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Wildlife Institute of India, Dehradun
Wildlife Institute of India,
Chandrabani, Subhash Nagar, Dehradun, Uttarakhand

Dated: 18/05/2022

To

Shri Jaydip Das
Flat no. 18, HSR Layout
Bangalore
Karnataka
560086

Registration Number : WLIOI/R/E/22/00023

Dear Sir/Madam

I am to refer to your Request for Information under RTI Act 2005, received vide letter dated 19/04/2022 and to say that *kindly see the attached cover letter. Due to the large size, the Annexure-I, II & III mentioned in the cover letter have been sent to you through a separate email dated 18 May 2022*.

In case, you want to go for an appeal in connection with the information provided, you may appeal to the Appellate Authority indicated below within *thirty days* from the date of receipt of this letter.

Dean, FWS
FAA & Dean
Address: Wildlife Institute of IndiaChandrabaniDehradun
Phone No.: 01352646202

Yours faithfully

(Rajiv Mehta)
CPIO & Deputy Registrar
Phone No.: 9286140979
Email : dyregistrar@wii.gov.in

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

No. WII/RTI/CPIO/2022-23 (Qtr-I)/11

Date: 18th May, 2022

To,

Mr. Jaydip Das
Flat No. 18, HSR Layout, Bangalore,
Karnataka – 560086
Email: jaydipdas07@gmail.com

Sub.: Information under RTI Act, 2005–reg.

Ref.: Your Online RTI No. WLIOI/R/E/22/00023 dated 19/04/2022

Sir,

Please refer to your application cited above under RTI Act, 2005. In this context, point-wise response to your queries is given below:

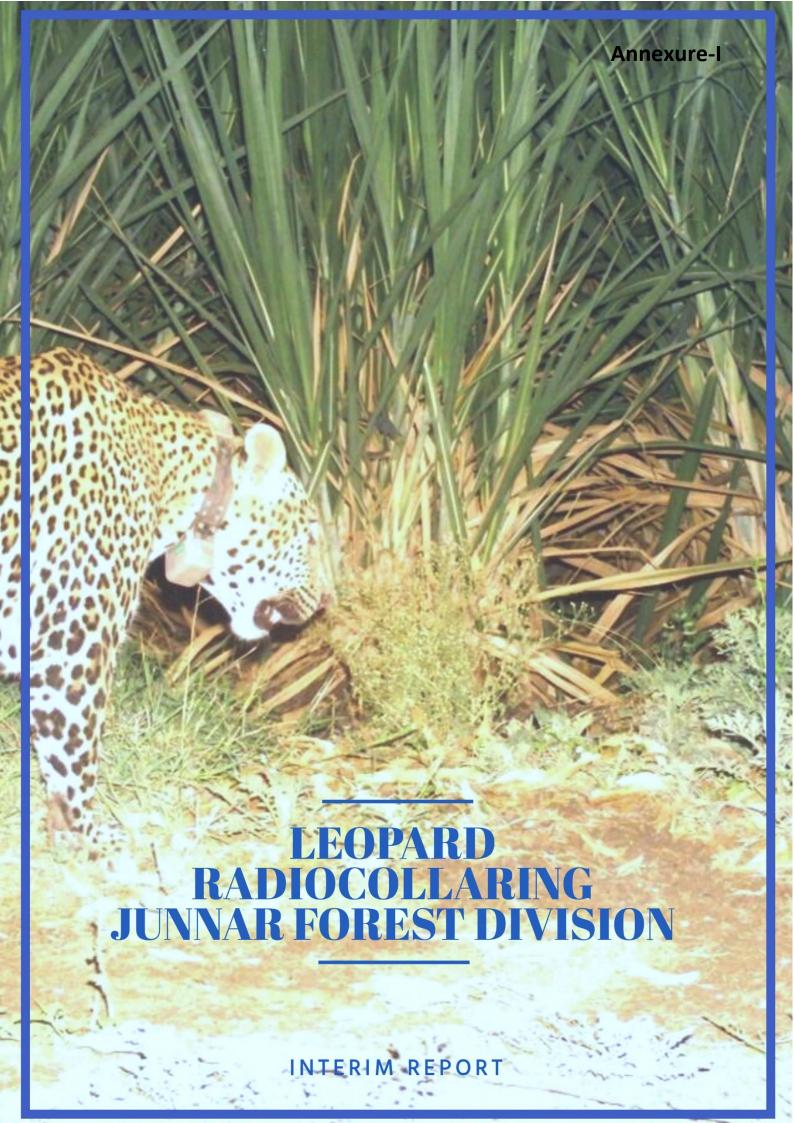| Information Sought under RTI	Reply
1. Response to your query No. 1 to 7 & 10	See the attached **Annexure-I & II**
2. Response to your query No. 8 & 9	See the attached **Annexure-III**

If you are not satisfied with the above reply, you may appeal to the Appellate Authority of Wildlife Institute of India, Dehradun.

Thanking you,

Yours faithfully,

(Rajiv Mehta)
CPIO

LEOPARD RADIOCOLLARING JUNNAR FOREST DIVISION

INTERIM REPORT

Report Title	**Interim Report – June 2021**
	Radio-collaring of Leopards in Junnar Forest Division, Maharashtra, India
Project Details	Understanding Population Dynamics, Space Use, Movement and Diet of Leopards in Junnar Taluka, Maharashtra for Human Leopard Conflict Mitigation
Principal Investigators	Dr. Bilal Habib Mr. Dodal, S. D., I.F.S
Co-Investigators	Dr. Parag Nigam Dr. Samrat Mondol Mr. Jayaramegowda R, I.F.S
WII Researchers	Kumar Ankit, JRF Rucha Ghanekar, SRF
Wildlife SOS Team	Dr. Nikhil Sopan Bangar Mr. Mahendra Balu Dhore Mr. Akash Dolas Mr.Shivaji Modhe Mr. Dilip Deshpande Mr. Balu Mundhe Mr. Salim Shaikh Mr. Babu Neharkar
Range Staff Team	Mr. Ajit Ambadas Shinde Mr. Yogesh Shivaji Mahajan Mrs.Manisha Jitendra Kale Mr. Rameshwar Kondiba Phulwad Mrs. Manisha Ramchandra Bansode Mrs. Kalyani Ramdas Potawade Mr. Dhondu Yama Kokane Mr. Tanhaji Nivrutti Kadam Mr. Sampat Subhash Tandale
Forest Department Team	Mr. Amit Laxman Bhise Mr. Sandesh Babanrao Patil Mr. Manohar Namdev Mhasekar Mr. Ajit Ambadas Shinde Mr. Yogesh Shivaji Mahajan Mr. Yogesh Tanajirao Ghodke Mr. Pradip Shivram Kasare
Funding Agency	**Maharashtra Forest Department**

Note: *The online version of this report shall be available at*
https://mahadata.wii.gov.in.

Design and Layout:
Dr. Bilal Habib

Photo Credits:
Junnar Leopard Project

Further Contact:

Dr. Bilal Habib
Scientist E/HoD
Department of Animal Ecology and Conservation Biology
Wildlife Institute of India
PO Box #18 Chandrabani,
Dehradun – 248 001
Tel: 00 91 135 2646283
E-mail: bh@wii.gov.in, bilalhabib1@gmail.com

Shri. Dodal S. D; I.F.S
Chief Conservator of Forests (T) Pune
Van Bhavan, Bhamburda Van Vihar
Gokhalenagar, Pune 411 016
Tel: 022 - 25664184
Email: ccftpune@gmail.com, ccftpune@mahaforest.gov.in

Citation: *Habib, B., Dodal, S. D., Nigam, P., Mondol, S., Jayaramegowda, R., Ghanekar, R. and Kumar A (2021):* radio-collaring of leopards in Jumar Forest Division – Interim Report. *Wildlife Institute of India and Maharashtra Forest Department. Pp 15.*

Introduction:

The growing human population creates along with it an increasing demand for space and resources, thus leading to shrinking habitats of wild species. (Karanth et al., 2013). Co-adaptation strategies whereby humans, predators and scavengers modify their behaviour towards each other based on benefit trade-offs in a closed system is the key to their coexistence in the 21st century (Carter and Linnell, 2016). However, this coexistence depends on studying how these animals modify their movement patterns in a human-modified landscape, their adaptation to different prey base, which will also benefit humans.

The leopard, *Panthera pardus* represents one of the most widely distributed and adaptable members of the Felidae family. In Indian subcontinent leopards are often regarded undesirable/ pests by humans due to their association with attacks on human and livestock (Athreya et al. 2013, 2016). Traditionally, management actions to curb these attacks often include compensation schemes and use of deterrent to keep carnivores away from these areas. With advancement of technology in telemetry, there is also a shift in paradigm in the conservation of wildlife species and management. Movement ecology can provide knowledge needed to understand movement of species and help us identify novel management actions.

Junnar Forest Division in Pune district, Maharashtra provides a good habitat for leopards owing its proximity to Western ghats, availability of water, sugarcane belt, prey species surviving in agricultural landscape and food subsides aided by humans (domestic dogs, livestock). However, there is limited documentation of movement and spatial use of leopards in such modified human-dominated landscapes. The on-going research project by Wildlife Institute of India in association with Maharashtra Forest Department aims to generate baseline information on the spatio-temporal use of leopards in Junnar Forest Division. The movement ecology objective of this project will highlight the pattern of landscape use by the leopards and will try to identify parameters which govern the movement of the animals.

Study Area:

This study is carried out in Junnar Forest Division (JFD) (18°27'51.48"-19°24'03.6" N and 73°31'18.84"-74°35'09.24" E) located in Pune district of Western Maharashtra (Figure 1). It has a geographical area of 4,360 km^2 and is in proximity to the Western Ghats. Two protected areas lie adjacent to JFD: Bhimashankar Wildlife Sanctuary to the West and Kalsubai Harishchandragad Wildlife Sanctuary to the North-west. JFD covers four administrative blocks (*talukas)* viz. Junnar, Shirur, Ambegaon, and Khed, which together comprise of 637 villages. The area is characterized by a mosaic of hills and human settlements with high human and livestock density. It is an agriculture-dominant landscape with sugarcane being the major crop. Sheep belonging to the nomadic shepherd community are abundant in the area during different cropping seasons. JFD has an intermittent forest cover of approximately nine percent, which is predominantly dry-deciduous (Champion and Seth 1968). The area is drained by the rivers like Bhima and Ghod, and their tributaries Kukdi, Puspawati, and Mina that support seven irrigation projects. Leopard, Striped hyena *(Hyaena hyaena)*, Indian wolf *(Canis lupus)*, Indian fox *(Vulpes bengalensis)*, Jungle cat *(Felis chaus),* and Rusty-spotted cat *(Prionailurus rubiginosus)* are the resident wild carnivores in the study area. Whereas wild pig *(Sus scrofa)* and Indian hare *(Lepus nigricollis)* are some of the medium and small-sized wild prey species which inhabit the area. There is a significant population of feral and domestic (owned by farmers) dogs in the area who are mostly free ranging during the daytime.
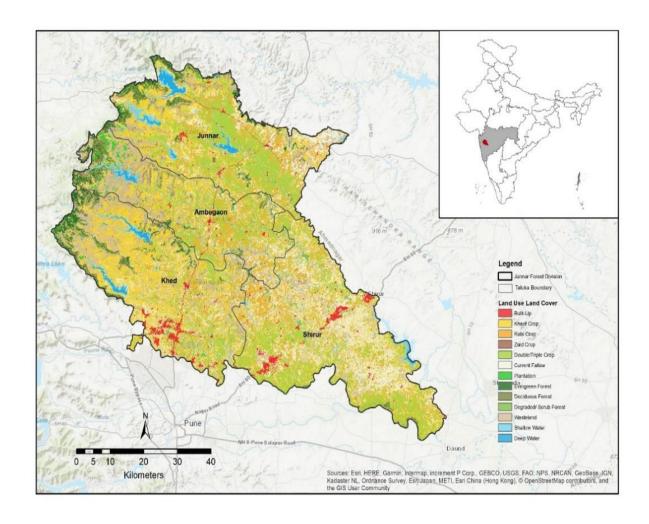
Figure 1: Land use land cover map of Junnar Forest Division, Maharashtra, India

Materials and methods
Capture and radio-collaring

In 2021, three leopards were radio-collared to study their movement and space-use in human-dominated landscape of Junnar Forest Division, Pune, Maharashtra. These leopards were captured using cages with drop door mechanism. These cages are deployed in multiple villages in Junnar Forest Division. Healthy adult individuals were selected for radio collaring exercise. These trapped individuals were chemically immobilized by wildlife veterinarian using a combination of ketamine and xylazine drugs. These individuals were fitted with Vetronics GPS collars that were programmed to take fixes at different intervals (Table 1 & 2) (Figure 2 a, b and c). After fully recovering from the drug effect, they were released back in the forest patch selected by the forest department. These collared individuals are currently being tracked on-field, and GPS data is downloaded using satellite links (Figure 3).

