Pandharkawada Forest Division

Status of Tigers, CoPredators & Prey

2021

Report Title:
Status of Tigers, Co-Predators and Prey in Pandharkawada Forest Division (Territorial) Tiger Reserve

Project Title:
Long-term monitoring of tigers, co-predators and prey in tiger bearing areas of Vidarbha Maharashtra

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Executive Summary

The Phase IV monitoring for the Pandharkawada Forest Division (Territorial) was conducted from March –April (2021) as part of the project "Long Term Monitoring of Tigers, Co-Predators and Prey species in Vidarbha Landscape, Maharashtra, India". The exercise aimed to cover an area of 655.336 km^2 of the forested area of the entire division. The objective of the Phase IV Monitoring is to estimate the minimum number of tigers in the Pandharkawada Forest Division using Spatially-Explicit-Capture-Recapture Sampling and density estimation of prey species using Line transect based Distance Sampling. 110 pairs of camera traps were placed in the forested area of Pandharkawada Forest Division following a sampling grid of 2 km^2 in all four blocks. The camera traps were active for average 30 days in each block yielding a sampling effort 3508 of trap nights of data which is used for further analysis. From the camera trap photographs 11 tigers (unique to Pandharkawada Forest Division) and 10 leopards have been identified. Tiger density per 100 km^2 based on the Spatially Explicit Capture-Recapture (SECR) model was 2.356 (SE ± 0.727) in the forest division while that of leopards based on the same method was 2.99 (SE ±1.03). To estimate prey density, 84 line-transects were laid randomly all over the division and were sampled 7 times during the sampling period, with a total walking effort of 1176 km was invested. The observations include chital (Axis axis), nilgai (Boselaphus tragocamelus), chousingha (Tetracerus quadricornis), langur (Semnopithecus sp), wild boar (Sus scrofa), chinkara (Gazella bennetii), Indian hare (Lepus nigricollis) and peafowl (Pavo cristatus). As per the observations, Nilgai (n=278) is the most observed species followed by Wild boar (n=77), Peafowl (n= 54), Indian hare (n=45) and Chital (n=44). The overall prey density of Pandharkawada Forest Division is 10.977 (SE± 1.19). Due to very low observations (n<20) densities of chousingha and chinkara could not be estimated.

To study the activity, we used the camera trap images. The times recorded on camera trap photos provide information on the period during the day that a species is most active. Species active at the same periods may interact as predator and prey, or as competitors. Sensors that record active animals (e.g. camera traps) build up a record of the distribution of activity over the day. Records are more frequent when animals are more active and less frequent or absent when animals are inactive. The area under the distribution of records thus contains information on the overall level of activity in a sampled population. We used IDW (Inverted distance weighted) to map the intensive area used by different animal species.

1. Introduction

The tiger (*Panthera tigris*) is the largest extant cat species on the earth. 100 years ago, it was easy to see a tiger in its natural habitat - around 100,000 of them roamed across Asia, including several sub-species that are now extinct. Today the number of tigers in the wild has declined exponentially. The remaining population of tigers is threatened by habitat destruction and habitat fragmentation. They require large patches of undisturbed territories to sustain their dietary needs. While tigers are generally found throughout Southeast Asia and China, India remains the most prolific home of these magnificent animals and boasts of having the highest population. Being a charismatic umbrella species, the tiger is also a crusader for the protection of other species. India is known to harbour the highest population of tigers amongst the 13 range countries in Asia: Central India being one of the last strongholds of the big cat. As an apex predator, the tiger shapes the community structure of the ecosystem. It also prevents over-grazing by limiting herbivore numbers and maintains the ecological integrity of the ecosystem.

The tiger bearing areas of the Vidarbha landscape (Figure 1) include Melghat Tiger Reserve, Pench Tiger Reserve Maharashtra, Navegaon Nagzira Tiger Reserve, Tadoba-Andhari Tiger Reserve, the Brahmapuri (Territorial) Forest Division, Umred Karhandala Wildlife Sanctuary, Tipeshwar Wildlife Sanctuary (TWLS), Pandharkawada Forest Division (Territorial), Painganga Wildlife Sanctuary and Bor Tiger Reserve. Vidarbha holds two-thirds of Maharashtra's mineral resources and three-quarters of its forest resources and is a net producer of power. It has a forest cover of 28% which holds around 300 tigers despite having a human population of more than 5.2 million.

The Pandharkawada Forest Division (PKFD) lies in the Yavatmal district of Maharashtra. The forest division has a geographic area of 3881km^{2}within which 655.336 km^2 is the total forested areas confining of 78°55'32.6'' to 78°56'09.4'' East (longitude) and 19°'39.6'' to 19°50'09.5'' North (Latitude). Tipeshwar wildlife sanctuary is a protected area resides at the southern part of the Pandharkawada forest division which lies very close to the state border dividing Telangana and Maharashtra.
The region is rich in black cotton soil, and it is no wonder that cotton is the major cash crop for farmers in the region. The forest division is also home to a diverse set of flora and fauna. The forest division is largely isolated and has limited connectivity with protected areas like Kawal Tiger Reserve in Telangana to the South and Melghat Tiger Reserve to the North. Although the forest division shares boundaries with Adilabad forest division of Telangana, Yavatmal Forest division and Pusad Forest Division of Maharashtra State, limited carnivore movements have been reported within these forest areas.The forests of Pandharkawada division can be classified as tropical dry and moist deciduous. The forest is dominated by Teak (*Tectona grandis*) along with other species like Dhawada (*Anogeissus latifolia*), Ain (*Terminalia alata*), Tendu (*Diospyros melanoxylon*), Sehna (*Lagerstroemia parviflora*), Bherra (*Chloroxylon switenia*), Kallam (*Mitragyna parviflora*), Beheda *(Terminalia bellirica*), Salai (*Boswellia serrata*), Bija (*Pterocarpus marsupium*), etc.

The forest is a mosaic of woodlands along with lush meadows. The forest division is home to major large carnivores like Tiger (*Panthera tigris*), Leopard (*Panthera pardus*), Wolf (*Canis lupus*), Striped Hyaena (*Hyaena hyaena*),Sloth Bear (*Melursus ursinus*), meso-carnivore like Golden Jackal (*Canis aureus*) and Honey badger (Mellivora capensis), and also small carnivores like Jungle Cat (*Felis chaus*), Bengal Fox (*Vulpes bengalensis)*, Rusty spotted cat (*Prionailurus bengalesis*) and prey species like Wild Boar (*Sus scrofa*), Rhesus Macaque (*Macaca mulatta*), Langur (*Semnopithecus spp.*), Nilgai (*Boselaphus tragocamelus*), Four Horned Antelope (*Tetracerus quadricornis*), Chinkara (*Gazella bannettii*), Blackbuck (*Antilope cervicapra*).Around 180 species of birds and 26 species of reptiles are also reported from Pandharkawada Forest Division.

The mosaic of agriculture and forest induces high overlapping areas between human and wild animals and thereby increasing human-animal conflict cases like crop raiding by wild herbivores, livestock depredation and attacks on human by large carnivores. Thus, wildlife conservation in these areas need continuous monitoring of wild animals for making conservation strategies and implementation.

As a part of the research project titled “Long-term monitoring of Tigers, Co-predators and prey in Tiger reserves and other Tiger bearing areas of Vidarbha, Maharashtra”, the Wildlife Institute of India has initiated this study in 2019 having the following objectives:

Objective 1: Status of tigers, co-predators, and their prey in the landscape

a) Field surveys will be conducted to detect the presence of tigers, co-predators, and prey species using animal signs (tracks, scats, direct sightings, calls, etc.) in an occupancy-based framework. The data will be analysed in the occupancy framework to estimate the occupancy of the target species. Single season or multiple season occupancy models will be used depending on data collection approaches. These occupancy field surveys will be carried in all the tiger areas. The data collection will be followed by modelling and estimation approaches described in detail by Mackenzie et al., (2002, 2006).

b) Density, abundance, and demography of tigers and co-predators will be carried by using camera traps in all the tiger areas followed by analysing the data in the capture-recapture framework. Rigorous field methods will be followed to achieve a smaller covariance and high precision. These field surveys will be conducted in all the tiger areas.

c) Estimation of abundance and density of the key ungulate species will be conducted using distance sampling employing line-transect survey protocols. These field surveys will be conducted in the entire study area. The survey protocols and analyses of this data set will be based on the modelling and estimation approached developed by Buckland et al. (2001, 2004).

d) Estimation of recruitment, survival, transience, temporary emigration, permanent emigration, and dispersal rates of tigers and leopards. Will be based on data collected from radiotelemetry. The information will be supplemented by data generated by camera trap surveys.

e) Scat analysis is an indirect, non-invasive, and unbiased technique for recording the frequency of occurrence of prey in the diet of large carnivores and hence it is most widely used (Johnson et al., 1983; Leopold and Krausman, 1986; Jhala, 1993; Mukherjee et al., 1994a, b; Spaulding et al., 1997; Jethva, 2002; Biswas and Sankar, 2002). Scats will be collected at regular time intervals, generally every week. The scats will be collected in polythene bags, labelled, and sun-dried in the field. Information on habitat, substratum where scat will be found, and its GPS location will also be recorded.

Objective 2: Development of database on tigers across the landscape

The photo database generated by the methodology delineated above will be collated at every tiger area level. Identification of unique individuals will be done from these collated photographs and a database of identified tiger individuals will be generated. New photographs from every camera trapping session will be compared with the existing database, whereby recaptured individuals will be noted, and any new individuals found will be added to the database.

Objective 3: Identification of tiger dispersal in the landscape

On an event when a previously captured individual goes missing in pictures from the current camera trapping exercise, or when a new individual is discovered, it will be cross-checked against tiger databases of adjoining areas. This will enable us to find out if a missing individual has dispersed to a new area.

Objective 4: Development of feedback for management intervention at reserve and landscape level

The outputs of the project will help in developing management feedback for the State of Maharashtra to effectively manage tiger populations.

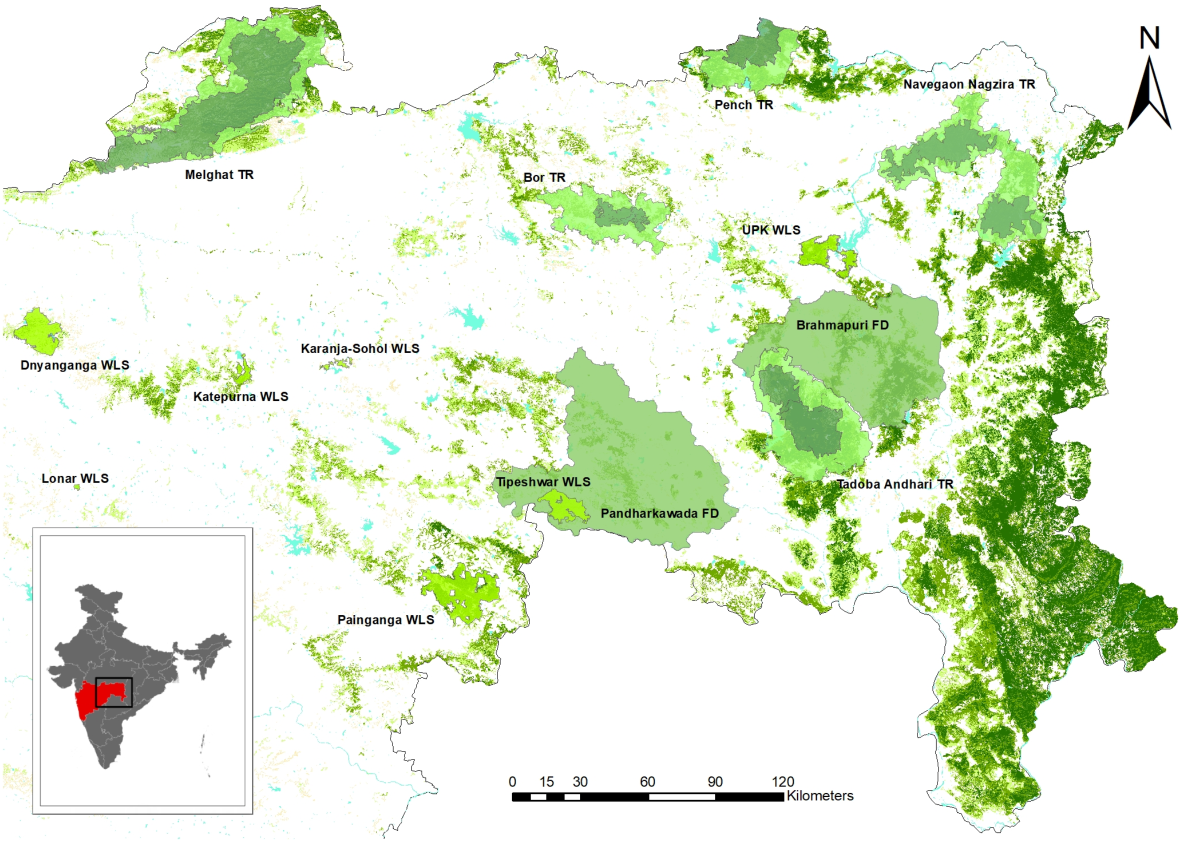


Figure 1: Landscape map of Vidarbha, Maharashtra showing Pandharkawada Forest Division (Territorial)

2. Status of Prey in Pandharkawada Forest Division

Introduction

The presence of wild herbivores is crucial for the survival of the large carnivores (O'brian et al. 2003). It has been observed that herbivore density and abundance play an important role in determining the distribution of large carnivores. Herbivores also play a vital role by influencing the vegetation structure and the nutrient cycle in an ecosystem (Valeix et al. 2007). That is why maintaining a healthy population of herbivores is very important to conserve the predator population and also the habitat of the species. For that, the estimation of the prey density is so important, both for management purposes and ecological study purposes. But, due to many field conditions and the elusive nature of the ungulate, difficulties arise to estimate the population.

