

# STATUS OF TIGERS COPREDATORS & PREY IN PENCH TIGER RESERVE, 2023 & 2024



भारतीय वन्यजीव संस्थान  
Wildlife Institute of India

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भारतीय वन्यजीव संस्थान  
Wildlife Institute of India

**Status of Tigers, Co-Predators and Prey in  
Pench Tiger Reserve**

*Long-term monitoring of tigers, co-predators  
and prey in tiger reserves and other tiger  
bearing areas of Vidarbha, Maharashtra*

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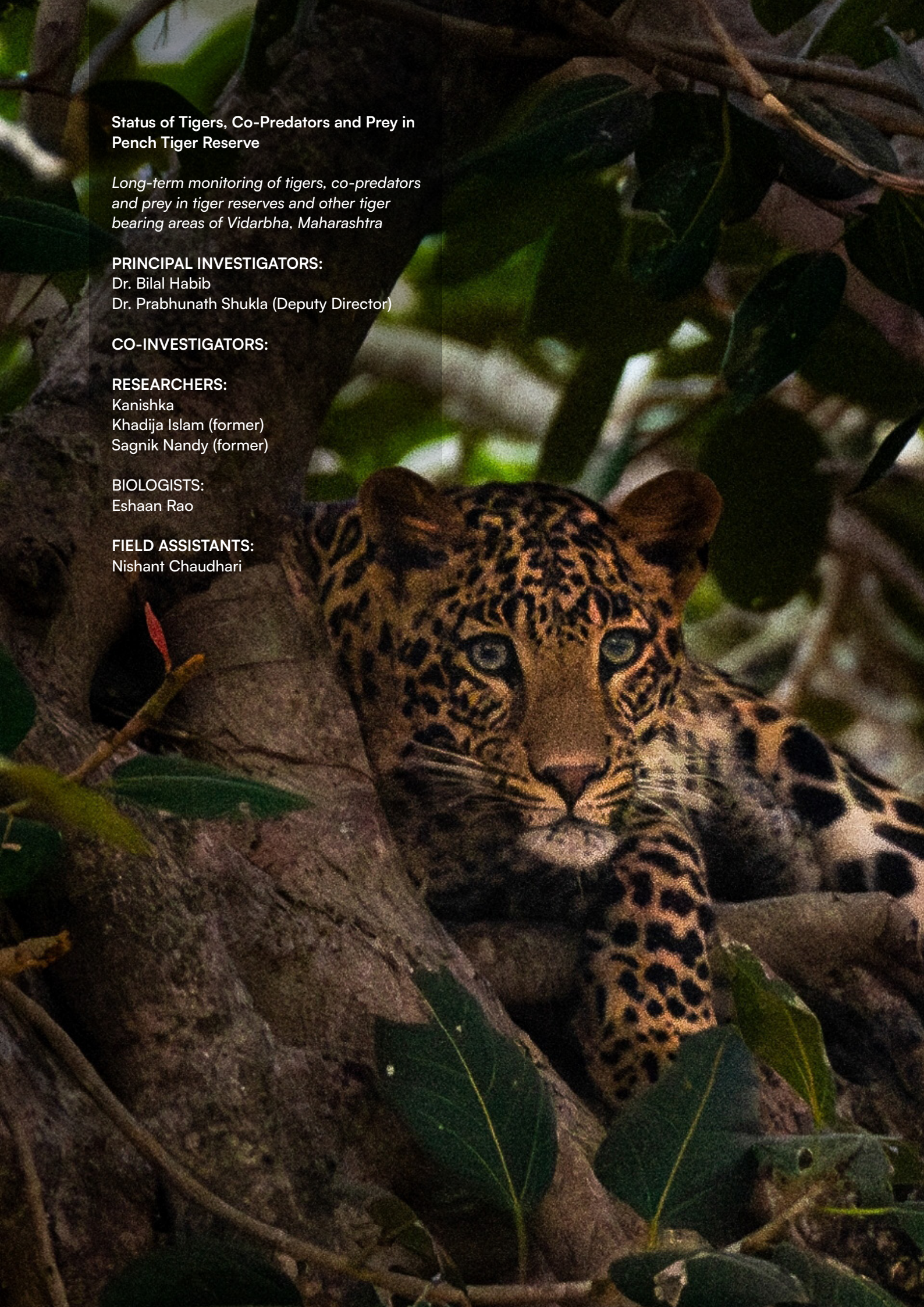
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A leopard is walking through a forest. The leopard's body is covered in dark spots on a lighter background. The forest is lush with green leaves, some of which are in the foreground, partially obscuring the leopard. The lighting is natural, suggesting a daytime setting in a wooded area.

# Acknowledgments

We acknowledge the support from the Field Staff of Pench Tiger Reserve — The unsung heroes of the Pench. We thank all the Assistant Conservator of Forests, Range Forest Officers of all Ranges of Pench Core and Buffer, Foresters, Forest Guards and other Field Staff . Our thanks are due to the National Tiger Conservation Authority and Maharashtra Forest Department for permissions and all necessary logistic support including permits. We thank the Director, Dean and Research Coordinator WII for trust and all the support. We thank our field assistant Nishant Chaudhari for his dedication, support of Ms. Vedanshi Maheshwari and Mr. Ishwar D. Uikey during the field work. Finally, we are grateful to the Principal Chief Conservator of Forests (Wildlife)/Chief Wildlife Warden, Additional Principal Chief Conservator of Forests (Wildlife), Deputy Director of Pench Tiger Reserve for their encouragement and support. This research is financially supported by Forest Department, Govt. of Maharashtra.



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## Executive Summary

Phase IV monitoring for the Pench Tiger Reserve (PTR) core and buffer was conducted from March — May in the year 2023 and February — March in 2024 covering an area of 741.22 sq. km as a part of the project “Long-term Monitoring of Tigers, Co-predators and Prey in Tiger Reserves and other Tiger bearing areas of Vidarbha, Maharashtra”. The objective of the Phase IV Monitoring is to estimate the minimum number of tigers in the reserve using Capture-Recapture Sampling and density estimation of prey base using Distance Sampling.

Camera traps were placed in 296 and 313 grids of 2.01 sq. km. area each in the core and buffer area of PTR in 2023 and 2024 respectively. In each sampling block, camera traps were active for 30 days. During 30 days of camera trapping survey with a sampling effort of 9104 and 9314 trap nights, 49 and 51 adult individual tigers were photographed in the sampled area of PTR in 2023 and 2024 respectively. Estimated population (N) of tigers based on the best fit (SECR Heterogeneity) model was 49 ( $\pm 0.73$ ) and 51 ( $\pm 0.9$ ) for both respective years. Tiger density per 100 sq. km. based on the Spatially Explicit Capture-Recapture (SECR) model was 7.95 (SE  $\pm 1.14$ ) and 8.3 (SE  $\pm 1.17$ ) for both respective years. Along with tigers 73 and 76 adult individual leopards were photographed in the sampled area of PTR and estimated population (N) based on the best fit (SECR Heterogeneity) model was 85 ( $\pm 5.86$ ) and 83 ( $\pm 3.35$ ) in 2023 and 2024 respectively. Leopard density per 100 sq. km. based on the Spatially Explicit Capture-Recapture (SECR) model was 12.55 ( $\pm 1.47$ ) and 13.5 ( $\pm 1.58$ ) for both respective years.

To estimate prey density, 70 and 64 line transects in core and buffer of PTR were sampled 7 times during the sampling period, with a total walking effort of 980 and 938 km in 2023 and 2024 respectively. During the sampling, a total of 576 and 802 species observations were made. The overall individual density per km<sup>2</sup> of major prey species in PTR in the year 2024 was; Chital 32.12 (SE  $\pm 6.39$ ), Sambar 5.03 (SE  $\pm 1.02$ ), Gaur 3.78 (SE  $\pm 1.02$ ), Wild Boar 6.99 (SE  $\pm 0.59$ ), Langur 14.97 (SE  $\pm 3.25$ ), Barking Deer 1.17 (SE  $\pm 0.34$ ), Nilgai 3.22 (SE  $\pm 0.59$ ), Peafowl 1.99 (SE  $\pm 0.51$ ) and Rhesus macaque 10.21 (SE  $\pm 2.54$ ). A basic understanding of sympatric carnivore ecology with asymmetric competition enables us to hypothesize that to coexist and not just co-occur there must be niche segregation on at least one of the three axes: space, time, and/or diet. To understand how three large sympatric predators co-occur in space and in time, camera trapping was carried out. Temporal activity overlaps were derived by using kernel density. All the sympatric predators were found to co-occur in the sampled area of PTR. There was a distinct difference in the space-use pattern observed for all three carnivores and a strong spatial segregation pattern found between Tigers, Dholes, and Leopards. It showed significant segregation and avoidance of each other's space. There was a significant overlap between the temporal activity pattern of tigers and leopards. While tigers and leopards show a strong, unimodal, nocturnal activity pattern, dholes show a bimodal, crepuscular activity pattern.



# Introduction

The tiger (*Panthera tigris*) is the largest extant cat species. 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 also 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 Vidarbha (Figure 1) include Melghat Tiger Reserve, Pench Tiger Reserve Maharashtra, Navegaon-Nagzira Tiger Reserve, Tadoba-Andhari Tiger Reserve, the Brahmapuri (Territorial) Forest Division, Umred-Pauni-Karhandla Wildlife Sanctuary, Tipeswar 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% and a tiger number of 315 despite having a human population of more than 5.2 million.