Table 1: Details of leopards collared from Jan-March 2021, Junnar Forest Division, Maharashtra

Individual Id	Sex	Age	Area of capture and release	Capture date	Release Date (after collaring)	Collar type
Suryaji/ Male 1	Male	Adult	Narayangaon, Junnar *taluka*	10-01-2021	14-01-2021	Vetronics, Iridium
Jija/ Female 1	Female	Adult	Girawali, Ambegaon *taluka*	15-01-2021	16-01-2021	Vetronics, Iridium
Hirkani/ Female 2	Female	Adult	Gunjalwadi, Junnar *taluka*	29-01-2021	31-01-2021	Vetronics, Iridium

Table 2: Morphometry details of leopards collared from Jan-March 2021, Junnar Forest Division, Maharashtra

Details (Length in cms)	Suryaji/ Male1	Jija/ Female1	Hirkani/ Female2
Weight (in kgs)	59.5	36.7	35
Age (in yrs)	8 to 9	6 to 7	4 to 5
Body Length	150	116	116
Tail Length	96	83	85
Forelimb Length	71	58	61
Forelimb Paw length	11	9	8
Forelimb Paw breadth	9	7	6
Hindlimb Length	69	62	68
Hindlimb Paw length	10	8	7
Hindlimb Paw breadth	7	6	5
Neck Girth	50	46	40
Chest Girth	80	66	64
Abdomen Girth	88	70	68

Figure 2 (a): Male1 leopard being collared in Junnar, Junnar Forest Division, Pune, Maharashtra

Figure 2 (b): Female2 leopard being collared in Junnar, Junnar Forest Division, Pune, Maharashtra

Figure 2 (c): Female3 leopard being weighed before being collared in Junnar, Junnar Forest Division, Pune, Maharashtra

Figure 3: On field tracking of animals in Junnar Forest Division, Maharashtra, India.

Analysis

Home range

Range estimation of species is critical for ecology, wildlife management and conservation. Estimating range involves estimating distribution of species based on locations received from tracking an animal. Kernel density estimation is a statistically efficient non-parametric method for probability density estimation. These fixed kernel density estimation maps (figure 4 (a, b & c), 5, and 6(a, b and c)) give us a utilization distribution of our collared individuals in the study area. Home range analysis was done using ArcMap 10.2.2.
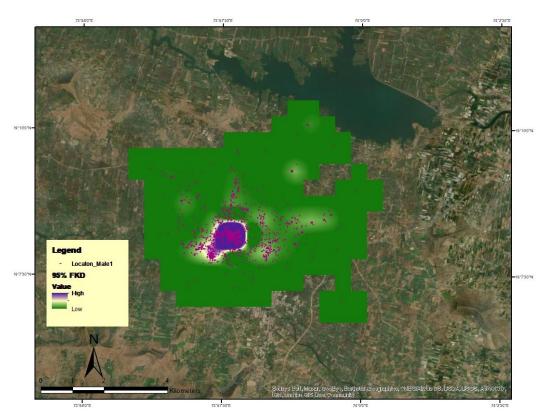
Figure 4 (a): Fixed Kernel Density Estimate of male1 leopard in Junnar taluka, Junnar Forest Division, Pune, Maharashtra
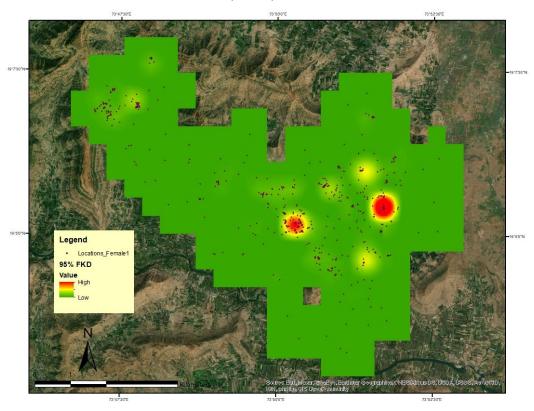

Figure 4(b): Fixed Kernel Density Estimate of female1 leopard in Ambegaon taluka, Junnar Forest Division, Pune, Maharashtra
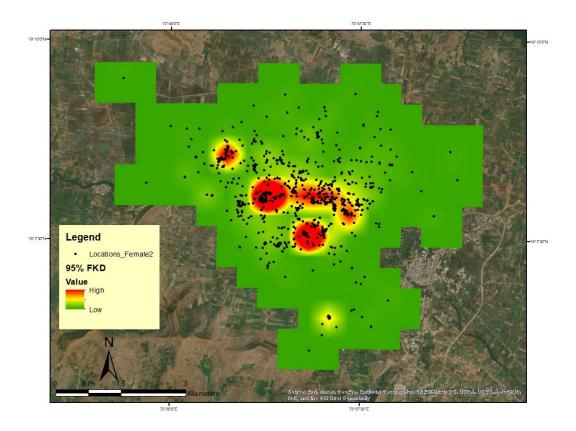
Figure 4(c): Fixed Kernel Density Estimate of female2 leopard in Junnar taluka, Junnar Forest Division, Pune, Maharashtra

Habitat Characterisation

Along with this, during on-going tracking field researchers are also collecting data for habitat characterization. Especially collecting data where individuals are spending considerable amount of time while moving across the agricultural landscape; preference in site-selection for refuge is recorded in the form of crop/plantation height and area, human infrastructure in the vicinity.
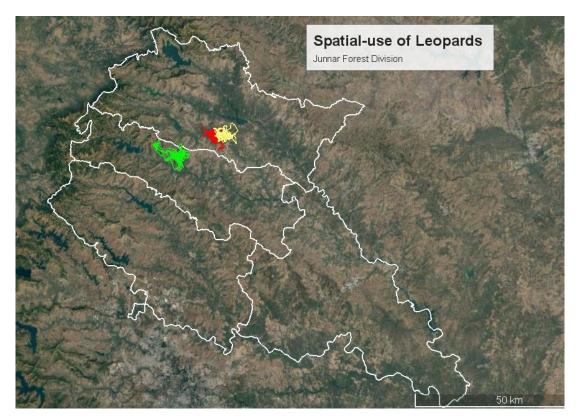
Figure 5: Map showing spatial use of collared leopards in Junnar and Ambegaon *taluka*, Junnar Forest Division, Maharashtra, India, 2021

Figure 6 (a): Female3 leopard captured on camera during camera trap exercise in Junnar Range, Junnar Forest Division

Figure 6 (b): Female3 leopard captured on camera during camera trap exercise in Junnar Range, Junnar Forest Division
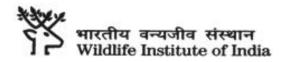

Figure 7: Male1 leopard captured on camera during camera trap exercise in Junnar Range, Junnar Forest Division

References:

Athreya V, Odden M, Linnell J D C, Krishnaswamy J and Karanth K U 2016 A cat among the dogs: Leopard Panthera pardus diet in a human-dominated landscape in western Maharashtra, India *Oryx* **50** 156–62

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Carter, N.H., and Linnell J.D.C. Co-adaptation is key to coexisting with large carnivores. Trends in Ecology & Evolution 31.8 (2016). 575-578.

Karanth K. K., Gopalaswamy A. M., Prasad P. K. and Dasgupta S. 2013. Patterns of human-wildlife conflicts and compensation: Insights from Western Ghats protected areas *Biol. Conserv.* **166** 175–85
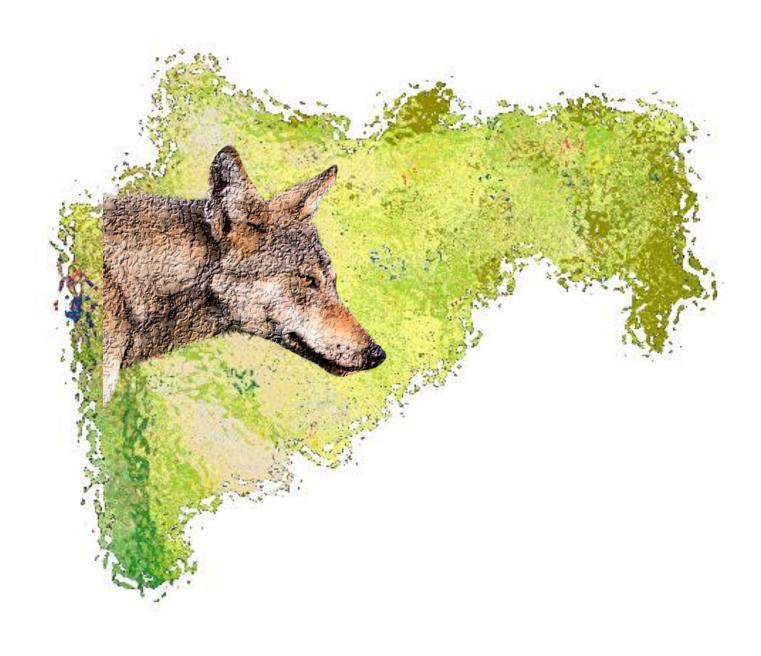
Dr. Bilal Habib
Head Department of Animal Ecology and Conservation Biology
Wildlife Institute of India, Chandrabani
Dehradun, India 248 001
Tell: 00 91 135 2646283
Fax: 00 91 135 2640117
E-mail:bh@wii.gov.in

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

ECOLOGY OF WOLVES WITH EMPHASIS ON DISPERSAL IN A HUMAN-DOMINATED LANDSCAPE, MAHARASHTRA, INDIA

Department of
Science &
Technology,
Government of
India

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

Project Title	**Ecology of Wolves Emphasis on Dispersal in a human-dominated landscape, Maharashtra, India**
Duration of the Project	**3 Years**
Principal Investigator	**Bilal Habib (PI)** (Scientist-E)
Co-Principal Investigator	**Salvador Lyngdoh (Co-PI)** (Scientist-D)
Researcher	**Sougata Sadhukhan** **Shaheer Khan**
Funding Agency	**Department of Science and Technology**
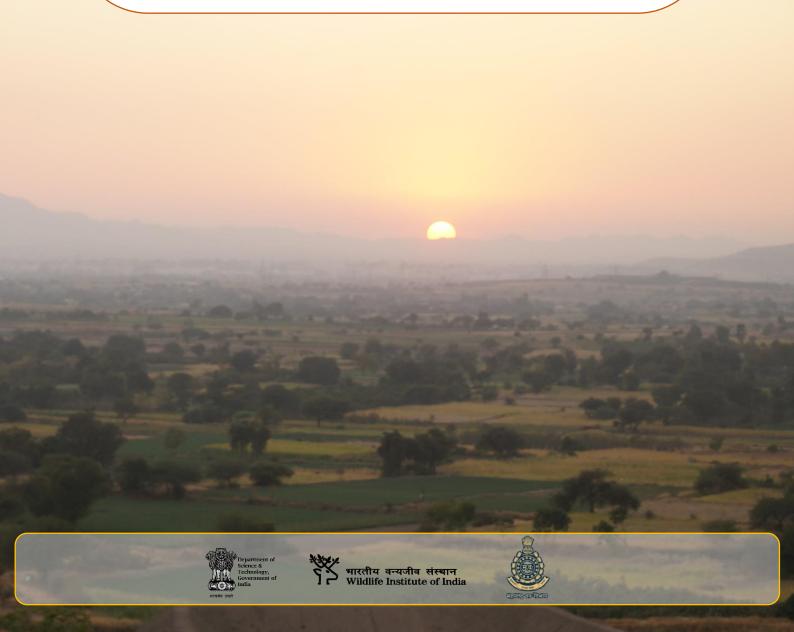
Department of Science & Technology, Government of India

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

Further Contact:
Dr. Bilal Habib
Department of Animal Ecology and Conservation Biology
Wildlife Institute of India, Chandrabani
Dehradun, India 248 001
Tell: 00 91 135 2646283
Fax: 00 91 135 2640117
E-mail; bh@wii.gov.in

Landuse/landcover Data Reference: LULC-AWiFS data for the year 2015-16 was obtained for the State of Maharashtra. It was obtained vide request ID 14780 from Bhuvan Portal of NRSC.