Among many techniques like dung count, strip transects, track count, etc. line transect based distance sampling has been found to be most robust method to estimate the abundance and density of wild ungulates (Jathanna et al. 2003).

Distance sampling

Distance sampling is the most established method to estimate the density of prey species in an area using line transect. Transects lines of uniform, pre-determined lengths are laid randomly covering all the vegetation and terrain types of the study area. All the animals (species, sex, number, age class) that are observed during the walk are recorded along with the habitat, terrain type features, perpendicular distance from the line and GPS coordinates.

A total of 84transects of 2km length are marked in 84beats of Pandharkawada FD (Table 1). Transects are randomly distributed all over the 655 sq.km. forested area of the forest division (Figure 2). Each transect is walked 7 times (in March- April 2021). A total of 1148 km of walking effort (Table 2) has been invested in line transects and a total of 541 observations of all types of prey species have been recorded.

Table 1: No. of transects in each range of Pandharkawada FD in Phase IV 2021

S. No.	Range	Total number of transects in each range
1	Parwa	13
2	Ghatanji	14
3	Pandhrkawada	15
4	Jamni	7
5	Mukutban	8
6	Maregaon	17
7	Wani	10

Table 2: Transect monitoring effort and species reported from Pandharkawada FD during Phase IV 2021

Survey details	
Number of transects	84
Length of each transect	2 km
Number of replicates	7
Total distance covered	1176
Beats	84
Number of species recorded	8

The observations include Chital (*Axis axis*), Nilgai (*Boselaphus tragocamelus*), Chousingha (*Tetracerus quadricornis*), Langur (*Semnopithecus sp*), Wild boar (*Sus scrofa*), Indian hare (*Lepus nigricollis)*, Peafowl (*Pavo cristatus*), and Chinkara (*Gazella bennetii*).

As per the observations, Nilgai (n=278) is the most observed species followed by wild boar (n= 77), peafowl (n= 54) and Indian hare(n=45), and chital (n=44). The table below shows the number of observations for each species and total number of individuals observed of each species (Table 3).

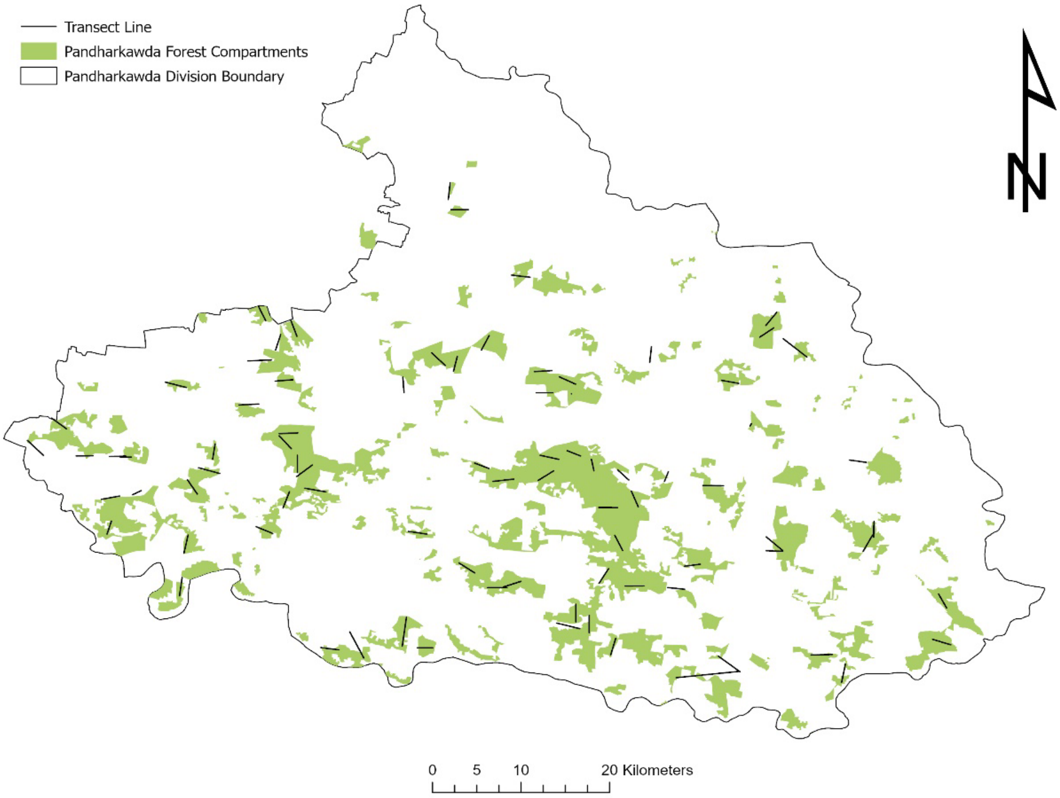


Figure 2: Map of Pandharkawada Forest Division (Territorial) showing transect lines surveyed during Phase-IV Monitoring 2021.

Table 3: No. of observations and the total number of individuals seen of different species

S. No.	Species	No. of observations	Total no. of individuals observed
1	Nilgai	278	1323
2	Chital	44	124
3	Wild boar	77	420
4	Chousingha	18	33
5	Chinkara	2	3
6	Indian Hare	45	47
7	Langur	23	192
8	Peafowl	54	24

The overall prey density of Pandharkawada Forest Division (Territorial) is 10.97 individuals per sq.km (Table 4). Nilgai has the highest density of 5.39 (± 0.671) individuals per sq.km followed by Wild boar and Langur having the density of 2.61 (± 0.619) and 1.372 (± 0.588) respectively. Chital (0.507/ sq.km) and Indian hare (0.59/ sq.km) have been observed to have low densities. Due to a low number of observations (n<20) density of chousingha and chinkara could not be estimated. Detection function graphs for major prey species are given in Figure 3.

Table 4: Individual Density, group density, Effective strip width, average group size, P-value of major prey species in Pandharkawada Forest Division in 2021.

Parameters	Overall Prey	Nilgai	Wild boar	Chital	Langur	Hare	Peafowl
Density(individual/sq.km)	10.977	5.3907	2.614	0.507	1.3724	0.59	1.065
Standard error	1.19	0.671	0.619	0.225	0.5881	0.162	0.262
Percent CV	10.84	12.47	23.69	44.43	42.86	27.53	24.65
95%CI	8.873-13.579	4.223-6.881	1.6495-4.1424	0.217-1.1809	0.605-3.117	0.34-1.008	0.659-1.72
Group density (Number of groups/sq.km)	3.1593	1.359	0.48	0.252	0.156	0.531	0.4202
Standard error	0.3101	0.144	0.0892	0.1089	0.048	0.145	0.093
Percent CV	9.82	10.64	18.58	43.11	30.83	27.39	22.31
95%CI	2.6046-3.8232	1.1031-1.6754	0.33-0.69119	0.1108-0.575	0.086-0.28	0.31-0.90	0.27-0.65
Effective strip width (ESW) in meters	58.915	69.973	55.056	59.809	48.351	28.423	44.128
Standard error	3.22	4.5729	4.81	2.2731	7.717	3.34	2.57
Percent CV	5.47	6.54	8.74	38.01	15.94	11.75	5.84
95%CI	52.91-65.59	61.534-79.569	46.278-65.498	28.500-125.51	34.76-67.24	22.444-35.996	39.256-49.603
Average group size	3.474	3.965	5.442	2.007	8.783	1.1113	2.535
Standard error	0.159	0.257	0.799	0.215	2.61	0.0306	0.265
Percent CV	4.60	6.50	14.69	10.74	29.77	2.75	10.47
95%CI	3.17-3.80	3.489-4.500	4.0684-7.2808	1.617-2.491	4.782-16.130	1.05-1.17	2.05-3.12
Probability of a greater chi square value (P)	0.797	0.916	0.856	0.595	0.763	0.969	0.809

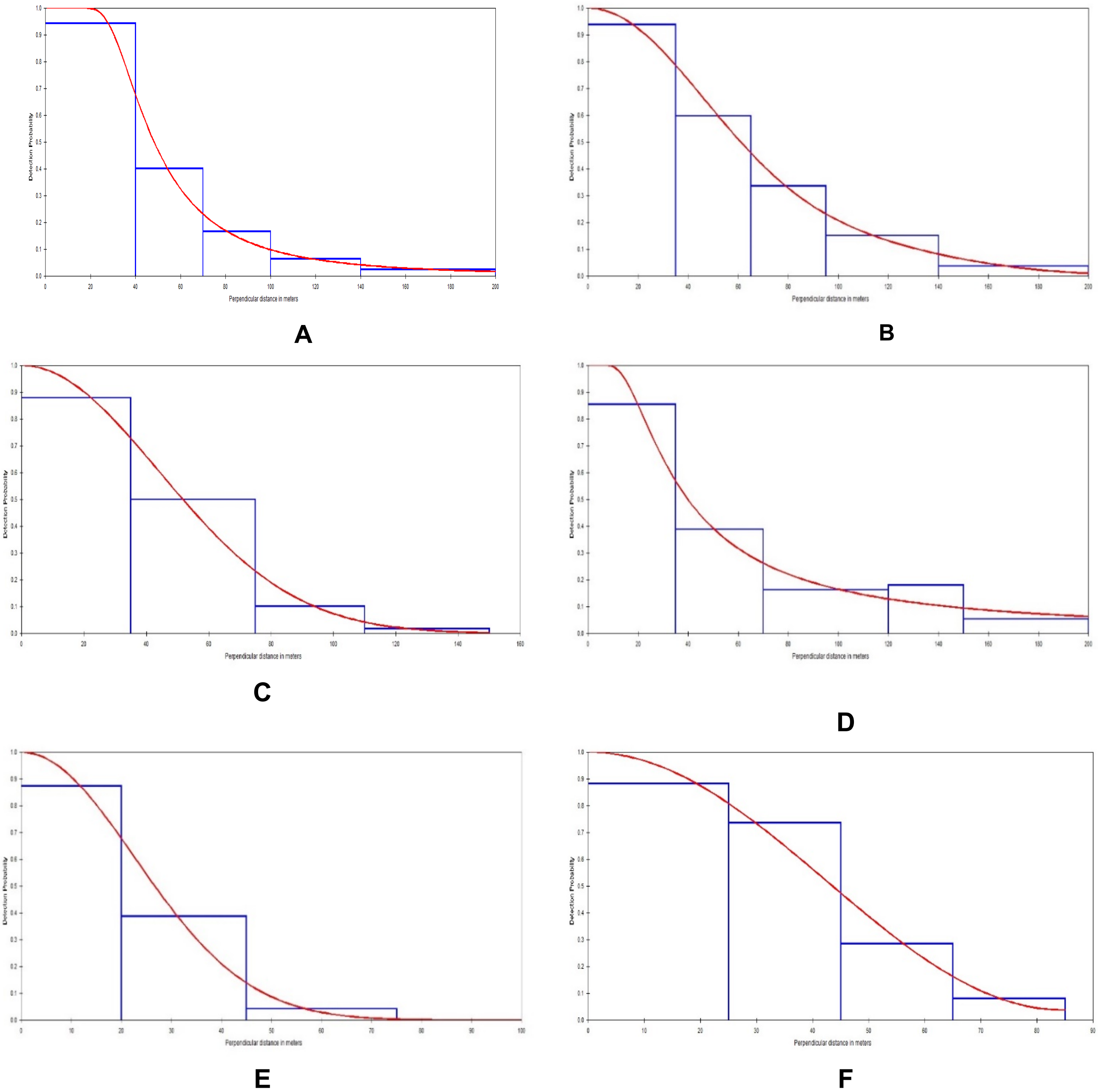


Figure 3(A-F): Detection functions of the best-selected model for prey species during prey estimation survey in Pandharkawada Forest Division, Phase-IV monitoring, 2021 A) All prey species, B) Nilgai and C) Wild boar D) Chital E) Indian Hare and F) Peafowl.

3. Status of Predator in Pandharkawada Forest Division

Introduction

The persistence of an ecosystem is majorly dependent on its biodiversity. Predators play a crucial role in maintaining the eco-system healthy (Talbot, 1978). The ecological role of predators is widely recognized because they exert a top-down effect that controls the population of other animals. The conservation of tiger is difficult because of their elusive nature, long-ranging behaviour, low detectability of indirect signs. Especially, it is hard to infer the absence of tigers based on the signs. The collection of quantitative data on the abundance of tigers is limited by small data size, low detectability, and many other logistical issues.