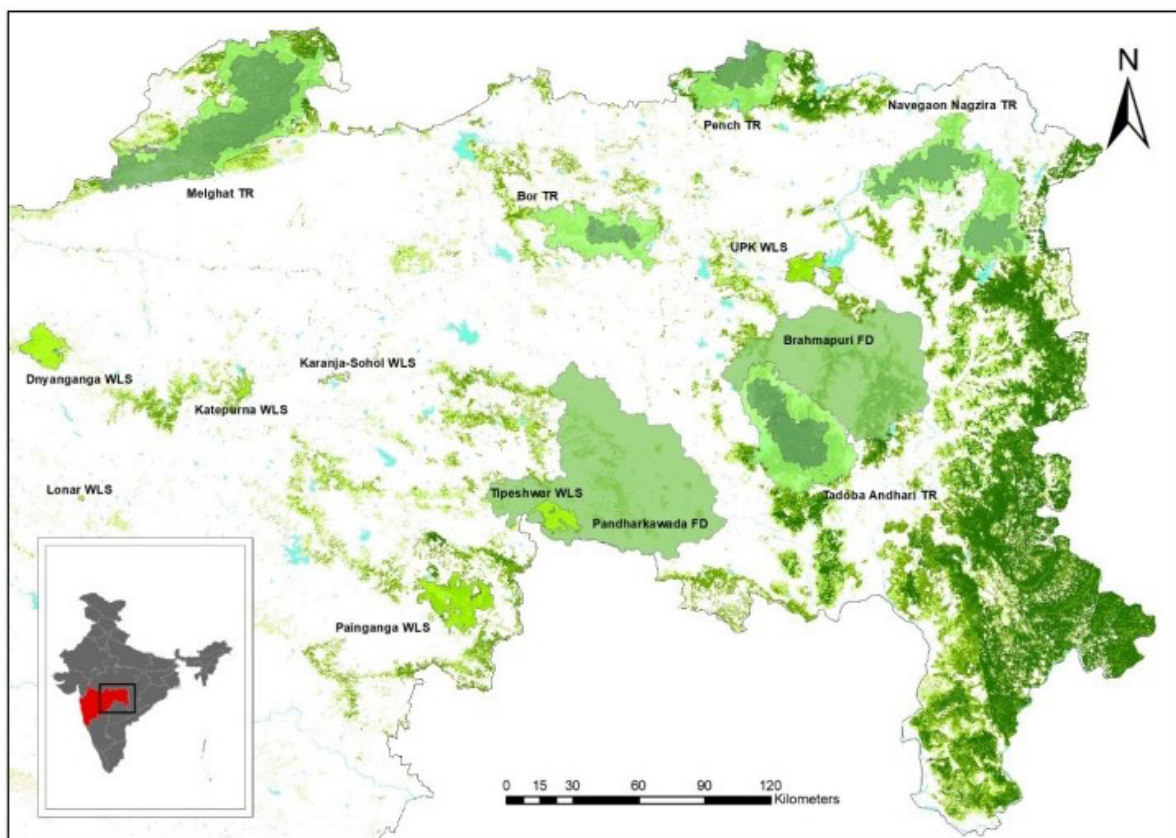


Figure 1: Map showing the location of Pench Tiger Reserve along with other tiger reserves and protected areas in the Vidarbha landscape of Maharashtra

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 objectives that are as follows:

**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 occupancy-based framework. The data will be analyzed 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 analyzing the data in capture—recapture framework. Rigorous field methods will be followed to achieve a small CV 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. The survey protocols and analyses of this data set will be based on modelling and estimation approaches 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 camera trapping and radiotelemetry.

e) Scat analysis is indirect, non-invasive, and unbiased technique for recording 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 in 1b 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.

# Pench Tiger Reserve

Pench Tiger Reserve (PTR) falls in the Nagpur district of the Vidarbha region of Maharashtra, between 21° 31' 59.34" N, 78° 59' 19.41" E and 21° 37' 37.43" N, 79° 23' 31.60" E. It shares its boundary towards the north with the Pench Tiger Reserve that lies in the neighbouring state of Madhya Pradesh. PTR includes Pench National Park (257 sq. km.) and Mansingdeo Wildlife Sanctuary (195 sq. km.) The reserve has a unified area of 741.22 sq. km. of which the core contributes 483.96 sq. km. of critical tiger habitat and a buffer of 257.26 sq. km. (Figure 2). The unified area of the tiger reserve is under the control of the Field Director of Pench (MH) Tiger Foundation with the office located in Nagpur.

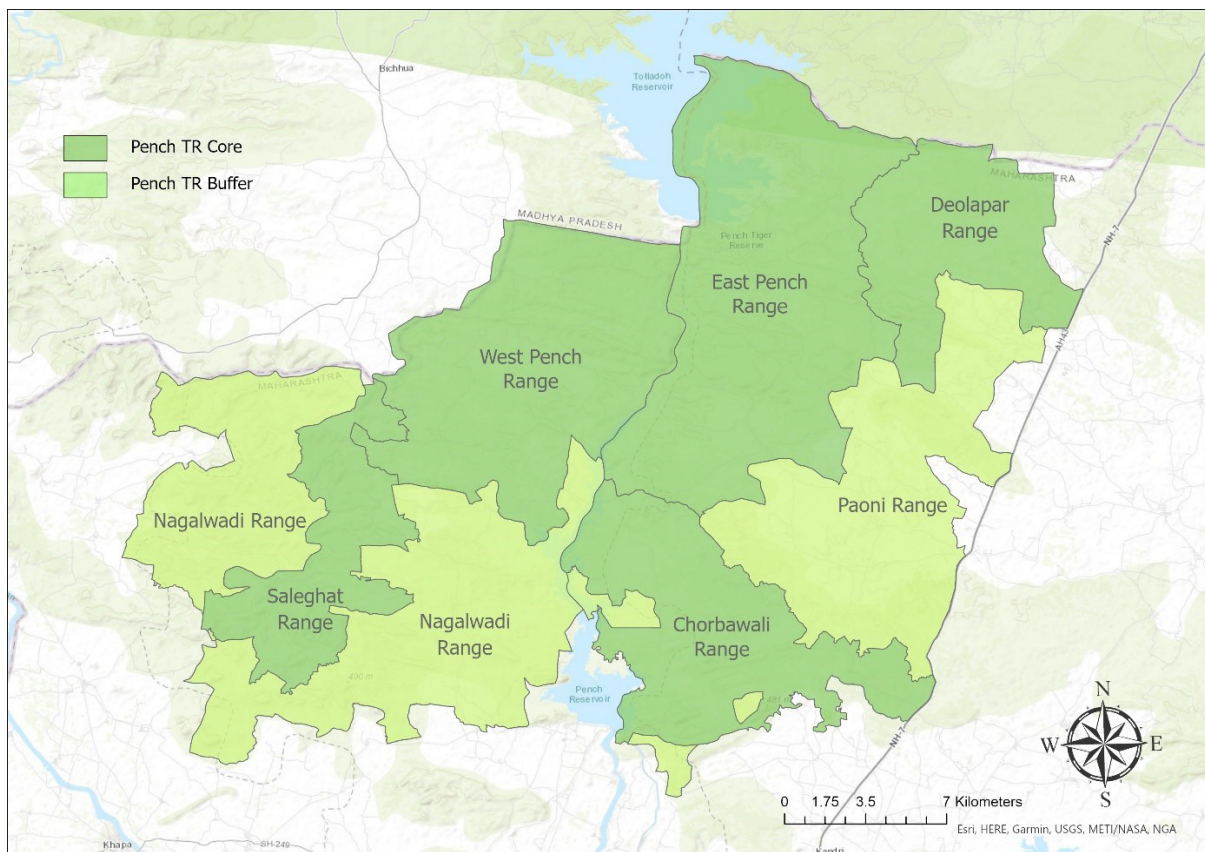


Figure 2: Map depicting Critical Tiger Habitat (core) and Eco-Sensitive Zone (buffer) of Pench Tiger Reserve, Maharashtra, India

PTR has an elevation gradient of 284 to 591 meters (Figure 3). The reserve is divided into two parts from east to west by the river Pench. The northern part of PTR has hilly terrain while the southern part has more plain areas. Pench has corridor connectivity with the Melghat Tiger Reserve to the west, Navegaon-Nagzira Tiger Reserve to the southeast, Pench Tiger Reserve (MP) to the north, and Kanha Tiger Reserve (MP) to the northeast.

The forest can be mainly classified as tropical moist and dry deciduous forest (Figure 4). Teak (*Tectona grandis*) is the most common species along with Garadi (*Cleistanthus collinus*), Bherra (*Chloroxylon swietenia*), Dhawada (*Anogeissus latifolia*), Arjuna (*Terminalia arjuna*), Ain (*Terminalia elliptica*), Mahuwa (*Madhuca longifolia*), Salai (*Boswellia serrata*), Tendu (*Diospyros melanoxylon*), Palash (*Butea monosperma*), Bael (*Aegle marmelos*), Bamboo (*Dendrocalamus strictus*) etc.