Table of Contents

List of Figures

The Grey wolf (*Canis lupus*) is one of the widely distributed land mammals and found in almost all type of habitats in the Northern Hemisphere. In India two subspecies of wolf have been recognized, one Tibetan wolf (*Canis lupus chanco*) and another is Indian grey wolf (*Canis lupus pallipes*). The Indian wolf distributed across central India, extended up to Rajasthan in the north and Karnataka in the south, is categorized as Endangered by the IUCN (Canid Specialist Group of IUCN) and is a Schedule I species as per the Wildlife (Protection) Act 1972. The number of Indian wolves is declining due to various reason and few scientific studies have been undertaken to study the population size, and ecological aspects of wolves in India. However, important aspects have not been tried to understand in-depth, leaving a significant gap in our knowledge about the species, on which future conservation strategies can rely. To facilitate the continued survival and recovery of this endangered canid, it is critical to gain insights about their ecology.

In this study, a total of four adult wolf (two males and two females) and four subadult wolves (two males and two females) were captured. The howling survey was conducted to evaluate the population status of wolves. To evaluate the social dynamics and behaviour, the howling pattern of collared packs were studied. The Land Use Land Cover (LULC) type within the home range and core area were evaluated for collared wolves to understand the habitat utilisation of wolves in different areas. Species distribution model was used to evaluate the critical habitat for wolves in the state of Maharashtra.

A total of 233 howls were recorded from different parts of Maharashtra through 37 responses in 199 howling surveys. A total of 54 good quality (based on the signal and noise ratio) solo howls were analysed with DFA using F_0 (Fundamental frequency), simple scalar variables (nine variables: Minf, Maxf, Meanf, Rangef, Abrupt 1, Abrupt 2, SD, PosMin, Cofm, Cofv), 100% accuracy was achieved. A total of seven dimensions were created to identify groups (howls from a different individual). First two Canonical variables (weighted combinations of all four variables) contributed 91.2% in identification of the group. The Dendrogram grouped six howling clusters at six clustering scale. Furthermore, 33 out of 51 howls were correctly identified with the accuracy of 64.7%. Closely related (Captive wolves of Jaipur Zoo have same parental lineage) captive wolf howls were identified with 52% accuracy. In the case of wild individuals, 72.4% accuracy was achieved. To study social behaviour and dynamics, the howling pattern of the packs of collared individuals were investigated. The collared individuals responded for howling

playbacks more in their core area (n=48, p=0.65) as compared to their home range (n=18, p=0.33). The rate of response decreased as the howling playback locations moved away from the core area. The response rate was higher for chorus howls (p=0.61) compared to the solo wolf howls (p=0.25). The average home range of the three adult wolves of Solapur and Baramati area were found to be 336.53 km² whereas the home range of subadult wolves of Ahmednagar and Pune area were found 6.86 km². The home range of female from Solapur area was found to be 325.92 km² whereas for Solapur male, it was found 399.56 km². The minimum home range among adults was found 284.11 km² for Baramati female (Firky). The average home range of subadults of Pune area (75.35 km²) was found larger than Ahmednagar area (9.19 km²). The core area for adult wolves Merry, Breeze and Firky were found 19.03 km², 31.56 km² and 54.43 km² respectively. The average core area of subadult wolves of Ahmednagar and Pune were found 1.16 km² and 5.09 km² respectively.

To understand the habitat utilization of wolves, a comparative study between the habitat use of core area (50% BBMM) and home-range (95% BBMM) were done. The result suggested that the core area of wolves mainly comprises of agricultural areas (58.36%) followed by grassland (38.01%). Out of the total area of home range, 96% of the area comprised of agricultural areas and grassland. Our results also suggest that there is a significant difference between the built-up area, agricultural area and grassland composition of the core area and home range of the same individual ($P_{builtup}$=0.033, P_{agri}=0.037, P_{grass}=0.032). The MaxEnt analysis was used to determine the critical habitat for wolves in Maharashtra. Our results show that out of the total area of Maharashtra, 15,888 km² area was found highly suitable for the wolves.

This study proposed the potentiality of a howl as a tool to identify individual wolf. Therefore, howl survey can be used in mark-capture recapture framework. Since our study also specifies the factors which influence the howling response, this could lead us in designing a robust howling survey for mark-recapture based population estimation. The fine-scale habitat utilisation data from radio telemetry helped us to delineate the wolf habitat in a more precise manner which is going to be beneficial during choosing study area for howling survey. The population status of Indian wolf is unknown till date, but our endeavour with howling survey could be the front-runner toward a successful estimating the population of the wolf in the human-dominated landscape of Maharashtra, India.

INTRODUCTION

The Grey wolf (*Canis lupus*) is one of the widely distributed land mammals and found in almost all type of habitats in the Northern Hemisphere (Mech and Boitani, 2003). Out of 38 subspecies of *Canis lupus*, globally recognized, 13 subspecies are considered to be extinct in last 150 years (Wozencraft, 2005). In India two subspecies of wolf have been recognized, one Tibetan wolf (*Canis lupus chanco*) and another is Indian grey wolf (*Canis lupus pallipes*). The Indian wolf distributed across central India, extended up to Rajasthan in the north and Karnataka in the south (Shahi, 1982), is categorized as Endangered by the IUCN (Canid Specialist Group of IUCN) and is a Schedule I species as per the Wildlife (Protection) Act 1972. The number of Indian wolves is declining due to various reason and few scientific studies have been undertaken to study the population size, and ecological aspects of wolves in India (Jhala and Giles, 1993; Jethva and Jhala, 2003; Singh and Kumara, 2006; Habib, 2007). However, important aspects have not been tried to understand in-depth, leaving a significant gap in our knowledge about the species, on which future conservation strategies can rely.

In the life history of animal, various events are important which governs the species survival and dispersal is one of them. It is the principal mean by which animal leave their natal area to reproduce and potentially expand their population's geographic range (Fuller, Mech and Cochrane, 2003). Genetic variation in a population is determined by dispersal success and sustaining populations for a long term requires ensuring gene flow. In social carnivores like wolves, dispersal is an essential mechanism for population regulation (Lidicker, 1975), it plays a vital role in the spatial distribution and genetic structure of populations (Taylor and Taylor, 1977; Vila *et al.*, 2003), therefore it may influence population viability (Boyce, 1992; Waser, 1996; Nilsson, 2004). In a situation of limited and already occupied suitable habitat, dispersal becomes a crucial factor determining the ecology and behaviour of the species. Evaluation of these factors will generate clearer understating of wolf habitat use and critical information of the species ecology.

The dispersal of wolves depends on many factors and the new recruits in the pack determined by various factors and conditions such as food availability, critical habitat etc. If the suboptimal habitat is the only habitat available, then resources will be constrained, and conflict among the dispersing individuals with already established individuals or packs will increase. In such situations, wolves may opt for delayed dispersal. Furthermore, delayed dispersal would lead to an outcome in increasing the sociality among the individuals of the pack.

With changing scenarios of land use pattern and urbanisation, the habitat of wolves is under tremendous pressure in a country like India, where the human population is increasing at a very high rate. It is crucial to keep track of various changes, which are occurring in wolf range, and its capability of adaptation to save this dwindling species. In light of this situation, this study is very critical necessary for developing management plans for this apex predator of grasslands.

To facilitate the continued survival and recovery of this endangered canid, it is critical to gain insights about their ecology. Since the wolves are surviving in the Human dominated
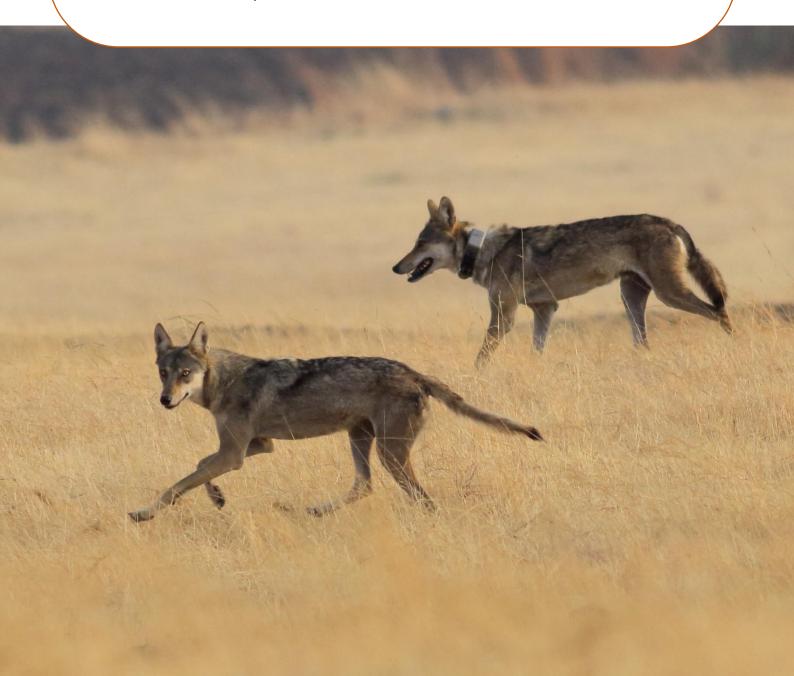
landscape by their own ability and their elusive behavior, it is difficult to monitor wolf pack directly due to their avoidance of humans and due to their large home range. So, to gain information on wolf ecology, we used radio telemetry technique which is a useful method in understanding the various aspects of the ecology of species and has been used extensively to study wolves throughout their range (Blanco, Cortés and Virgós, 2005). So far, all the telemetry studies in India concentrated on wolf were used VHF radio collars. In this study, we used GPS telemetry to understand, how wolf exploits and utilises human-dominated landscapes. The study will help in the understanding of what are the critical wolf habitats within a human-dominated mosaic that need to be conserved for long term viability of wolf populations.

OBJECTIVES

- What is the current population status of wolves in Maharashtra State?

- To estimate the home-range/territorial behaviour of dispersing individuals.

- To study the dispersal pattern and habitat use of the existing wolf packs dwelling in the human-dominated landscape of Solapur, Osmanabad, Pune and Ahmednagar districts of Maharashtra, India.

- To study the social structure and dynamics of the selected wolf packs for individual behaviours within the pack and their interaction with other wolf packs in the vicinity.

- To delineate critical habitat patches and factors governing their utilisation in a human-dominated landscape.

METHODOLOGY
Capturing and Collaring of Wolves

A total of four adult wolf (two males and two females) and four subadult wolves (two males and two females) were captured using soft leghold traps. 20-25 traps were set placed in a circle, and coyote & wolf gland lure No. 100 (Stanley Hawbaker and Sons, Fort London, Pennsylvania) were used to attract wolf. Fresh scats from different packs were also used and placed around the traps. The traps were connected to GSM based device named "MinkPolice". This device operates with a magnetic switch which got triggered every time an animal stepped on the traps and send alert message on registered numbers. Trapped wolves were held using double-threaded nylon hockey net and immobilised using Ketamine–Xylazine by injecting intramuscularly on their hind leg and fitted with radio collar (Habib, 2007). We captured one adult male and female from Solapur Forest Division and one male and female from Baramati forest Division. We also captured subadult male and female of the same pack of Ahmednagar and one subadult male and female of the same pack from Saswad, Pune. A total of eight wolves from five different packs (four females and three males) were fitted with GPS plus collar, and one male was fitted with proximity collar (Table 1) (Figure 1).
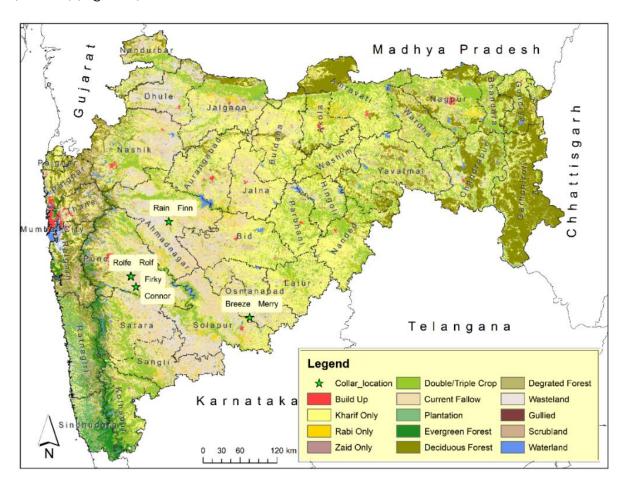
FIGURE 1. MAP SHOWING THE COLLAR WOLVES LOCATIONS IN THE STATE OF MAHARASHTRA

