86.29

Table 5: Model selection results for probability of civets

Since, this was a preliminary feasibility study; we did not use any site or sampling covariates to fit in the model.

4.3.2. Abundance index: A total of 12 carnivore species were recorded (Table 6, Figure 3) based camera trap sampling, but tiger presence could not be established. Camera trap capture rate was maximum for leopard (0.0217/trap night), followed by sloth bear (0.0214/trap night), ruddy mongoose (0.0176/trap night), small Indian civet (0.0121/trap night), dhole (0.0104/trap night), common palm civet (0.0060/trap night), brown palm civet (0.0046/trap night), grey mongoose (0.0044/trap night), stripe-necked mongoose (0.0024/trap night), jungle cat (0.0022/trap night), leopard cat (0.0016/trap night) and rusty spotted cat (0.0002/trap night).

Species	Effort (number of total camera nights)	No of captures	No. of cameras in which captured	Capture rate (= no of captures/effort)
Leopard	3636	79	35	0.0217
Sloth bear	3636	78	37	0.0214
Ruddy mongoose	3636	64	25	0.0176
Small Indian civet	3636	44	17	0.0121
Dhole	3636	38	13	0.0104
Common palm civet	3636	22	8	0.0060
Brown palm civet	3636	17	10	0.0046
Grey mongoose	3636	16	5	0.0044
Stripe necked mongoose	3636	9	5	0.0024
Jungle cat	3636	8	6	0.0022
Leopard cat	3636	6	2	0.0016
Rusty spotted cat	3636	1	1	0.0002

Table 6: Representing species-wise camera capture results

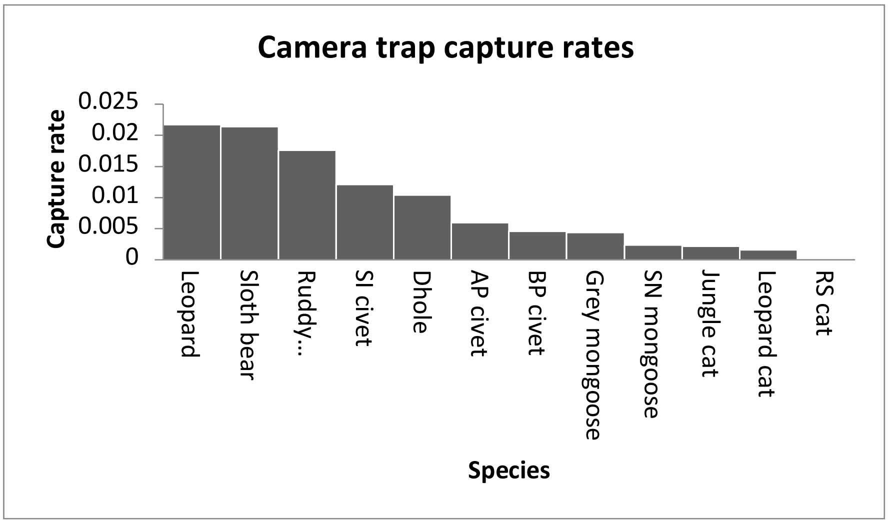

Figure 3: Capture rates of carnivores from camera traps

Leopard

Sloth bear

Leopard cat

Rusty spotted cat

Dhole

Jungle Cat

Ruddy Mongoose

Grey Mongoose

Common Palm Civet

Brown Palm civet

Small Indian Civet

Stripe-necked Mongoose

4.4. Discussion:

Extensive camera trapping exercise in STR revealed no presence of tigers. However, other sympatric carnivores are well abundant in the area. Sloth bears and leopards form the majority of this group. Sign surveys results indicate the same. The last tiger reported in STR was in 2011 in Chandoli National Park and in 2008 in Koyana Wildlife Sanctuary. Local anthropogenic pressure has significantly reduced the tiger population in and around STR. Nevertheless, camera trap surveys as well as sign surveys show a rich assemblage of other carnivores representing five families viz., felidae, herpestidae, viverridae, ursidae and canidae. The occupancy analyses, which was carried out from the sign survey data, also reveal that sloth bears and leopards occupy the landscape well in proportion, compared to other carnivores.

Our surveys were conducted during summer only; thus, predictions from the resulting models should be limited to this season. This restriction may be important in attempting to identify important habitat components for each of the target species. The ability to efficiently and effectively sample species especially those characterized as rare, wide-ranging or elusive continues to challenge wildlife researchers (Long et al. 2011). Carnivores meet all of these criteria, and are also often of management and conservation concern. Our main objective with the occupancy analyses was to predict species occurrence accurately across the whole of STR. However, as Betts et al. (2009) observe that "Models developed for prediction may include covariates whose functional link to the response is not obvious but which are excellent predictor variables"; we did not consider any covariates in this study. We will incorporate relevant variables in the following studies. This will help us understand the tiger and co-carnivore dynamics better. Even though the results are based on surveys carried out in only one season, the results are a snapshot of the overall species occurrence in the entire STR landscape.

From a tiger recovery/reintroduction point of view, presence of a large number of leopards may be a hindrance, as competition between the big cats is highly probable. Other carnivores have separate niches in nature and will not be much of a concern in this regard.

Sahyadri Tiger Reserve is a relatively newly declared tiger reserve. Maharashtra as a state has six tiger reserves viz., Melghat (1974), Tadoba (1993), Pench (1977), Nawegaon-Nagzira (2013), Bor (2014) and Sahyadri (2007). All the other five are in the eastern part of Maharashtra; STR is the only tiger reserve in the Western part of the state. Compared to well-known tiger reserves such as Melghat, Pench or Tadoba, Sahyadri has been low tiger density reserve from the beginning. The presence of tigers from our feasibility study could not be established. However, the 5–8 tigers had been reported based on scat DNA and model based predictions in STR (Jhala et al. 2015). Our results suggest that there is no resident/breeding tiger population in STR and even if few individuals had escaped from our sampling, it will be precariously low. Given the low number or local extinction, and the habitat suitability including moderate prey base, tiger augmentation would be required to ensure viable tiger population in STR.

We present a brief note of the habitat, ecology and conservation threats to all the carnivores recorded in STR:

1. Leopard (*Panthera pardus*): Leopards occur in the widest of range of habitats among any of the Old World cats (Nowell and Jackson, 1996). They are found in the desert and semi-desert regions of southern Africa in Namibia and Botswana. There are remnant populations in the arid regions of North Africa in Egypt, as well as the Arabian Peninsula. They persist in rugger montane regions of southwest Asia in Iran, in a varied range of landscapes in India and in the savannah grasslands of East and southern Africa. Leopards line in mountainous environments up to an altitude of 4,600 m on Mt. Kenya and 5,200 m in the Himalayas. They also thrive in the rainforests of West and Central Africa as well as Sri Lanka and Southeast Asia. A remnant leopard subpopulation also persists in the snowy regions of the Russian Far East. Leopard subpopulations also occur in suburban and urban environments in India and parts of sub-Saharan Africa. Leopards have survived outside protected areas in many parts of India since historical times (Daniel, 1999) and even today high density of leopards do occur among high human densities (Singh, 2005; Athreya et al. 2013; Stein et al. 2016). Its IUCN status is Vulnerable (VU). Primary threats to leopards are anthropogenic. Habitat fragmentation, reduced prey base and conflict with livestock and game farming have reduced leopard populations globally throughout most of their range (Nowell and Jackson, 1996; Ray et al. 2005; Hunter, 2013). The conversion of forest habitat patches and savannah systems to agriculture, livestock farming and urban sprawl have significantly reduced leopard range. This conversion typically leads to the depletion of natural prey species through poaching thereby reducing the natural prey base in these areas (Stein et al. 2016). In the face of changing land-use, prey availability and direct mortality from humans, leopards have persisted where other large predators have not. Their ability to live within human-dominated landscapes and feed on a variety of prey have given many people the impression that leopards require little concern, however, recent trends have shown that current threats have substantially reduced leopard populations throughout West and Central Africa, South-west and South-east Asia and China.

2. Sloth bears (*Melarsus ursinus*): Sloth bears subsist primarily on termites, ants, and fruits. They are the only species of bear adapted specifically for myrmecophagy (Garshelis et al. 1999a; Sacco and Van Valkenburgh, 2004). Sloth bears occupy a wide range of habitats on the Indian mainland including wet and dry tropical forests, savannahs, scrublands, and grasslands (Joshi et al. 1995; Sreekumar and Balakrishnan, 2002; Akhtar et al. 2004; Yoganand et al. 2006, Seidensticker et al. 2011; Ramesh et al. 2012). They are primarily a lowland species. Most Sloth bear range in India, Nepal and Sri Lanka is limited to habitats below 1500 m, although the

species may occur as high as 2000 m in the forests of the Western Ghats (Johnsingh, 2003; Seidensticker et al. 2011). In areas where forest cover is sparse but daytime temperatures are high (a large part of the range), the bear principally nocturnal or crepuscular and shelters in rock outcrops, thickets, and tree cavities during the heat of the day (Dharaiya et al. 2016).

Major threats to this species are habitat loss or degradation, retaliation from human-bear conflicts, and poaching (Johnsingh, 2003; Chauhan, 2006, Yoganand et al. 2006; Bargali et al. 2012; Bargali and Sharma, 2013). In some parts of the rangne, encounters between people and sloth bears have led to numerous serious human injuries and many deaths (Rajpurohit and Krausman, 2000; Bargali et al. 2005; Dharaiya and Ratnayeke, 2009; Ratnayeka et al. 2014). Such incidents occur where people frequently use bear habitat, and where the habitat has become severely degraded, prompting bears to seek food and water in closer proximity to humans. The only natural (non-human) threats to sloth bears are tigers and possibly leopards. The threat of tiger predation may account for aggressive nature of sloth bears (Joshi et al. 1999). Sloth bears have been observed fending off tigers, but they are also occasionally killed by tigers (Gopal, 1991).

3. Dhole (*Cuon alpinus*): The Dhole is a habitat generalist, and can occur in a wide variety of vegetation types, including primary, secondary and degraded forms of tropical dry and moist deciduous forests: evergreen and semi-evergreen forests, temperate deciduous forests, boreal forests, dry thorn forests, grassland-scrub-forest mosaics, temperate steppe, and alpine steppe (Kamler et al. 2015). The Dhole is one of only three canid species with specialised dental adaptations for an exclusively carnivorous diet, termed hypercarnivory (Van Valkenburgh, 1991). Although Dholes consume a wide variety of prey species, ranging from small rodents and hares to Gaur (Karanth and Sunquist, 1995; Andheria et al. 2007; Ramesh et al. 2012b, Selvan et al. 2013a), the preferred prey are ungulates with a body mass of 40–60 kg (Selvan et al. 2013b). However, if this prey size is not available, Dholes will selectively prey upon both smaller and larger ungulate species (Kamler et al. 2012). Due to demands imposed by hypercarnivory, sufficient numbers of ungulate prey are the Dhole's major habitat requirements. In India, tropical dry and moist deciduous forest may represent optimal habitats, based on the areas thought to hold the largest Dhole populations. Besides prey numbers, other important factors that many influence habitat use include levels of human disturbance, water availability, tiger presence, and suitability of breeding sites (Steinmetz et al. 2013; Srivathsa et al. 2014, Kamler et al. 2015).

It is enlisted as Endangered in the IUCN Red List (Kamler et al. 2015). There is no widespread exploitation of Dholes for fur or other purposes, and there apparently is little if any value for their use as traditional medicines. Thus, wildlife trade does not directly affect Dholes. Major threats to Dholes are depletion of prey base, habitat loss and transformation, persecution, disease and pathogens and competition with other species such as tigers and leopards. Although Dholes are much smaller in body size, packs of Dholes reportedly have killed both tigers and leopards, although the reverse also has been reported (Burton, 1940). Free-ranging dogs also may compete with Dholes for limited food resources where prey numbers are low.

4. Common Palm Civet (*Paradoxurus hemaphroditus*): This species is adapted for forest living, yet it tolerates living in areas near people commuting along wires and pipes, sleeping in barns, drains, or roofs during the day, and coming out at night to catch rats or forage for mango, coffee, pineapples, melons, and bananas; it also eats insects and molluscs (Spaan et al. 2014). It is reported to be crepuscular or nocturnal (Duckworth, 1997; Azlan, 2005), partly arboreal and the extent of arboreal activity perhaps caries across its range or between habitats. Although its IUCN status is Least Concern (LC) (Duckworth et al. 2016) and is included in Schedul II of the Indian Wild Life (Protection) Act, 1972. Globally its distribution includes Afghanistan, Bangladesh, Bhutan, Brunei Darussalam, Cambodia, China, India, Indonesia, Lao PDR, Malaysia, Myanmar, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Thailand, and Vietnam, Although distributed in most parts of India, the species is poorly studied for its distribution, ecology or trade (Jelil et al. in press). Common Palm civet is hunted for wild meat in some parts of its range, such as southern China, parts of North-east India, Lao PDR, Vietnam, Thailand and probably throughout northern South-east Asia and widely elsewhere in its range (Lau et al. 2010, Duckworth et al. 2016).