Pench is also home to a host of faunal species like Tiger (*Panthera tigris*), Leopard (*Panthera pardus*), Wild Dog (*Cuon alpinus*), Wolf (*Canis lupus*), Sloth Bear (*Melursus ursinus*), Golden Jackal (*Canis aureus*), Jungle Cat (*Felis chaus*), Wild Boar (*Sus scrofa*), Sambar (*Rusa unicorn*), Spotted Deer (*Axis axis*), Nilgai (*Boselaphus tragocamelus*), Four Horned Antelope (*Tetracerus quadricornis*), Gaur (*Bos gaurus*), Barking Deer (*Munticus muntjac*) etc. Around 255 species of birds have also been recorded from the region.

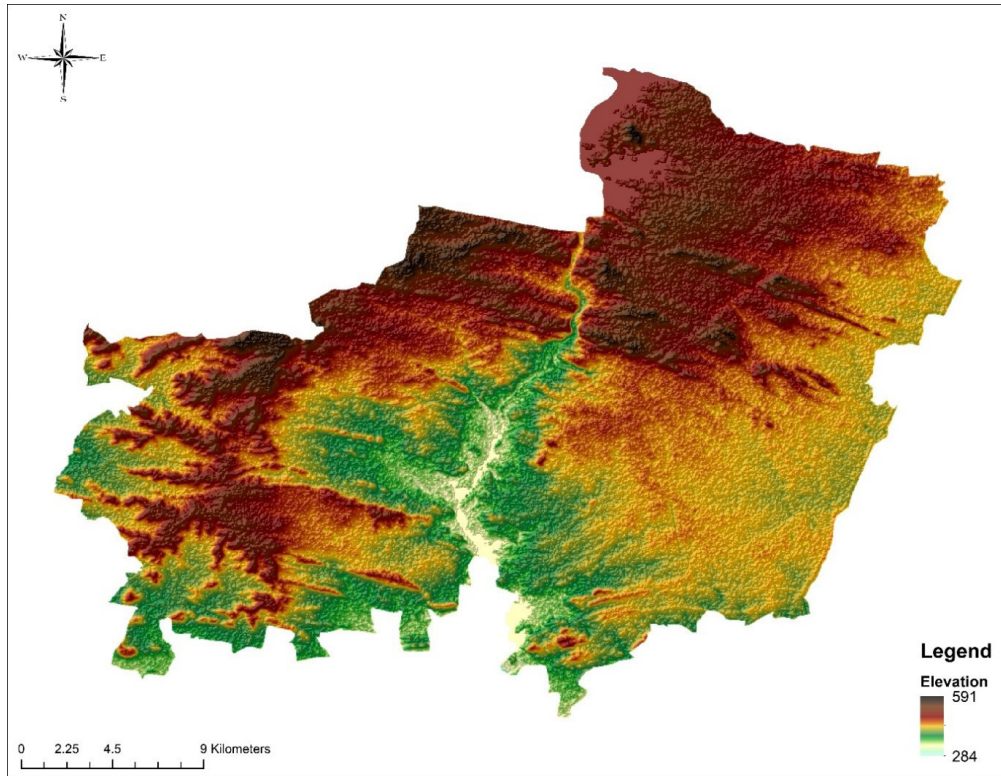


Figure 3: Map depicting the elevation gradient of Pench Tiger Reserve, Maharashtra, India

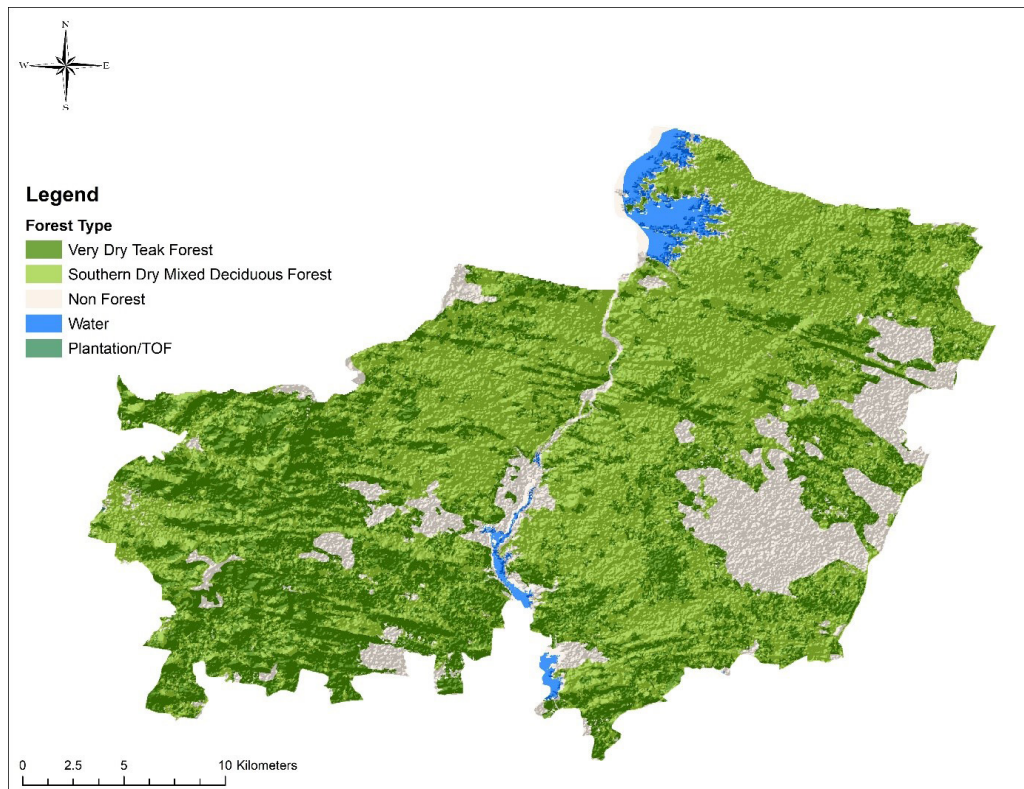


Figure 4: Map depicting the forest types and cover of Pench Tiger Reserve, Maharashtra, India

## Status of Prey Species in Pench Tiger Reserve

A total of 70 and 64 transects of 2 km in length were marked and monitored in the 64 beats of PTR in the year 2023 and 2024 respectively. Figure 5 shows the distribution of line transects across PTR. Transects are well spread over an area of 622 sq. km. of Pench Tiger Reserve covering almost all the vegetation types in the area. Each line transect was walked 7 times during the month of March in 2023 and 2024 to record prey species across the whole area of PTR. Thus, a total walking effort of 980 km (in 2023) and 938 km (in 2024) was invested in line transect surveys which generated a total of 576 and 802 observations of all types of prey species in both years respectively. This includes the major prey species like Spotted Deer (*Axis axis*), Sambar (*Rusa unicolor*), Barking Deer (*Muntiacus muntjak*), Gaur (*Bos gaurus*), Wild Boar (*Sus scrofa*), Nilgai (*Boselaphus tragocamelus*), Chinkara (*Gazella bennettii*), Langur (*Semnopithecus spp.*), Rhesus Macaque (*Macaca mulatta*), Indian Hare (*Lepus nigricollis*), Red Junglefowl (*Gallus gallus*), Grey Junglefowl (*Gallus sonneratii*) and Peafowl (*Pavo cristatus*).

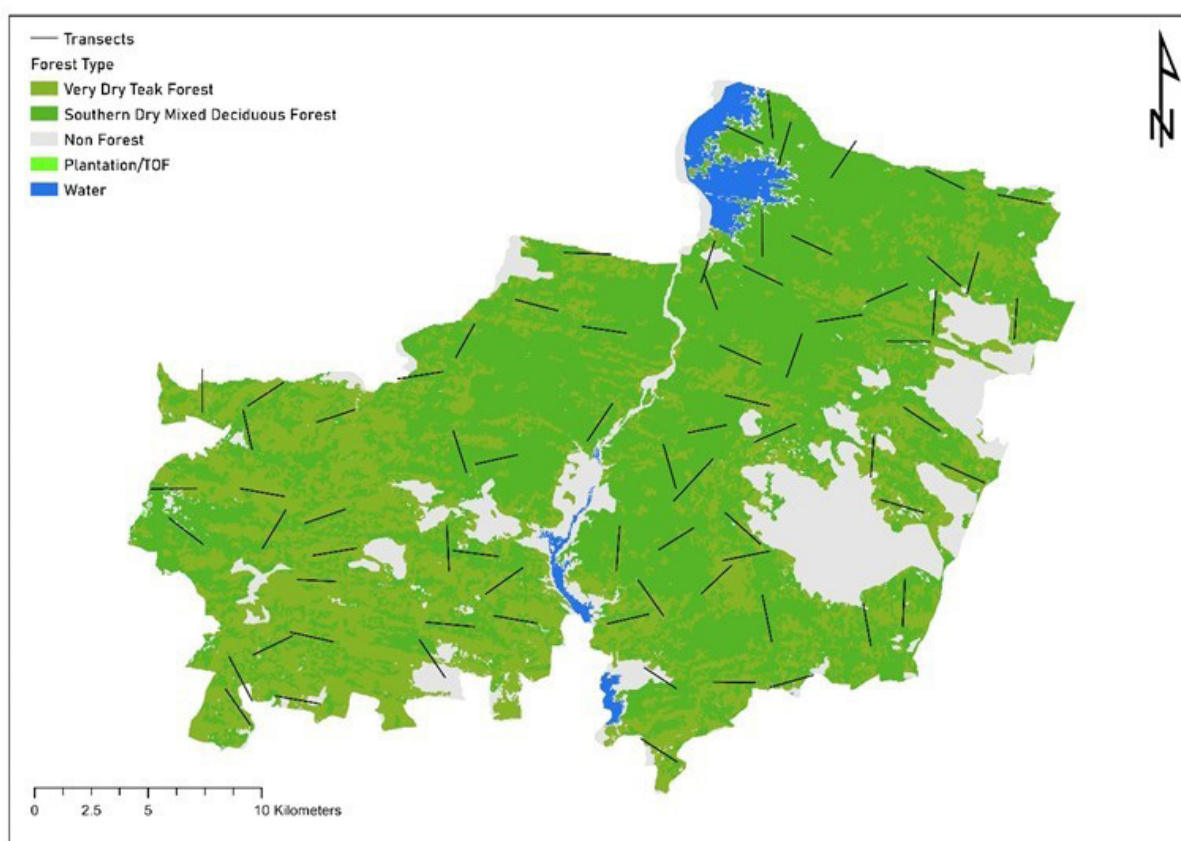


Figure 5: Locations of line transects in the Pench Tiger Reserve, Maharashtra, India during the year 2023 and 2024