Wolf Name	Sex	Collar ID	Date of capture	Collar type	Area
Merry	F	26139	25.12.17	GPS plus Activity + Proximity	Gangewadi
Breeze	M	21263	29.12.17	GPS plus Activity	Gangewadi
Firky	F	26140	22.12.17	GPS plus Activity + Proximity	Morgaon
Connor	M	7085	22.12.17	Proximity with VHF	Morgaon
Finn	M	21592	22.06.19	GPS plus Activity	Ahmednagar
Rain	F	21591	24.06.19	GPS plus Activity	Ahmednagar
Rolf	M	21590	26.06.19	GPS plus Activity	Saswad
Rolfe	F	26137	27.06.19	GPS plus Activity + Proximity	Saswad

Howling Survey

The wolf howl is a very low frequency and high amplitude vocalisation, which can be recorded from as long as 3km distance. Therefore, a howling survey is a potent tool to monitor long-ranging vocal species like a wolf (Harrington and Mech, 1982; Suter *et al.*, 2016). The data collection to record wolf howl was done in the early morning and early evening hours (time varies depending on sunrise and sunset). Each howling session consisted of five trials with three-minute intervals. A 50-second-long pre-recorded series of solo howls (recorded from Jaipur Zoo) were played three times with increasing volume using speakers followed by 50-second-long chorus howls which were played twice. In the case of the howling response, the session was terminated and repeated after 15 to 20 minutes. In each sampling session, the data was collected such as GPS location, howl type (solo or chorus), field estimate (number of individuals only if it was a chorus howl) along with other variables. All howls were recorded in a single microphone setup, using a Sennheiser ME67 microphone and a digital recorder (Zoom H4N Handheld Audio Recorder) with a sampling rate of 44.1kHz and 16-bit accuracy.
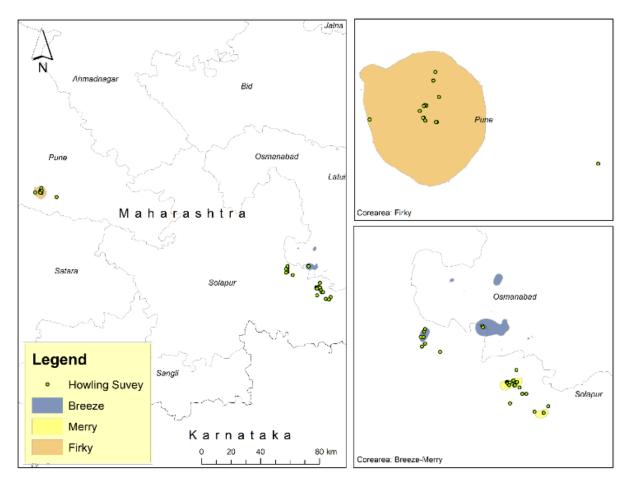
FIGURE 2. MAP SHOWING HOWLING SURVEY LOCATIONS TO DETERMINE THE FACTORS THAT INFLUENCE HOWL RESPONSE. THE EXPERIMENT WAS DONE ON THE COLLARED PACK OF MAHARASHTRA.

To evaluate the social dynamics and behaviour, we studied the howling pattern of collared packs. The collected data has provided insight into the howling variation in known individuals and the factors affecting it, which in turn will help us to increase the efficiency of identifying individuals from howl and result in population estimation with higher accuracy. We collected the howl data by regular monitoring and howling surveys. Four radio-collared individuals (Merry, Breeze, Firky and Connor) were tracked using a VHF telemetry. The howling survey was done after the sunset when the radio-collared individuals were within a 1-kilometre radius. A total of 66 howling surveys were conducted on collared individuals (Figure 2). Howling survey for the unknown wolf packs were also done in the districts of Ahmednagar, Pune, Solapur, Osmanabad, Nagpur and Gondia districts of Maharashtra and a total of 200 howling survey sessions were conducted in different parts of Maharashtra (Figure 3).
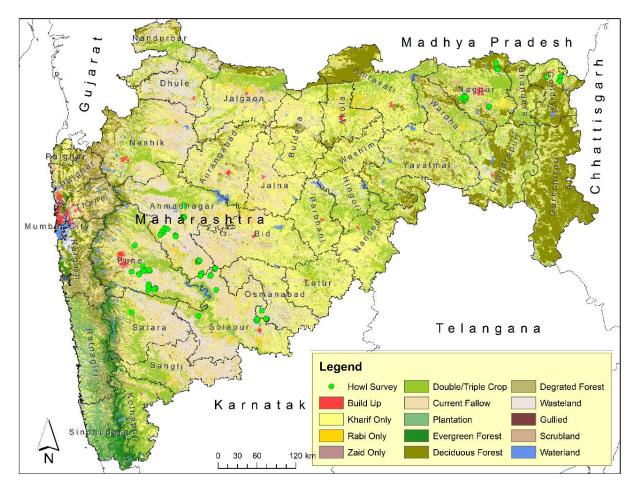
FIGURE 3. MAP SHOWING HOWLING SURVEY LOCATION FOR THE UNKNOWN WOLF PACK IN SIX DISTRICTS OF MAHARASHTRA.

The spectrograms of each howl were created using Raven Pro 64 bit version 1.5 software (Bioacoustics Research Program, 2014) using the default Hann window, 1,024Hz time resolution, and spectrum view; followed by Digitization of Fundamental Frequency (F_0) through Software Web Plot Digitizer (Rohatgi, 2017). For the analysis, we excluded the howls that were shorter than 5 seconds and a total of 12 parameters were measured from the selected howls (Table 2**Error! Reference source not found.**).

TABLE 2. PARAMETERS MEASURED FROM FUNDAMENTAL FREQUENCY (F_0) OF HOWLS

Parameter	Description
Minf	Minimum frequency of Fundamental
Maxf	Maximum Frequency of Fundamental
Meanf	Average Frequency of Fundamental
Rangef	Range of Fundamental (Maxf – Minf)
Abrupt1	Number of abrupt changes in pitch of the fundamental (> 25 Hz)
Abrupt2	Number of abrupt changes in pitch of the fundamental (> 50 Hz)
Abrupt3	Number of abrupt changes in pitch of the fundamental (> 100 Hz)
SD	Standard deviation of the frequency of fundamental
PosMax	Position in the howl at which the maximum frequency occurs, (time of Maxf)/Dur
PosMin	Position in the howl at which the minimum frequency occurs, (time of Minf)/Dur
Cofm	Coefficient of frequency modulation of the fundamental or average per cent change in frequency at per unit time
Cofv	Coefficient of frequency variation of the mean frequency

Forty-four howls from eight known individuals, including three known captive individuals from Jaipur Zoo and five wild individuals (solo howling with direct sighting), were selected to verify the significance level of the parameters. Analysis of variance was done using SPSS v22.0 (IBM, 2013). Abrupt3 (F_{cal}=1.420, P=0.222) and PosMax (F_{cal}=1.555$_{(.174)}$) and the results were found non-significant for distinguishing howls between different individuals (Table 3). Nine variables (Minf$_{(.000)}$, Maxf$_{(.000)}$, Meanf$_{(.000)}$, Rangef$_{(.001)}$, Abrupt 1$_{(.001)}$, Abrupt 2$_{(.000)}$, SD$_{(.000)}$, PosMin$_{(.019)}$, Cofm$_{(.000)}$, Cofv$_{(.020)}$; among twelve variables were found significant in the ANOVA test. Thus, those nine variables significantly varied with at least one individual from the rest of the seven individuals. As Rangef (frequency range) is the subtracted value of the maximum and the minimum frequency, we dropped this parameter for further analysis.

TABLE 3. TABLE SHOWING ANALYSIS OF VARIANCE OF 12 PARAMETERS FROM 44 HOWLS OF 8 INDIVIDUALS

		Sum of Squares	df	Mean Square	F	Sig.
Minf	Between Groups	.061	7	.009	13.332	.0001
	Within Groups	.029	44	.001		
	Total	.089	51			
Maxf	Between Groups	.297	7	.042	30.343	.0001
	Within Groups	.061	44	.001		
	Total	.358	51			
Meanf	Between Groups	.170	7	.024	33.302	.0001
	Within Groups	.032	44	.001		
	Total	.202	51			
Rangef	Between Groups	.023	7	.003	4.416	.001
	Within Groups	.032	44	.001		
	Total	.055	51			
Abrupt1	Between Groups	35.986	7	5.141	6.039	.0001
	Within Groups	37.457	44	.851		
	Total	73.442	51			
Abrupt2	Between Groups	2.793	7	.399	6.984	.0001
	Within Groups	2.514	44	.057		
	Total	5.308	51			
Abrupt3	Between Groups	.181	7	.026	1.420	.2221
	Within Groups	.800	44	.018		
	Total	.981	51			
SD	Between Groups	.006	7	.001	5.754	.0001
	Within Groups	.006	44	.000		
	Total	.012	51			
PosMin	Between Groups	6.919	7	.988	2.745	.019
	Within Groups	15.845	44	.360		
	Total	22.764	51			
PosMax	Between Groups	71.006	7	10.144	1.555	.174

	Within Groups	286.990	44	6.523		
	Total	357.996	51			
Cofm	Between Groups	.430	7	.061	23.569	.0001
	Within Groups	.115	44	.003		
	Total	.545	51			
Cofv	Between Groups	155.909	7	22.273	2.719	.020
	Within Groups	360.421	44	8.191		
	Total	516.330	51			

Nine variables that were found significantly different between howling of varying individuals were used in Discriminant Function Analysis (DFA). DFA performs a multivariate test of differences between groups (howls from different individuals were considered as different groups). Also, DFA was used to determine the minimum number of dimensions needed to describe these differences. A total of 52 howls from eight known individuals were analysed using DFA in software SPSS (IBM, 2013).

As first two DFA functions explained for 91.1% (DFA1 73.3 and DFA2 17.8) of the variance for differentiating between howls of different individuals, we calculated DF1 (Equation 1) and DF2 (Equation 2) to plot those 52 howls in two dimensions and verify the accuracy.

EQUATION 1

DF1= -26.2414+ (4.260215* Minf) + (15.38787*Maxf) + (44.43618*MeanF) + (-0.22006*Abrupt1) + (-0.68357*Abrupt2) + (-383.075*SD) + (0.479685+PosMin) + (11.443418Confm) + (1.354311*cofv);

EQUATION 2

DF2= -7.09747 + (0.006623*Minf) + (13.41889*MaxF) + (10.50522+MeanF) + (0.25256*Abrupt1) + (3.308972*Abrupt2) + (-31.0621*SD) + (-0.97581*PosMin) + (-21.0902*ConFM) + (0.133816*CoFv)

Centroid clustering with Minkowski 2nd order function was found most efficient in order to identity howls from different individuals with the help of DF1 and DF2. Centroid clustering with Minkowski 2nd order function identified 52 howls from eight individuals with 64.7% accuracy.

DF 1 and DF 2 of 34 unknown howls (from seven different areas) were calculated with the help of pre-derived equations, and Dendrogram was constructed with those two functions using centroid clustering with Minkowski 2nd order function.

We evaluated the rate of howling responses of the collared individuals concerning their home range utilisation distribution. The multi-regression analysis was performed to assess the collective effect of factors influencing response- months, howl Stimulus type, sunset time, Utilisation distribution, Euclidean distance from settlement and effort.

Home-range Delineation and Habitat Utilisation

We used the Brownian Bridge Movement Model, BBMM (Bullard, 1999) to evaluate home ranges of all collared individuals. BBMM is a widely used method that estimates the path of an animal's movement probabilistically from data recorded at brief intervals. BBMM quantifies the utilisation distribution of an animal-based on movement paths, accounts for temporal autocorrelation, and high data volumes (Fischer, Walter and Avery, 2013). The model approximates the movement path between two following locations by applying a conditional random walk. We quantified BBMM at 50% and 95% contours using ArcMET extension tool (Wall, 2014) in ArcGIS 10.2. 95% BBMM was considered as the overall home range and 50% BBMM as the core area of the animal home range (Fischer, Walter and Avery, 2013). All GPS locations collected during Dec17 – July20 were analysed to understand the home-range pattern of wolves in the human-dominated landscape.

We evaluated Land Use Land Cover (LULC) type within the home range and core area of collared wolves to understand the habitat utilisation of wolves in different areas. The LULC of 1:25000 scale was acquired from Bhuvan's open-source website (http://bhuvan.nrsc.gov.in/). The LULC maps were generated using "Resourcesat AWiFS" satellite imagery, which classified Maharashtra into 13 land use classes. These elementary classes were reclassified into five significant classes for analysis. The LULC values were extracted using ArcGIS 10.2.