Camera Trapping

The success of camera trapping depends on the sites chosen for deploying the camera traps. The traps are deployed at trails, dried streams, dirt roads, etc. to maximize the probability of capturing the target animal. Prior to camera trapping, a survey is done in the area to look for signs like pugmarks, scat, rake marks, scrape marks, etc. Since there is already an established system of patrolling and recording in PKFD, the camera trap sites were chosen based on the data collected by the forest department staffs. The exercise followed the protocol prescribed by Karanth and Nicholes (1998). Potential locations for the camera traps were mapped using ArcGIS Pro. The size of the grid was 2.0164 sq.km (1.42km x 1.42km). A total of 110 sites were chosen for the camera trap deployment (Figure 4). A pair of Cuddeback (C1 & Ambush) cameras were deployed at each site facing each other to capture both of the flanks of tiger, leopard, and other co-predators.

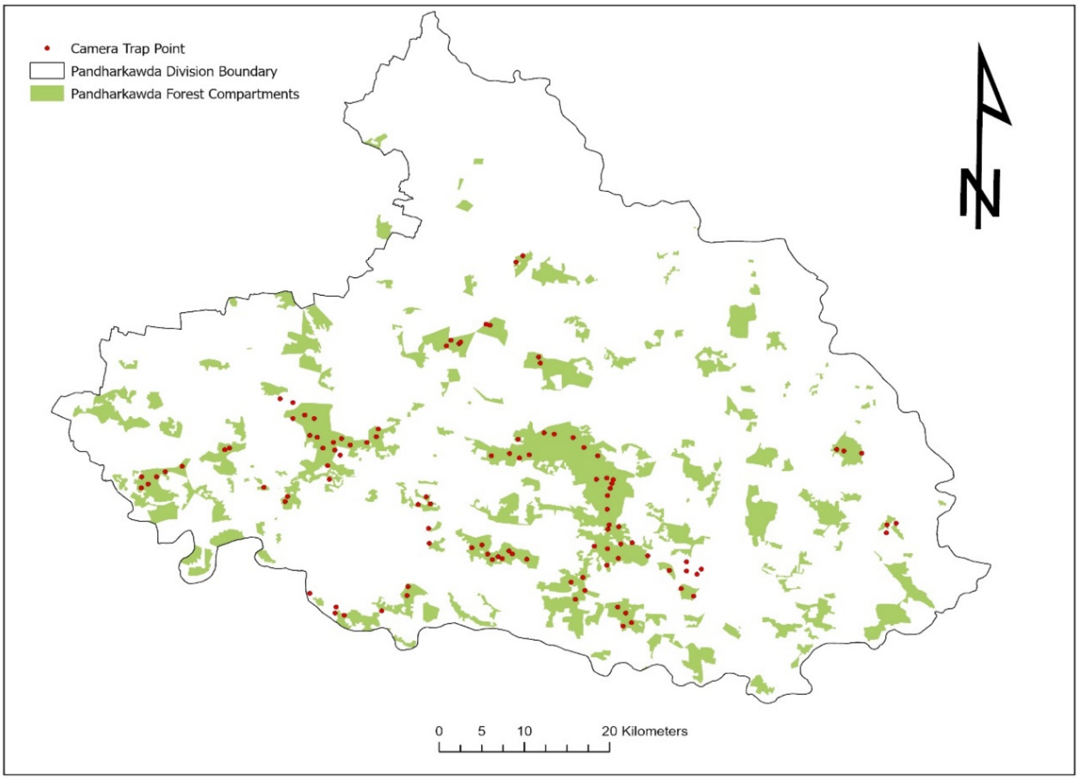


Figure 4: Map showing camera trap points in Pandharkawada FD during Phase IV 2021

The camera traps were tied up on tree trunks 35-40 cm (knee height) above the ground. Each camera was set at no delay, multiple shot mode. It should be mentioned that both cameras should not face each other directly because the flash from one might burn the image of the other. The tigers are identified individually by matching their stripe patterns with each other. The existing tiger booklet has been used to do that. Similarly, leopards are identified individually by matching their rosette pattern.

Each camera trap was operational for 24 hours. Each trap was given a unique ID and each capture recorded the time, date, and temperature of every occasion. Every tiger and leopard were given a unique id after examining the stripe and rosette patterns respectively. For the closed population estimation, there is one critical assumption that the population is supposed to be demographically and geographically closed (Otis et al. 1978). To maintain that the sampling effort was kept minimum (25-30 days). Capture history was analysed in the R environment with the package 'secr' (Efford, 2015) using a model developed for closed populations. The best model was chosen based on the Akaike information criteria (AIC). The density was estimated with the maximum likelihood calculated from the model fitted with 'SECR'.

Population estimation of predators

During 30 days of camera trapping for tigers and co-predators, a total sampling effort of 3508 trap nights were invested in Pandharkawada Forest Division. From camera trap photographs tigers and leopards were identified [m(t+1)] and used for estimating density (D) and population size. For estimating the density, we used Spatially Explicit Capture-Recapture (SECR) method.

Spatially explicit capture-recapture (SECR) is a set of methods for modelling animal capture-recapture data collected with an array of 'detectors.' The methods are used primarily to estimate population density and have advantages over non-spatial methods when the goal is to estimate population size (Efford and Fewster 2013). SECR methods overcome edge effects that are problematic in the conventional capture-recapture estimation of animal populations (Otis et al. 1978). Here detectors are camera traps that take photographs of tigers and leopards, and they are recognized by their natural marks and stripes. Camera-traps are proximity detectors because they can detect multiple animals within an occasion, and they do not detain detected animals, which remain free to be detected by other camera-traps within each occasion. Like other statistical methods for estimating animal abundance (Borchers et al. 2012), SECR also combines a state model and an observation model. The state model describes the distribution of animal home ranges in the landscape, and the observation model (a spatial detection model) relates the probability of detecting an individual at a particular detector to the distance of the detector from a central point in each animal's home range.

Unlike the maximum-likelihood and Bayesian estimation methods, it is not based on an explicit likelihood function and does not have the same inference foundation as these methods. In SECR the basic parameter for the population is density instead of the number. The detectors in this case are the camera traps. The photographs are then manually scanned for identification of individuals based on their stripe or rosette pattern.

From the camera trap data 11 tigers and 10 leopards have been identified which are used in density estimation using SECR framework. There are three common tigers (TIP_T5_M, TIP_T8_M and TIP_T7_F) between TWLS and Pandharkawada Forest Division which are not used in density estimation of tigers in Pandharkawada Forest Division, but their capture locations are shown in MCP maps.

Tiger density per 100 sq.km based on SECR heterogeneity model was estimated to be 2.356 (SE ±0.72) and leopard density per 100 sq.km based on SECR heterogeneity model was estimated to be 2.99 (SE ±1.03) for Pandharkawada Forest Division. The best model for the density estimate is chosen according to the AIC (Akaike Information Criterion). Details are given in the table (Table 6). Minimum convex polygons of tigers and leopards in Pandharkawada Forest Division are given in Figure 5-8.

Table 6: Density estimates of tigers and leopards using Spatially Explicit Capture-Recapture

Parameters	**Tiger**	**Leopard**
mt+1	11	10
Model	Heterogeneity	Heterogeneity
Detection Function	Half-normal	Half-Normal
Density Estimate (Ind/100 sq.km)	2.356	2.99
Density SE	0.727	1.03
Density CI	1.30-4.25	1.55-5.77
g0 Estimate (pmix1)	0.005	0.0029
g0 Estimate (pmix2)	0.01	0.0029
g0 SE(pmix1)	0.0007	0.0007
g0 SE(pmix2)	0.001	0.0007
g0 CI (pmix1)	0.040-0.070	0.0017-0.0049
g0 CI (pmix2)	0.011-0.019	0.0017-0.0049
Sigma Estimate(pmix1)	2.35km	2.65km
Sigma Estimate(pmix2)	6.23km	7.86km
Sigma SE(pmix1)	0.212	0.703
Sigma SE(pmix2)	0.358	1.03
Sigma CI(pmix1)	1.977-2.813	1.59-4.42
Sigma CI (pmix2)	5.56-6.97	6.08-10.17
Estimated Population	11	15.84
Estimate population SE	0.869	3.73
Estimated population CI	11.00-16.93	10.26-29.45

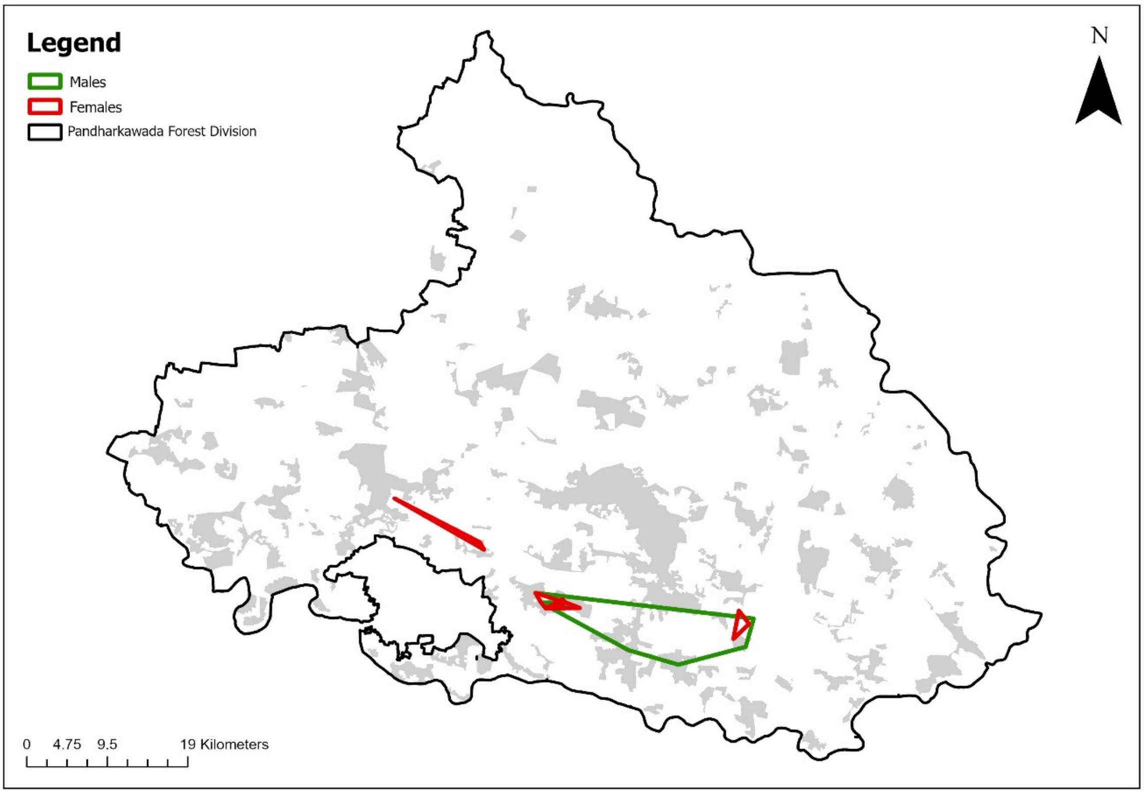


Figure 5: Minimum Convex Polygon of Male and Female tigers of Pandharkawada Forest Division, Phase-IV monitoring, 2021

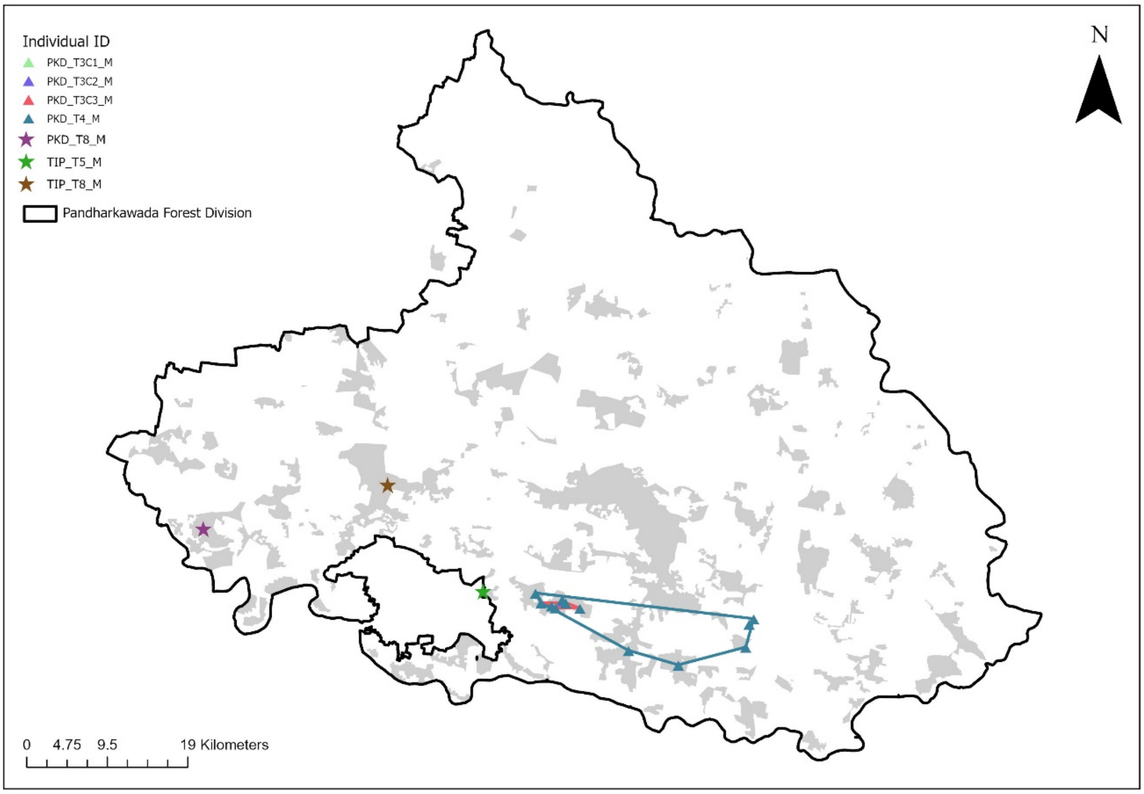


Figure 6: Minimum Convex Polygon of Male tigers of Pandharkawada Forest Division, Phase-IV monitoring, 2021