During the transect exercise of Pench Tiger Reserve in 2023 and 2024, a total of 576 and 802 sightings of 10 and 12 prey species were recorded in the respective years. In 2023, Spotted Deer was the most frequently recorded species in core and buffer area with 142 and 31 sightings, with 1312 and 150 individuals (Table 3). Also in the year 2024, Spotted Deer was the most frequently recorded species in core area with a total of 155 sightings and 1897 individuals while in buffer the most frequently recorded species was Wild boar with 32 sightings and 202 individuals (Table 4). Moreover, during the transect survey carnivore species such as tiger, leopard, wild dog and sloth bear were also sighted.

Table 1: Transect monitoring effort and species reported from Pench Tiger Reserve, Maharashtra, India during the year 2023

Survey Details	Core	Buffer
Number of transects	47	23
Length of each transect	2 km	2 km
Number of replicates	7	7
Total distance covered	658 km	322 km
Beats	47	23
Number of species recorded	17	14

Table 2: Transect monitoring effort and species reported from Pench Tiger Reserve, Maharashtra, India during the year 2024

Survey Details	Core	Buffer
Number of transects	43	21
Length of each transect	2 km	2 km
Number of replicates	7	7
Total distance covered	602 km	336 km
Beats	43	21
Number of species recorded	11	12

Table 3: Details of species recorded in the Pench Tiger Reserve, Maharashtra, India during the year 2023

Species Recorded	Core		Buffer	
	Number of Sightings	Individuals recorded	Number of Sightings	Individuals recorded
Spotted Deer	142	1312	31	150
Sambar	94	360	26	60
Gaur	61	206	10	23
Nilgai	21	65	14	42
Wild Boar	54	205	24	185
Barking Deer	22	35	11	13
Langur	60	717	26	163
Indian Hare	9	12	-	-
Peafowl	50	133	11	27
Rhesus Macaque	39	301	13	195

Table 4: Details of species recorded in the Pench Tiger Reserve, Maharashtra, India during the year 2024

Species Recorded	Core		Buffer	
	Number of Sightings	Individuals recorded	Number of Sightings	Individuals recorded
Spotted Deer	155	1897	23	141
Sambar	103	325	11	25
Gaur	49	196	12	46
Nilgai	64	156	23	52
Wild Boar	56	311	32	202
Barking Deer	29	53	5	7
Langur	72	715	13	87
Indian Hare	9	9	8	8
Peafowl	41	122	13	34
Rhesus Macaque	40	338	24	134
Chinkara	-	-	1	1
Red & Grey Junglefowl	8	14	11	27

Density of all prey species (all the individual prey species combined) of PTR is 42.59 and 77.11 per sq. km in 2023 and 2024 respectively. The Individual Density, Group Density, Effective Strip Width, Average Group Size and Encounter Rate of species reported during Phase IV Monitoring 2023 and 2024 in the Core area, Buffer area and overall of Pench Tiger Reserve, Maharashtra, India is given in Table 5 (a-e). The major species sighted from line transect survey in core area were spotted deer (*Axis axis*), sambar (*Rusa unicolor*), nilgai (*Boselaphus tragocamelus*), wild boar (*Sus scrofa*) and langur (*Semnopithecus spp.*), while in buffer area the major species sighted were wild boar (*Sus scrofa*), spotted deer (*Axis axis*), nilgai (*Boselaphus tragocamelus*) and rhesus macaque (*Macaca mulatta*). However, in the year 2024 a noticeable sampling skew was present, with most spotted deer observations recorded at low radial distances, possibly leading to an overestimation of its density in the core area of PTR.

Table 5(a): Individual Density, Group Density, Effective Strip Width, Average Group Size and Encounter Rate of various ungulate species reported from the Core of Pench Tiger Reserve, Maharashtra, India during the year 2023

Parameters	Spotted Deer	Sambar	Gaur	Wild Boar	Langur	Rhesus Macaque	Peafowl
Individual density (Animals/Km <sup>2</sup> )	16.28	6.42	4.16	3.05	10.89	5.75	4.12
Standard error	4.26	1.28	0.98	0.88	2.6	2.1	1.26
Percent CV	26.16	19.96	23.66	28.88	24.89	36.55	30.74
95% confidence interval	9.74-27.21	4.34 — 9.49	2.62 -6.61	1.74 - 5.34	6.66 — 17.6	2.84 - 11.64	2.27 - 7.47
Group density (No of groups/Km <sup>2</sup> )	1.76	1.28	0.77	0.86	0.98	0.63	1.72
Standard error	0.43	0.22	0.14	0.18	0.23	0.20	0.49
Percent CV	24.62	17.31	18.67	21.88	23.53	32.75	28.51
95% confidence interval	1.086 - 2.87	0.91- 1.80	0.53 -1.11	0.56 -1.33	0.61 — 1.55	0.33 -1.20	0.98 — 3
Effective strip width	61.05	55.63	59.89	47.31	46.41	46.55	22.04
Standard error	4.24	4.59	6.52	7.65	6.75	6.04	3.51
Percent CV	6.95	8.26	10.89	16.18	14.55	12.98	15.93
95% confidence interval	53.22 -70.04	47.23- 65.53	48.20 -74.41	34.27 -65.32	34.73 — 62.00	35.83- 60.47	16.03- 30.30
Average group size	9.21	5.00	5.38	3.05	11.02	9.04	2.39
Standard error	0.81	0.22	0.14	0.88	0.87	1.46	0.27
Percent CV	8.84	17.31	18.67	28.88	7.95	16.22	11.48
95% confidence interval	7.74 -10.97	0.91- 1.80	0.53 - 1.118	1.74 - 5.34	0.61 -1.55	6.52 -12.54	1.90- 3.01
Probability of a greater chi-square value, P	0.61	0.48	0.8	0.51	0.39	0.79	0.71

Table 5(b): Individual Density, Group Density, Effective Strip Width, Average Group Size and Encounter Rate of various ungulate species reported from the Core of Pench Tiger Reserve, Maharashtra, India during the year 2024

Parameters	Spotted Deer	Sambar	Gaur	Wild Boar	Nilgai	Hanuman Langur	Rhesus Macaque	Indian Peafowl	Indian Hare
Individual density (Animals/Km <sup>2</sup> )	40.2	7.5	5.09	5.56	4.06	21.4	15.28	3.4	-
Standard error	8.24	1.53	1.40	1.45	0.84	5.16	4.58	1.00	-
Percent CV	29.48	20.29	27.62	26.06	20.70	24.06	29.96	29.52	-
95% confidence interval	26.84-60.33	5.05-11.2	2.97-8.70	3.36-9.24	2.71-6.11	13.38-34.37	8.51-27.42	1.91-6.06	-
Group density (No of groups/ Km <sup>2</sup> )	3.28	2.64	1.07	1.15	1.65	2.11	1.87	1.14	-
Standard error	0.64	0.49	0.25	0.22	0.31	0.49	0.54	0.32	-
Percent CV	19.41	18.91	23.69	19.49	19.07	23.45	28.83	28.13	-
95% confidence interval	2.23-4.83	1.81-3.84	0.67-1.71	0.78-1.69	1.13-2.40	1.33- 3.34	1.06-3.29	0.66-1.99	-
Effective strip width	39.69	32.39	37.90	40.44	32.26	28.35	17.29	29.80	-
Standard error	2.46	2.39	5.22	3.21	3.09	3.63	2.09	2.32	-
Percent CV	6.21	7.37	13.76	7.93	9.57	12.80	12.12	7.80	-
95% confidence interval	35.11-44.86	27.9-37.5	28.77-49.94	34.51-47.40	26.65-39.04	21.99-36.56	13.53-22.08	25.45-34.88	-
Average group size	12.38	3.15	4.00	5.55	2.44	10.17	8.15	2.97	-
Standard error	0.68	0.21	0.46	0.67	0.24	0.55	0.66	0.27	-
Percent CV	5.50	6.71	11.41	12.12	9.75	5.40	8.17	8.98	-
95% confidence interval	11.11-13.80	2.76-3.60	3.18-5.03	4.36-7.07	2.01-2.96	9.13- 11.32	6.91-9.62	2.48-3.57	-
Probability of a greater chi-square value, P	0.77	0.71	0.30	0.84	0.60	0.43	0.65	0.76	-