The core utilisation areas of the collared pack were identified using 50% BBMM. The location which falls under the core areas of each wolf were used to build maximum entropy model using MaxEnt (v3.4.1). MaxEnt is widely used robust method of correlating environmental variables which could lead to a bias towards auto-correlated variables, and less sensitive to the number of occurrence points (Phillips, Dudik and Schapire, 2004). We used eleven environmental variables which may govern the core utilisation areas of a wolf pack in human-dominated landscapes. The environmental layers used in this analysis were the average Normalised Difference Vegetation Index (NDVI), *Euclidean Distance* (ED) from nearest human settlements, ED from double and triple cropland, ED from grassland, ED from kharif cropland, ED from a nightlight, precipitation during the wettest quarter, ED from rabi croplands, ED from scrubland, ED from scrub forest or degraded forest, ED from water and ED from zaid cropland. Each GIS layer was processed using ArcGIS 10.2. For this analysis, we used 13009 wolf presence locations (GPS location of seven collared wolves) from four districts of Maharashtra. 75% of the total locations were used for training the model, and 25% presence points were used to test the accuracy. We used the jack-knife method to measure variable importance.

RESULTS
Individuals Identification through howling surveys

A total of 233 howls were recorded from different parts of Maharashtra through 37 responses in 199 howling surveys. The fundamental frequencies of those howls range from 164 to 955Mhz. Adults usually tend to have a narrow range in their fundamental frequency of howls with lesser frequency modulation whereas the howls of sub-adults and pups contain a high degree of frequency modulation. A total of 54 good quality (based on the signal and noise ratio) solo howls were analysed with DFA using F_0 (Fundamental frequency) Simple scalar variables (nine variables: Minf, Maxf, Meanf, Rangef, Abrupt 1, Abrupt 2, SD, PosMin, Cofm, Cofv), 100% accuracy was achieved (Table 4). A total of seven dimensions were created to identify groups (howls from a different individual). First two Canonical variables (weighted combinations of all four variables) contributed 91.2% in identification of the group (

Table 5).

	ID	Predicted Group Membership								Total
		1	2	3	4	5	6	7	8	
Count	1	9	0	0	0	0	0	0	0	9
	2	0	3	0	0	0	0	0	0	3
	3	0	0	11	0	0	0	0	0	11
	4	0	0	0	14	0	0	0	0	14
	5	0	0	0	0	3	0	0	0	3
	6	0	0	0	0	0	5	0	0	5
	7	0	0	0	0	0	0	5	0	5
	8	0	0	0	0	0	0	0	2	2
%	1	10	.0	.0	.0	.0	.0	.0	.0	100.0
	2	.0	100.0	.0	.0	.0	.0	.0	.0	100.0
	3	.0	.0	100.0	.0	.0	.0	.0	.0	100.0
	4	.0	.0	.0	100.0	.0	.0	.0	.0	100.0
	5	.0	.0	.0	.0	100.0	.0	.0	.0	100.0
	6	.0	.0	.0	.0	.0	100.0	.0	.0	100.0
	7	**.0**	**.0**	**.0**	**.0**	**.0**	**.0**	**100.0**	**.0**	**100.0**

TABLE 5. EIGENVALUES OF 7 DISCRIMINATE DIMENSIONS. THE LARGER EIGENVALUE IS ASSOCIATED WITH A STRONGER FUNCTION. HERE DF 1 AND DF 2 HAVE SIGNIFICANTLY HIGHER EIGENVALUE. DF1 AND DF2 ALONE RESPONSIBLE FOR 91.2% VARIANCE

Function	Eigenvalue	% of variance	Cumulative %	Canonical Correlation
1	9.188[a]	73.3	73.3	.950
2	2.236[a]	17.8	91.2	.831
3	.497[a]	4.0	95.1	.576
4	.341[a]	2.7	97.9	.504
5	.204[a]	1.6	99.5	.412
6	.057[a]	.5	99.9	.232
7	.008[a]	.1	100.0	.088

Two Canonical Variables (DF 1 and DF 2) were calculated for every howl (52 howls from 8 individuals), to build a dendrogram. Centroid clustering was created using Minkowski 2nd order function and found six clusters at nine clustering scale with overall 64.7% accuracy (Figure 4). Three captive individuals (from Jaipur Zoo) were found closely related.

The Dendrogram grouped six howling clusters at six clustering scales (Figure 4). Furthermore, 33 out of 51 howls were correctly identified with the accuracy of 64.7%. Closely related (Captive wolves of Jaipur Zoo have same parental lineage) captive wolf howls were identified with 52% accuracy. In the case of wild individuals, 72.4% accuracy was achieved.
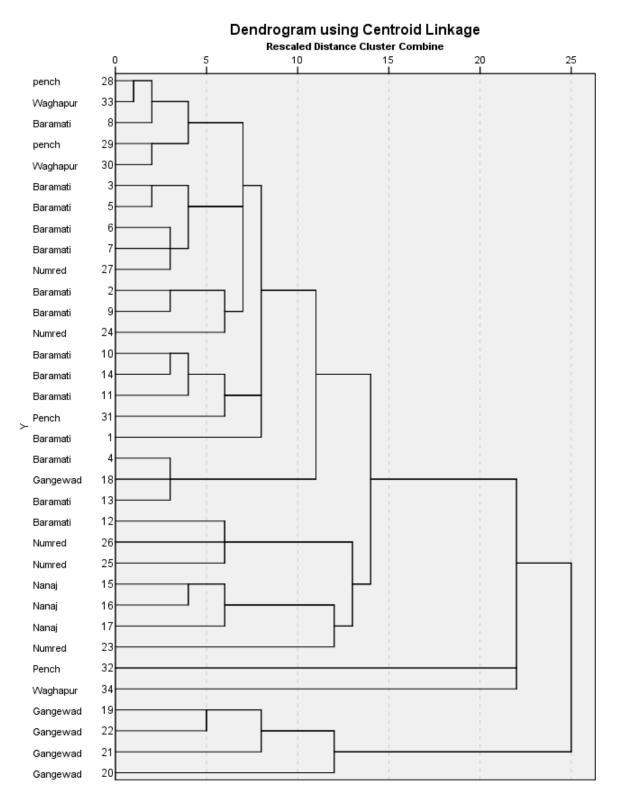
FIGURE 4. DENDROGRAM OF 34 HOWLS USING CENTROID CLUSTERING. GROUPS WERE INTERPRETED BASED ON 9 CLUSTERING SCALE

	CG1	CG2	BMT	NU	NNJ	GNGW	Ungrouped	Total	Correct ID	%
CG1	8	1	0	0	0	0	0	9	8	88.89
CG2	7	4	0	0	0	0	0	11	4	36.36
CG3	3	0	0	0	0	0	0	3	0	0
BMT	0	0	13	1	0	0	0	14	13	92.86
NU	0	0	2	2	0	0	1	5	2	40
NNJ	0	0	0	0	3	0	0	3	3	100
GNGW	0	0	0	0	0	3	2	5	3	60
Pench	0	0	2	0	0	0	0	2	0	0
								52	33	63.4
							Wild	29	21	72.4
							Captive	23	12	52.17

Canonical variables (DF1 and DF2) for unknown individuals were calculated from Equation 1 and Equation 2. Five clusters and four ungrouped howls were formed using two canonical variables in the Cluster analysis of 34 howls from seven different forest ranges.
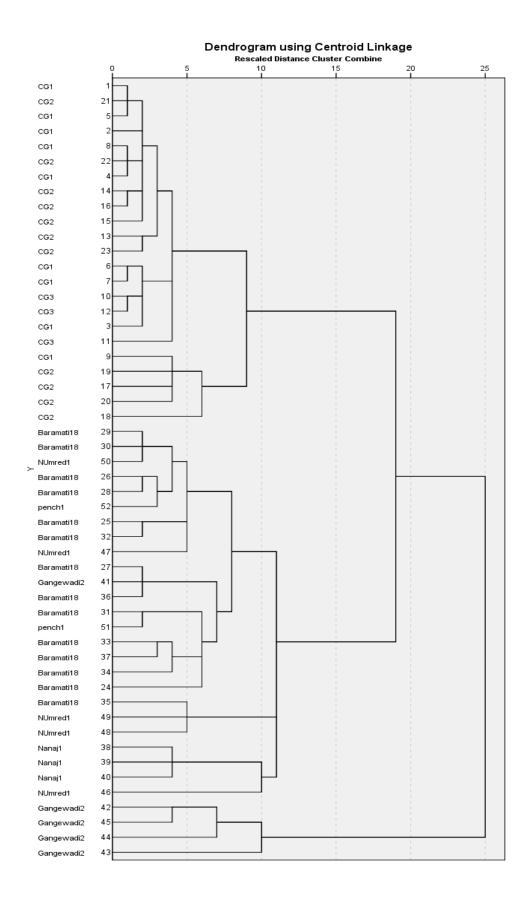
FIGURE 5: DENDROGRAM OF 52 HOWLS FROM EIGHT KNOWN INDIVIDUALS OUT OF WHICH 64% HOWLS WERE CORRECTLY IDENTIFIED AT 9 CLUSTERING SCALE.

Howling Behaviour of Wolves

To study social behaviour and dynamics, we investigate the howling pattern of the packs of collared individuals. The collared individuals responded for howling playbacks more in their core area (n=48, p=0.65) as compared to their home range (n=18, p=0.33) (Figure 6). The rate of response decreased as the howling playback locations moved away from the core area (Figure 7). The response rate was higher for chorus howls (p=0.61) compared to the solo wolf howls (p=0.25). Additionally, the response also varied concerning the time of the day and season.
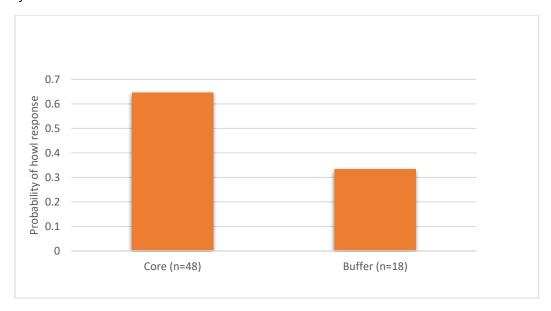

FIGURE 6. GRAPH SHOWING THAT THE RATE OF HOWL RESPONSE TO A HOWLING SURVEY IN THE CORE AREA AND HOME RANGE OF WOLVES.

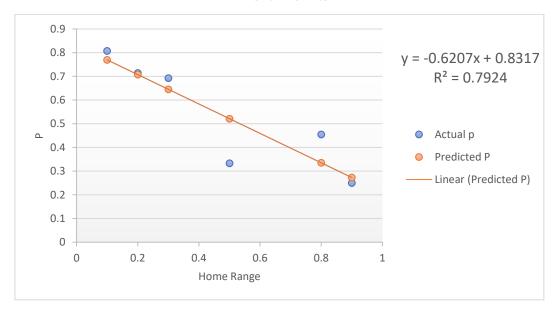

$$y = -0.6207x + 0.8317$$
$$R^2 = 0.7924$$

FIGURE 7. GRAPH SHOWING THAT WOLF RESPONSES WERE MORE IN CORE AREAS COMPARING TO THE LOW UTILISATION ZONE. (0.1 REPRESENTS HIGH UTILISATION ZONE, AND 1 MEANS VERY LOW UTILISATION ZONE)

Home-range estimation

The average home range of the three adult wolves of Solapur and Baramati area were found to be 336.53 km² whereas the home range of subadult wolves of Ahmednagar and Pune area were found 6.86 km². The home range of female from Solapur area was found to be 325.92 km² (Figure 8) whereas for Solapur male, it was found 399.56 km² (Figure 9). The minimum home range among adults was found 284.11 km² for Baramati female (Firky) (Figure 10). The average home range of subadults of Pune area (75.35 km²) (Figure 13 and Figure 14) was found larger than Ahmednagar area (9.19 km²) (Figure 11 and Figure 12).

The core area for adult wolves- Merry, Breeze and Firky were found 19.03 km², 31.56 km² and 54.43 km², respectively (Table 7. The home ranges and core areas of seven GPS collared wolves in Maharashtra (Table 7). The average core area of subadult wolves of Ahmednagar and Pune were found 1.16 km² and 5.09 km², respectively (Table 7).