5. Brown Palm civet (*Paradoxurus jerdoni*): Brown Palm civet has been recorded only in evergreen forest and in degraded and anthropogenic habitats over former evergreen forest such as coffee plantations; there are no records from deciduous forests. It inhabits large continuous forests, high-altitude montane evergreen forest patches or sholas, and small forest fragments amid plantations of tea and coffee (Rajamani et al. 2002; Mudappa et al. 2007; Kalle et al. 2013). It seems to be most common in altitudes above 1000 m (Mudappa, 2001), but Rajamani et al. (2002) suspect that its distribution may depend more on the structure and floristics of forests, rather than on altitude. It is largely arboreal although descending regularly to the ground, as indicated by success in live-trapping and camera trapping (Mudappa 1998; Rajamani et al, 2002). It was also captured in our camera traps, although with only 17 number of captures, but it was still more captured than species like grey mongoose, stripe-necked mongoose and jungle cat. It is nocturnal and mainly frugivorous, feeding on at least 50 rainforest tree and liana fruit species, although it does supplement its diet with birds, rodents and insects (Pocock, 1939; Mudappa et al. 2010).

This species is endemic to the Western Ghats and populations have declined greatly during the main era of deforestation in the Western Ghats. But for the last few decades forest loss rates in its range have been low, and habitat-based declines are also assessed as low. Potentially more serious for this species could be the conversion of coffee and cardamom plantations into tea or other non-agroforestry used. However, all these changes are too limited at present to consider as active threats. The species is tolerant of fragmented landscapes (Mudappa, 2007). In most of its range, hunting is unlikely to be a major threat, but illegal hunting is still locally common in privately not enough to cause declines. Because of its prime frugivorous and arboreal habits, it can survive in heavily encroached areas provided some fragments remain with relatively unbroken canopy and adequate food resources, such as coffee and cardamom plantation, but not tea, eucalyptus, or teak (Rajamani et al. 2002).

6. Small Indian Civet (*Viverricula indica*): Small Indian civets are protected under the Indian Wild Life (Protection) Act, 1972 as a Schedule II species. The species occurs in Sri Lanka, Pakistan, most of India, Nepal, southern and central China, Taiwan, Bnagladesh, mainland Southeast Asia and various islands of Indonesia (Mudappa, 2013). In India, it is distributed from the Himalayan foothills to Kanyakumari in the south (Menon, 2014). The species prefers scrub and dry forests to undisturbed evergreen patches. It can live close to human habitation and often finds refuge in attics or drainpipes of houses. Although it has a wide distribution in India, owing to its elusive nature, the species is understudied (Mahananda and Jelil, 2017) compared to other carnivores. The species is widely used for various reasons. They are harvested for skins in China (Lau et al. 2010) and probably to some extent elsewhere. It is the second most commonly traded civet in Java, Indonesia, where they are kept as pets. While hunting is rare in some parts, a large part of its range i.e. Northeast India, southern China and northern Southeast Asia has heavy to very heavy mammal hunting for domestic consumption and sale into urban and international wildlife trade. For the civet musk industry, large numbers of civets are kept in India and increasingly in Thailand. These threats are not causing steep declines in India, Myanmar and southern China, the situation is less clear in northern South-east Asia, where hunting is highest, because of the species' limited occurrence in closed evergreen forest (Choudhury et al. 2015).

7. Grey mongoose (*Herpestes edwardsii*): Although it is common semi-synanthropic species, the natural history of the Indian grey mongoose is little studied. It has been recorded in disturbed areas, in dry secondary forests, and thorn forests (Shekhar, 2003). This species feeds on a wide variety of animal food including insects ad snakes (Santiapillai 2000). Shekhar (2003) noted that this species is often captured and sold as a pet. Northern Indian people use hook snares to capture individuals for skins, which are then sold in local markets in Nepal (Shekhar, 2003). In India, all mongoose species are in demand for the wildlife trade (Van Rompaey and Jayakumar, 2003). The meat is eaten by several tribes and the hair is used for making shaving brushes, paint brushes, and good luck charms (Hanfee and Ahmed, 1999). Indian Grey mongoose has no range-wide threats to sufficiently decline the population. It is likely that in some areas the levels of harvest are sufficient to reduce local densities. Over recent centuries the species has probably benefitted from conversion of closed evergreen forest to open habitats (Mudappa and Choudhury, 2016).

8. Ruddy mongoose (*Herpestes smithii*): The population status and ecology of the Ruddy mongoose remains little known. Most records are from open forest, including dry forests and dry thorn areas, and disturbed forests (Mudappa and Choudhury, 2016). Ruddy mongoose is perhaps partly crepuscular, although there are many records by day and some by night. It climbs in trees at least occasionally, but evidently spends most of the time on ground (Mudappa and Choudhury, 2016). There appear to be no major threats to the global Ruddy mongoose population. Local scale threats include hunting and snaring.

9. Stripe-necked mongoose (*Herpestes vitticollis*): Stripe-necked mongoose has been recorded in deciduous and evergreen forest, open scrub and along watercourses (Webb-Peploe, 1947; Van Rompaey and Jayakumar, 2003). In deciduous forests it is usually found in swampy clearings, along watercourses and in open scrub (Krishnan, 1972). It is more common in the hills than in the lowlands, and has been found up to 2200 m (Hill, 1939; Van Rompaey and Jayakumar, 2003, Mudappa et al. 2016). It is diurnal and feeds on small mammals, birds, birds' eggs, reptiles, fish, insects, grubs and roots (Van Rompaey and Jayakumar, 2003). There are no major threats to the global stripe-necked mongoose population, although local consumption and use is present (Hanfee and Ahmed, 1999). The population presumably fell steeply during the main phase of deforestation in the Western Ghats many decades ago, but rates of clearance are now low, and the species is often seen not just in degraded and fragmented forest, but also in non-forest habitats interspersed with forest fragments (Mudappa et al. 2016).

10. Jungle cat (*Felis chaus*): The Jungle cat is actually strongly associated with wetlands, habitats with water and dense vegetation cover, especially reed swamps, marsh and littoral and riparian environments-scrubland and deciduous dipterocarp forest (Gray et al. 2014).Jungle cats have adapted well to irrigated cultivation, having been observed in many different types of agricultural and forest plantations throughout their range, such as sugarcane in India. In a study in Pench Tiger Reserve, Madhya Pradesh, Inda, this cat was mostly active in the night hours (Majumdar et al. 2011), whereas in Cambodia, jungle cats were found to be more active during the day (Gray et al. 2014). The biggest threat to Jungle cat is habitat loss particularly industrialization an urbanization of low intensity agricultural areas and scrubland in the Indian subcontinent (Gray et al. 2016). Unselective trapping, snaring and poisoning around the agricultural and settled areas have caused population declines in many areas throughout its range (Abu-Baker et al. 2003; Duckworth et al. 2005). India formerly exported large numbers of Jungle cat skins before the species came under legal protection, and some illegal trade continues (Sunquist and Sunquist, 2002, Choudhury 2010), elsewhere in South Asia (Choudhury et al. 2015) as well as un Egypt (Glas, 2013) and Afghanistan (Habibi, 2004). The scarcity of jungle cat in mainland Southeast Asia is likely the result of high levels of hunting in open and accessible deciduous dipterocarp forest (Duckworth et al. 2005).

11. Rusty spotted cat (*Prionailurus rubiginosus*): Studies report the presence of this cat in proximity to human habitation (Worah, 1991; Nowell and Jackson, 1996; Mukherjee, 1998; Nekaris, 2003). A niche modelling study suggested that at a broad scale this cat's distribution is limited by large contiguous tracts of hostile habitat, specifically intensive, irrigated agriculture (Silva et al. 2015). These prime regions correspond with dry and moist deciduous forests showing relatively low forest fragmentation according to landuse and land cover maps of India (Roy et al. 2012). This species is understudied due to nocturnal and elusive habits. According to Bhardwaj and Dutta, (2014), the total extent of prime habitat of the Rusty spotted cat in India and Nepal is equivalent to around 25% of the range of the species in these countries. This accounts for 75% of the current habitat in India and Nepal facing an imminent danger of conversion to urban areas, industry, mining and other forms of land use hostile to Rusty-spotted cat. As much of the distributional range constitutes marginal habitat for the species, this 75% loss of habitat could translate to a decline of around 20–25% of the current population over three generations. Given the much smaller landmass of Sri Lanka, the mainland population constitutes perhaps 90% or a little more of the global population. Since much of the species' range is within hugely human-dominated areas undergoing rapid land use change, fragmentation of habitat and disease should be considered as serious threats. There are concerns regarding possible hybridization of rusty-spotted cats with domestic cats (Kittle and Watson, 2004). However these information have to substantiated and measured to determine if this factor is indeed a threat to this cat.

12. Leopard cat (*Prionailurus bengalensis*): Leopard cats can range up to 3240 m asl (Ghimirey and Ghimire, 2010) and occur in a wide variety of habitats from tropical rainforest to temperate broadleaf and marginally coniferous forest, as well as shrub forest and successional grasslands. The northern boundary of its range is limited by snow cover, as the Leopard cat does not occur in deep snow. They occur commonly in dense secondary growth, including logged forest (Ross et al. 2010; Mohamed et al. 2013) and have been found in Acacia (Giman et al 2007), oil palm (Ross et al. 2010) and sugarcane plantations (Lorica and Heaney, 2013). They are excellent swimmers and have successfully colonized offshore islands throughout their range (Nowell and Jackson, 1996; Sunquist and Sunquist, 2002). It is predominantly nocturnal (Grassman et al. 2005; Cheyne and Macdonald, 2011; Lynam et al. 2013; McCarthy et al 2015) with high crepuscular activities in some areas (Grassman et al. 2005), but some diurnal activity has been recorded as well (Saxena and Rajanshi, 2014).

In China, commercial exploitation has been heavy, hundreds of thousands of leopard cat skins per year were exported in the 1980s. Island populations are small and seriously threatened in the Phillipines and Japan. Hybridization in the wild has been reported, but is not considered a significant threat. Although this species is less dependent on forest cover than others, habitat loss and fragmentation is still a threat across most of its range (Nowell and Jackson, 1996).

Chapter V:

Anthropogenic Status in Sahyadri Tiger Reserve

5.1. Introduction:

Forests and their natural resources are facing rising challenges in terms of climate change and anthropogenic pressures. Anthropogenic pressure is one of the persistent problems that began many years back and is increasing with time. The killing of wild animals for their flesh, skin and body parts and collection of nontimber forest produces (NTFP), fuelwood, timber, selective logging, cutting and grazing of livestock have caused degradation of forest by overexploiting the critical micro and macro habitats that are preferred by various wild animals for feeding, resting and breeding. Globally, protected areas provide havens and refuge areas for biodiversity and play an important role in conservation (Leroux et al. 2010). Currently, there are more than 161,000 protected areas worldwide covering 10-15% of land surface of the earth (Soutullo 2010; Jenkins and Joppa 2009).

Extensive deforestation and habitat fragmentation continue at alarming rates throughout the world and the survival of innumerable forest species, mainly in the tropics is in jeopardy (Marsh & Mittermeier 1987). World's most of the protected areas are under tremendous pressure of human population growth, which creates disturbance and alteration in the forest ecosystem and forest habitats, which affects the wildlife and their population and causes the deforestation and extinction of many species from wild. In view of biological conservation and to minimize degradation of natural ecosystems, Protected Areas (PAs) have been established that cover about 5% of the world's land area (Groombridge 1992; Singha 1997). The extraction of biomass resources, such as fuelwood, timber and fodder by rural communities, perhaps once within the carrying capacity of surrounding forests, has now crossed this limit in many resource-rich areas of the world (Reid et al. 1990). Harvesting of fuelwood and timber has profound effects on the biodiversity of forest Ecosystem (Sayer and Whitemore 1991), often leading to the change in species composition and vegetation structure (Bormann et al. 1977; Berkmuller 1988; Berkmuller et al. 1990; Kouki 1994). The uncontrolled grazing by domestic livestock is another aspect of removal of biomass from natural ecosystems, which has a direct impact on the regeneration process of forest floor by removing young saplings and soil loss due to trampling (Kelt and Valone 1995; Saberwal 1995).

In India, although the degree of anthropogenic pressures varies in different parts of the country, the man-made disturbance has become a widespread feature in most of the forests (Singh et al. 1984; Singh and Singh 1989; Singh and Singh, 1992). The consequences of degradation in the forest ecosystems have been more precious since they are considered as ecologically fragile and the regeneration of such degraded ecosystems is extremely difficult due to the physical instability and environmental characteristics of the area. Therefore, understanding the level of anthropogenic pressure and its distribution on these forests is urgently needed to address the site-specific conservation problems and sustainable use of natural resources of the region. Concerns about the widespread degradation of natural resources in various regions of the country express by many researchers in past (Babu et al. 1984; Singh et al. 1984; Moench and Bandopadhyay 1986; Shiva and Bandyopadhyay 1986; Bhatt 1992) also substantiate the importance of such types of studies. Anthropogenic pressure can cause uncontrolled influences that bring changes in floral and faunal diversity, habitat, landscape, soil degradation and may also lead to considerable alterations in the environmental conditions. Many, traditional societies utilize their natural resource base based on their perceptions, experience and response to patterns of resource uses by others (Samant and Dhar, 1997). The present study highlights the quantitative estimates of various dominating factors of anthropogenic pressures: human and cattle population, grazing, cutting, encroachment, collection of minor forest produce (MFP) and generation of income, associated with hunting and trading of animals and plants by local people and occurrence of incidental forest fire in Sahyadri Tiger Reserve (STR). Just like tigers, spotted deer (chital) also have experienced a drastic population decline and finally got extinct from the forest of STR.