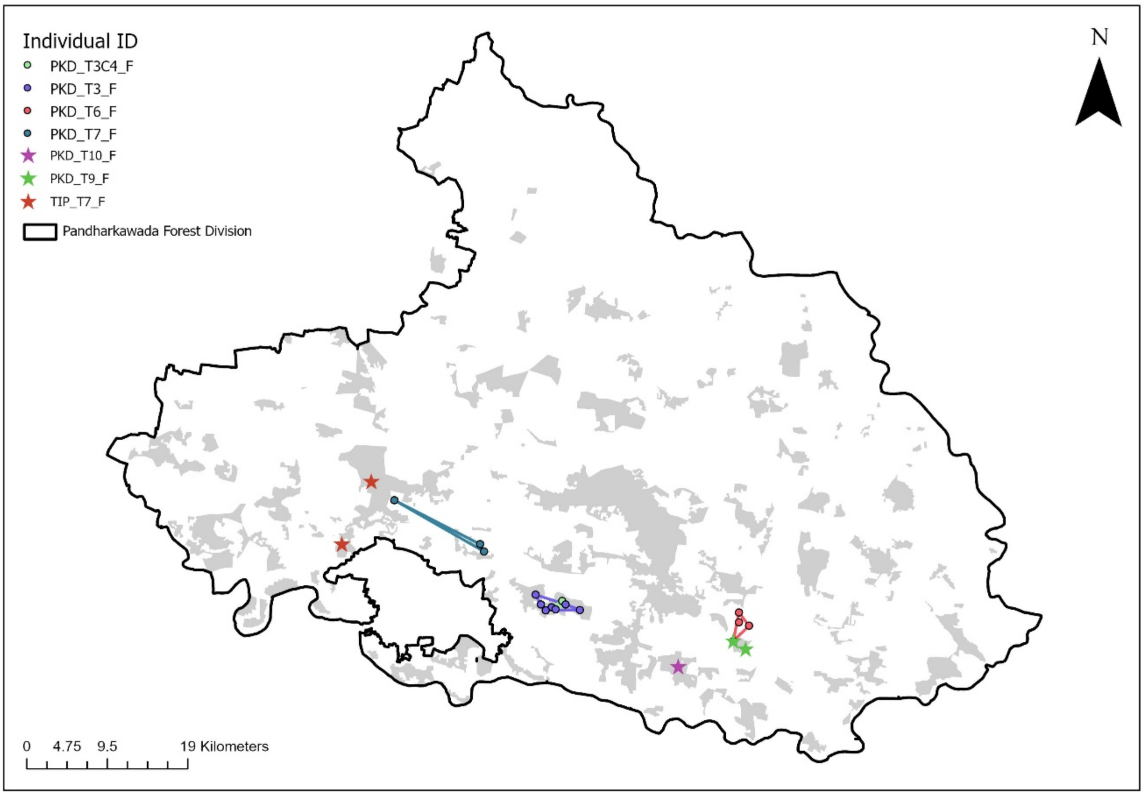


Figure 7: Minimum Convex Polygon of Female tigers of Pandharkawada Forest Division, Phase-IV monitoring, 2021

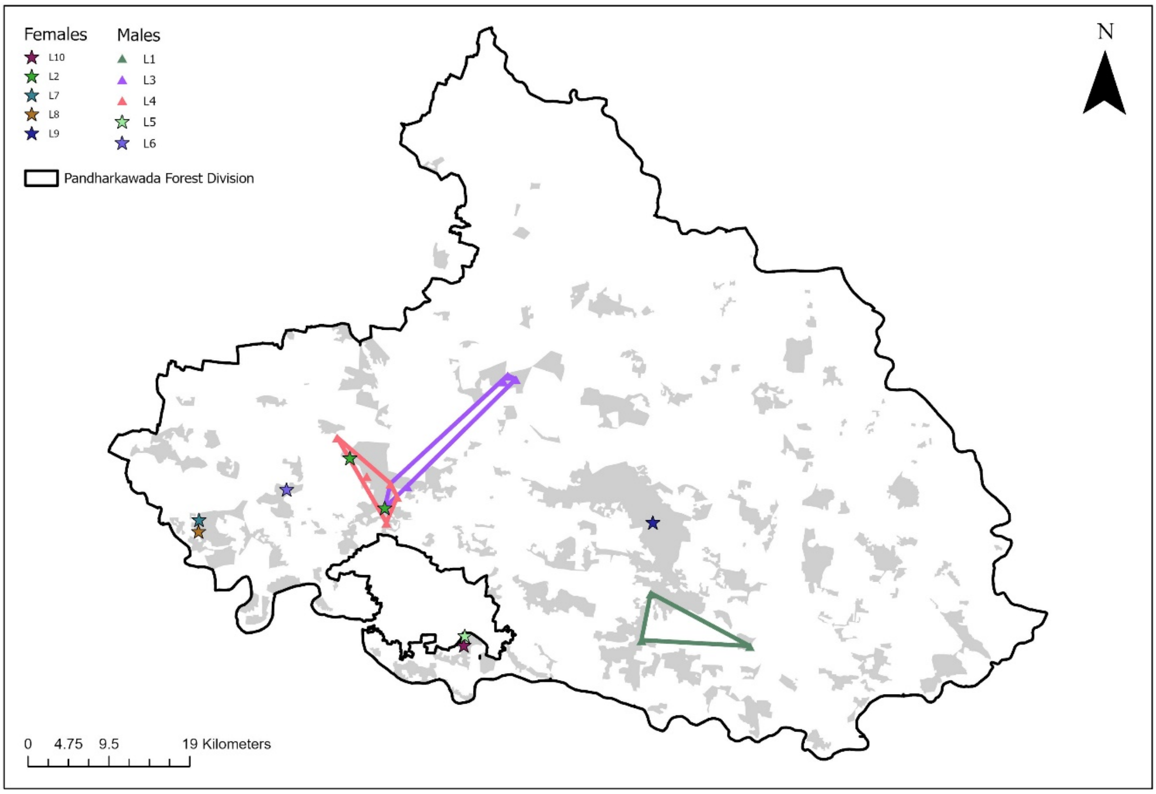


Figure 8: Minimum Convex Polygon male and female leopards of Pandharkawada Forest Division, Phase-IV monitoring, 2021

4. Modelling Spatially Explicit Intensive Use Areas: Predator & Prey Species

Introduction

Camera trap locations with number of captures of each species were modelled in a GIS domain using IDW (Inverse distance weighted) interpolation technique to generate spatially explicit capture surfaces. Inverse Distance Weighting (IDW) interpolation is mathematical (deterministic) assuming closer values are more related than further values with its function. IDW function is used when a set of points is dense enough to capture the extent of local surface variation required for the analysis. IDW assumes that each measured point has a local influence that diminishes with distance. It gives greater weights to points closest to the prediction location, and the weights diminish as a function of distance, hence the name inverse distance weighted. IDW is an exact interpolator, where the maximum and minimum values in the interpolated surface can only occur at sample points. The output surface is sensitive to clustering and the presence of outliers (Figure 9). IDW assumes that the phenomenon being modelled is driven by local variation, which can be captured (modelled) by defining an adequate search neighbourhood. Intensive use areas by different species based on camera trap data are shown in Figure 10-21.

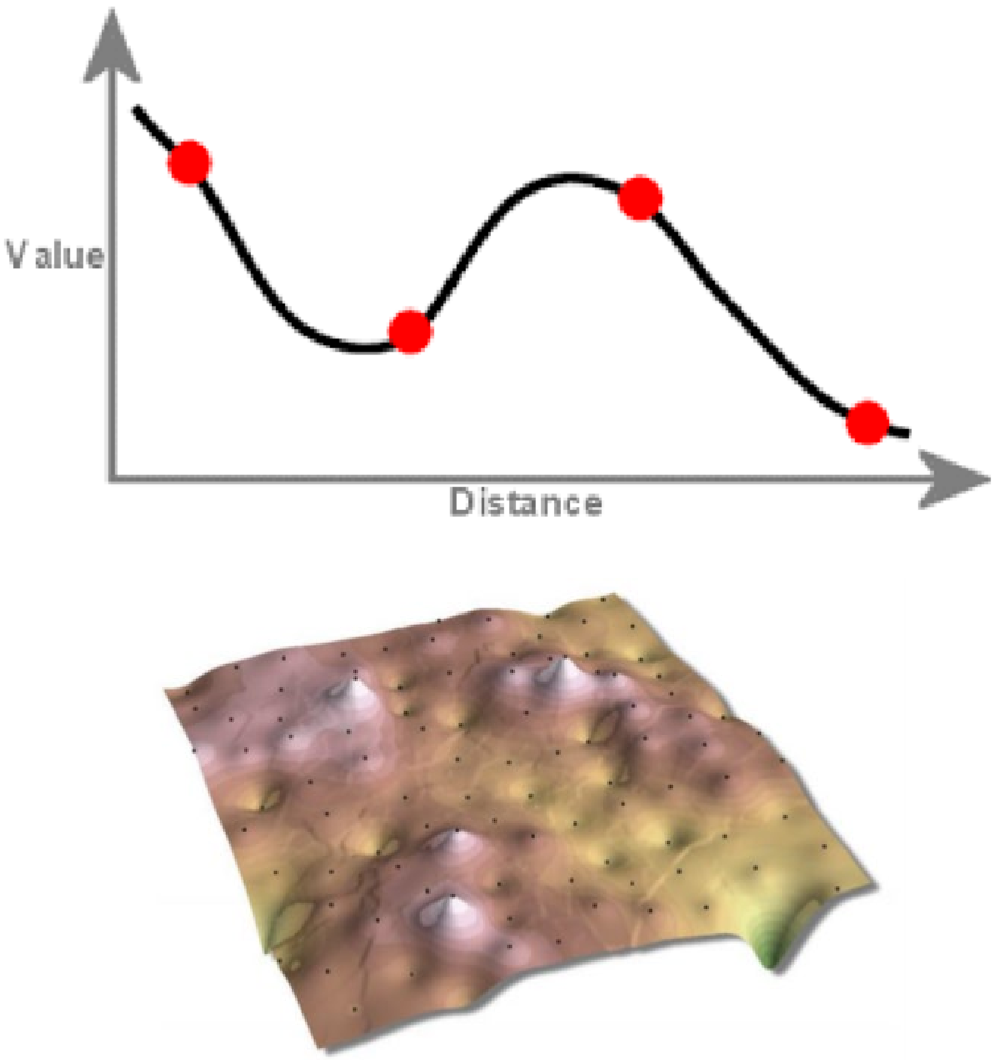


Figure 9: Visual representation of Inverse distance weighted (IDW)