TABLE 7. THE HOME RANGES AND CORE AREAS OF SEVEN GPS COLLARED WOLVES IN MAHARASHTRA

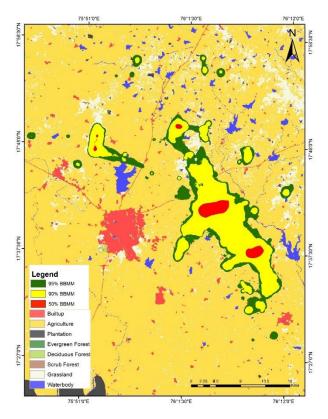| Individual wolf	Area	95% MCP (km²)	95% BBMM (km²) or Home range	50% BBMM (km²) or Core Area
Breeze (M)	Gangewadi, Solapur	519.70	399.56	31.56
Merry (F)	Sangdari, Solapur	981.48	325.92	19.03
Firky (F)	Morgaon, Baramati	110.59	284.11	54.43
Finn (M)	Ahmednagar	4.92	4.7	0.63
Rain (F)	Ahmednagar	13.17	13.96	1.69
Rolfe (F)	Saswad (Pune)	180.52	96.39	7.07
Rolf (M)	Saswad (Pune)	141.52	54.35	3.11

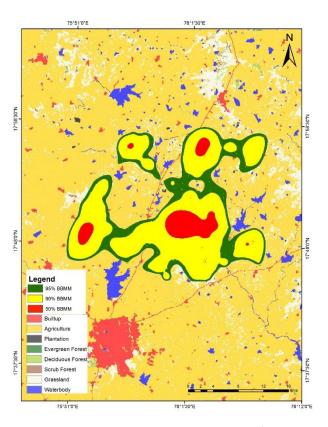**FIGURE 8. MAP SHOWING THE HOME RANGE AND CORE AREAS OF SOLAPUR FEMALE (MERRY)**

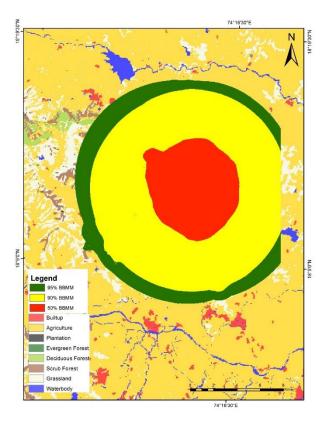**FIGURE 9. MAP SHOWING THE HOME RANGE AND CORE AREAS OF SOLAPUR MALE (BREEZE)**

FIGURE 10. MAP SHOWING HOME RANGE AND CORE AREAS OF BARAMATI FEMALE (FIRKY)
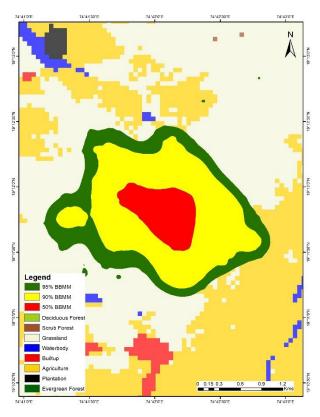

FIGURE 11. MAP SHOWING THE HOME RANGE AND CORE AREAS OF AHMEDNAGAR SUBADULT MALE (FINN)
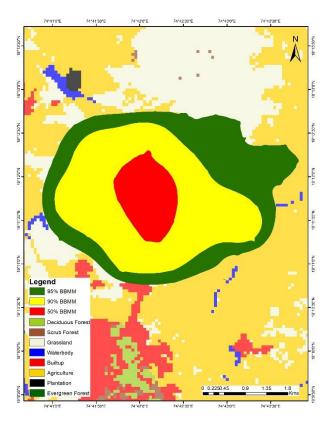
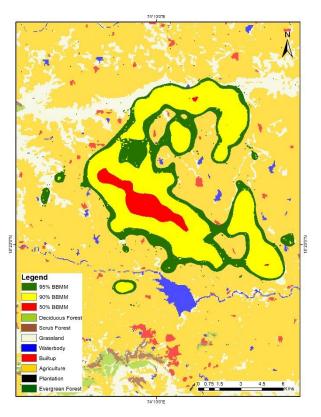**FIGURE 12. MAP SHOWING THE HOME RANGE AND CORE AREAS OF AHMEDNAGAR SUBADULT FEMALE (RAIN)**

FIGURE 13. MAP SHOWING THE HOME RANGE AND CORE AREAS OF SASWAD SUBADULT FEMALE (ROLFE)
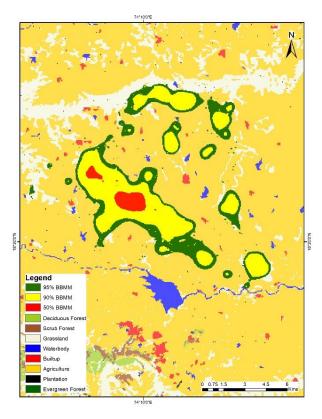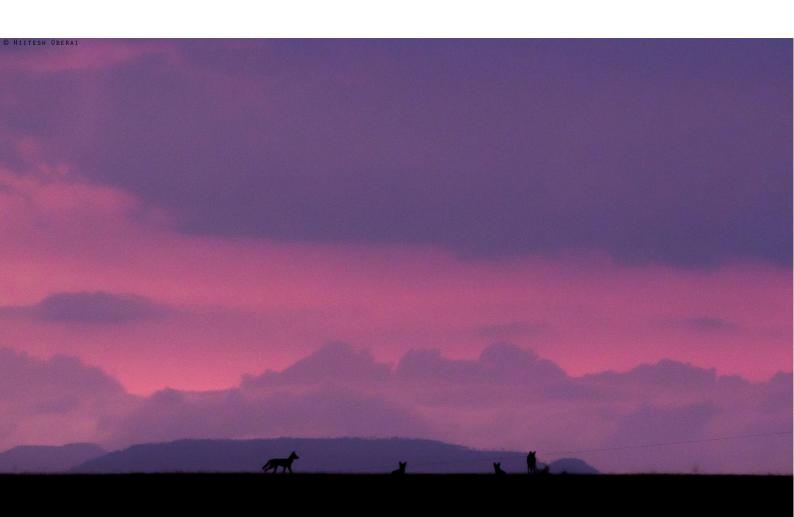
FIGURE 14. MAP SHOWING THE HOME RANGE AND CORE AREAS OF SASWAD SUBADULT MALE (ROLF)

Habitat Utilisation by wolves

To understand the habitat utilization of wolves, we did a comparative study between the habitat use of core area (50% BBMM) and home-range (95% BBMM). The result suggested that the core area of wolves mainly comprises of agricultural areas (58.36%) followed by grassland (38.01%) (Table 8). Out of the total area of home range, 96% of the area comprised of agricultural areas and grassland (Table 9) (Figure 15, Figure 16, Figure 17 and Figure 18). The land-use type within the home range of Ahmednagar male and subadult female wolves were only comprised of grasslands (Figure 18 and Figure 19), whereas the home range of Saswad male and female subadults wolves were comprised of agriculture and grasslands (Figure 20 and Figure 21). Our results also suggest that there is a significant difference between the built-up area, agricultural area and grassland composition of the core area and home range of the same individual ($P_{builtup}$=0.033, P_{agri}=0.037, P_{grass}=0.032).

TABLE 8. TABLE SHOWING DIFFERENT LAND-USE CLASS COMPOSITION WITHIN THE CORE AREA (50%BBMM) OF COLLARED WOLVES

Landuse Classes	Solapur ♀	Solapur ♂	Baramati ♀	A.Nagar ♂	A.Nagar ♀	Pune ♀	Pune ♂	Total Area	Area Proportion
				Area in km²					
Builtup	-	-	0.25	-	-	0.08	0.02	0.35	0.27
Agriculture	16.26	21.23	32.85	-	0.03	4.02	1.58	75.97	57.55
Plantation	-	0.64	-	-	-	0.003	-	0.643	0.49
Deciduous Forest	-	0.02	-	-	-	-	-	0.02	0.02
Scrub Forest	0.11	0.74	0.02	-	-	-	-	0.87	0.66
Grassland	3.42	18.46	22.96	0.64	1.65	2.97	1.44	51.54	39.04
Waterbody	0.04	2.19	0.39	-	-	-	-	2.62	1.98
							Total	**132.013**	

TABLE 9. TABLE SHOWING DIFFERENT LAND-USE CLASS COMPOSITION WITHIN THE HOME-RANGE (95%BBMM) OF COLLARED WOLVES

Landuse Classes	Solapur ♀	Solapur ♂	Baramati ♀	A.Nagar ♂	A.Nagar ♀	Pune ♀	Pune ♂	Total Area	Area Proportion
				Area in km²					
Builtup	2.68	3.75	3.6	-	0.04	0.24	0.17	10.48	0.86
Agriculture	259.56	296.84	209.72	0.51	4.63	77.43	40.95	889.64	73.02
Plantation	0.61	2.75	0.2	-	-	0.06	0.04	3.66	0.30
Deciduous Forest	0.29	0.16	0.6	-	-	-	-	1.05	0.09
Scrub Forest	1.58	1.62	6.28	-	-	-	-	9.48	0.78
Grassland	67.93	101.07	72.89	4.15	9.12	18.03	11.89	285.08	23.40
Waterbody	6.38	9.95	1.53	-	0.16	0.55	0.42	18.99	1.56
							Total	**1218.38**	
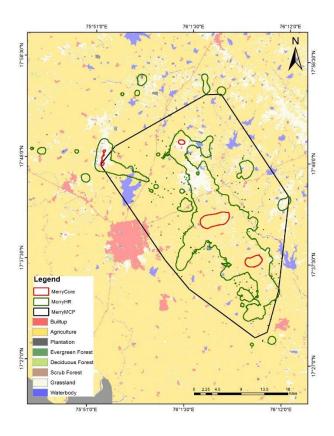
FIGURE 15. MAP SHOWING LAND USE LAND COVER TYPE WITHIN THE HOME RANGE AND CORE AREAS OF SOLAPUR FEMALE (MERRY)

FIGURE 16. MAP SHOWING LAND USE LAND COVER TYPE WITHIN THE HOME RANGE AND CORE AREAS OF SOLAPUR MALE (BREEZE)

FIGURE 17. MAP SHOWING LAND USE LAND COVER TYPE WITHIN THE HOME RANGE AND CORE AREAS OF BARAMATI FEMALE (FIRKY)

FIGURE 18. MAP SHOWING LAND USE LAND COVER TYPE WITHIN THE HOME RANGE AND CORE AREAS OF AHMEDNAGAR MALE (FINN)

FIGURE 19. MAP SHOWING LAND USE LAND COVER TYPE WITHIN THE HOME RANGE AND CORE AREAS OF AHMEDNAGAR FEMALE (RAIN)
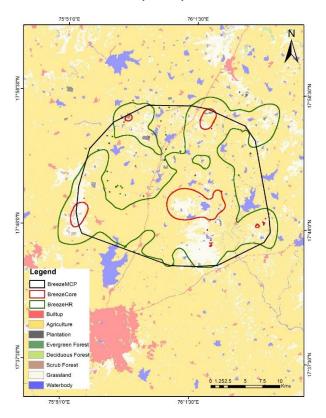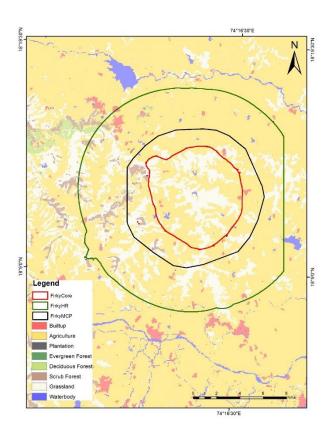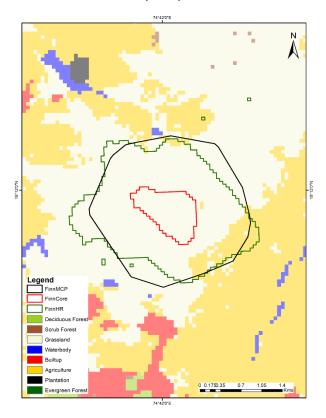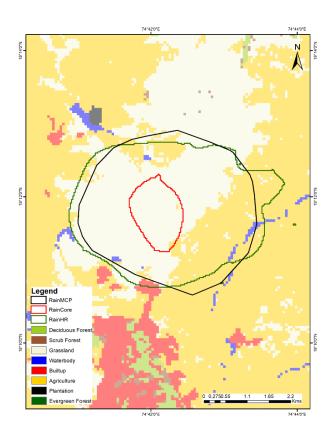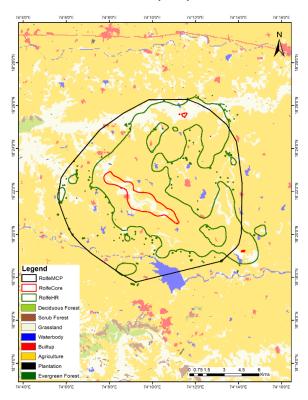