5.2. Methodology:

We conducted feild assessment to find out the anthropogenic pressure and people's perception towards tigers and other wildlife,. The survey was conducted from March 2017 to November 2017. Using a standard questionnaire format, village heads, businessman, farmers and other local people were interviewed to assess the present threats to the wildlife in STR and for understanding the pressure on natural resources and which areas are the most disturbed by humans and their livestock. The camera traps installed were also used to calculate capture rate and activities of humans and livestock inside the forest. Questionnaire surveys were conducted in all the five range villages of STR. From each of the ranges, 30% of the total households were surveyed, interviewees were selected from each village based on the stratified random sampling technique and the first person encountered in the house was questioned based on the extent to which the people depended on natural resources, their proximity to the forest occurrence of wildlife and perception towards tigers. The primary data were collected through open-ended questionnaire and interviewing of forest department officials and field staff, and secondary data was collected through field observation and extracted from camera trap data.

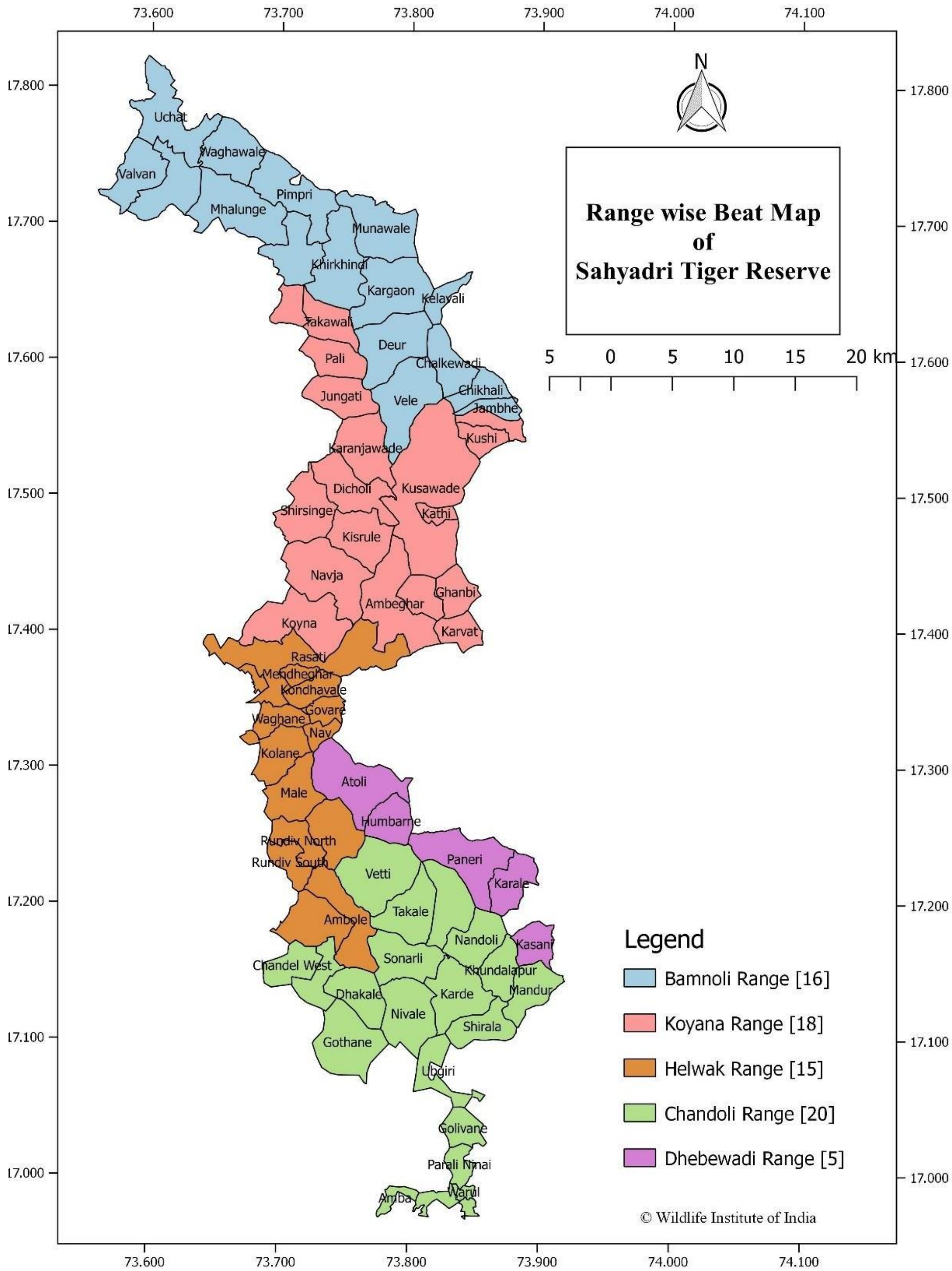

Figure 1: Range-wise beat map of STR

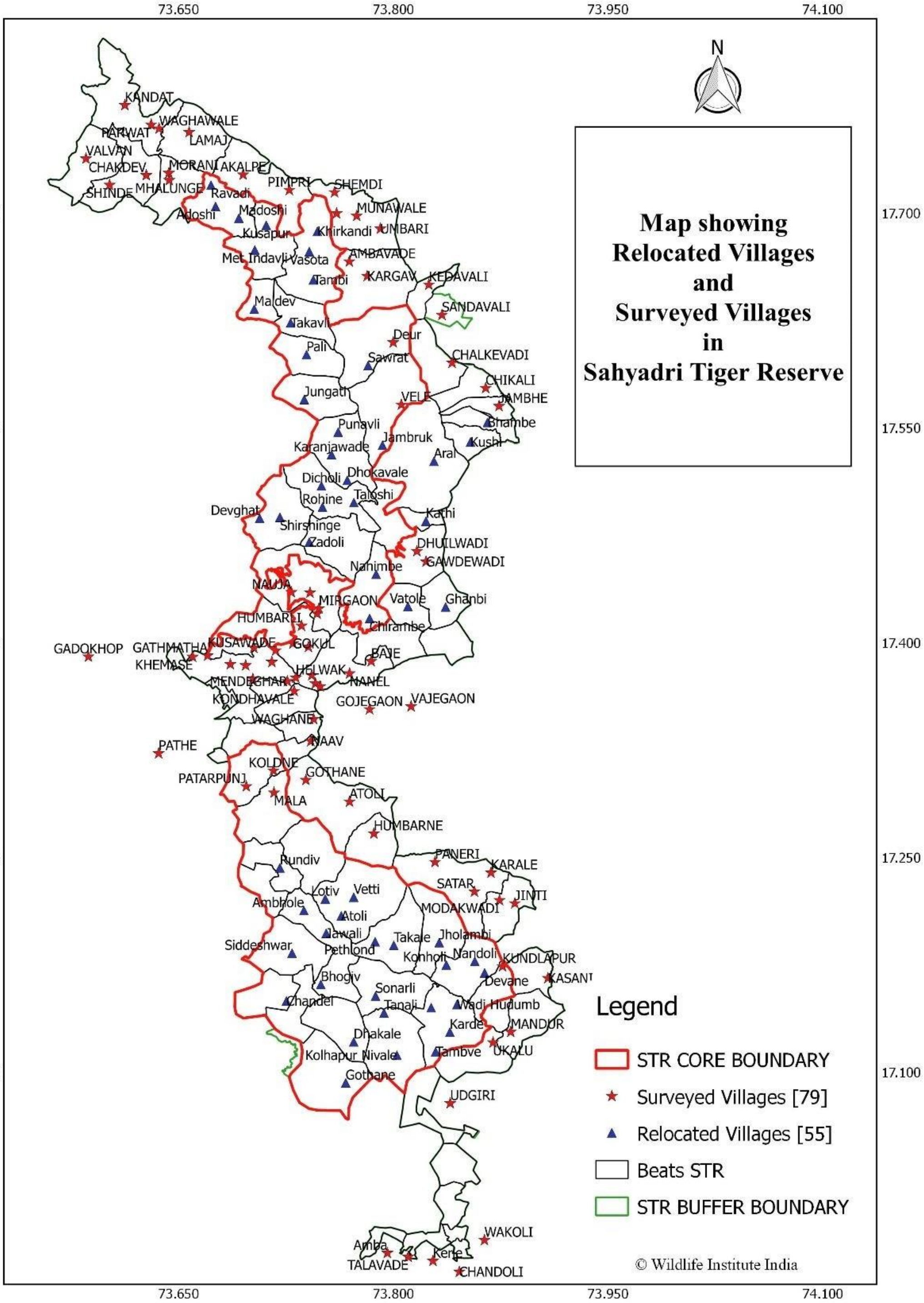

Figure 2: Showing relocated and settled villages in STR

5.3. Results:

There are 79 villages in 5 ranges of STR; out of the 79 villages, 18 are in core zone and 61 in buffer zone of STR (Figure 2; Table 1). The village having the highest population is Rasati with total population 2050 in buffer zone of Helwak range and the village having the lowest population is Khemase with total population 15 in buffer zone of Helwak. The total village population is 39731 out of which 9506 people are living in the core zone of STR and 30225 people are living in the buffer zone. The total number of households in 5 ranges is 3601. All the 79 villages are inhabited by Schedule caste (SC), Schedule tribe (ST), Nomadic tribe (NT), Bodh Samaj and Muslim community. People of these villages mostly dependent on agricultural activities and forest products i.e. 69.34%; and 30.66% peoples are engaged in other activities like labour, working in Mumbai and Pune in private companies etc. The total number of interviews taken was 1034 from all the 5 ranges. Out of 1034 interviewees, 697 were males and 337 were females with average age 48.47 ± SD 15.51 years; and the total members in their households are 6512 out of which 2448 are males, 2324 are females and 1751 are children. Locals use fuelwood more than any other forest product (56.98%) followed by fruits (26.93%) and livestock grazing (11.12%). They use fruits for consumption and for trading purposes like Jamun, *Carissa*, Jackfruit and Mango.

Our questionnaire results show that out of 100%, 7.93% people of core villages are accepting the tiger reintroduction whereas 38.2% people of buffer villages are accepting the tiger reintroduction totaling 46.13%. Rest of the 53.87% people of buffer and core zones are not accepting tiger reintroduction.

5.3.1. Human settlement:

There were 134 villages in STR before it was declared as tiger reserve (Figure 2), after it was declared as tiger reserve govt. relocated 55 villages from core and buffer zone of STR. Now there are 79 villages remaining in the 5 ranges of STR (Table 1). These villages are inhabited by Maratha community (SC/ST/OBC Caste) with the highest percentage (87.04%) followed by Nomadic tribe (7.73%), Bodh community (5.02%), and Muslim community (0.19%) and very few villages are having mixed community such as nomadic tribe, Maratha community, Hindu Sutar and Hindu Satar community (Figure 3). Inside these villages, people are living in wadis (colony) based on their community type.

A total of 3601 households were reported to exist in these 79 villages, comprising a total population of 39731 people. The largest village is Rasati with a total population of 2050 of Helwak range and the smallest village is Khemase with a total population of 15 people of Helwak range. Rasati village is the most developed village among all the other villages of STR and less dependent on agricultural activities and forest products except fuelwood. But the other villages are habituated in doing the agricultural activities in and around the forest land and from where they are also using forest products. All these activities are affecting the wildlife and the forest.

Range	Beat	Zone	Village name	Population	No. of households
Debewadi	Karale	Buffer	Karale	935	72
		Buffer	Modakwadi	350	50
		Buffer	Jinti	450	60
	Paneri	Buffer	Paneri	700	50
	Satar	Buffer	Satar	675	68
	Humbarne	Buffer	Humbarne	400	40
	Atoli	Buffer	Gothane	370	63
		Buffer	Atoli	1100	60
	Kasani	Buffer	Kasani	760	82
Helwak	Rasati	Buffer	Baje	350	22
		Buffer	Kisrule	210	29
		Buffer	Bopoli	400	25
		Buffer	Dastan	500	70
		Buffer	Nanel	60	10
		Buffer	Nechal	700	45
		Buffer	Sivdheswar	200	21
		Buffer	Dhankal	400	50
		Buffer	Rasati	2050	235
		Buffer	Gadokhop	500	80
		Buffer	Khemase	15	4
	Helwak	Buffer	Helwak	1050	80
	Territorial	Buffer	Pathe	45	13

Range	Beat	Zone	Village name	Population	No. of households
		Buffer	Gojegaon	250	12
		Buffer	Vajegaon	700	55
	Mendeghar	Buffer	Mendeghar	450	50
	Waghane	Buffer	Waghane	300	21
		Buffer	Naav	450	60
		Buffer	Kondhavale	600	40
	Kolne	Core	Kolne	450	40
		Core	Patarpunj	600	55
	Male	Core	Male	450	60
Koyana	Koyana	Core	Torane	300	17
		Core	Kusawade	500	18
		Core	Deshmukhwadi	400	46
		Core	Humbarli	650	70
		Core	Ghatmatha	221	25
		Core	Gokul	900	50
	Kusawade	Core	Gawdewadi	1200	40
		Core	Dhuilwadi	430	45
	Nauja	Core	Kamargaon	500	90
		Core	Mirgaon	350	40
		Core	Manainagar	375	40
		Core	Nauja	1500	75
Bamnoli	Vele	Core	Vele	250	30
		Buffer	Jambhe	500	6
		Buffer	Chalkewadi	750	70