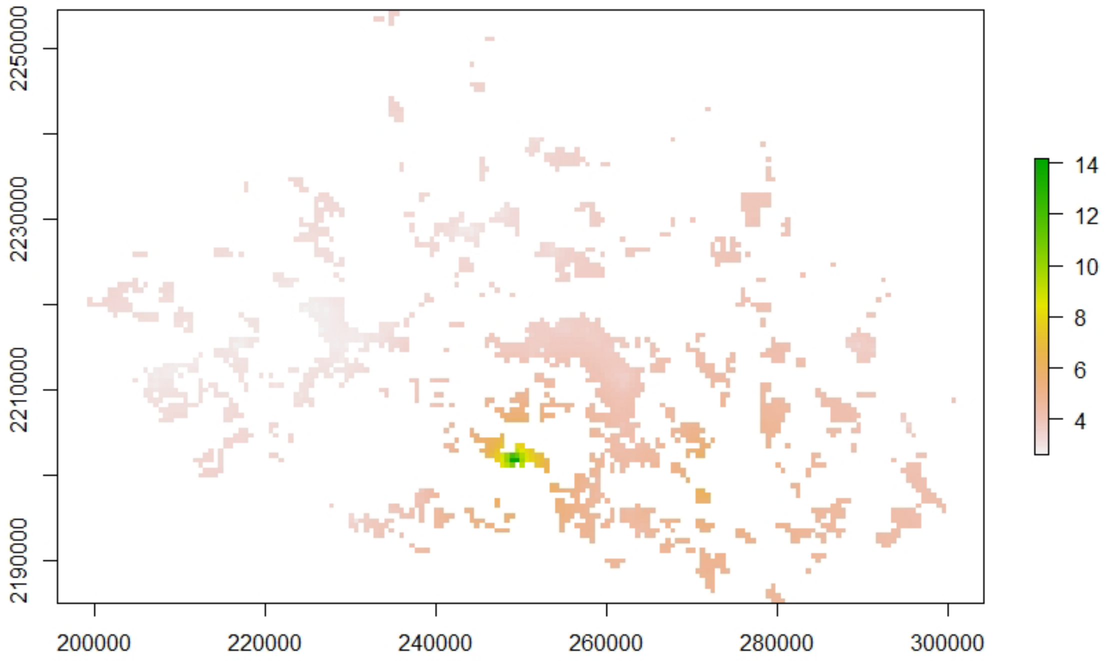


Figure 10: Intensive area used by tiger in Pandharkawada Forest Division, Maharashtra

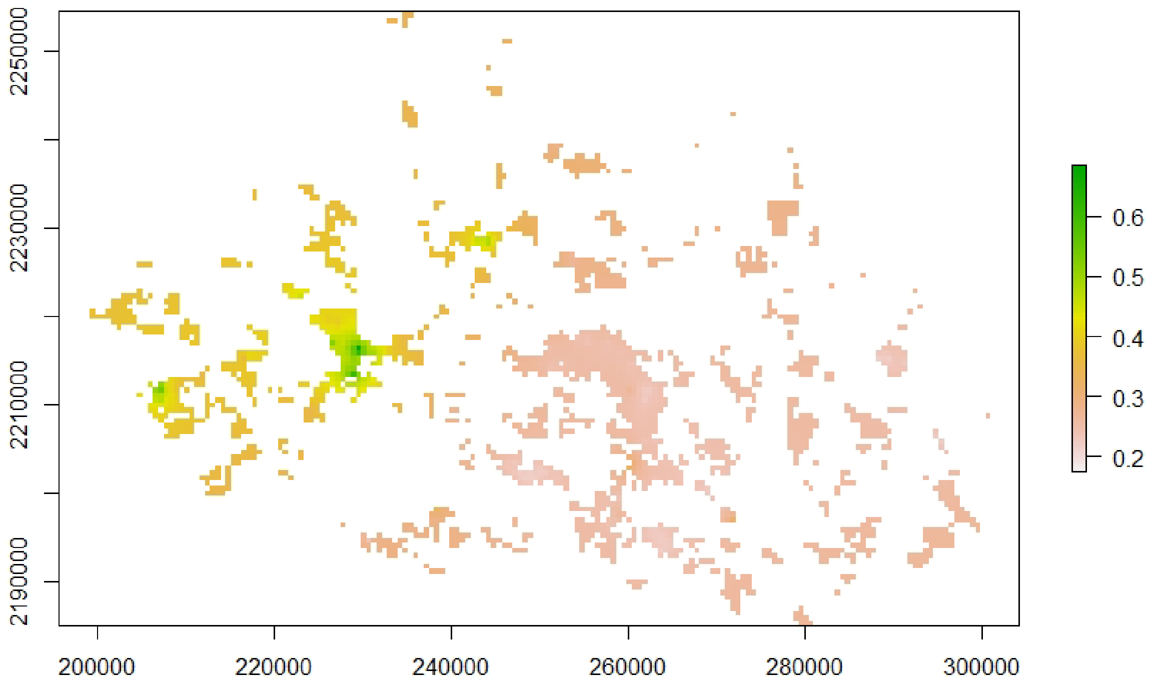


Figure 11: Intensive area used by leopard in Pandharkawada Forest Division, Maharashtra

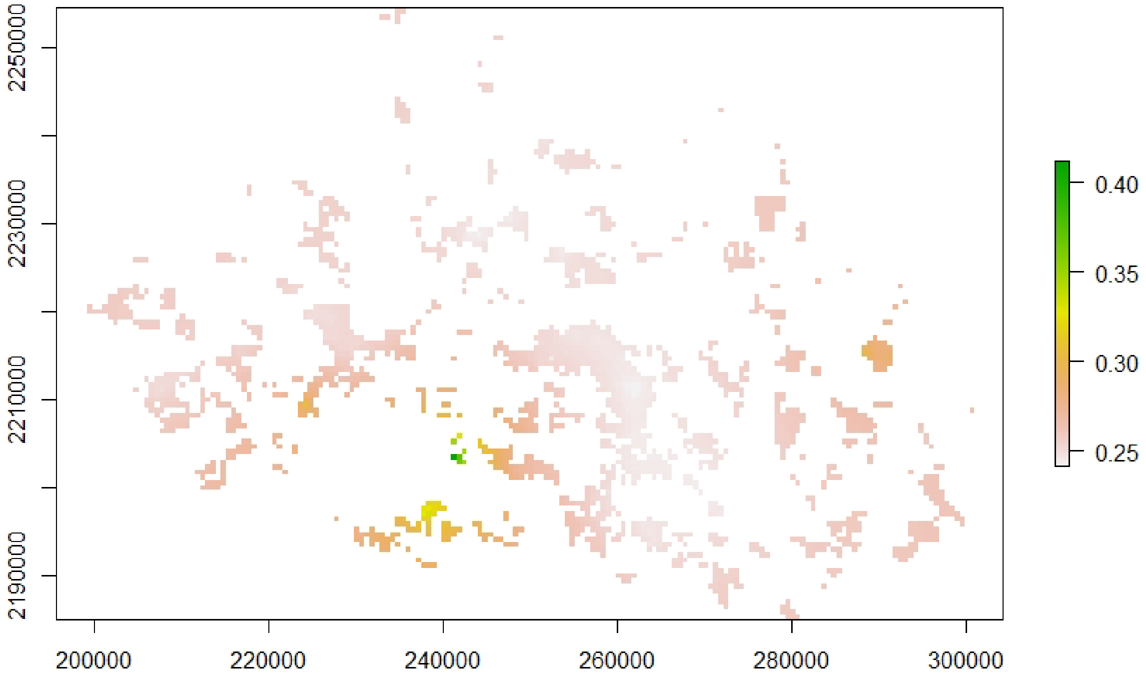


Figure 12: Intensive area used by Sloth Bear in Pandharkawada Forest Division, Maharashtra

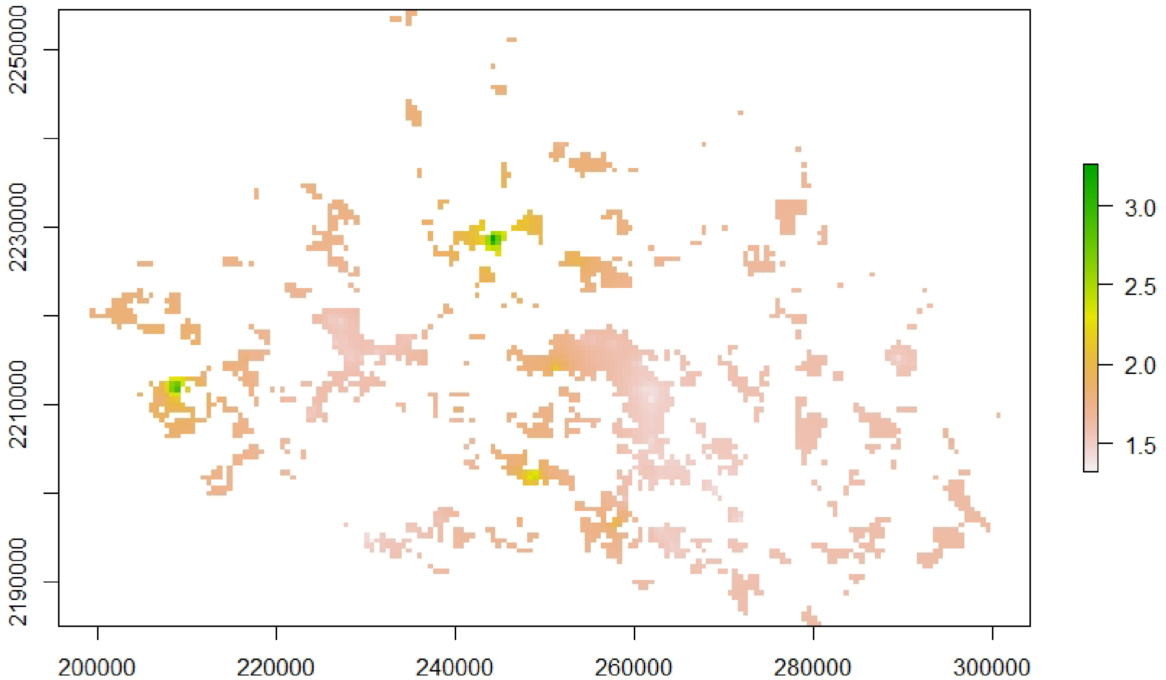


Figure 13: Intensive area used by Jungle cat in Pandharkawada Forest Division, Maharashtra

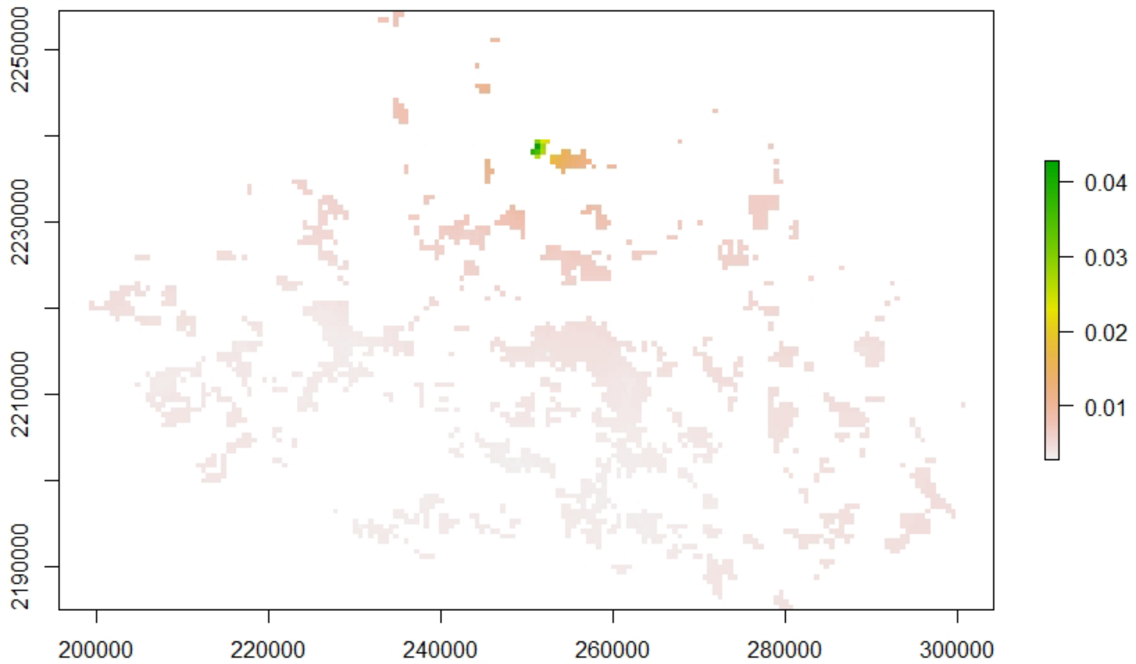


Figure 14: Intensive area used by Hyaena in Pandharkawada Forest Division, Maharashtra