FIGURE 20. MAP SHOWING LAND USE LAND COVER TYPE WITHIN THE HOME RANGE AND CORE AREAS OF SASWAD, PUNE FEMALE (ROLFE)
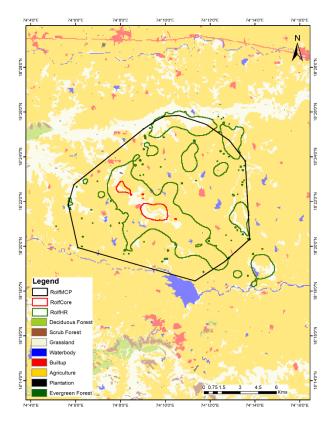
FIGURE 21. MAP SHOWING LAND USE LAND COVER TYPE WITHIN THE HOME RANGE AND CORE AREAS OF SASWAD, PUNE MALE (ROLF)

Delineating critical habitat for wolves in Maharashtra

The Maxent analysis was used to determine the critical habitat for wolves in Maharashtra. The maxent model evaluated the average test AUC 0.990 (15 replicate), and the standard deviation was 0.003, both indicate a better model performance and prediction (Young, Carter and Evangelista, 2011). Our results show that out of the total area of Maharashtra, 15,888 km^2 area was found highly suitable for the wolves (Table 10, Figure 23). Out of different environmental variables, the precipitation during the wettest quarter was the most critical variable (39.2%) determining wolf distribution. Maxent model predicted that core areas of wolves mostly grasslands (15.7% contribution) and they prefer habitats which are 1-2km away from scrub forests (18.1% contribution) (
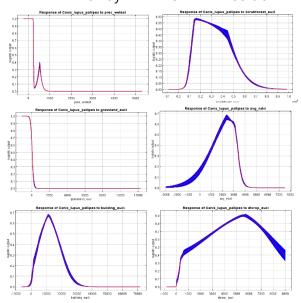
Figure 22). The probable reason behind that scrubland provides hides. The presence probability of wolf shows a quadratic relation with NDVI in the range of 500-3000 NDVI value (6.4% contribution), indicating that wolves use barren and open grasslands. The response curve of Euclidean distance from build-up land-use class showed that most of the wolf habitats are 5 to 15km away from build-ups (5.6% contribution). The core areas of the collared packs are mostly 500 meters to 6km away from double and triple croplands, the reason behind this is either wolfs use croplands as hides or agricultural patches are encroaching the wolf habitat (Figure 22).

TABLE 10. TABLE SHOWING SUITABLE AREA CRITICAL FOR THE CORE RANGE OF WOLVES BASED ON CORE AREA LOCATION DELINEATED FROM COLLARED WOLVES OF MAHARASHTRA

Classes	Area in km²	Area Proportion %
Not Suitable	2,75,125	94.5
Least Suitable	7,829	2.7
Moderately Suitable	5,264	1.8
Highly Suitable	2,795	1.0
Total Area	2,91,013	
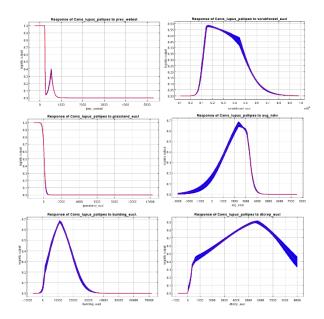
FIGURE 22. RESPONSE CURVES FROM MAXENT ANALYSIS: IT DEPICTS THE CORRELATION BETWEEN DIFFERENT VARIABLE AND THE PROBABILITY OF FINDING WOLF CORE HABITAT. (TOP LEFT) PRECIPITATION DURING WETTEST QUARTER; (TOP RIGHT) SCRUB FOREST; (MIDDLE LEFT) GRASSLAND; (MIDDLE RIGHT) AVERAGE NDVI; (BOTTOM LEFT) BUILDING; (BOTTOM RIGHT) EUCLIDEAN DISTANCE FROM DOUBLE/TRIPLE CROP LAND.
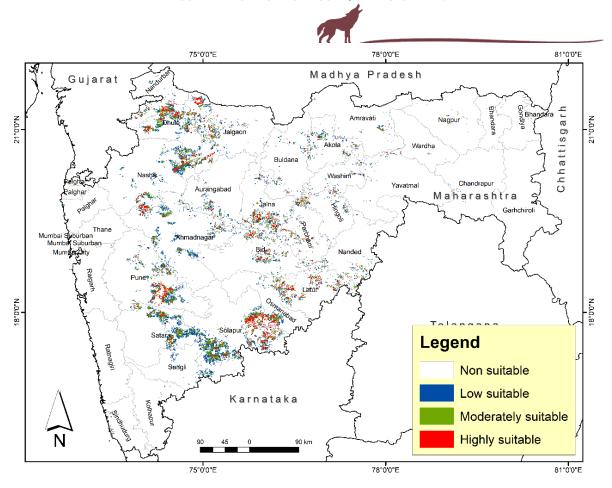
FIGURE 23. MAP SHOWING PROBABILITY DISTRIBUTION OF CORE AREAS DELINEATED FROM THE GPS LOCATION WITHIN THE CORE AREA (50% BBMM) IN THE STATE OF MAHARASHTRA

DISCUSSION

Population estimation of wolves

Wolves (*Canis lupus*) are difficult to survey, and in most countries, snow foot marks are used for identifying the species, counting individuals, recording movements and determining the social position (Blanco and Cortés, 2012). As howling can be detected as long as three kilometres from the origin (Suter *et al.*, 2016), we were able to record 37 howling responses irrespective of their vast territory. In many cases, we found that they approached the howling source. So, even if we had missed detecting the initial reply, we effortlessly recorded the approaching responses. Moreover, we conducted a howling survey during dawn and dusk, which minimises the potential conflict with the activity of local people or villagers.

There are no studies on estimating numbers from an unknown set of wolf howls. From our initial study, we reached 64.7% accuracy in identifying individuals from their vocal signatures. However, the accuracy was significantly low for the captive individuals (52%); this might result from sampling artefact, as all the captive individuals are closely related (siblings from Jaipur Zoo). Accuracy might improve further by sampling distantly related or unrelated captive individuals. The overlapping of howls of related individuals also generated a new question of howling as a group in our study; we achieved 75% accuracy in identifying wild individuals from their howling; where the distance from recorder and source varies significantly.

In this study, we standardised a new protocol to identify and estimate wolf populations. This study opens up new horizons in population estimation of long-ranging vocal animal-like wolves, overcoming constraints such as long home range and non-identical coat patterns. The primary aim of this study was to check the feasibility of a wolf pack census through howling. We are still working on this method to increase the accuracy and reliability of this protocol. Estimating the wolf population can be achieved scientifically by further improvement of this technique and systematic sampling, which in turn will help us to get the appropriate status of wolves in India and continuous population monitoring.

Estimation of the home-ranges and habitat utilisation

Information on size, shape and spatial distribution of wolf home ranges and their core areas are crucial for any conservation or management activities. This study gives an idea about home ranges of seven different individuals and their core areas based on data collected from Dec 17 to July 20 by using the radio-telemetry technique. The results showed that wolves had been adapted very well to local conditions by integrating their movements and home-range configuration. They used the extensive home range to maximise their foraging efforts in proximity to human habitation.

The MCP method provides a general indication of range use, based on the GPS movement data. MCPs for long-ranging animals such as wolves, need to be viewed with some caution, given their ability to travel considerable distances, their MCP may appear to be quite large when in fact upon further analysis, they are utilising a significantly smaller portion of their

range during critical seasons. Post-natal dispersal movements are often necessary for finding a mate, to establish new packs or in joining other packs (Demma and Mech, 2009; Herfindal, 2012). A better methodology for determining range utilisation would be through the Brownian bridge movement model (BBMM) which provides a much better insight into how wolves use their range based on habitat preferences or seasonality (i.e. core area use). We used both the MCP and BBMM method to understand the home range and core area used by wolves.

Out of eight radio-collared wolves, one female reared six pups in 2018 and 5 pups in 2019 in Morgaon area and shows a most modest home range (284.11 km^2), and on the other hand, one female which radio-collared in Gangewadi area dispersed to a new area and established her territory. Although the Solapur male and female were collared from the same area, Solapur female dispersed after two months to a new area and established her own territory.

The home range of our adult collared individuals i.e. Solapur Male and Solapur female overlaps, whereas another pack was far away from them without any overlap. Ahmadnagar subadult male (Finn) and female (Rain) were from the same pack, and were roamed with the alpha pair till Oct 2019 and then dispersed towards Beed area to established its own territory. This subadult male were tracked till Sept 2019 and then the collar stopped communicating and female subadult is moving along with the alpha pair. One subadult male from Saswad area got killed by the dhangars in Sept 2019 whereas collared female is moving with the alpha pair.

Habitat use data from collared individuals revealed that wolves core range mainly comprises of agricultural land and grasslands, and the grassland ratio within the core area was found higher as compared to home-ranges. This data shows the pressure of growing agricultural land in the core areas of the collared wolf and how wolves are adapting to this anthropogenic pressure.
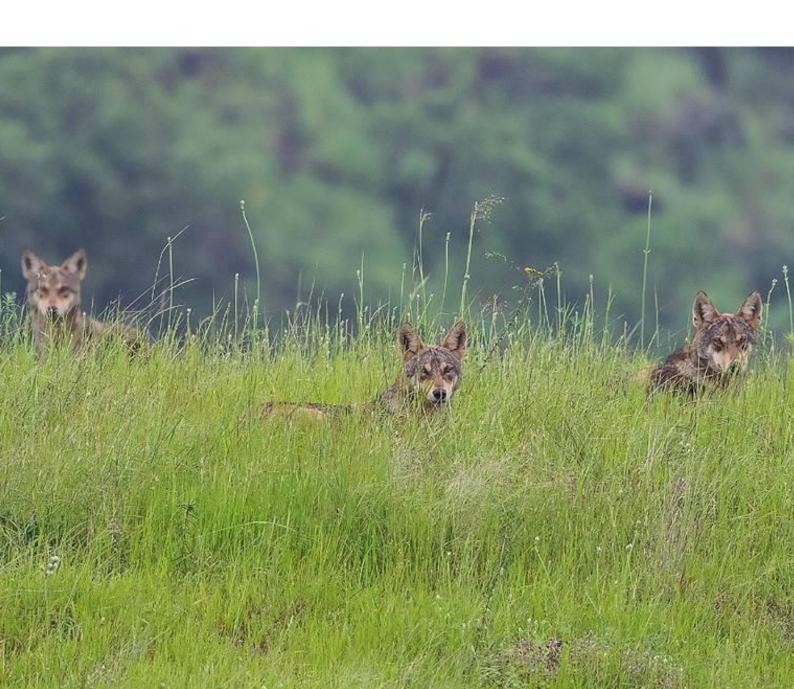
Social structure and dynamics

We studied the howling behaviour of three wolf packs and found that the rate of response was double in the core areas as compared to home ranges (buffer). Our results suggest that the rate of response decreases with increasing human footprint within wolf territories. Howling in high human footprint area may result in conflict, that may be a survival strategy by the wolves to survive and exploit the human-dominated landscape to foster co-existence. Our results also suggest the best season to conduct the howling surveys are winter season (November and December), and the best time of the day is half an hour after sunset. These results are crucial for successful implementation of howling survey in population estimation of wolves in future studies.