Range	Beat	Zone	Village name	Population	No. of households
		Buffer	Chikali	750	100
	Deur	Core	Deur	30	65
		Buffer	Kedavali	260	30
		Buffer	Sandavali	100	15
	Munawale	Buffer	Shemdi	350	30
		Buffer	Munawale	700	50
		Buffer	Umbari	1200	40
	Kargav	Buffer	Kargav	65	8
		Buffer	Ambavade	40	12
		Buffer	Wagholi	60	12
	Aarav	Buffer	Aarav	300	35
		Buffer	Chakdev	30	10
	Waghawale	Buffer	Waghawale	700	40
		Buffer	Lamaj	550	60
		Buffer	Nivale	400	30
	Uchat	Buffer	Uchat	450	35
		Buffer	Parwat	50	10
		Buffer	Kandat	100	15
	Shinde	Buffer	Shinde	350	40
	Valvan	Buffer	Valvan	250	40
		Buffer	Morani	40	10
	Akalpe	Buffer	Akalpe	550	70
		Buffer	Pimpri	100	20
	Mhalunge	Buffer	Mhalunge	80	10

Range	Beat	Zone	Village name	Population	No. of households
Chandoli	Kundhlapur	Core	Kundhlapur	400	40
	Udgiri	Buffer	Udgiri	550	40
		Buffer	Ukalu	750	75
	Mandur	Buffer	Mandur	1200	100
	Kandavan	Buffer	Wakoli	350	30
		Buffer	Chandoli	750	40
		Buffer	Talavade	380	40
		Buffer	Kerle	750	45
		Buffer	Amba	1800	120
Total				39731	3601

Table 1: Forest villages in Sahyadri Tiger Reserve with population and respective number of households

(Source: Forest Department Record)

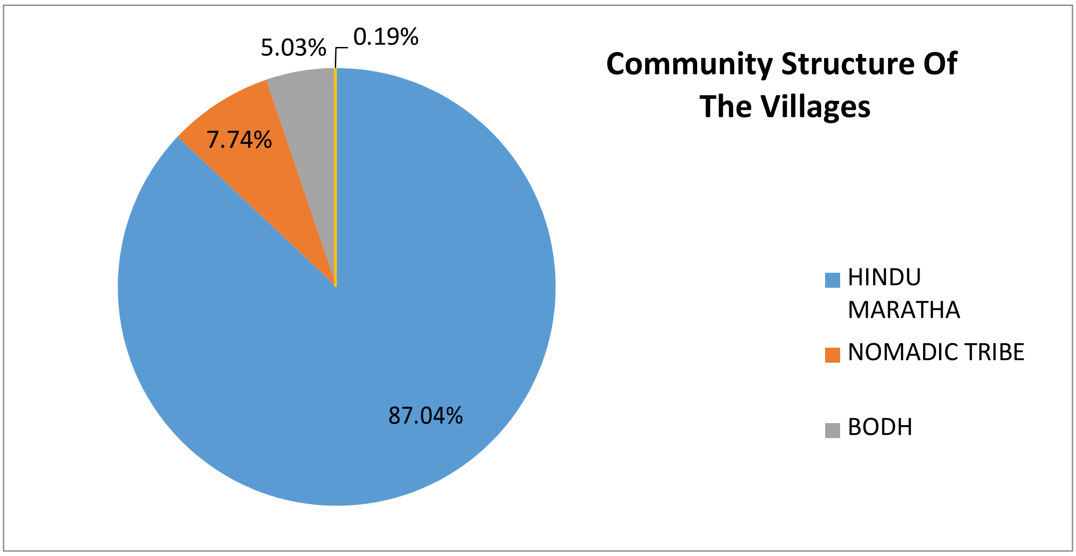

Figure 3: Showing the community structure of the villages.

5.3.2. Livelihood options:

Dependence of humans on forest resources in all possible ways is the main reason for anthropogenic pressure in any area. People are staying near forest area or inside the forest are using forest product for their day to day life which affects the wildlife. Agriculture was found to be the primary occupation for 69.34% peoples interviewed in the villages. They are cultivating rice, wheat, corn, pulses, groundnuts etc. and this is the main source of income for them followed by 4.74% people who are working in the cities like Mumbai, Pune, Chiplun in private companies and hotels. Only 1.06% peoples are following business as their occupation (Figure 4).

In these villages, about 56.98% of the total population relies on fuelwood. Fuelwood is gathering on daily basis from the forest by every family living in the forest area mostly during summer time. Collection of dead and fallen trees timber and plant leaves for making of house roof and for cattle shelter results in harmful effect on the soil, depriving it of nutrition and ground cover; and cutting of fuelwood and timber from grown trees has tremendous effect on the forest and wildlife other than fuelwood and timber people are also dependent on fruits of the forest. About 26.93% of wild fruits are been collected by the local people of the villages and around 15% out of 26.93% they are using for trading purpose. Syzygium, Carissa, Mango, Jackfruit, Morus, Zizyphus are the main fruits for the trading in local markets, bus stand etc, the fruits they are collecting are also eaten by wild animals so this leads to the lack of food for them. Other than fuelwood timber and fruits; collection of fodder, medicinal plants and honey also came to our knowledge during the survey but the collection of these products is very less in comparison with fuel wood and fruits (Figure 8).

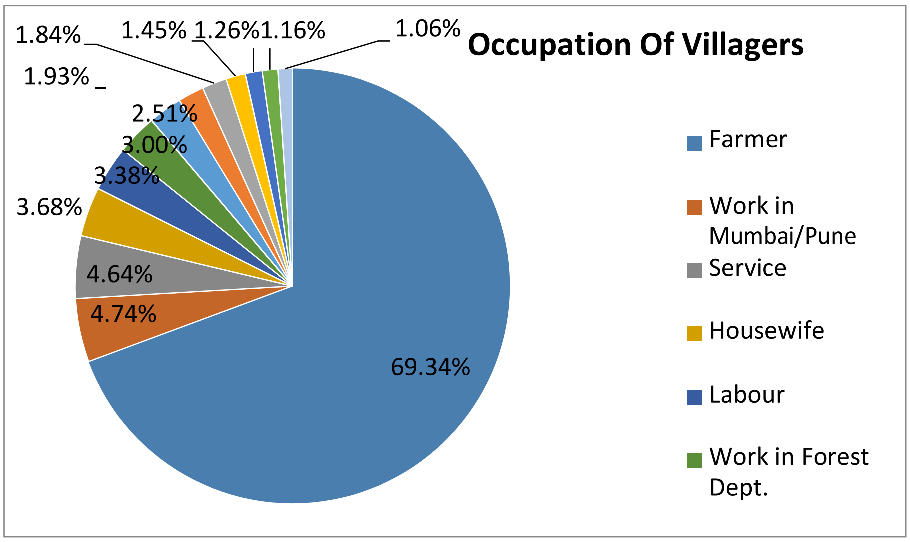

Figure 4: Showing the occupation of the villagers in STR.

Figure 5 (A, B, C, D): Collection and use of forest products by locals in STR

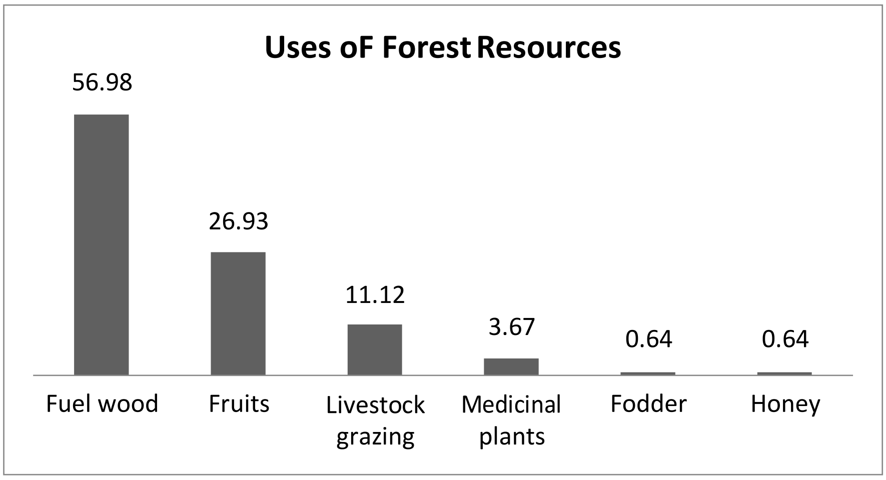

Figure 6: Showing use of forest resources by the villagers

5.3.3. Hunting:

A few years back, before STR was declared as a tiger reserve, people used to hunt in a large scale for consumption of flesh as food and organs as a medicinal value. But after it was declared as tiger reserve they stopped killing the wild animals which has resulted in the growth of wildlife and it still keeps on growing. However the people are saying that they stopped killing wild animals, there is some probability that they are still hunting the animals for food, not for trading purposes.

5.3.4. Habitat disturbance:

Construction of road and selective logging is the reason for habitat fragmentation and activities like agricultural practices, felling of trees for commercial purposes are the reasons for habitat destruction. Other indirect threats for habitat are the collection of timber, grazing by livestock and human interference and movement inside the forest land. During the movement, they make noise which disturbs the wild animals while they are feeding or resting.

During the study, we deployed camera traps to find out the disturbance caused by humans and livestock and we found out the capture rate for a human is 0.202 per day and for livestock is 1.146 per day in all 5 ranges of STR. The disturbance caused by humans and their livestock is high which leads to habitat destruction. Livestock grazing can be the main reason of threat for wildlife. The actual effect of livestock grazing in the study area has not been quantified, but some of their feeding activities can be discussed. Cattles destroy most of the seedling by walking and grazing, and they were found during study period temporarily live inside the forest. So they are causing more harm to the forest and competition between herbivorous wild animals and livestock for food. Other than disturbance created by humans and livestock, there is one more factor which affects the health of the forest i.e. forest fire. In some parts, a forest fire was found to be made intentionally for the benefit of the fuelwood collectors because, after the fire, dry woods can be gathered. The fire also caused loss of various small plant species from that area.

5.3.5. Traditional use:

Peoples are collecting timber to build their traditional houses which are supported by a framework of wood with a roof of grass and iron frame. They are also using timber for poles instead of pillars and beams and for fencing of their houses, a shelter for livestock. Villagers are collecting building materials illegally from the surrounding forest. Although they are using commercially less important tree species they are important ecologically for the forest.

People are also using medicinal plants for wounds and cuts, snake bites, joint pain, etc. they are also capturing wild birds and hare from the forest and keeping them as a pet (picture 8).

Figure 7 (A, B, C, D): Use of forest produce in building poles, roofs and pet cages

5.3.6. Perception:

We asked people about their perception towards tigers mainly (as our main focus is on tiger reintroduction); some people are not ready to accept the tiger reintroduction whereas some people showed positive response. Our questionnaire results show that in total villages of core and buffer zone only 46.13% peoples are ready to accept tiger reintroduction in their area and rest 53.87% peoples are not ready to accept. Range wise result shows that Bamnoli range has the highest acceptance (16.44%) and Koyana range have the lowest acceptance (4.54%) (Figure 8).The reason for not accepting tiger reintroduction came to our knowledge during the survey is that they think tiger is a large predator and as they go inside the forest for the collection of fuelwood, tiger will attack them, they are afraid of it. On the other hand, people also think that wildlife is very important for them and somewhere humans and wildlife are connected with each other. We also asked them about the attack on a human by any wild animal and the result we found is there is no attack on a human by tiger and leopard since last 5 to 10 years, only wild boar and gaur attack them in their fields. Although leopard attack on their livestock in the forest but never attacked on a human. We have also asked them if there is any conflict and any attack on livestock in the future what will they do, 92.35% answered that they will complain to the forest department and want compensation for any loss and rest 7.64% people having no idea about that.

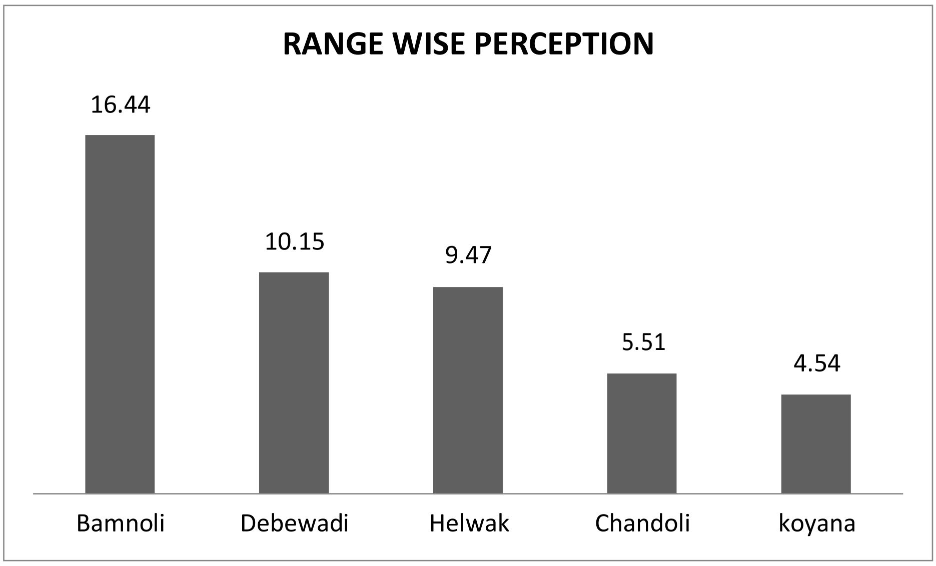

Figure 8: Showing range wise perception result for tiger reintroduction.