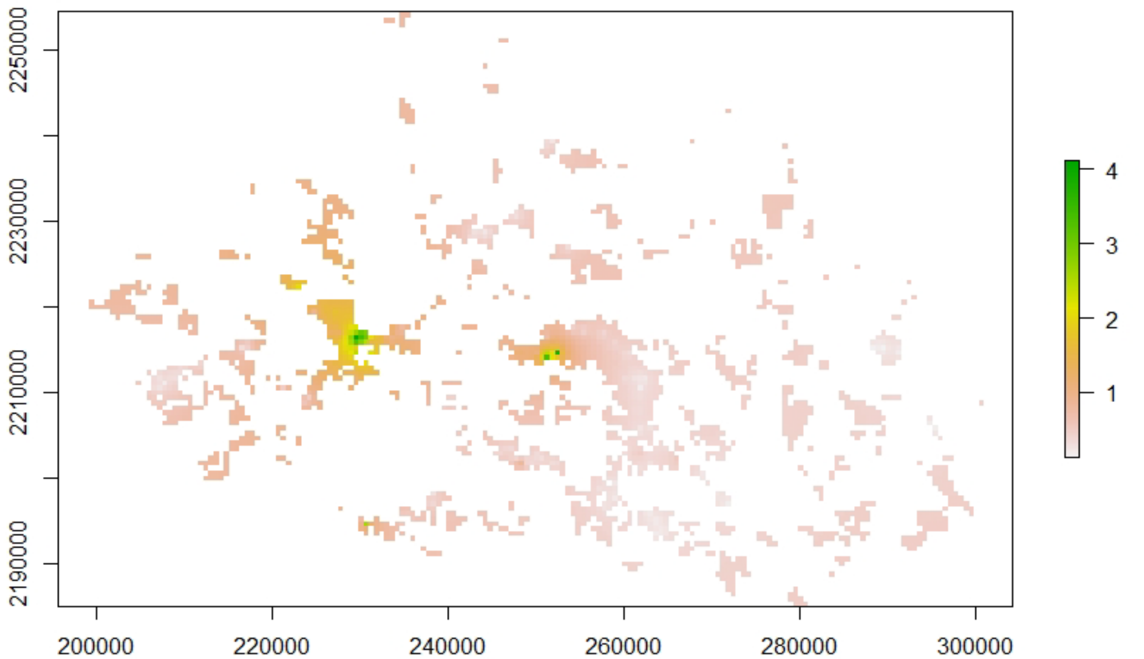


Figure 15: Intensive area used by the Wolf in Pandharkawada Forest Division, Maharashtra

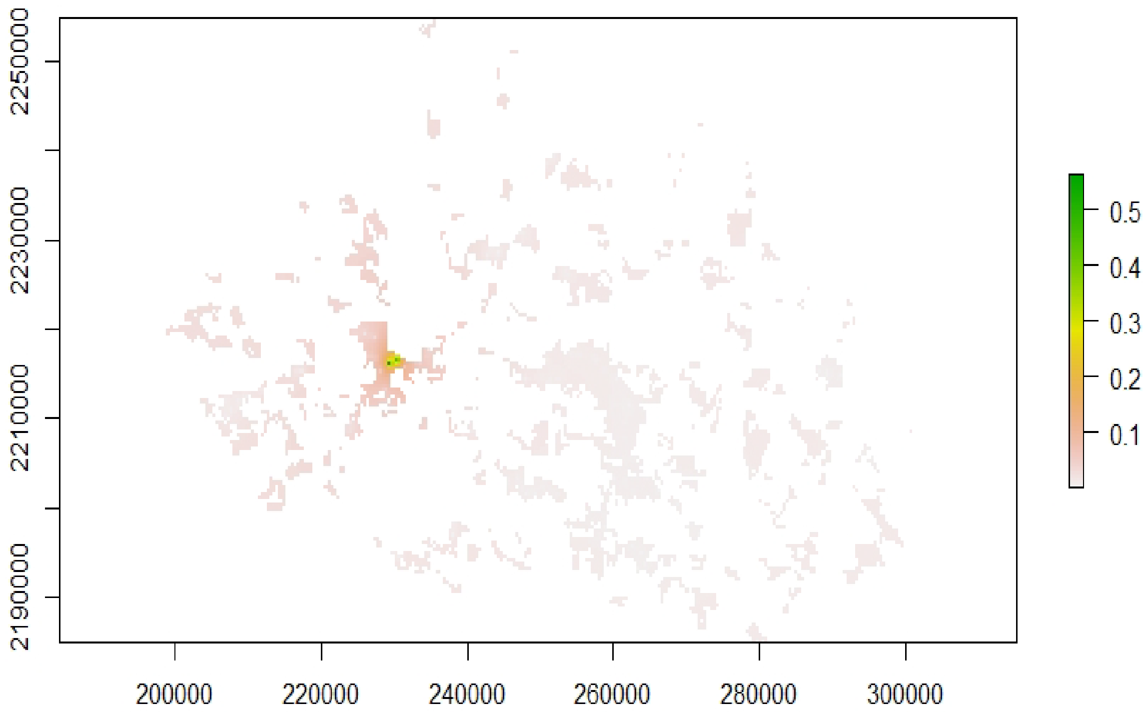


Figure 16: Intensive area used by Ratel in Pandharkawada Forest Division, Maharashtra

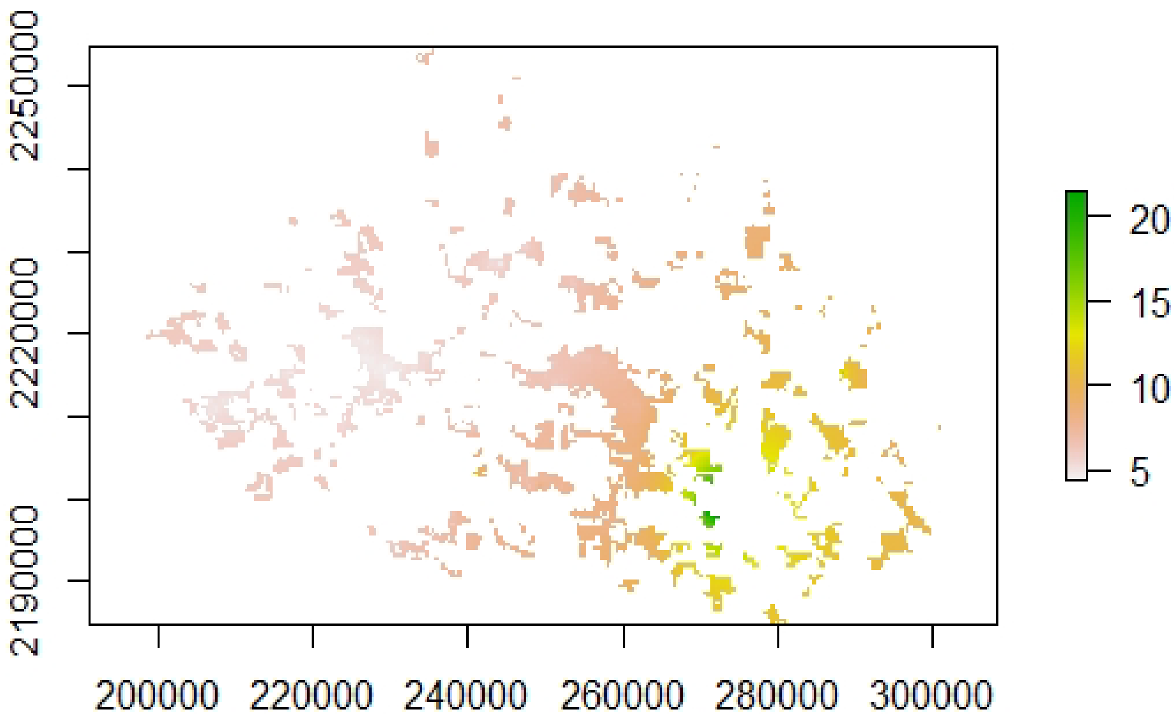


Figure 17: Intensive area used by Chital in Pandharkawada Forest Division, Maharashtra

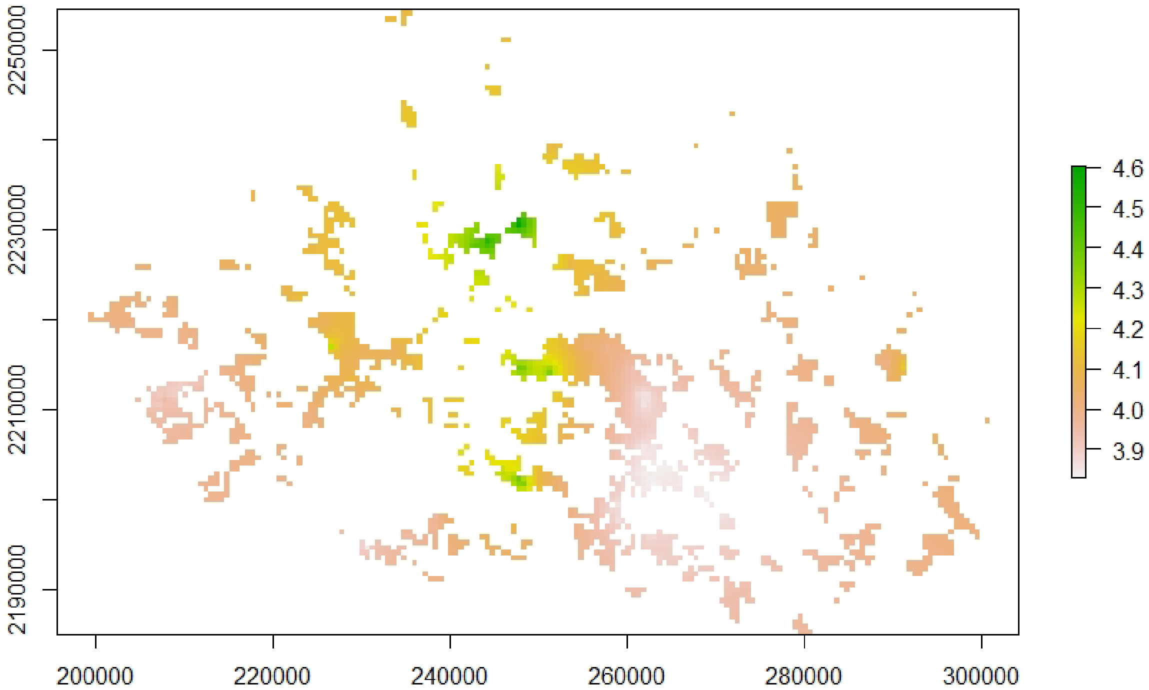


Figure 18: Intensive area used by Chousingha in Pandharkawada Forest Division, Maharashtra

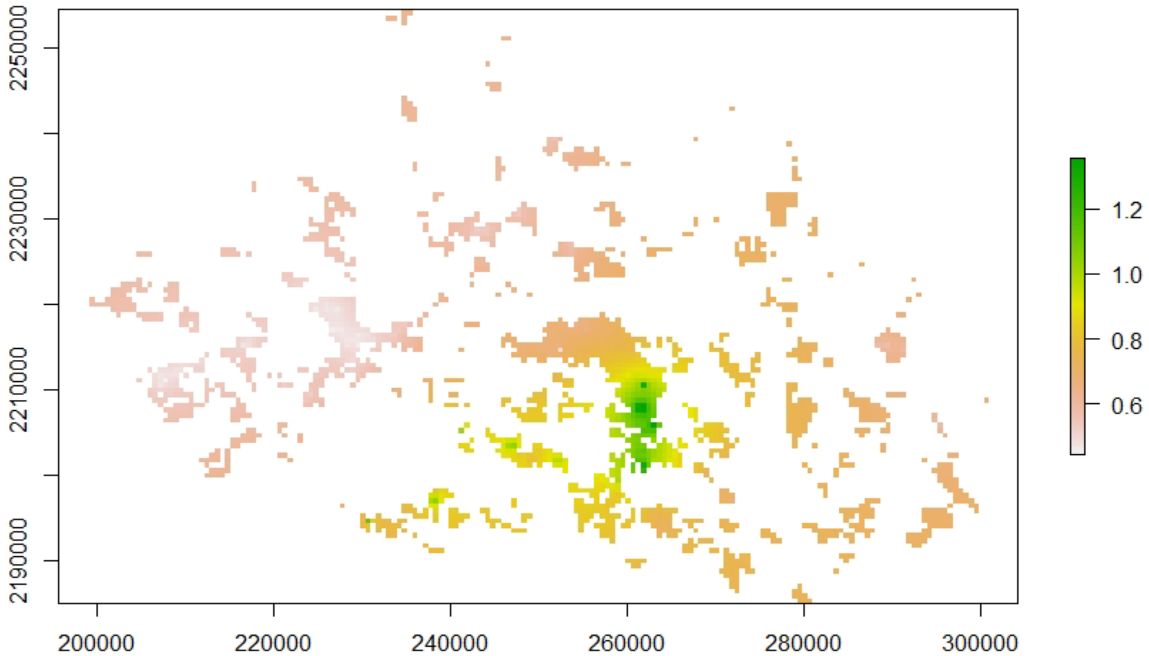


Figure 19: Intensive area used by Hare in Pandharkawada Forest Division, Maharashtra