Delineating critical habitat patches and factors governing their utilisation
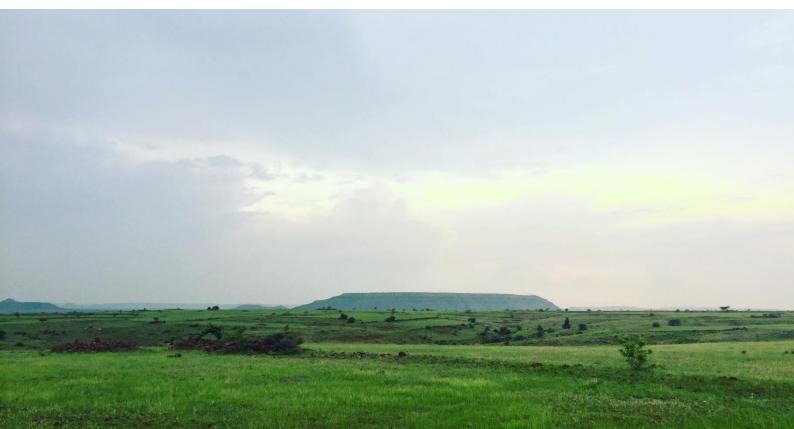
We used the maxent model with the core area's GPS locations collected from GPS collar to generate probable wolf distribution using MaxEnt model. Our results suggested that the core ranges of the packs mostly within the low precipitate areas. The intensely use grassland and habitat which were close to the scrub forest. Our results also suggest that wolf mostly use barren land or grassland near human settlements. Most of these habitats are situated outside protected areas and local people and Dhangars (the traditional shepherd community from Maharashtra) use them as grazing land. The populations of wild prey such as Chinkara and Black-buck are significantly affected due to competition from livestock. As the prey population decreases, wolves are becoming dependent on livestock which leads to intensive human-wolf conflict. These conflicts sometimes result in poisoning the kill or den destruction by the livestock owners.

CONCLUSION

This study showed the potentiality of a howl as a tool to identify individual wolf. Therefore, howl survey can be used in mark-capture recapture framework. Since our study also specifies the factors which influence the howling response, this could lead us in designing a robust howling survey for mark-recapture based population estimation. The fine-scale habitat utilisation data from radio telemetry helped us to delineate the wolf habitat in a more precise manner which is going to be beneficial during choosing study area for howling survey. The population status of Indian wolf is unknown till date, but our endeavour with howling survey could be the front-runner toward a successful estimating the population of the wolf in the human-dominated landscape of Maharashtra, India.

Telemetry data showed that home range of wolf is more than 300km^2, which is considerably higher than the previous study (~250km^2) (Habib, 2007) in the same landscape. The increase in the size of home-range might be due to the result of increasing anthropogenic pressure and lower prey availability. Anthropogenic pressure on wolf habitat is the apprehension towards the urgency of conservation of this schedule 1 endangered species. Habitat utilisation data revealed that agricultural land acquisition is fragmenting the wolf habitat, forcing the wolf to use the croplands. Due to fragmentation, most of the collared individuals are using multiple cores split by anthropogenic land-use pattern. Fragmentation also prompts the vulnerability of a wolf toward roadkill and death occurring due to human-animal conflict such as electrocution, poisoning. High fragmentation is an emerging challenge to the dispersing subadults finding and establishing their territory and pack. Since the collared subadults are yet to disperse from their parental pack, this is not clear till this point how they manage to disperse with high anthropogenic pressure, what are the critical risk factor and what is the success rate of their pack establishment. The study lays the groundwork for the future work on monitoring the dispersal success of wolves and dynamism of their survival in Anthropocene. The study is also a precursor to developing a scientific method of population estimation for wolves using the uniquely identifiable patterns of individual howls.

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A Report on T-161 tiger of Tadoba-Andhari Tiger Reserve on 29th March 2022 at Tadoba – Andhari Tiger Reserve:

As a part of the Tiger Dispersal Project titled "Studying dispersal of tigers across the Eastern Vidarbha Landscape, Maharashtra," a sub-adult male tiger, one of the three cubs of female T-19, was radio-collared on 26th April 2019 at the Mahalgaon area of Tadoba-Andhari Tiger Reserve (TATR). Following were the objectives of the project

- *To understand the movement of tigers that drives population connectivity on a landscape scale.*

- *To validate the modeled corridors and identify new functional corridors and habitats in a highly dynamic landscape.*

- *To help in practical conservation and management of tigers beyond the Protected Area (PA) system.*

The sub-adult male tiger was fitted with a GPS satellite collar and was monitored in the field through VHF ground tracking. The movement parameters of the tiger in its natal area are given in Table 1. We used the Brownian Bridge Movement Model, BBMM (Bullard, 1999), to understand the home range. BBMM is a widely used method that probabilistically estimates an animal's movement path from data recorded at intervals. The core area (50% BBMM) was estimated to be 1.28 km^2, and the home range was 7.85 km^2 (95% BBMM) (Table 2).

Table 1: Movement summary of collared tiger T161 in Tadoba-Andhari Tiger Reserve

Average displacement per move (m)	Average daily displacement (m)
333.86	1168.52

Table 2: Estimated home range (95% BBMM), core area (50% BBMM) and 95% MCP of male tiger T-161 from the Tadoba-Andhari Tiger Reserve

Tiger ID	Sex	Stage	BBMM Estimation		MCP
			50% core area (sq. km)	95% home-range (sq. km)	95% home-range (sq. km)
T-161	Male	Pre-dispersal	1.28	7.85	8.92

The initial movement of the tiger was in the Mahalgaon and Junona area, both in the core and buffer area of Tadoba-Andhari Tiger Reserve. The movement of the tiger T-161 is shown in Figure 1. Subsequently, the collar battery drained during the month of July 2019. The tiger T-161 dispersed approximately at the age of 21 months from its natal area. The tiger continued the movement in the area until the end of November 2019 and extended its movement to the west of Mahalgaon. Efforts were then made to remove the radio collar through the drop-off mechanism which has been tested on more than 20 tigers in the State of Maharashtra and worked very well.

However, the drop-off mechanism did not work in the present collar due to unknown and unexpected technical reasons. The efforts of collar removal were pursued rigorously till December 2019.
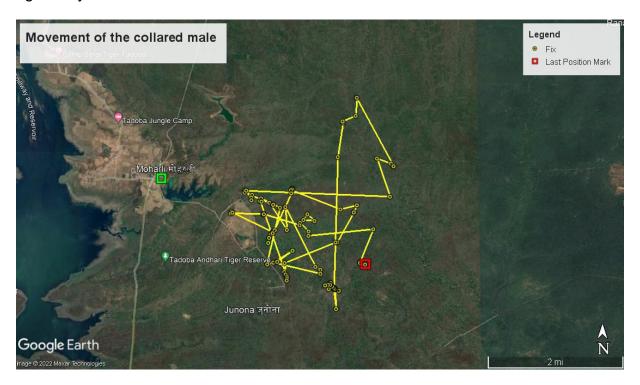

Figure 1: Movement of the collared male T-161 in its natal area in the Tadoba-Andhari Tiger Reserve

Since it was a dispersing individual, the tiger seemed to have moved from Tadoba, with no records of presence found in the natal area despite intensive monitoring. During the Phase-IV 2020 camera trapping exercise, the individual was captured on three sporadic occasions within the limits of TATR (Table 3). *Ad libitum* monitoring efforts other than Phase IV monitoring were not fruitful in capturing any records of the individual. In 2021, the individual was captured in 20 locations (Table 4). The animal was normal and there was no apparent issue related to the collar. The MCP of his home range area during the year 2021 is shown in Figure 2.

Table 3: Details of capture history of T161 during the Phase IV monitoring 2020 in the Tadoba-Andhari Tiger Reserve

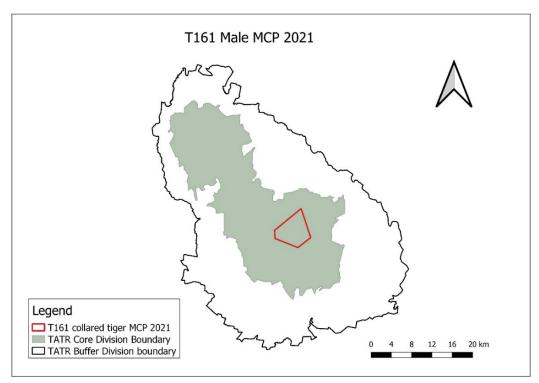| S. No.	Latitude	Longitude	Capture dates	Total captures
1	20.21928	79.44031	14.02.2020	1
2	20.19381	79.40194	02.02.2020	1
3	20.13906	79.37356	04.02.2020	1

Figure 2: The home range of T-161 in the Botezari-Rantalodhi area
in the Tadoba-Andhari Tiger Reserve

Table 4: Details of capture history of T161 during the Phase IV monitoring 2021 in
the Tadoba-Andhari Tiger Reserve

S. No.	Latitude	Longitude	Capture dates				Total captures
1	20.24484	79.47568	03-04-21				1
2	20.22794	79.45647	02-04-21				1
3	20.21606	79.44986	28-03-21				1
4	20.2055	79.42592	23-03-21	01-04-21	02-04-21	09-04-21	4
5	20.20467	79.4462	10-04-21				1
6	20.19089	79.42719	06-05-21	19-05-21			2
7	20.19083	79.43847	19-05-21	23-05-21			2
8	20.19372	79.45919	11-05-21	23-05-21	24-05-21	27-05-21	4
9	20.19167	79.46786	06-04-21				1
10	20.19336	79.49431	29-03-21	06-04-21			2
11	20.17531	79.47039	22-05-21				1

Efforts continued to monitor animal regularly to remove the collar. The animal was using area away from tourism zone and was very shy of human presence. In the month of February 2022 the animal started using Botezari-Rantalodhi area of the Kolsa and Karwa range. The individual was frequently sighted at Botajhiri Talav. As soon as the animal started showing presence, the intensive monitoring efforts were put in place to identify frequently used areas to organize the capture operation. Considering the battery issues and visualizing the collar getting tight around the neck, the removal of the collaring exercise was initiated by employing physical capture of the animal. We initiated the collar removal exercise in February 2022 and placed 25 camera traps (Figure 3) in frequently used areas.
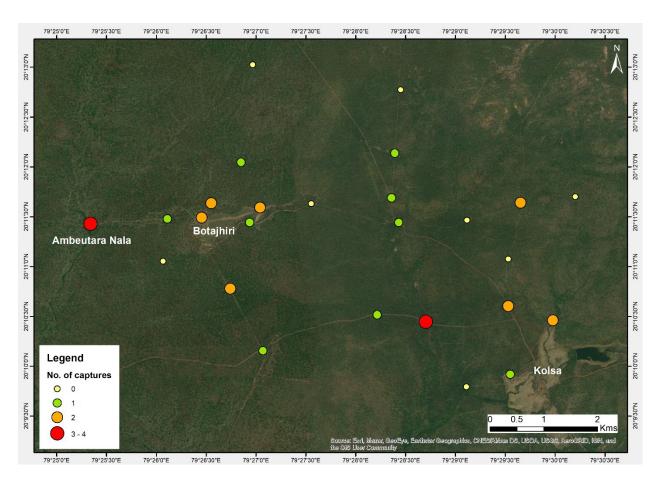
Figure 3: The camera trap placement and no. of captures of T161 during the collar removal exercise in the Botezari-Rantalodhi area in the Tadoba-Andhari Tiger Reserve

Since February 2022, intensive monitoring was jointly done by Forest Department, veterinary doctors, and researchers of WII for capturing T-161 but did not result in darting the tiger. The individual was sighted on many occasions, and the movement was found normal. On 14th March, the individual killed a prey at Botajhiri Talav. Later on 27th and 28th March, the tiger killed prey at Ambeutara Nala and was sighted near the kill by the team. The team again sighted the tiger on 29th March at 0845 hrs near Ambeutara (Videographed), and attempts were made to dart the animal but were unsuccessful owing to the use of the dense forest by the animal. All photographs on kill site and the video on 29th March 2022 at 0845 hrs indicated normal behaviour especially gait while walking. On 30th March at 0900 hrs, during the search operation, ACF TATR sighted the dead body of the individual at Ambeutara Nala, Range Karwa, Round Rantaladhi, Beat Ambeutara (Latitude 20^0 11' 28"; Longitude 79^0 25' 18").

Photo capture of T-161 on 28/02/2022 at Kolsa to Dewada road.

Photo capture of T-161 with a kill on 28/03/2022 at Ambeutara Nala.

Photo capture of T-161 with a kill on 29/03/2022 at Ambeutara Nala.

Since there was an issue with satellite communication of the collar, we are still not sure about the animal's movement during the year 2020 -21. We hope to retrieve the data from collar. If possible, this may reveal more information about the movement of the tiger during the year 2020 – 21. Both WII and MFD was aware about the issue from Feb. 2022 and the efforts were in place to remove the collar. Owing to difficulty in field conditions and the shy behaviour of the tiger due to its use of non-tourism area and presence of 4 adult males sharing territories, the capture operation proved to be unsuccessful. The tiger was video-graphed after killing the prey on 29th March 2022 (0845 h), and no apparent change was noticed while walking. Everyone was astonished by the sudden death of the tiger on probably 29th March 2022.

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Dr. Bilal Habib
Scientist – E
Wildlife Institute of India

22nd April 2022