5.4. Discussion:

Reintroduction is an increasingly important tool for conservation of large carnivores (Hayward & Somers 2009). Before reintroduction of any wild animal especially large carnivore, consultation with the villagers of that are living close to the reintroduction site or around the site should be taken. If the villagers accept the reintroduction than it becomes easy with their support. In Sariska tiger reserve the villagers consented to the reintroduction of tigers in the area, citing reasons of preying on the weak cattle by the tigers, which according to them was a process of natural selection. Adequate measures for compensation in event of cattle kills were put in place. The local people of Sariska tiger reserve considered tigers to be beneficial for the habitat and supported the idea of reintroduction (Sankar, et al. 2008). Many studies were done on the reintroduction of wild animals around the world and all studies first consulted with the local people about the reintroduction idea. In STR we consulted with the villagers and as required under the NTCA protocol, the local people of STR considered tiger and other wild animals to be beneficial for the habitat, but still, they are not ready to accept the reintroduction mainly because of fear.

46.13% (~50%) people are ready to accept the reintroduction of tiger and rest of the people not ready. The reason they are not accepting the reintroduction is that they haven't seen any large predator in their area so they are afraid of what will happen once the tiger reintroduced. However, there is no harm to human lives as there is no record of attacking human by leopard or tiger; except livestock is been attacked by leopards in some villages inside the forest. But still, they think if tigers are reintroduced then it will attack farmlands and livestock. There are few incidences where wild boar attacked the human in their farmland during monsoon. But no other wild animal ever attacked on humans. Out of 100, 47.96% people think that the wild animals like leopard and tiger are a psychological and economical threat to human and livestock and the remaining people have no idea about the threat. Behind this perception, lack of awareness about wild animals of the local people is one of the main reason. Only 3% peoples are well aware of the wildlife and the rest of the percentage of people is unaware. Even with this perception and lack of awareness, 97.38% people believe that the wildlife and forest are important for them to survive; they need forest around their villages. But still 53.38% people of STR villages are readily willing to relocate anytime from that area and the remaining people who were not ready stated that they will relocate if assure by attractive packages of land, money and other facilities like water, electricity etc.

Nearly all the interviewees believed that wild animals are important for the forest ecosystem but they are afraid of the after-effects of tiger reintroduction. But they also stated that they will accept if the tiger number will increase in the future but there must be some surety of the safety of human lives. There is a great possibility that the percentage we got in the results for the acceptance of tiger reintroduction will change after close relationships are built with the locals through various ways and they are taken into confidence. This has already shown some promise and positive results as there have been initiation of various camps and formation of women self-help groups by the reserve authority. The efforts of the field director and deputy director in this regard have showed positive responses. With more of such initiatives and close work with the locals, we hope that the tiger recovery project will gain more acceptance and people being more tolerant towards large carnivores.

Chapter VI:

Strategic Action Plan for Tiger Recovery

6.1. Feasibility statement:

Sahyadri Tiger Reserve has seen a sharp decline in tiger population in the recent past. Since its very inception as a tiger reserve, it was amongst the low tiger density areas in India. Hence, a recovery program was imperative to restore the tiger population in the reserve. Recovery or reintroduction projects need to assess the viability of long term plans due to the involvement of enormous funds, resources and man power. In the first phase, we followed the feasibility assessment framework put forth by Gray et al (2017), where they provide the most vital components or factors for assessing a landscape to see if a landscape is ready to receive management interventions in regards to restoring wild tiger populations. The four major components are a. habitat suitability, b. prey availability, c. management effectiveness of the concerned park authorities and d. the social acceptance of the fringe communities. We present it concisely in this section. We state that Sahyadri Tiger Reserve needs immediate actions in regards to tiger recovery and that it is ready to receive recovery efforts given the absence of breeding tigers in STR, sufficient prey numbers to begin with, available inviolate habitats in the core, the present and rapidly growing effective management.

6.2. Habitat suitability:

We have presented detailed status of the habitat and landscape of STR in the second chapter. Based on the remotely sensed and ground data collected over one year (February, 2017–December 2017), we further present a habitat suitability model here. This was carried out to identify the potential suitable habitats for tiger within the reserve. For suitability analysis, Boolean approach was used to achieve better results. Datasets preparation for the analysis includes classification of all the datasets in two categories suitable and unsuitable. The descriptions of different thresholds for different parameters are as following:

a. Slope: Slope is the measure of steepness or the degree of inclination of a feature relative to the horizontal plane, which ranges from 0 degree to 67.18 degree for STR. This is categorized into two classes 0°–35° as suitable and more than 35° as not suitable (Figure 1 A).

b. Water Availability: For assessing the water availability for STR, a stream network was generated from flow accumulation with threshold of 500. A buffer of 1 km distance was generated for the stream network which shows that the entire STR as suitable (Figure 1 B).

c. NDVI: Normalized Difference Vegetation Index represents the vegetation cover of the ground and it ranges from -1 to 1. For STR, the highest NDVI value was found to be 0.91 and lowest -0.43. This was further reclassified into two classes, viz. more than 0.30 as suitable and less than 0.30 as not suitable (Figure 1 C).

d. Human Disturbance: To investigate the human disturbance within STR point, locations of all the villages including core and buffer area were extracted and a buffer distance of 1 km was classified as unsuitable and rest of the area as suitable area (Figure 1 D).

The site suitability analysis estimates a total area of 451 km^2 as potentially suitable habitat for tiger following all the thresholds of different criteria (Figure 2). The area resultant as suitable area mostly falls under the core area and situated in the western part of the reserve. The model suggests that the western part of the tiger reserve is more suitable in comparison to the eastern part. This was also found in the Radius of Gyration analysis in Fragstats (refer Chapter II), which shows a strong connectivity between forest patches across the western parts of the reserve.

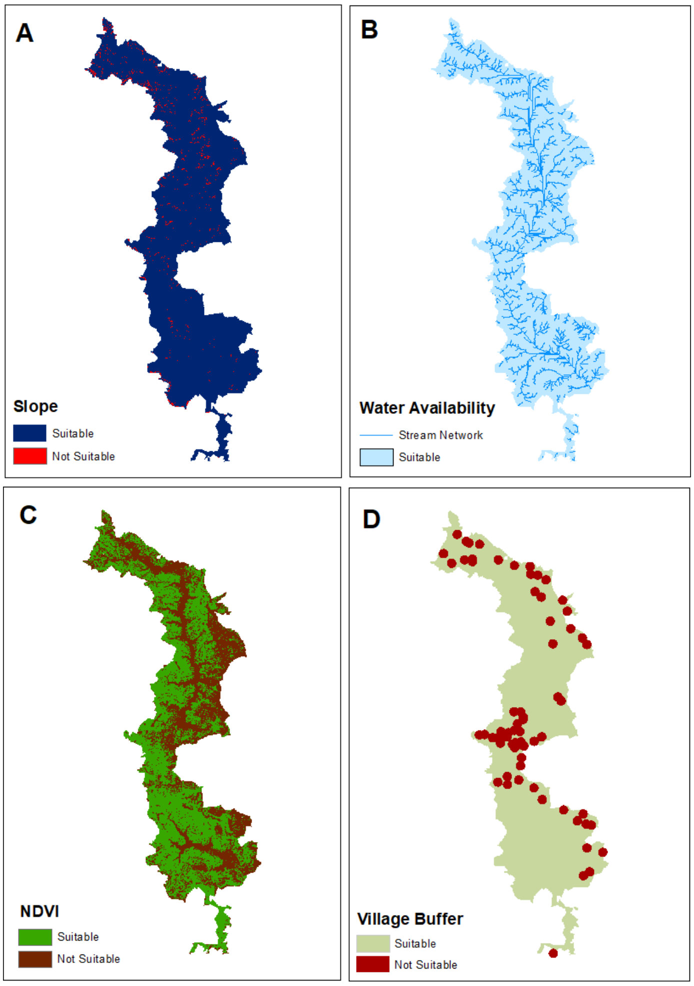

Figure 1: Showing the different parameters considered for the habitat suitability analysis (A) Slope (B) Stream network (C) NDVI (D) Village locations

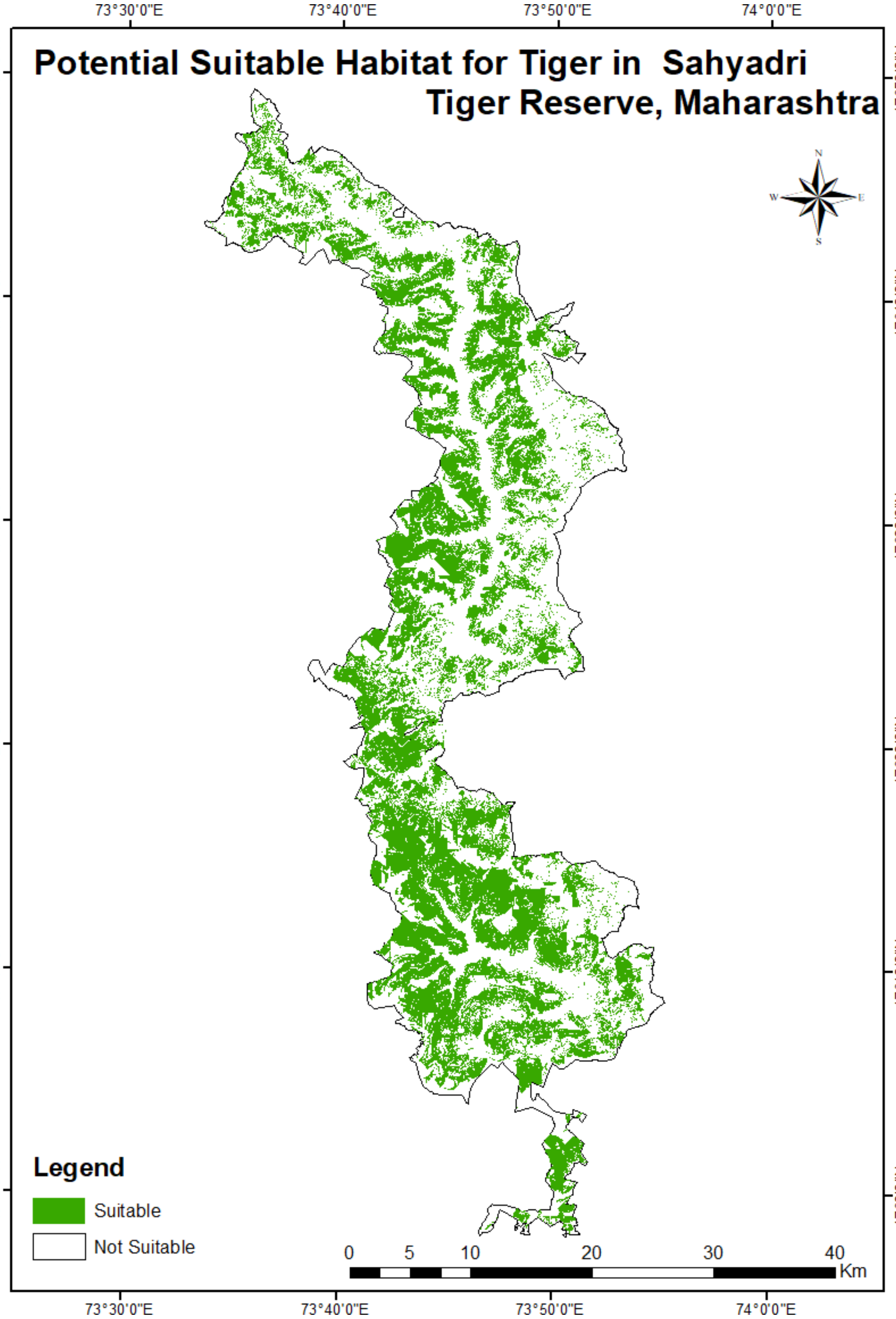

Figure 2: Habitat suitability map for tiger

6.3. Prey availability:

As discussed, in detail, in Chapter III, we found that wild ungulate density to be 9.5 per km^2, which we believe is an underestimation given the terrain complexity and poor detection during the line transect sampling (detection has been prevalent in the camera traps). However, this is enough to support 12 tigers, but this is just the wild ungulate density, other forms of prey such as livestock and primates in and near the reserve are also present. This data is from the line transects carried out beat-wise; we compared the camera capture rates (cameras which were also installed beat-wise) with this data (Figure 5, in Chapter III) and found that the estimation of density from transects is actually underestimation as stated above. Due to rugged terrain of STR landscape, the encounters in transects were low. Although we conclude that the existing prey base is adequate to sustain a small reintroduced tiger population; we also recommend prey augmentation/ supplementation in order to ensure viable populations of tigers in the long-term.

6.4. Management Effectiveness Evaluation:

Evaluating management effectiveness and using the results for adaptive and better management is at the core of good PA management. Mathur et al. (2014) describe protected area (PA) management effectiveness evaluating (MEE) is defined as the assessment of how well Pas are being managed. It reflects and focuses on three themes of PA management: (a) Designing issues relating to both individual sites and PA systems; (b) The adequacy and appropriateness of management systems and processes; (c) Delivery of the objective of Pas, including conservation of values. In India, MEEs take place every four years, the most recent MEE took place in January in 2018 and the reports will be available soon. The older MEE in 2011 describes Sahyadri Tiger Reserve as 'satisfactory'. Following the IUCN World Commission on Protected Areas (WCPA) framework (Hockings et al. 2006), the evaluation committee, ranked the Tiger Reserves as (a) Very good (b) Good (c) Satisfactory and (d) Poor.