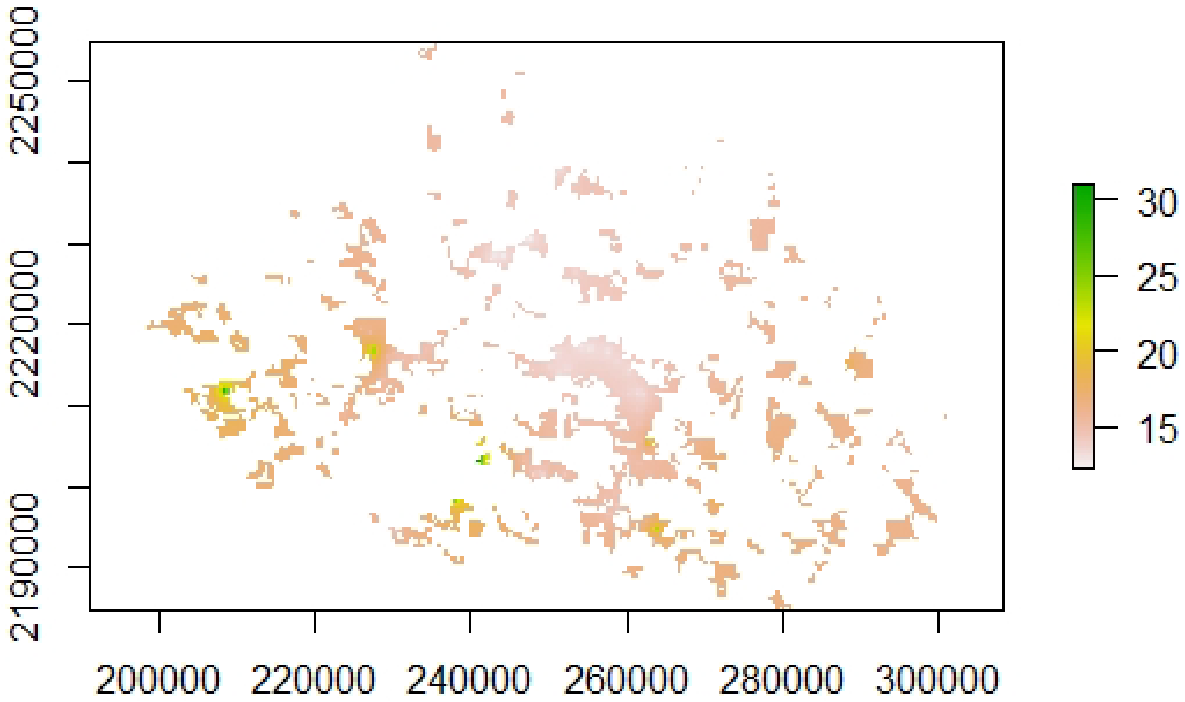


Figure 20: Intensive area used by Nilgai in Pandharkawada Forest Division, Maharashtra

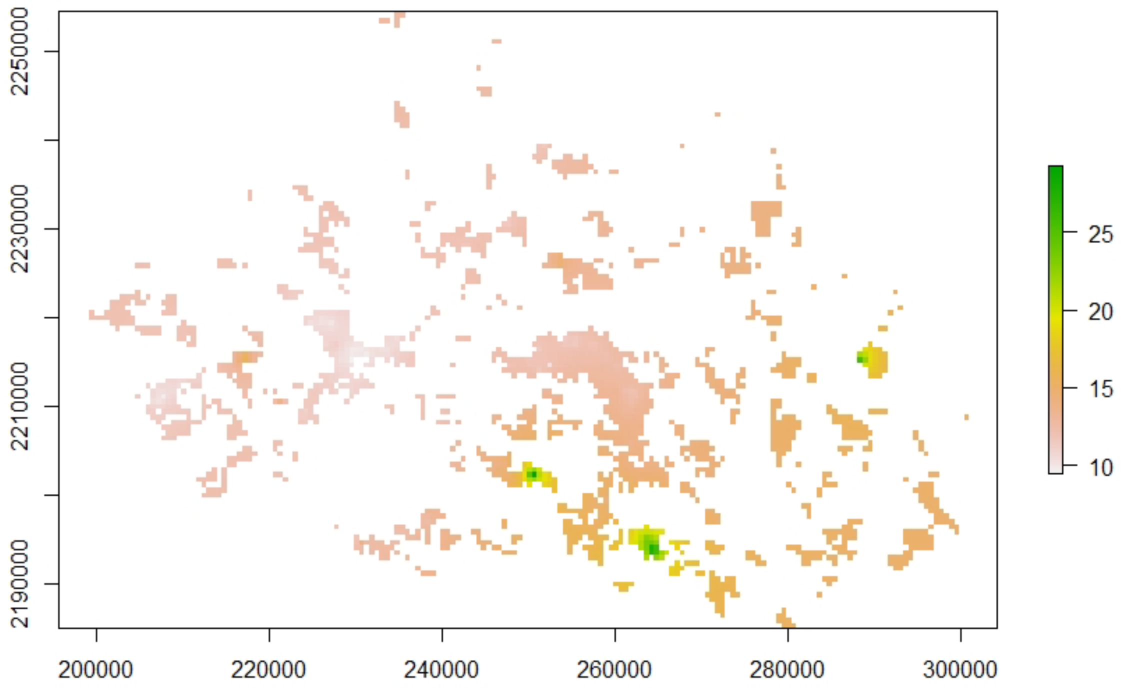


Figure 21: Intensive area used by Wild boar in Pandharkawada Forest Division, Maharashtra

5. Temporal Activity of Predator and Prey Species in Pandharkawada Forest Division

Introduction

Predator and prey are involved in an evolutionary arms race which modifies their behaviour and activity. Predators always look to exploit the vulnerability of prey to maximize hunting success and prey, in response, trade-off optimal foraging area to avoid the predator. Depending on the intensity of the competition among the predators and the interaction with prey species the activity pattern changes (Lima 1988). Landscape characteristics also play a crucial role in shaping up this dynamic relationship. The activity of animals is primarily dependent on the acquisition of food (Suselbeek et al. 2014). Thus, it makes sense to study the activity patterns of prey and predators both spatially and temporally complimenting it with an understanding of their actual diet through scat analysis. Time-stamped camera trap images are widely used to study the temporal activity pattern of different species in a community, such as a niche partitioning and activity overlap. The camera trap photographs have the time which shows when the animal was active. The number of photographs of a particular species will be more frequent in its activity period. Activity overlap indicates inter-specific competition or predation.

Methods and Results

The temporal pattern of the predators and their prey was analysed using R statistical software (version 3.6) and Microsoft Office Excel 2016. The approach established by Linkie and Ridout (2009) was used to study temporal activity patterns and the package “overlap” which estimates the coefficient of temporal overlap non-parametrically using kernel density estimates was used. In the package ‘overlap’, data are regarded as a random sample from the underlying distribution that describes the probability of a photograph being taken within any particular interval of the day. The probability density function of this distribution is then referred to as the activity pattern, which assumes that the animal is equally likely to be always photographed when it is active (Ridout & Linkie 2009). It is a two-step process. In the first step, each activity pattern is estimated non-parametrically, using kernel density estimation. The kernel density estimates used a bandwidth parameter, which is selected following the procedure developed by Taylor (2008). For the second step, a measure of overlap between the two estimated distributions was calculated. Ridout and Linkie (2009) reviewed several alternative measures of overlap between two probability distributions, favouring the coefficient of overlapping, Δ (Weitzman 1970), which ranges from 0 (no overlap, e.g., one species entirely diurnal, the other entirely nocturnal) to 1 (complete overlap). This is defined as the area under the curve that is formed by taking the minimum of the two density functions at each time point. A useful interpretation of the coefficient of overlapping is that for any time period during the day the proportion of activity that occurs during that period differs between the two distributions by $<1-\Delta$. 1000 bootstrap samples are used to derive the confidence intervals.

These estimators use kernel density estimates fitted to the data to approximate the true density functions f(t) and g(t). Schmid & Schmidt (2006) propose five estimators of overlap.

Dhat1 is calculated from vectors of densities estimated at T equally spaced times, t, between 0 and 2π.

For circular distributions, Dhat2 is equivalent to Dhat1, and Dhat3 is inapplicable. Dhat4 and Dhat5 use vectors of densities estimated at the times of the observations of the species, x, and y.

$$\hat{\Delta}_1 = \frac{2\pi}{T} \sum^{T} \min\{ \hat{f}(t_i) - \hat{g}(t_i)\}$$

$$\hat{\Delta}_4 = \frac{1}{2} \left(\frac{1}{n} \sum_{i=1} \min\left\{1, \frac{\hat{g}(x_i)}{\hat{f}(x_i)} \right\} + \frac{1}{m} \sum_{j=1} \min\left\{1, \frac{f(x_j)}{\hat{g}(x_j)} \right\} \right)$$

$$\hat{\Delta}_5 = \frac{1}{n} \sum_{i=1}^{n} \mathrm{I}\{ \hat{f}(t_i) < \hat{g}(t_i)\} + \frac{1}{m} \sum_{j=1}^{m} \mathrm{I}\{ \hat{f}(y_j) \geq \hat{g}(y_j)\}$$

Where n, m are the sample sizes and I is the indicator function (1 if the condition is true, 0 otherwise). The kernel density estimates of overlap of daily temporal activity patterns of different predator-prey species are shown in Table 8 and overlap of predator-predator species is given in Table 9. From the kernel density estimators, the tiger-wolf and leopard-sloth bear were observed to have a high degree (0.76 and 0.71 respectively) of overlap as indicated by the estimated overlap coefficients. Similarly, it has been observed that tiger has a high degree of overlap with wild boar (0.81) which is one of its main prey species. Leopard has been observed to have a high degree of overlap with Indian hare (0.78) whereas Wolf has highest degree of overlap with both the nilgai and wild boar (0.74).

Table 8: Activity overlap of predator and prey in Pandharkawada Forest Division

Species	Tiger	Leopard	Wolf
Chital	0.49	0.36	0.67
Nilgai	0.56	0.39	0.74
Wild boar	0.81	0.56	0.74
Hare	0.66	0.78	0.56

Daily temporal activity overlaps between the predator and prey species in Pandharkawada Forest Division, Maharashtra are given in the pages. The red and blue lines represent the kernel density estimates based on individual photograph times. The overlap is shown by the shaded area in each plot (Figure 22 & 23).

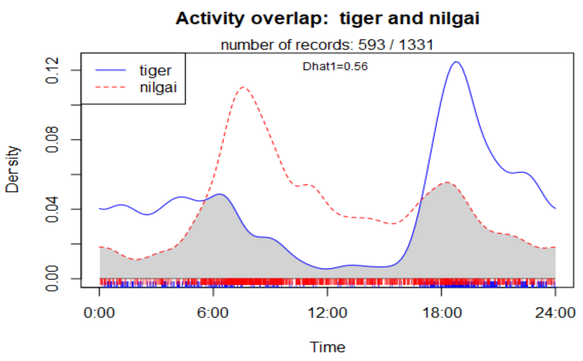


Figure 22a: Tiger vs Nilgai

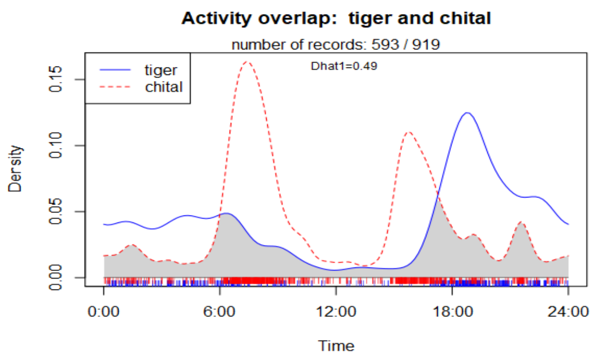


Figure 22b: Tiger vs Chital

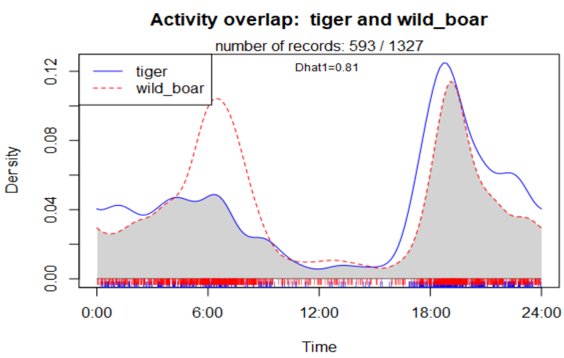


Figure 22c: Tiger vs Wild Boar

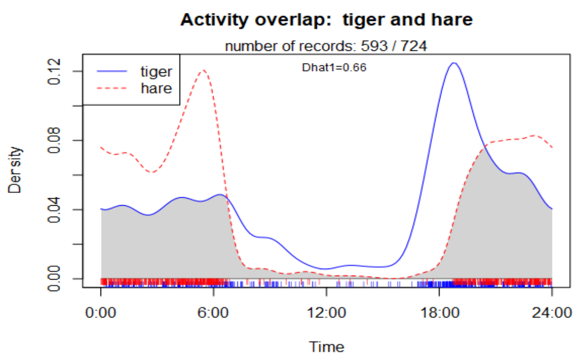


Figure 22d: Tiger vs Hare

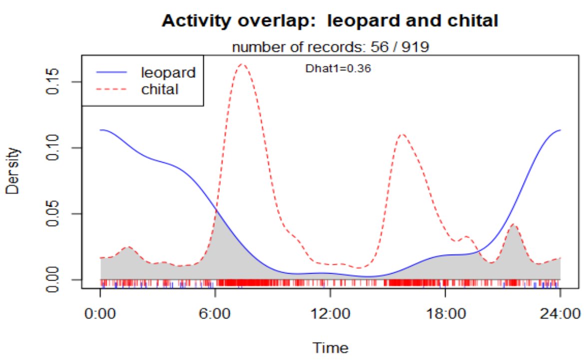


Figure 22e: Leopard vs Chital

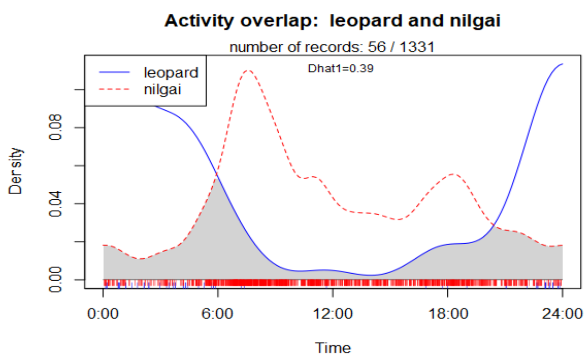
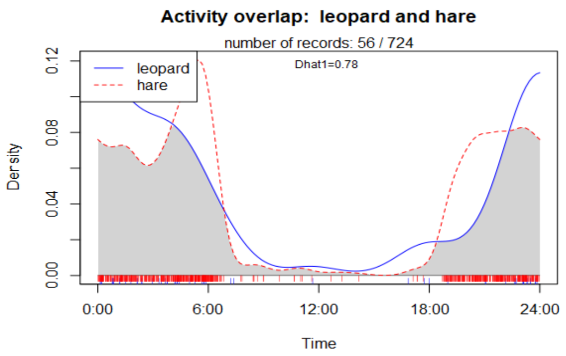