Table 5(c): Individual Density, Group Density, Effective Strip Width, Average Group Size and Encounter Rate of various ungulate species reported from the Buffer of Pench Tiger Reserve, Maharashtra, India during the year 2023

Parameters	Spotted Deer	Sambar	Langur	Wild Boar
Individual density (Animals/Km <sup>2</sup> )	4.51	1.68	1.58	5.54
Standard error	1.34	0.56	0.42	2.64
Percent CV	29.88	33.33	27.81	47.69
95% confidence interval	2.51 - 8.101	0.88 — 3.22	0.89-2.68	2.22-13.82
Group density (No of groups/Km <sup>2</sup> )	0.91	0.60	0.604	1.02
Standard error	0.23	0.177	0.133	0.28
Percent CV	25.77	29.31	27.81	27.55
95% confidence interval	0.54- 1.51	0.33-1.08	0.89-2.68	0.59-1.77
Effective strip width	52.84	66.58	66.79	36.30
Standard error	7.764	12.54	3.64	5.54
Percent CV	14.69	18.84	5.46	15.27
95% confidence interval	39.21- 71.22	45.32- 97.82	59.68-74.75	26.51-49.69
Average group size	4.95	2.78	2.55	5.4
Standard error	0.23	0.4412	0.39	2.1
Percent CV	25.77	15.87	23.11	38.93
95% confidence interval	0.54-1.51	2-3.85	0.377-0.967	2.47- 11.77
Probability of a greater chi-square value, P	0.35	0.66	0.43	0.97

Table 5(d): Individual Density, Group Density, Effective Strip Width, Average Group Size and Encounter Rate of various ungulate species reported from the Buffer of Pench Tiger Reserve, Maharashtra, India during the year 2023

Parameters	Spotted Deer	Sambar	Wild Boar	Nilgai	Hanuman
Langur					
Individual density (Animals/Km <sup>2</sup> )	4.36	-	7.32	1.81	-
Standard error	1.42	-	2.31	0.62	-
Percent CV	32.60	-	31.52	34.32	-
95% confidence interval	2.31- 8.24	-	3.97- 13.49	0.92- 3.53	-
Group density					
(No of groups/Km <sup>2</sup> )	0.70	-	1.52	0.66	-
Standard error	0.21	-	0.29	0.19	-
Percent CV	29.44	-	24.98	30.17	-
95% confidence interval	0.39- 1.25	-	0.71- 1.89	0.36- 1.21	-
Effective strip width	46.76	-	41.08	51.63	-
Standard error	8.23	-	7.17	6.95	-
Percent CV	17.59	-	17.45	13.46	-
95% confidence interval	32.52- 67.23	-	28.85- 58.49	39.10- 68.18	-

Average group size	6.23	-	6.31	2.26	-
Standard error	0.87	-	1.21	0.38	-
Percent CV	14.01	-	19.22	16.73	-
95% confidence interval	4.66- 8.32	-	4.28- 9.31	1.60- 3.19	-
Probability of a greater chi-square value, P	0.62	-	0.86	0.84	-

Table 5(e): Individual Density, Group Density, Effective Strip Width, Average Group Size and Encounter Rate of various ungulate species reported from the overall of Pench Tiger Reserve, Maharashtra, India during the year 2024

Parameters	Spotted Deer	Sambar	Wild Boar	Nilgai	Gaur	Barking Deer	Langur	Rhesus macaque	Pea-fowl
Individual density (Animals/Km <sup>2</sup> )	32.12	5.03	6.99	3.22	3.78	1.17	14.97	10.21	1.99
Standard error	6.39	1.02	1.53	0.59	1.02	0.34	3.25	2.54	0.51
Percent CV	19.91	20.29	21.94	18.59	25.61	29.30	21.74	24.92	25.67
95% confidence interval	21.71-47.50	3.37-7.49	4.56-10.72	2.23-4.63	2.3-6.22	0.66-2.06	9.77-22.93	6.27-16.63	1.21-3.29
Group density (No of groups/Km <sup>2</sup> )	2.56	1.81	1.23	1.36	0.82	0.64	1.46	1.37	0.98
Standard error	0.49	0.34	0.19	0.23	0.18	0.17	0.30	0.33	0.23
Percent CV	18.84	19.07	15.85	17.19	22.28	27.26	20.74	23.88	24.05
95% confidence interval	1.77-3.72	1.24-2.63	0.90-1.68	0.97-1.90	0.53-1.27	0.38-1.09	0.97-2.20	0.86-2.19	0.61-1.56
Effective strip width	39.66	35.23	39.39	34.51	40.75	29.53	32.02	25.19	30.39
Standard error	2.57	2.45	2.75	2.97	5.04	5.84	2.39	1.73	2.22
Percent CV	6.49	6.96	6.98	8.62	12.37	16.41	7.49	6.88	7.33
95% confidence interval	34.90-45.07	30.69-40.44	34.29-45.25	29.09-49.95	31.84-52.15	21.19-41.16	27.59-37.16	21.95-28.90	26.15-35.08
Average group size	12.51	3.07	5.78	2.31	3.98	1.76	9.69	7.44	2.90
Standard error	0.79	0.19	0.6	0.19	0.39	0.29	0.50	0.52	0.24
Percent CV	6.44	6.44	10.68	8.36	9.90	16.41	5.16	7.09	8.41
95% confidence interval	11.01-14.20	2.70-3.49	4.68-7.14	1.96-2.73	3.27-4.85	1.26-2.46	8.75-10.74	6.45-8.56	2.45-3.44
Probability of a greater chi-square value, P	0.67	0.96	0.75	0.53	0.39	0.60	0.77	0.35	0.41

Table 6(a): Comparison of prey density in the Core of Pench Tiger Reserve, Maharashtra, India during the years 2020 - 2024 (standard errors are given in the parenthesis)

Species Recorded	2020	2021	2022	2023	2024
Spotted Deer	25.54 ( $\pm 4.44$ )	24.28 ( $\pm 4.83$ )	24.09 ( $\pm 5.38$ )	16.28( $\pm 4.26$ )	40.2 ( $\pm 8.24$ )
Sambar	7.23 ( $\pm 1.10$ )	6.08 ( $\pm 0.98$ )	5.33 ( $\pm 1.13$ )	6.42( $\pm 1.28$ )	7.5 ( $\pm 1.53$ )
Gaur	2.55 ( $\pm 0.55$ )	1.56 ( $\pm 0.39$ )	2.69 ( $\pm 0.98$ )	4.16( $\pm 0.98$ )	5.09 ( $\pm 1.40$ )
Wild boar	8.25 ( $\pm 1.50$ )	4.31 ( $\pm 0.90$ )	6.22 ( $\pm 1.96$ )	3.05( $\pm 0.88$ )	5.56 ( $\pm 1.45$ )
Langur	16.81 ( $\pm 4.01$ )	17.02 ( $\pm 3.56$ )	4.10 ( $\pm 1.56$ )	10.89( $\pm 0.42$ )	21.4 ( $\pm 5.16$ )
Nilgai	2.27 ( $\pm 0.44$ )	1.91 ( $\pm 0.41$ )	3.65 ( $\pm 0.93$ )	-	4.06 ( $\pm 0.84$ )
Barking Deer	0.99 ( $\pm 0.22$ )	0.59 ( $\pm 0.15$ )	-	-	-
Indian Hare	1.15 ( $\pm 0.29$ )	1.12 ( $\pm 0.32$ )	0.72 ( $\pm 0.27$ )	-	-
Peafowl	3.05 ( $\pm 0.78$ )	2.49 ( $\pm 0.60$ )	1.56 ( $\pm 0.65$ )	4.1( $\pm 1.26$ )	3.4 ( $\pm 1.00$ )
Rhesus Macaque	-	-	-	5.75 ( $\pm 2.1$ )	15.28 ( $\pm 4.58$ )

Table 6(b): Comparison of prey density in the Buffer of Pench Tiger Reserve, Maharashtra, India during the years 2020 - 2024 (standard errors are given in the parenthesis)

Species Recorded	2020	2021	2022	2023	2024
Spotted Deer	6.65 ( $\pm 2.50$ )	8.63 ( $\pm 4.15$ )	2.59 ( $\pm 1.21$ )	4.51( $\pm 1.34$ )	5.30 ( $\pm 1.82$ )
Sambar	1.52 ( $\pm 0.69$ )	-	-	1.68( $\pm 0.56$ )	-
Nilgai	1.44 ( $\pm 0.56$ )	1.36 ( $\pm 0.40$ )	-	-	1.81 ( $\pm 0.62$ )
Wild boar	4.57 ( $\pm 1.87$ )	-	-	5.54( $\pm 2.64$ )	7.32 ( $\pm 2.31$ )
Langur	6.98 ( $\pm 2.37$ )	-	-	1.58( $\pm 0.42$ )	-

# Status of Predators in Pench Tiger Reserve

## Camera Trapping:

Potential locations of camera trap stations were mapped using ArcGIS 9.3 (ESRI, Redlands, CA, USA) based on crucial data provided by the frontline forest staff of PTR. For the Phase IV exercise a total of 296 and 313 camera traps (pairs) were deployed in Pench Tiger Reserve (Figure 6) in a grid size of 2 sq. km. each in the year 2023 and 2024 respectively. The total camera-trapped area was covered as a double block in 2023 and single block in 2024 with a sampling period of 30 days. One pair of camera traps were deployed in each location for 28-30 days resulting in a cumulative sampling effort of 9104 and 9314 trap nights for both respective years. Four different models of camera traps (CuddeBack C1, CuddeBack Ambush, CuddeBack Professional Color and ScoutGuard) were used for this exercise.