The MEE report of 2014 describes a more detailed status of all the tiger reserves, rather than just classifying tiger reserves into separate categories. They chalk out a list of 'management strengths', 'management weakness', and then suggest some 'actionable points' for all the tiger reserves evaluated. In this report, the committee upgraded Sahyadri Tiger Reserve and changed the status to 'good' from 'satisfactory/fair'. This suggests that significant improvements have been made in the management of the reserve and STR still serves as a potential site for further tiger conservation efforts. We present excerpts of the relevant strengths and weakness expressed in MEE 2014(Table 1), which are most important in terms of long-term tiger recovery efforts.

Strengths	Weakness	Actionable points
Located in the Western Ghats Landscape Complex	Terrain is difficult to access	Improving infrastructure, staff housing, protection and strengthen monitoring and communication
Good availability of water	Lack of infrastructure, equipment and adequate numbers of trained staff	The few villages inside the tiger reserve may be brought under voluntary relocation programme
Large inviolate core (600 km^2)	Demand for land for windmills, resorts and road	The buffer areas in Satara division, Sangli division, Kolhapur division and Ratnagiri division may ne transferred under unified command to the STR
		Examining the possibility of repopulating the habitats with ungulate species

Table 1: Describing the strengths, weakness and actionable points suggested in MEE 2014 (Mathur et al. 2014)

These actionable points suggested by Mathur et al. (2014) have been taken well under consideration by the park management authority, especially regarding increasing staff members and improving infrastructure. This is reflected on ground in STR as the WII team has been working alongside the park staff from January 2017. We are certain that this will also be reflected in the MEE of 2018 report. However, significant improvements such as infrastructure, capacity building of staff are still possible and it is hoped that improvements will occur in times to come.

6.5. Social acceptance:

With the start of various village upliftment and awareness programmes initiated by the park authorities, there is a gradual change among the villagers in how they perceive wildlife. Policy changes, establishment of eco-development committees and schemes, especially, such as the 'Shyamprasad Mukherjee Jan Van Yojana' for development of villages around the tiger reserve have been quite successful in making the villagers more tolerant towards wildlife, in general. In our social surveys, almost half of the populations residing near STR are ready to accept tiger recovery activities. With strong management interventions which include people and eco-development committees, it is hoped that tiger recovery program in STR will be a success with complete social acceptance.

6.6. Carrying capacity and population viability of tiger:

Wilkinson and O'regan (2003) estimated tiger carrying capacity of an area by considering the habitat and home range of tigers. They estimated carrying capacity of Indonesian tigers by taking the whole area of islands divided by median home range of female tigers multiplied by two. We adapt this equation for STR and consider only the potential area of the core area (450 km^2 of 600 km^2). Since we have no reference of tiger home ranges for STR, we rely on data of reintroduced tigers in other parts of Indian tiger reserves. Tiger home ranges, globally, range from 20 km^2 to 400 km^2. We consider 50 km^2 as the median home range given adequate prey and cover available. Putting these values (suitable habitat of STR = 451 km^2; female tiger home range = 50 km^2), we find the total number of tigers that can be supported is 18. The carrying capacity formula is given below:

Carrying capacity = (Suitable area of STR/female tiger home range)*2

= (450/50)*2

= 18 tigers

When we input the total core area of STR (600 km^2), we get a carrying capacity of 24 tigers and this number (24) was modeled in the population viability analysis (PVA) to estimate the population growth and probability of survival of reintroduced tiger populations, with the assumption that efforts would be made to create the entire core as inviolate area and with improved prey population the carrying capacity will increase.

The equation provided by Wilkinson and O'regan (2003) considers only the total suitable area available and home range of tigers, without taking into account for the prey available. We therefore also use the equation provided by Karanth et al. (2004), which is highly accepted and takes into account all necessary factors. The equation is as follows:

$$Tj = AU_j^b \delta_j$$

Where A= 0.247 (95 % confidence interval 0.181 to 0.336), U_j = prey density/km^2, b= 1 and δ_j = 1, derived from the relationship between tiger and prey densities, based on harvest rate by tiger (i. e. 50 ungulates per year).

$$Tj = 0.247*9.5*1*1$$

$$= 2.34 \ /100 \ km^2$$

$$\sim 12 \text{ tigers } (600 \ km^2 \text{ core area})$$

This equation yields 12 tigers for STR. This estimate given based on the suitable habitat (18) and prey estimation (12) appears to be in alignment with our perception/ understanding that prey augmentation would increase the carrying capacity of tigers in STR.

We performed a population viability analysis (PVA) using Vortex (version 10) to further critically predict tiger reintroduction and survival in STR. PVA is a useful analytical tool to inform scientific management about reintroduced populations. It has widely been used previously in case of bears, wolves, lynx and tigers. This analysis helps scientists and managers to come up with and decide an estimate of minimum viable population size (MVP). With founder size of 08 individuals (3 males and 5 females), we had considered 5 scenarios as potential outcome of tiger reintroduction, details of which are presented in annexure I. The scenarios considered were as follows:

Scenario 1: Model with only demographic parameters and does not include catastrophe, inbreeding, harvest (in this case, poaching) and supplement

Scenario 2: Model with demography and includes catastrophe and inbreeding

Scenario 3: Model with demography and includes catastrophe, inbreeding and one poaching per year

Scenario 4: Model with demography and includes catastrophe, inbreeding, no poaching and supplement of 2 tigers every three years until year 10.

Scenario 5: Model with demography and includes catastrophe, inbreeding, supplement of 2 tigers every year three years, until year 10 and 1 poaching per year.

Based on PVA analysis and considering 5 scenarios, we identified that the 4th scenario is most feasible and practical on ground. For this augmentation/recovery programme, this option (4th scenario) is considered to be the most plausible, and therefore all strategies pertaining to supplement the population would be considered well in advance, and resources and financial commitment would be secured accordingly.

We summarize and present the results from the running the model in Figure 3 and Figure 4. Figure 3 shows the estimated mean population size in all the scenarios over 50 years and Figure shows the estimated survival probability in all the scenarios.

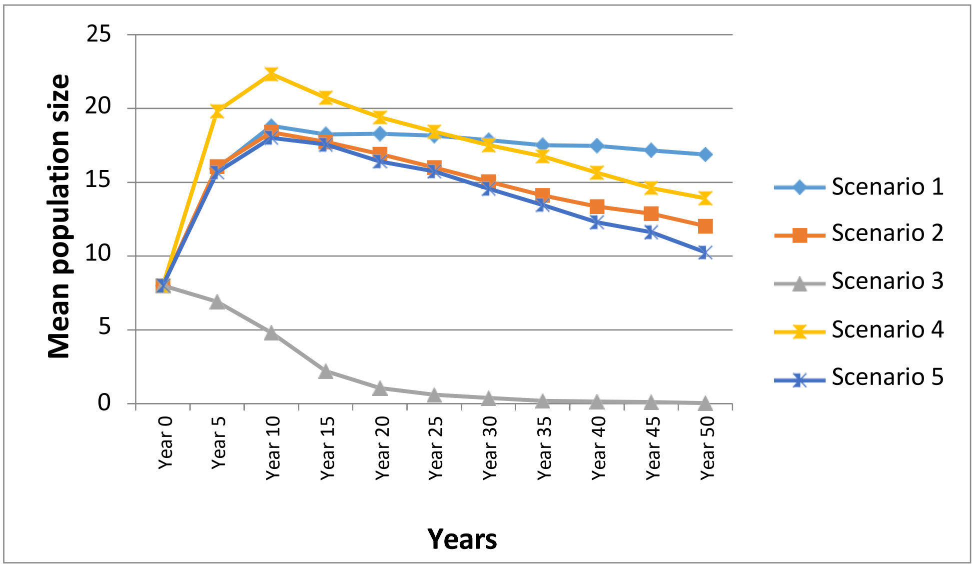

Figure 3: Representing the mean population size estimated in all the scenarios over 50 years

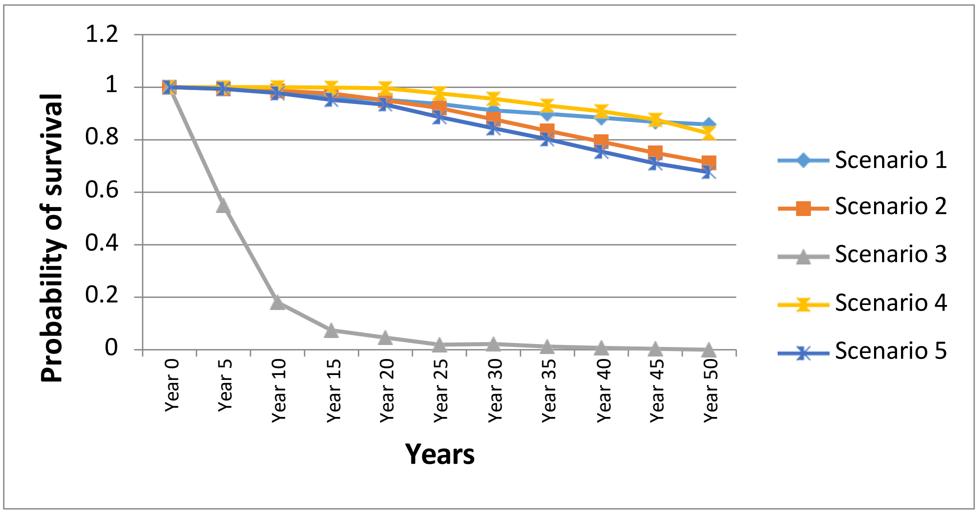

Figure 4: Representing the probability of survival in all the scenarios over 50 years

6.7. Recommendation and follow-up action:

6.7.1. Legal context:

In the context of tiger translocation and augmentation, NTCA has issued (1) a Translocation Protocol (largely aligned to IUCN Reintroduction Guidelines) and (2) a Standard Operating

Protocol for sourcing tigers for low-density areas. In terms of sourcing the tiger, where due importance is given to geographic and genetic closeness, the individuals from the Western Ghats Landscape (Natesh et al. 2017) is in line with the SOP for this purpose. Although the Translocation Protocol recommends only the dispersing young ones (2-3 years old), the transient adult may also be considered, since the original objective of recommending the dispersing young ones is to ensure that the source population is not affected by removal of any individual. Therefore, the transient adults would also be almost similar in terms of not affecting the source population growth.

6.7.2. Founder individuals:

The project would require eight founder individuals (03 males and 05 females), but we recommend beginning with three individuals (two females and one male) to be constituted as initial founder population. The composition of 3:5 (male:female) was to provide mate selection option for both males and females, and to enhance the breeding outcomes. In order to ensure heterogeneity, the individuals must be sources from more than one source populations. Therefore the individuals can be captured from anywhere from the Western Ghats complex, i. e. from neighboring Karnataka (Bandipur, Nagarhole, Dandeli-Anshi) and Tamil Nadu (Sathyamangalam, Mudumalai). Only in the absence of difficulties in sourcing the tiger from these Western Ghats region, individuals from geographically close population within Central India may be considered, with due inputs from genetic analyses. These animals should be either dispersing young animals and/or transient adults and could be picked from anywhere regardless of core, buffer or corridor, but it will appropriate to begin from the periphery to interior of the forest area.

6.7.3. Institutional Framework:

Tiger augmentation program is a long-term investment and commitment, and involves multitude of scientific, administrative and political supports. The program will have to be led and implemented by the Maharashtra State Forest Department and will be technically supported by Wildlife Institute of India and National Tiger Conservation Authority, while the Wildlife Conservation Trust will act as local partner to mobilize social support and other capacity building activities. If there is strong administrative and institutional mechanism in place, it is very likely that the project will achieve desired outcome. It is advisable to have (a) Project Steering Committee, which provides general guidelines for execution of the program and periodically reviews the progress of the work and accomplishment of the activities and (b) Project Execution team which will have to be spearheaded by a mission leader at the rank of Additional Principal Chief Conservator of Forests (Wildlife) and should include the Field director of the reserve as the field executive, dedicated veterinary professional, post-release monitoring team (security-based by the field staff as well as scientific monitoring by the Wildlife Institute of India), and implementation team involving the Deputy Director of the reserve, wildlife wardens and range officers and the co-opted NGO, which in this case is the Wildlife Conservation Trust.

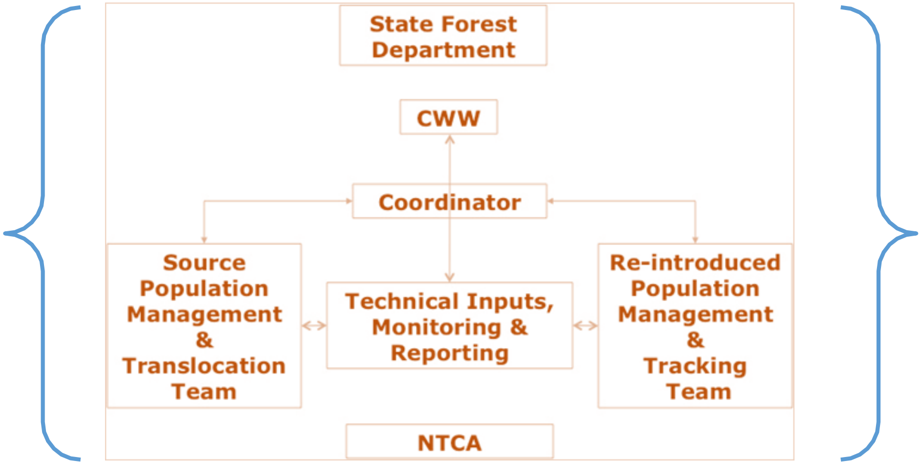

Figure 5: Institutional framework flow chart

6.7.4. Field preparation and mock drills:

The institutional arrangement and the specified committees should support preparatory activities and ensure that the execution team is fully prepared in terms of logistics, manpower, resources, equipment and trained monitoring team. This also includes establishing key roads and watchtowers for all-weather condition, supported by adequate transport system. Necessary field gears and walkie-talkie should be ensured so that the field execution of the project is never compromised by these logistic inadequacies. Soft-release enclosure in the form of holding facility should be established prior to translocation of the tiger; unless the choice is hard release and that there is sufficient safeguard for re-capturing and treating the animals if the medical and field conditions warrant so. For all the expected activities, mock drill should be carried out at least three times so that in the event of actual operation, the dedicated team executes the work professionally and without any glitches. The area should be totally surveyed to understand the bottleneck in terms of signal ranges and problem areas for field level implementation and monitoring.