Figure 22f: Leopard vs Nilgai



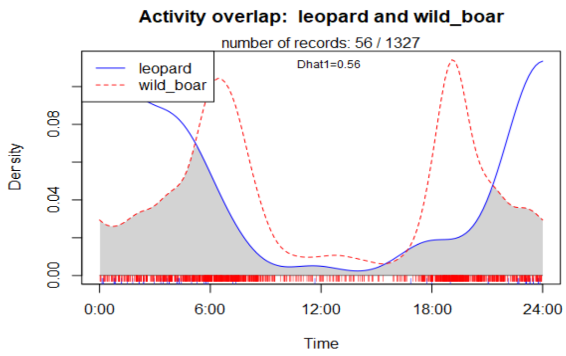
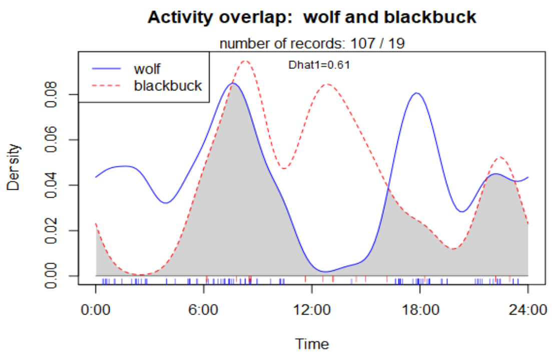


Figure 22g: Leopard vs Hare

Figure 22h: Leopard vs Wild Boar



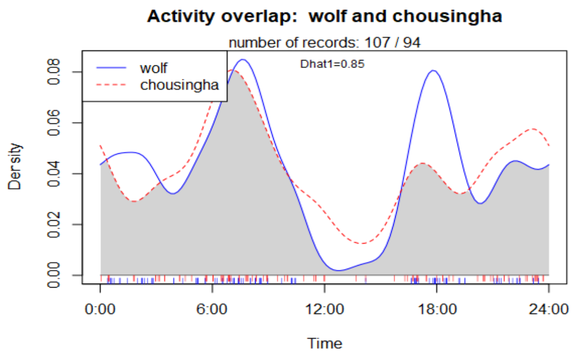
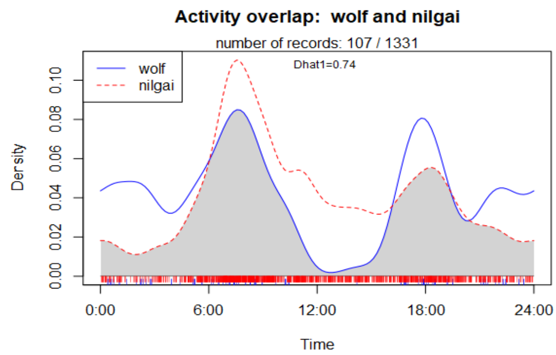


Figure 22i: Wolf vs Blackbuck

Figure 22j: Wolf vs Chousingha



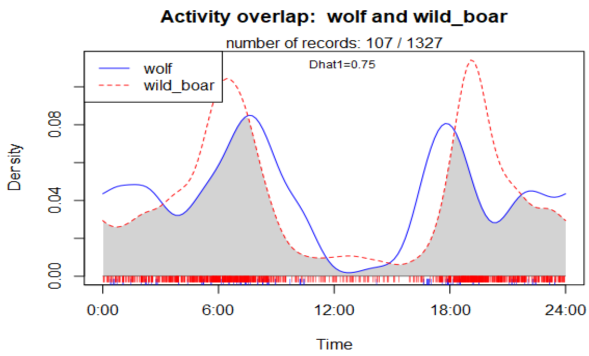


Figure 23k: Wolf vs Nilgai

Figure 23l: Wolf vs Wild boar

Figures 22 (a-l): Daily temporal activity overlap between the Predators (Tiger, Leopard and Dhole) and prey species in Pandharkawada Forest Division, Maharashtra during the year 2021

Daily temporal activity overlaps between the predator species in Pandharkawada Forest Division, Maharashtra are given in the next page (Figure 23). The lines represent the kernel density estimates based on individual photograph times. The overlap is shown by the shaded area in each plot.

Table 9: Temporal activity overlap among predators in Pandharkawada Forest Division, Maharashtra

Species	Tiger	Leopard	Jackal	Wolf	Sloth Bear
Tiger	NA	0.61	0.55	0.76	0.60
Leopard	0.61	NA	0.66	0.59	0.71
Jackal	0.55	0.66	NA	0.56	0.49
Wolf	0.76	0.59	0.56	NA	0.55
Sloth Bear	0.60	0.71	0.49	0.55	NA

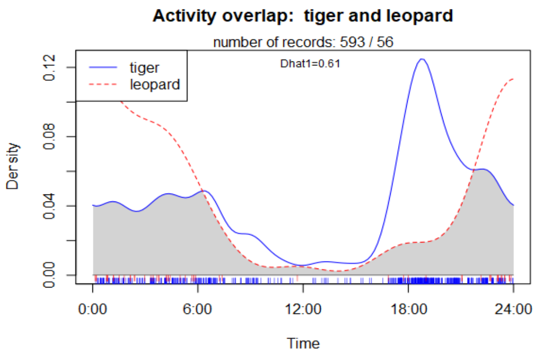


Figure 23a: Tiger vs Leopard

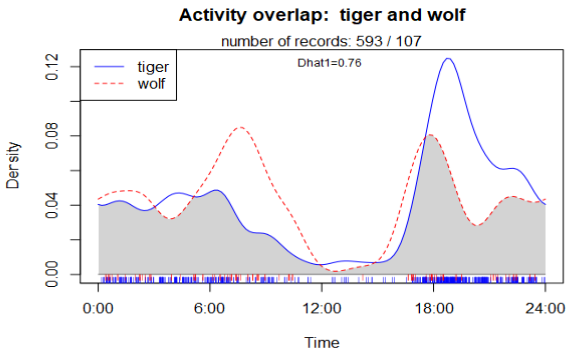


Figure 23b: Tiger vs Wolf

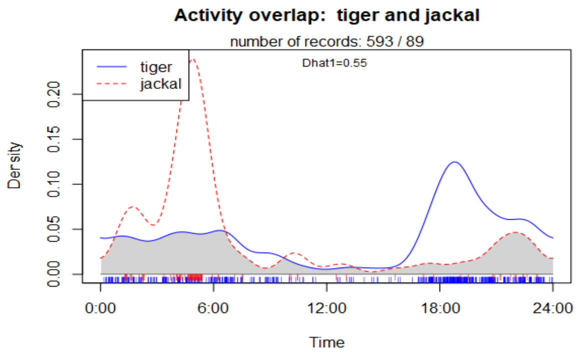


Figure 23c: Tiger vs Jackal

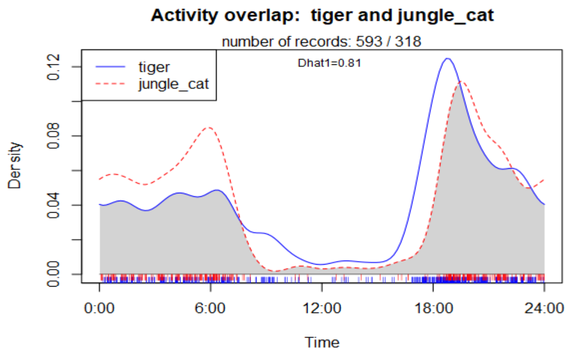


Figure 23d: Tiger vs Jungle Cat

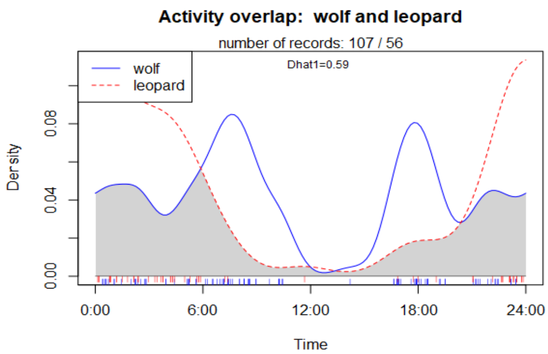


Figure 23e: Wolf vs Leopard

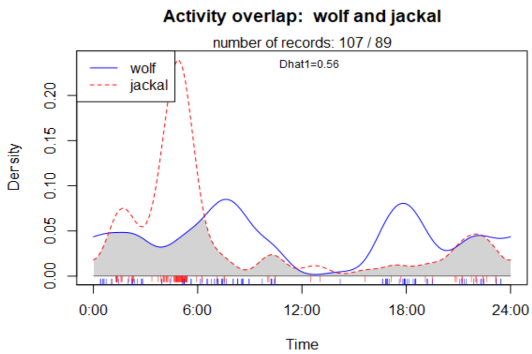
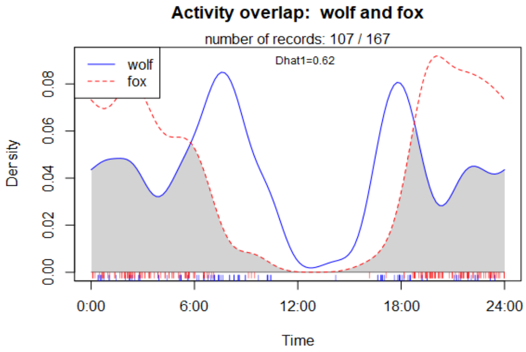


Figure 23f: Wolf vs Jackal



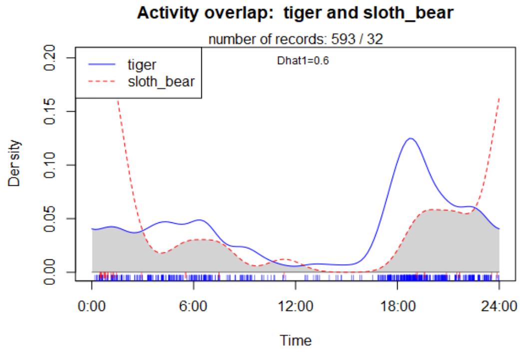
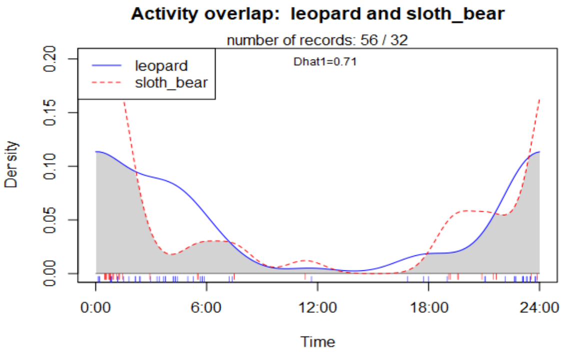


Figure 23g: Wolf vs Fox

Figure 23h: Tiger vs Sloth bear



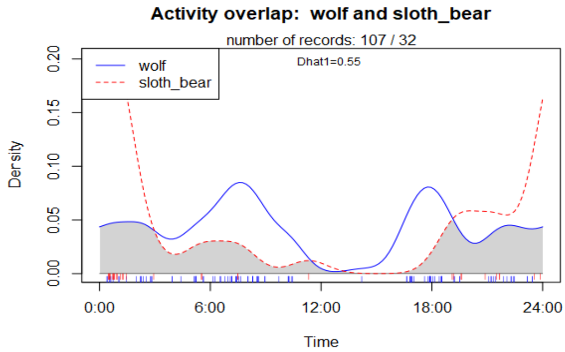


Figure 23i: Leopard vs Sloth bear

Figure 23j: Wolf vs Sloth bear

Figure 23 (a-j): Temporal activity overlap between predators in Pandharkawada Forest Division (Territorial), Maharashtra.

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