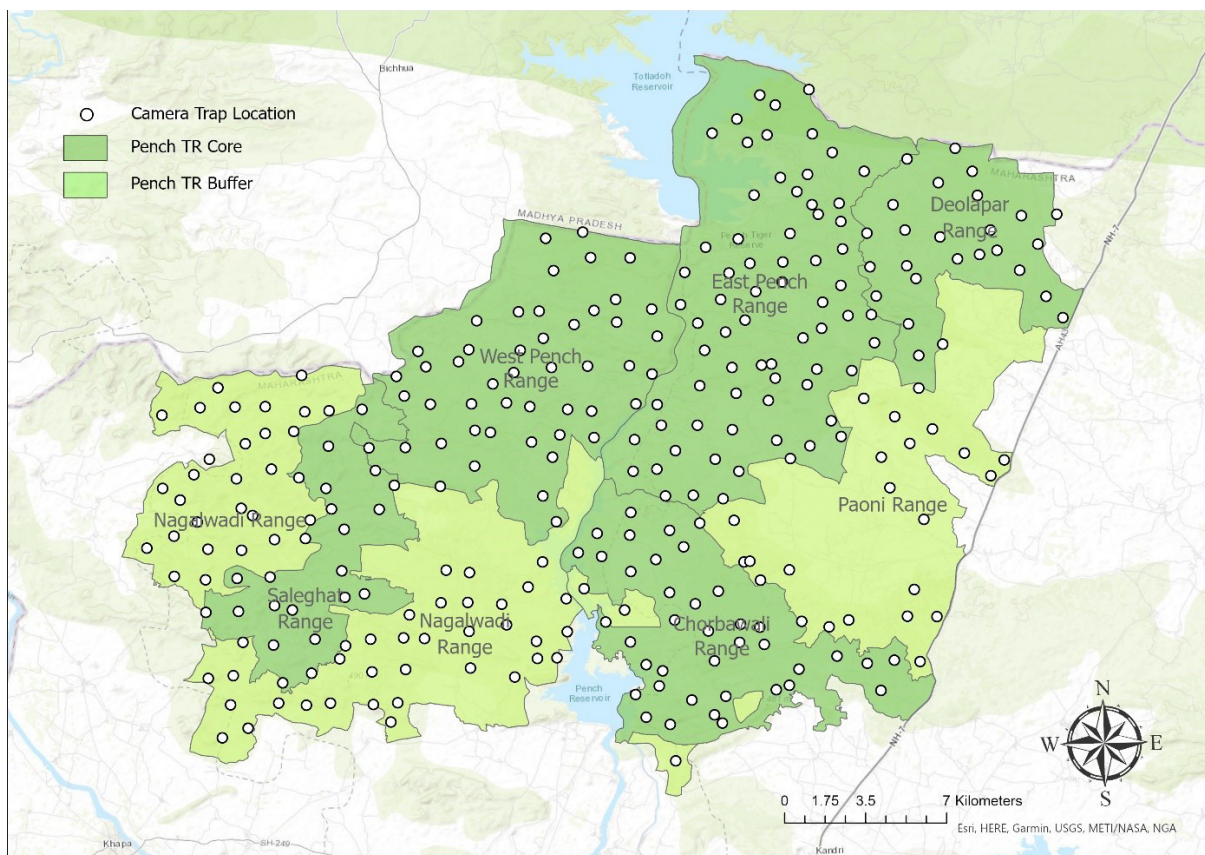


Figure 6: Map depicting camera trap placement locations in Pench Tiger Reserve, Maharashtra, India in the year 2023 and 2024

## Population Estimation for Tigers and Leopards:

During 30 days of camera trapping for tigers, a total sampling effort of 9104 and 9314 trap nights 49 and 51 adult individual tigers was photographed within the core and buffer area of PTR in 2023 and 2024 respectively. 74 and 76 adult leopards were identified based on the rosette pattern of the left flank (which had the maximum number of images) for both the respective years. However, only the right flanks have been used in the tiger album to maintain uniformity with previous years. For estimating the density and population, "SECR" instead of the conventional capture-recapture model was used. The MCPs of Tigers and Leopards are shown in Figure 7 (a – l).

Tiger density per 100 sq. km. based on the SECR Heterogeneity ( $g_0, \sigma$ ) model was estimated to be 7.95 (SE  $\pm 1.14$ ) and 8.3 (SE  $\pm 1.17$ ) for PTR in 2023 and 2024 respectively. Leopard density per 100 sq. km. based on the SECR Heterogeneity ( $\sigma$ ) model was estimated to be 12.54 (SE  $\pm 1.46$ ) and 13.5 (SE  $\pm 1.58$ ) for

PTR in 2023 and 2024 respectively. The best model for the density estimate is chosen according to the AIC (Akaike Information Criterion). The details for tigers are provided in Table 7 (a – d) and for leopards in Table 7 (e – h).  $g_0$  is the detection probability for the species, it is assumed to be constant or variable depending on the distribution. Sigma ( $\sigma$ ) is the distribution of the average movement of the animal. It increases if the individuals are captured at very far away locations.

Table 7(a): Density estimates of tigers using Spatially Explicit Capture-Recapture Models in Pench Tiger Reserve, Maharashtra, India for the years 2020 – 2024

Parameters	Tiger 2020	Tiger 2021	Tiger 2022	Tiger 2023	Tiger 2024
Model	Heterogeneity	Heterogeneity	Heterogeneity	Heterogeneity	Heterogeneity
Detection Function	Half normal	Half normal	Half normal	Half normal	Half normal
Density Estimate	6.26	7.11	6.57	7.95	8.3
Density Standard Error	1.01	1.08	1.03	1.14	1.17
Density Confidence Interval	4.57 - 8.57	5.29 - 9.56	4.84 – 8.93	6.01 – 10.53	6.33-10
$g_0$ Estimate	0.07	0.041	0.042	0.051	0.039
$g_0$ Standard Error	0.009	0.005	0.004	0.001	0.0007
$g_0$ Confidence Interval	0.06 - 0.09	0.032 - 0.053	0.035 – 0.050	0.050 - 0.051	0.022-0.062
Sigma Estimate	1.26	2.244	2.52	1.84	2.01
Sigma Standard Error	0.062	0.103	0.106	0.070	0.013
Sigma Confidence Interval	1.14 - 1.39	2.051 - 2.456	2.313 – 2.729	1.71- 1.98	1.32-2.83

Table 7(b): Population estimates of tigers in Pench Tiger Reserve, Maharashtra, India for the years 2020 – 2024

Year	Effective trapping area (sq. km.)	No. of Individuals Captured	Estimate	Density per 100 sq. km.
2020	622	39	39 ( $\pm 0.74$ )	6.26 ( $\pm 1.01$ )
2021	622	44	44 ( $\pm 0.94$ )	7.11 ( $\pm 1.08$ )
2022	622	41	41 ( $\pm 0.72$ )	6.57 ( $\pm 1.03$ )
2023	622	49	49 ( $\pm 0.73$ )	7.95 ( $\pm 1.14$ )
2024	622	51	51 ( $\pm 0.9$ )	8.3 ( $\pm 1.17$ )

Table 7(c): Comparison of number of tigers utilizing core and buffer of Pench Tiger Reserve, Maharashtra, India for the years 2020 – 2024

Details	2020	2021	2022	2023	2024
Tigers (Exclusively Core)	27	29	29	27	31
Tigers (Exclusively Buffer)	00	01	01	14	03
Tigers (Core and Buffer)	12	14	11	08	17

Table 7(d): Comparison of number of individual tigers (adult males and adult females) captured in Pench Tiger Reserve, Maharashtra, India for the years 2020 – 2024

Year	2020	2021	2022	2023	2024
Adult Males	16	19	17	24	28
Adult Females	23	22	24	22	19
Adult (Sex Unknown)	00	03	00	03	04

Table 7(e): Density estimates of leopards using Spatially Explicit Capture-Recapture Models in Pench Tiger Reserve, Maharashtra, India for the years 2020 – 2024

Parameters	Leopard 2020	Leopard 2021	Leopard 2022	Leopard 2023	Leopard 2024
Model	Heterogeneity	Heterogeneity	Heterogeneity	Heterogeneity	Heterogeneity
Detection Function	Half normal	Half normal	Half normal	Half normal	Half normal
Density Estimate	10.01	9.274	11.582	12.54	13.5
Density Standard Error	1.31	1.233	1.396	1.46	1.58
Density Confidence Interval	7.88 - 13.0	7.155 - 12.020	9.154 - 14.655	9.98 – 15.77	10.8 – 17
g0 Estimate	0.008	0.018	0.022	0.05	0.02
g0 Standard Error	0.009	0.003	0.002	0.001	0.0002
g0 Confidence Interval	0.0063 - 0.0102	0.013 - 0.025	0.019 - 0.026	0.053 – 0.059	0.012 – 0.03
Sigma Estimate	2.63	1.865	1.582	3.855	1.54
Sigma Standard Error	0.089	0.144	0.095	0.02	0.008
Sigma Confidence Interval	2.46 - 2.81	1.604 - 2.170	1.407 - 1.780	3.46 – 4.28	1.13 – 2.07