6.7.5. Identification of candidate individuals and schedule of release:

In the current era of continuous camera trapping, the respective field units monitor most of the individual tigers adequately. Therefore, the information on dispersing animals and transient adults could be identified based on capture history and the dynamism (the animal that is not showing site fidelity in the core area is most likely to be transient, and most operates in the periphery). Respective field directors may be requested to prepare a list of potential tigers that may be considered for translocation. Depending on the availability and chance of capture, the target individual should be captured and translocated. It is proposed that the following order of translocation is considered.

October 2018: One male and one female

November 2018: One female

February 2019: One male and one female

April 2019: One male and two females

Animals could be released in a soft-release holding facility of 1-2 ha, but if the animal is in good health, it could be hard-released directly. It was found from the earlier experiences in the Panna Tiger Reserve that release site does not determine the home range of tiger and that they explore the area widely and make choices based on individual preferences (Sarkar et al.. 2016). Therefore, the release site may be considered based on administrative and logistic feasibility, but it would be ideal to consider interior areas away from human interface.

6.7.6. Choice and quantity of radio-collar equipment:

The collar equipment and monitoring strategies have significant linkages with the overall success of the program. It is ideal to begin with GPS/satellite/VHF combination collar for males and VHF only collar for females. Vectronics GPS/Satellite/VHF collars and Telonics VHF collars are preferred choice based on the experiences and success of the collar performances. Given that the current founder number is 08 (three males and five females), there would be need for three Vectronics GPS/Satellite/VHF collars with activity, mortality and drop-off sensors and five Telonics MOD 500 VHF collars with bi-pole antenna, activity and mortality sensors. It is also proposed to procure two more Vectronics GPS/VHF/Satellite collars and three more Telonics VHF collars (01 MOD 500 and 02 MOD 400) with activity and mortality sensors. The back-up collars should be ordered after nine months so that these could be used in quick succession. In order to provide complete support system, all these collars require dedicated VHF receiver unit (receiver+antenna+coaxial cable). It is suggested that 05 multi-channel receivers (Communication Inc. R-1000) and 08 limited channel receivers (Telonics) are procured simultaneously, so that post-release monitoring is effective.

6.7.7. Capture and transportation:

Standard protocol of immobilization and transportation has already been established in reserves such as Panna Tiger Reserve, Madhya Pradesh and Sariska Tiger Reserve, Rajasthan. It is critical to involve full time veterinatian in this program as the field situation would require constant inputs and field level actions. All the NTCA protocols with respect to reintroduction need to be adhered to (Annexure 1). Similarly, the standard protocol adopted in the previous reintroduction sites should be followed (Annexure 2). It is important to profile each animal in terms of health and behavior. Visual examination, scat samples and biological samples should be used to periodically to measure stress and reproductive hormones, endo/ecto parasites and genetic analyses. Provisions to procure equipment to measure these parameters in the field should be in place. The research team of WII should be mandated to handle this activity with regular field updates. It may be worth profiling individuals in terms of genetic reproductive health, in order to implement specific administrative action on timely basis such as that once can predict reproductive performance of the animals.

There is a need for creating dedicated team for executing various activities. (a) Source population team: A small team should be assigned a task of communicating with the source population sites and constantly update the information on potential sites, so that specific choice could be made for translocation. This should include individuals who have experience of working in the various reserves and be aware of the population dynamics (b) Immobilization and capture team: The team should consist of Field director, Veterinary officer + one support staff, two domestic elephants with trained mahouts, and range officer with 08–10 persons for support role, with walkie-talkie (c) Radio-collaring team: This would be three-member team from WII and WCT for collaring and taking body measurement (d) Transportation and release team: This would involve the field team guided by the Field director and Veterinary officers, supported by the wildlife wardens, range officers and support staff. (e) Post-release monitoring team: This would include dedicated team of field staff deployed on rotational basis and technically guided by the Wildlife Institute of India. There would be two dedicated team (three person each – one forest guard and two support staff) and would rotated initially on 24 hour basis and once the animals settle, it would be on 8 hour bases. All these teams would have specific role assigned by the team leader/coordinator and should execute the job, without overlapping with other team duties, unless specifically asked for.

There would be need for dedicated transportation vehicle and transportation cage. In all the existing cases of tiger translocation and transportation, specifically in the case of Madhya Pradesh, specifically designed transportation vehicle is being used. This contains specific hydraulic system to lift and release animals, and the vehicle is supported with necessary equipment and space for support staff. Similarly, the transportation cage should be designed specifically so that the animal could be transported without stress and damage. The usual dimension of the transportation cage is 7 ft long, 3.5 ft wide and 4 ft height, and the cage should be designed in such a way that it has strong exterior and smooth interior to provide visual barrier and comfort for the animals.

6.7.8. Post-release monitoring protocol:

Post release monitoring is key to the success/failure of such recovery projects and there are enough evidences to back this claim. Therefore, the amount of effort or resource which is invested for the translocation phase, an equal amount of effort or resource, if not more, needs to be allocated for monitoring activities. It is important that all the founder animals, first generation females and certain dispersing animals are radio-collared. This should become an integral part of the project until the population has reached its carrying capacity or target level as set out by the carrying capacity analysis. Tiger monitoring would involve two types of dedicated teams (a) Security-based monitoring by the field staff using VHF tracking method and (b) Technical oriented monitoring by WII team using VHF as well as GPS/Satellite/GSM tracking method. A monitoring protocol would involve dedicated team of staff for each released tigers and the monitoring schedule should be shared at 24 hour/12 hour/8 hour/schedules on rotational basis, so that continuous monitoring is in place. Each team should consist of a forest guard supported by a watcher, along with transportation support. The monitoring schedule should be institutionalized in the prescribed format (Annexure 3) and there should be adequate supervising mechanism. Location of individual tiger should be reported twice a day (09 AM and 08 PM) to field coordinator (ranger or deputy ranger) and the information should flow to program coordinator and director on daily basis. The intensity of such monitoring can be modified after observing the behavior of released animals and a suitable decision can be taken up subsequently. Since Sahyadri is complex in terms of terrain, suitable vantage points should be established and monitored using multi-channel receiver.

Information should be synthesized on fortnightly basis in a dedicated register and should be catalogued in the database management unit (to be established in agreement of the field staff and WII team, preferably in Chandoli or Helwak range). The information should be processed in excel and summarized descriptively and in map form to be shared with CWW on fortnightly basis. There should be one-line of information flow and the technical aspect of the analyses would be guided by WII, through a dedicated researcher. There would be need to deploy dedicated research personnel to support (a) radio-tracking and monitoring of prey and tiger populations (b) camera trapping and population estimation of tiger and co-predators (c) line transect sampling for estimating prey/ungulate abundance across space and time and (d) genetic and reproductive health monitoring.

6.7.9. Media management:

There would always be attention and demand for update on the ongoing work from various quarters including media, which is highly active and volatile in Maharashtra. It would be helpful to have a dedicated person assigned for preparing press note on regular basis. Field director or his nominee should be the point person for engaging media on all administrative matters and when the specific queries are made related to technical matters, concerned person (veterinarian, scientists of WII) may be directed to for providing appropriate information.

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Annexures

Annexure I:

Population Viability Analyses models and results in detail

The PVA model takes into consideration life history traits of species, reproductive rates, mortality rates, population size, carrying capacity, harvest, catastrophes, genetic management and other variables important for predict population growth and survival. The population parameters considered in our PVA analyses (Figure 2) was taken by assessing literature (Smith and McDougal (1991); Bailey (1993); Mazek (1981); Sunquist and Sunquist (2002); Wilkinson and O'regan (2003))

Reproduction system parameters	Female	Male
Age when first offspring is had (start of breeding)	3	4
Cub mortality	50	50
Adult mortality	10	10
Adult in breeding pool	50	33
Sex ratio at birth	50	50
Maximum age of reproduction	15	
Maximum number of broods per year	1	
Maximum number of progeny per brood	4	
Mean progeny per female	2.5 (1 SD)	
Mortality rate parameters	Female	Male
Mortality from age 0 to 1	40	40
SD in 0 to 1 mortality due to EV	10	10
Mortality from age 1 to 2	25	25
SD in 1 to 2 mortality due to EV	5	5
Mortality from age 2 to 3	25	25
SD in 2 to 3 mortality due to EV	5	5
Mortality from age 3 to 4	10	10
SD in 3 to 4 mortality due to EV	3	3
Mortality after age 4	—	10
SD in mortality after age 4	—	3

Table: Values of reproduction and mortality considered in the PVA analysis

In order to obtain robust population predictions, five scenarios were constructed as below, and 500 iterations were performed on the population for each scenario to estimate survival probability and mean population sizes of tigers in STR for 50 years. We considered only one population, excluding the need to model metapopulation parameters. All these models were density independent, since density dependent factors will begin to operate only after certain minimum threshold is reached.

We ran the models with the initial population size of 6, with the carrying capacity of 24, but we found that the population size could not survive well. Hence we reran the model with an initial population size of 8 and carrying capacity of 24.

Scenario 1: Model with only demography parameters and does not include catastrophe, inbreeding, harvest, supplement or genetic management.

In 500 simulations of the population for 50 years, 71 went extinct and 429 survived. This gives a probability of survival of 0.858 (0.0156 SE). The mean final population size was 16.88 (0.37 SE; 8.18 SD). The mean time to first extinction to occur was 26.62 years (1.47 SE; 12.41 SD). Across all years, prior to carrying capacity truncation, the mean growth rate (r) was 0.057 (0.0014 SE; 0.2124 SD). The final observed heterozygosity was 0.641 (0.0092 SE; 0.1916 SD). This scenario is an ideal one, but it is practically unlikely due to environmental stochasticity and other unforeseen losses in the population.

Scenario 2: Model with demography and includes catastrophe and inbreeding

In 500 simulations of the population for 50 years, 144 went extinct and 356 survived. This gives a probability of survival of 0.712 (0.0203 SE). The mean population size was 12. 02 (0.41 SE; 9.14 SD). The mean time to first extinction to occur was 31.83 years (0.97 SE; 11.69 SD). Across all years, prior to carrying capacity truncation, the mean growth rate (r) was 0.034 (0.0016 SE; 0.2321 SD). The final observed heterozygosity was 0.670 (0.0104 SE; 0.1971 SD). The survival rate here, although, is reasonable, the population size is much below the target population size (of 20 tigers) and thus is not viable (Figure 3 and 4).

Scenario 3: Model with demography and includes catastrophe, inbreeding and one poaching (i. e. harvest) per year.

In 500 simulations of the population for 50 years, 500 went extinct and none survived. This gives a probability of 0 survival. The mean population size was 0.03 (0.02 SE; 0.45 SD). The mean time to first extinction to occur was 7.85 years (0.29 SE; 6.45 SD). Across all years, prior to carrying capacity truncation, mean growth rate (r) was – 0.034 (0.0050 SE; 0.2954 SD). The result obtained from this model reaffirms that poaching cannot be tolerated at all, and this is certainly not the option for this programme.

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Scenario 1: Model with only demography parameters and does not include catastrophe, inbreeding, harvest, supplement or genetic management.

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In 500 simulations of the population for 50 years, 500 went extinct and none survived. This gives a probability of 0 survival. The mean population size was 0.03 (0.02 SE; 0.45 SD). The mean time to first extinction to occur was 7.85 years (0.29 SE; 6.45 SD). Across all years, prior to carrying capacity truncation, mean growth rate (r) was – 0.034 (0.0050 SE; 0.2954 SD). The result obtained from this model reaffirms that poaching cannot be tolerated at all, and this is certainly not the option for this programme.

Scenario 4: Model with demography and includes catastrophe, inbreeding, no poaching and supplement of 2 tigers every three years for three consecutive years, until year 10.

In this scenario, 88 went extinct and 412 survived. This gives the probability of survival of 0.824 (0.0170 SE). The mean final population was 13.90 (0.37 SE; 8.30 SD). The mean time to first extinction was 37.31 years (1.02 SE; 9.66 SD). Across all years, the mean growth rate (r) was 0.47 (0.0014 SE; 0.2134 SD) prior to carrying capacity truncation. The final observed heterozygosity was 0.733 (0.0089 SE; 0.1798 SD). This scenario with high survivorship will reach its peak in 10th year (22 tigers), and will begin to decline gradually from 11th year onwards. This suggests that further supplementation may be required in case catastrophe and inbreeding problems start to occur. However, inbreeding is an unlikely cause in a shorter time scale, particularly given that the reintroduced tigers are from different populations and the progeny is likely to have high genetic diversity. It would be imperative to take care of the situation at the end of 10 years, and plan further strategy including supplementation if necessary. It is likely that the population would grow, and that further decision and efforts can be undertaken at an appropriate time around 10 year.

Scenario 5: Model with demography and includes catastrophe, inbreeding, supplement of 2 tigers every three years for consecutive years, until year 10 and 1 poaching per year.

In this scenario, 162 went extinct and 338 survived. This gives a probability of survival of 0.676 (0.0209 SE). The mean final population was 10.24 (0.39 SE; 8.82 SD). The mean time for first extinction was 30.27 years (0.95 SE; 12.09 SD). Across all years, the mean growth rate (r) was 0.026 (0.0015 SE; 0.2177 SD) prior to carrying capacity truncation. The final observed heterozygosity was 0.696 (0.0105 SE; 0.1926 SD). It is once again proved that even with supplementation, poaching will take a heavy toll on the reintroduced populations. Therefore, it is important that the number of individuals would have to be reviewed, meaning if poaching takes place, the whole strategy of supplementing individual tigers will have to be reviewed and increased accordingly. Given the recent records of human intervention and poaching cases such as in Chandoli where wild boar poaching took place in January 2017. The park authorities however managed to arrest the poachers on January 15, 2017.

It is reported in 2016, the tiger reserve authorities arrested around 50 people for crimes that took place inside the core area of the tiger reserve (Kulkarni, 2017, April 3). People from Konkan use traditional hunting routes to enter into the limits of STR. Previously, nine people were arrested from Sangameshwar in Ratnagiri for poaching two mouse deer. Two country-made rifles and weapons were seized from these poachers who were caught in camera trap images. Sangameshwar is a surrounding forest landscape of STR. This brings the whole landscape into focus, and that the entire programme would have to be seriously considered bringing the surrounding forests under one management unit or with strong positive collaboration with all the surrounding forest units to ensure the long-term survival of tigers in STR. Management of tigers in STR would have to be taken into the landscape context, and every effort has to be made, including policy interventions and making available a dedicated anti-poaching team to tackle any issue that may spring up in the future.

Annexure II:

Excerpt from protocol for tiger re-introduction

[National Tiger Conservation Authority]

TEAM CONSTITUTION

The Team will consist of representatives from Wildlife Institute of India, State Forest Departments, a Qualified Veterinarian and a Qualified Wildlife Biologist. The Team leader would be responsible for coordination between the various bodies and provision should be made for publicity and public education about the project. The provisions of the Wildlife Protection Act shall be adhered to at all times. The proposal, progress, and activities of the translocation exercises should be transparent and communicated through appropriate forum and media so as to gain public support.

The National Tiger Conservation Authority (NTCA) will keep an oversight on the translocation process and may also depute a representative as and when considered necessary.

PRE-PROJECT ACTIVITIES

Suitability of release stock of Tigers

- It is desirable that source tigers come from wild populations. If there is a choice of wild populations to supply founder stock for translocation, the source population should ideally be closely related genetically to the original native stock and show similar ecological characteristics to the original population.
- Removal of individuals for re-introduction must not endanger the wild source population. Stock must be guaranteed available on a regular and predictable basis, meeting specifications of the project protocol.
- Individuals should only be removed from a wild population after the effects of translocation on the donor population have been assessed, and after it is guaranteed that these effects will not be negative.
- To minimize impact on the founder / host population, preferably tigresses between the age of 2-3 years (Sub-adults) who have become independent of their mother but are yet to establish their own territories should be targeted. This cohort also has the highest reproductive potential and therefore ideal for starting a new population. Male tigers become sexually mature at the age of 2 years but rarely can they breed till 4 years of age in the wild. This age group (2-3 years) is ideal for translocation for reintroduction as their removal from the host population will not result in male turnovers and

subsequent infanticide episodes. All effort should be made not to translocate established breeding individuals from the host population. Potential individual tigers that are to be translocated should be monitored prior to their capture to ascertain their social status, health, and behavior.

PLANNING, PREPARATION AND RELEASE STAGES

- If release stock is wild-caught, care must be taken to ensure that: a) the tigers are free from infectious or contagious pathogens and parasites before translocation and b) the stock will not be exposed to vectors of disease agents which may be present at the release site (and absent at the source site) and to which it may have no acquired immunity.
- If vaccination prior to release, against local endemic or epidemic diseases of wild stock or domestic livestock at the release site, is deemed appropriate, this must be carried out during the "Preparation Stage" so as to allow sufficient time for the development of the required immunity.
- Appropriate veterinary measures as required ensuring health of released stock throughout the programme. This is to include adequate quarantine arrangements, especially where founder stock travels far or crosses international boundaries to the release site.
- Development of transport plans for delivery of stock to the site of re-introduction, with special emphasis on ways to minimize stress on the individuals during transport.

POST-RELEASE ACTIVITIES

- Post release monitoring is required of all tigers. This most vital aspect may be by direct (e.g. telemetry/Satellite tracking) methods as suitable.
- Demographic, ecological and behavioural studies of released stock must be undertaken.
- Study of processes of long-term adaptation by individuals and the population.
- Collection and investigation of mortalities.
- Interventions (e.g. supplemental feeding; veterinary aid) when necessary.
- Decisions for revision, rescheduling, or discontinuation of programme where necessary.
- Habitat protection or restoration to continue where necessary.
- Continuing public relations activities, including education and mass media coverage. Evaluation of cost-effectiveness and success of re- introduction techniques. Regular publications in scientific and popular literature.

Annexure III a:

Standard Protocol for Immobilization and Transportation

1. Location of the animal and observation for selection and suitability

The animal will be located possibly on a kill. Due consideration will be given for terrain and habitat where visibility is maintained for 10-15 minutes in case the animal moves after darting. Trackers will be deployed on nearby trees to observe the movement of the animal following darting. Behavioral aspects such as excitement etc. will also be considered. The operation will be preferably conducted in the forenoon hours. Visual examination of the health of the animal will be done using a binocular and also for any apparent physical injury. Approximate weight will be assessed for calculation of drug doses. Decision to immobilize animal will be jointly taken by Execution Team.

2. Approach to the target animal

A four-wheel field vehicle / elephants will be used to approach the animal approximately 25-30 meters with care/caution and an overriding degree of patience. Hindquarters will be preferred for tele-injection as it is well-muscled area. In a terrain where the vehicle cannot be used, possibility of darting the animal from a *machan* will also be considered.

3. Equipment and drugs

Light weight plastic darts of 3-5 ml. capacity using air powered/CO_2 tele-injection projector will be used for I/M injection on the hindquarters from a distance of 25-30 meters. A mixture of Xylazine and Ketamine will be used as a drug of choice for sedation and immobilization.

4. Induction phase

The time interval between injection (darting) and the point when the animal is rendered immobile is induction period. The total time for the completion of induction may vary from 7-15 minutes. A close observation will be kept by the team for any movement of the animal.

5. Handling and care of the immobilized animal

The animal will be approached quietly and following steps will be followed:

- Removal of dart
- Assess the state of animal, the degree of relaxation and the rate and depth of respiration. If the respiratory depression is pronounced, a partial dose of antagonist will be used to correct respiration.
- Blindfold the eyes to protect the cornea from direct sunlight, dust and injury.
- Position of body, head and neck. The animal will be placed either in sternal or lateral recumbancy.
- Monitoring vital signs. Vital signs such as respiration, heart rate and body temperature will be taken and monitored.
- The animal will be examined for any wounds and injuries and appropriate medical measures will be taken.

6. Radio collaring and biological sampling

This step will involve radio collaring of the immobilized animal and all body measurements. Complete physical examination of the animal will be done at this stage followed by collection of biological samples (blood, hair, saliva, etc) for reference.

7. Shifting of the animal to stretcher

The animal will be shifted to a stretcher on lateral or sternal recumbancy. Weight of the animal will be taken at this time using a spring balance. Animal will then be shifted to a transport container.

8. Assessment of anesthesia

After shifting the animal to a transport container, assessment of anethesia will be done using following methods;

- Monitor tissue perfusion: Anethetic drugs frequently depress the contractile force of the heart and vasodilatation results in decreased tissue perfusion. Evaluation of tissue perfusion will be done by observation, auscultation, palpitation and capillary refill time.
- Monitor gas exchange: Respiratory rates are highly variable during anesthesia.
- Quality of respiration will be evaluated by observing animals chest movement.
- Monitor CNS depression: Most effective monitors of CNS depression are evaluation of muscle tone-jaw and eye-reflexes.

9. Reversal of anesthesia

Specific Alfa-2 antagonist will be used to reverse the anesthesia. Based on various parameters of assessment of anesthesia, on the spot decision will be taken whether to reverse the drug before transportation or to allow the animal to be transported in sedation.

10. Transport of animal

Depending upon the facilities available, the animal will be transported by a vehicle.

11. Preparation at the site of release

Chain-linked fence enclosures at the release site will have visual barriers around them made of plastic or natural materials to avoid any disturbance to the animal. Animal will be monitored intensively inside the enclosure. Proper measures and equipment will remain in place to deal any emergency and management for the best care of the animal.

12. Monitoring of animal in enclosure

Surveillance camera and dedicated team of people from *machan* and watchtower would be deployed to monitor the activity of the tigers in the enclosure. If the animal exhibited any erratic behaviour, it will be attended to appropriately by getting into the enclosure in elephant back.

13. Release of animal into the wild

The animal would be release by 'soft release' approach after the keeping the animal for two to three days, and may be more depending on the local condition.

14. Plan of operation

Step 1: Location and selection of the animal, Approach to the target animal, Assessment of terrain, Visibility and Ambient temperature.

Step 2: Visual health examination and observation on behavioural aspects.

Step 3: Tele-injection of sedative and observation on the induction phase close observation for any movement of the animal.

Step 4: Handling and care of immobilized animal, monitoring of sedation physical measurement, biological sampling, radio collaring and measurement of weight.

Step 5: Shifting to transport container using a stretcher and transportation to STR.

Step 6: Shift container from vehicle to helicopter / vehicle.

Step 7: Animal transport by helicopter / vehicle (WII and STR team).

Step 8: Journey time

Step 9: Animal & container offloaded from helicopter to vehicle (complete examination of the animal, injection of any medicaments if needed).

Step 10: Animal released directly into the enclosure at STR.

Step 11: Monitoring of the released animal in the enclosure at STR (48-72 hours intensive monitoring).

Step 12: Release into the open forest and monitoring (CWW, Field Director, assisted by WII team).

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Annexure III b:

Data Sheet for Health Examination of tiger while immobilizing and collaring

Date :........................ Time :..................................

Location name...............................

GPS.................................. N, ...E

Species : ....Approx age.................... Gender :...............................

Condition :.........................Estimated Wt :.............. Actual Wt : ....

Drug details: Dart 1: -------------------------

Dart 2: -------------------------

Dart Time .... Target site ....

Symptom 1: .... Time : ....

Symptom 2: .... Time : ....

Symptom 3: .... Time : ....

Symptom 4: .... Time : ....

Induction time: .... Down Time : ....

Eye ointment : Y/N

Additional drug Used: .... Time : ....

Antidote Composition: .... Time : ....

Revival signs: .... Time : ....

Getting up time ....

Complication during decumbency (if any):

....
....

Body Measurement:

Nose to head base: .... Head base to tail base : ....

Tail base to tail tip: .... Shoulder height : ....

Chest girth: .... Neck girth : ....

Hind foot length:- Left :.................................. Right : ....

Total length between pegs : ....

Paw Measurement:

Front Right- length :................................ Width : ....

Front Left- length :................................. Width : ....

Hind Right- length :................................. Width : ....

Hind Left- length :................................. Width : ....

Claws missing : ....

Teeth Measurement:

Upper Right Canine –Length :............................ Thickness at base : ....

Upper Left Canine –Length :............................ Thickness at base : ....

Lower Right Canine –Length :............................ Thickness at base : ....

Lower Right Canine –Length :........................... Thickness at base : ....

Photos take : Yes/No .... Teeth / Genitals No.

Sample taken :

Blood whole : ....Blood alcohol : .... Blood EDTA / Heparin ....

Hairs : .... Parasites : ....

Anal swabs : ....

Physiological Condition:

1) Temperature :	Time	2) Temperature :	Time
3) Temperature :	Time	4) Temperature :	Time
5) Temperature :	Time	6) Temperature :	Time
7) Temperature :	Time	8) Temperature :	Time
9) Temperature :	Time	10) Temperature :	Time
11a) Respiration :	Time	11b) Respiration :	Time.
11c) Respiration :	Time	11d) Respiration :	Time
11e) Respiration :	Time	11f) Respiration :	Time
11g) Respiration :	Time	11h) Respiration :	Time
11i) Respiration :	Time	11j) Respiration :	Time
12a) Heart rate:	Time	12b) Heart rate:	Time

Collar Details:

Make: .... Model: ....

Frequency: .... Ext / Int antenna: ....

Colour: .... Magnet Removed: ....

Battery Life: ------------------------- Pulse Rates:----------------------

Annexure IV:

Data Sheet for Monitoring Radio-collared Tiger in Sahyadri Tiger Reserve

Date: Group No. Shift No. Team Members:

Start Time: Start GPS Location:

End Time: End GPS Location:

Time	GPS (Latitude)	GPS (Longitude)	Direction (Compass Bearing)	Approx. Distance	BPM (Pulse Rate)	Location & Compartment	Habitat & Terrain	Kill Details	Remarks (Behaviour, any other info & photo taken)