Table 7(f): Population estimates of leopards in Pench Tiger Reserve, Maharashtra, India for the years 2020 – 2024

Year	Effective trapping area (sq. km.)	No. of Individuals Captured	Estimate	Density per 100 sq. km.
2020	622	61	63 (±1.83)	10.01 (±1.31)
2021	622	60	68 (±3.76)	9.27 (±1.23)
2022	622	74	86 (±4.56)	11.58 (±1.40)
2023	622	74	85 (±5.86)	12.55 (±1.47)
2024	622	76	83 (±3.35)	13.5 (±1.58)

Table 7(g): Population estimates of leopards in Pench Tiger Reserve, Maharashtra, India for the years 2020 – 2024

Details	2020	2021	2022	2023	2024
Leopards (Exclusively Core)	26	36	52	41	49
Leopards (Exclusively Buffer)	16	17	10	19	18
Leopards (Core and Buffer)	19	7	12	13	9

Table 7(h): Population estimates of leopards in Pench Tiger Reserve, Maharashtra, India for the years 2020 – 2024

Year	2020	2021	2022	2023	2024
Adult Males	18	18	24	26	30
Adult Females	25	22	38	37	34
Adult (Sex Unknown)	18	20	12	11	12

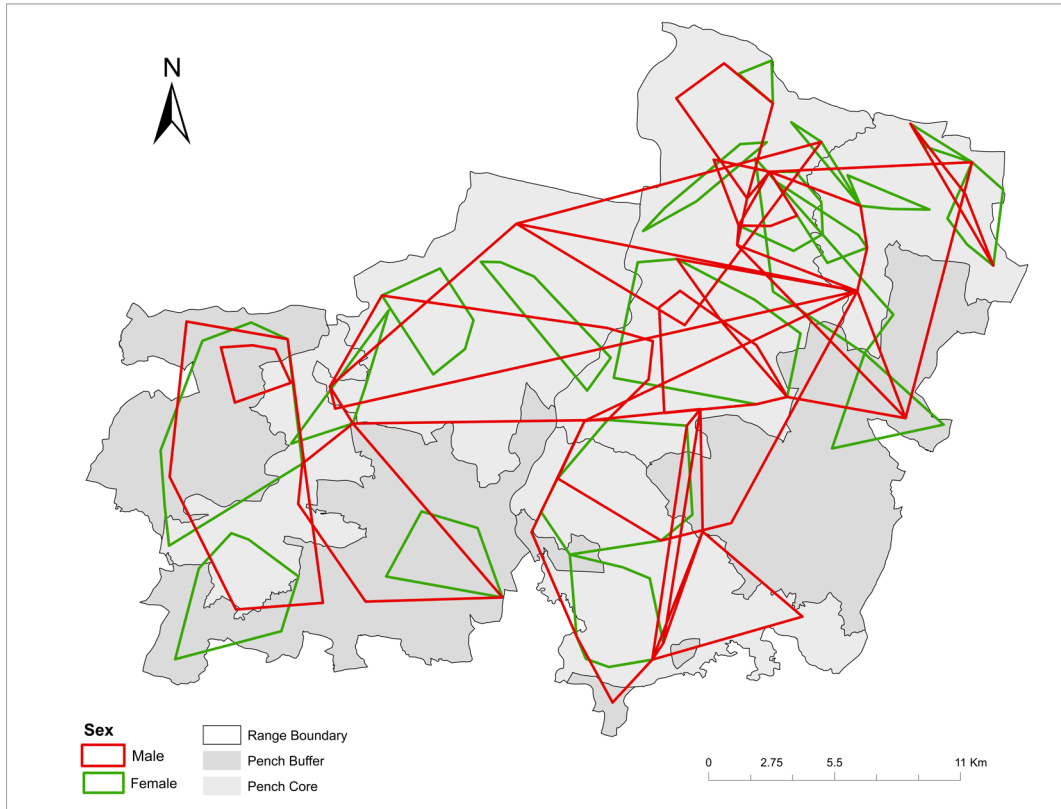


Figure 7(a): Minimum Convex Polygon of Tigers (Male - Female overlap) in Pench Tiger Reserve, Maharashtra, India during the year 2023

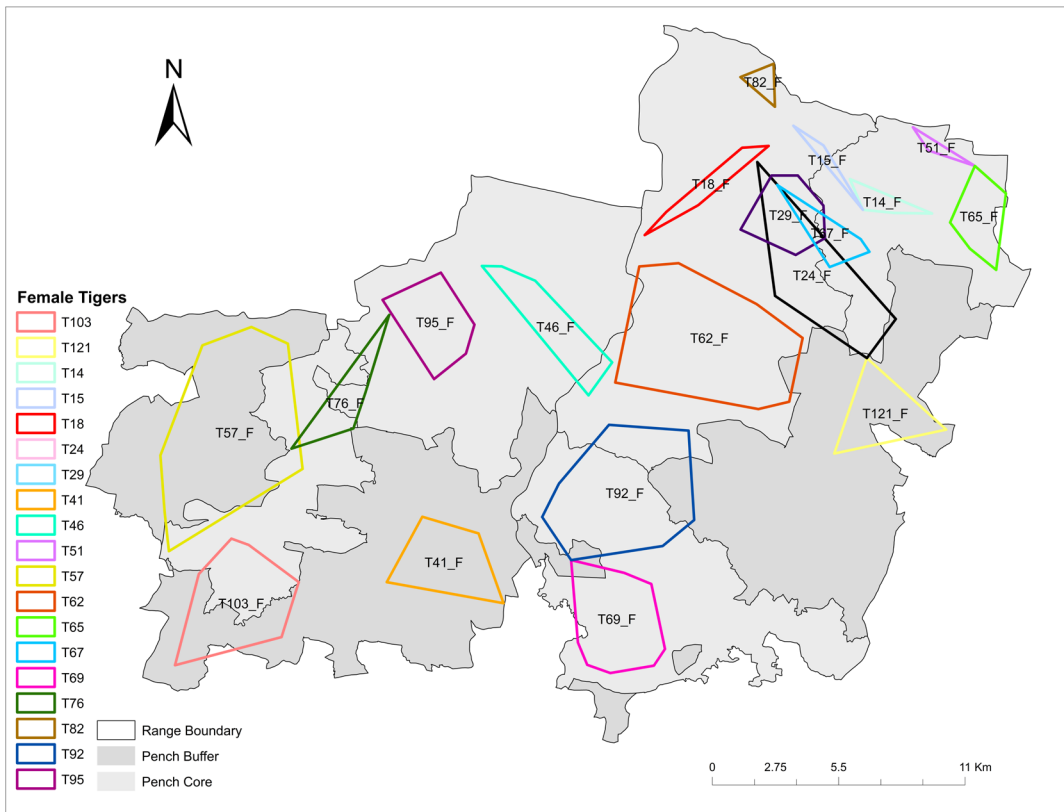


Figure 7(b): Minimum Convex Polygon of Tigers (Females) in Pench Tiger Reserve, Maharashtra, India during the year 2023

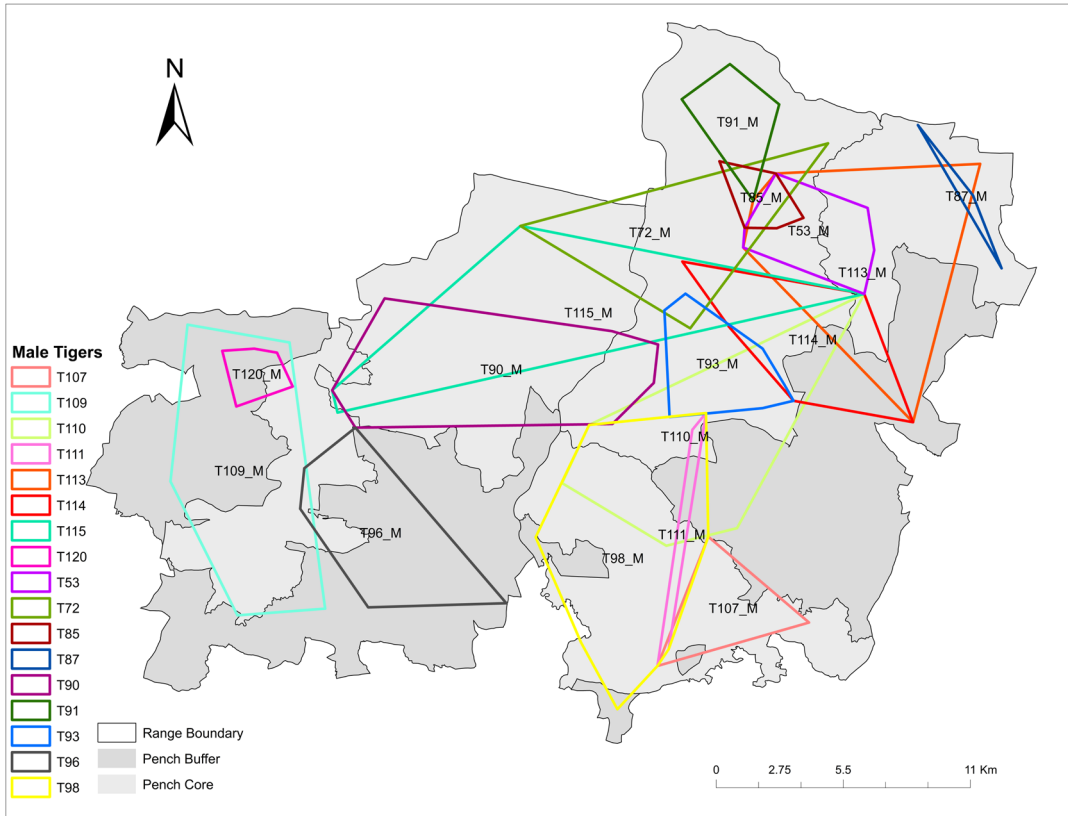


Figure 7(c): Minimum Convex Polygon of Tigers (Males) in Pench Tiger Reserve, Maharashtra, India during the year 2023

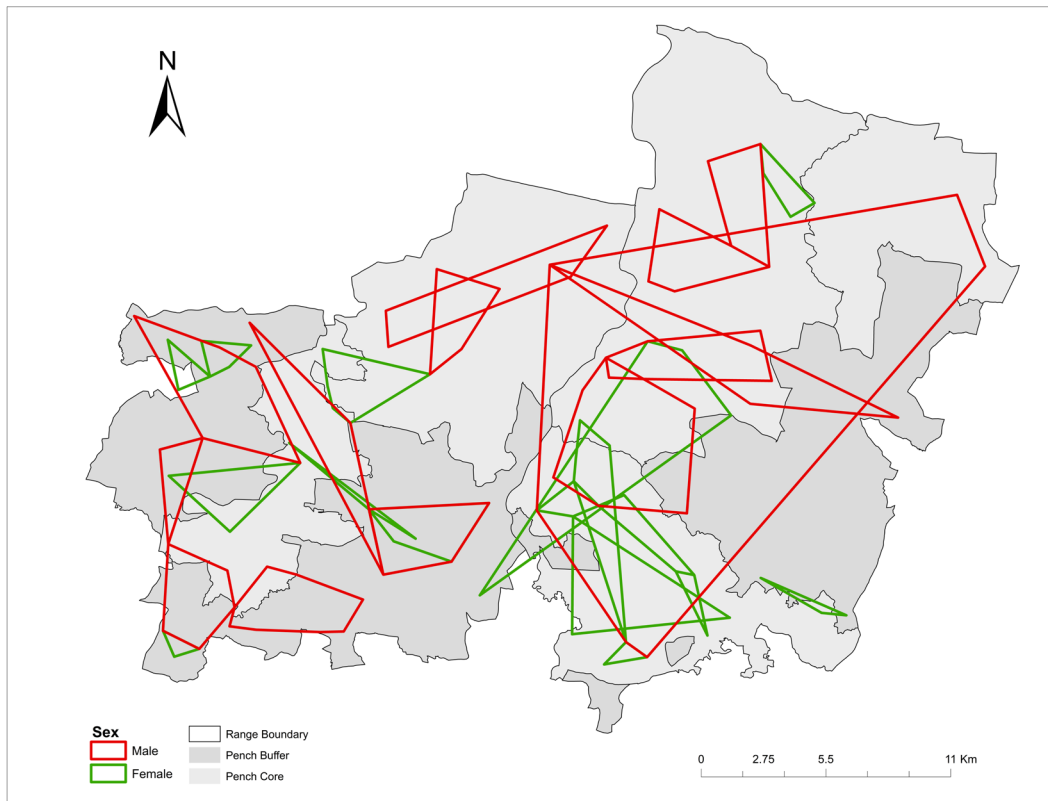


Figure 7(d): Minimum Convex Polygon of Leopards (Male - Female overlap) in Pench Tiger Reserve, Maharashtra, India during the year 2023



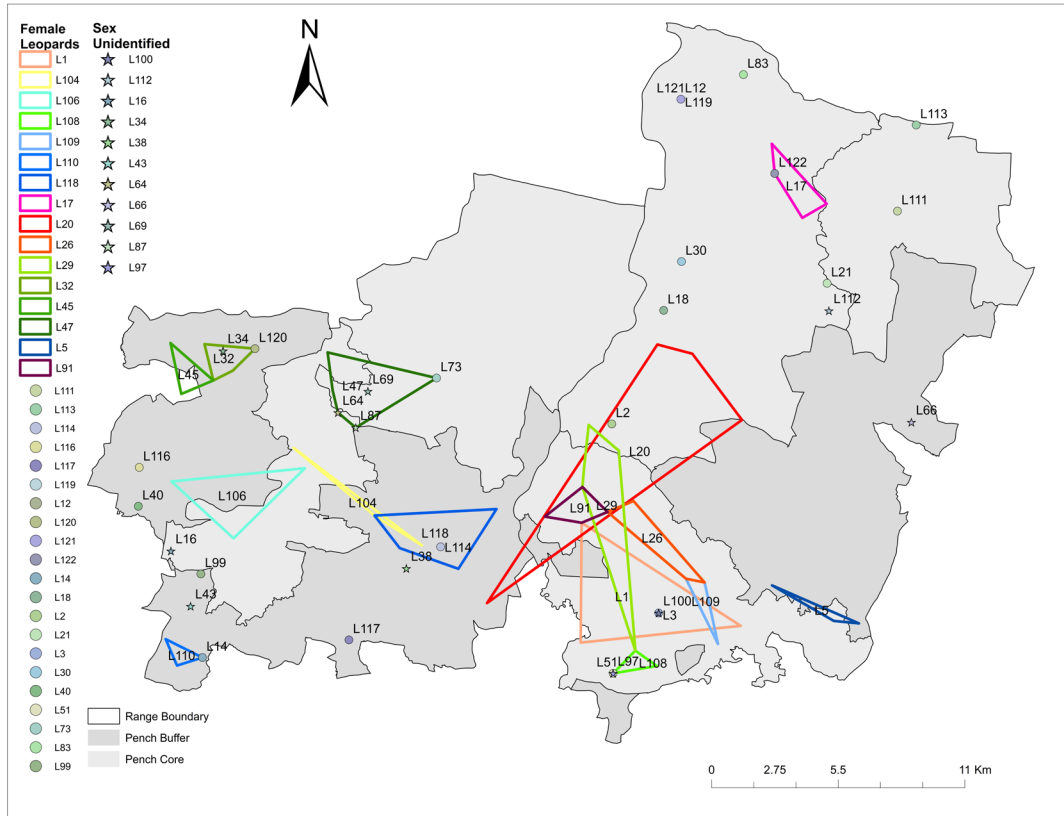


Figure 7(e): Minimum Convex Polygon of Leopards (Females) in Pench Tiger Reserve, Maharashtra, India during the year 2023

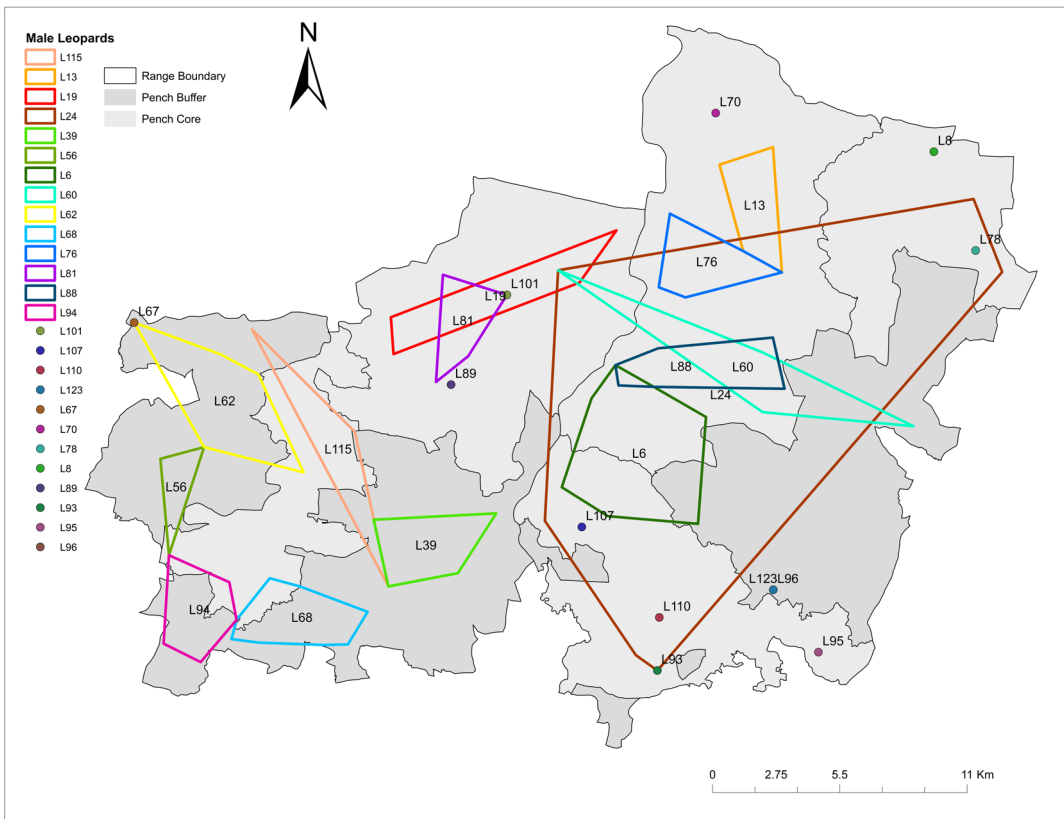


Figure 7(f): Minimum Convex Polygon of Leopards (Males) in Pench Tiger Reserve, Maharashtra, India during the year 2023

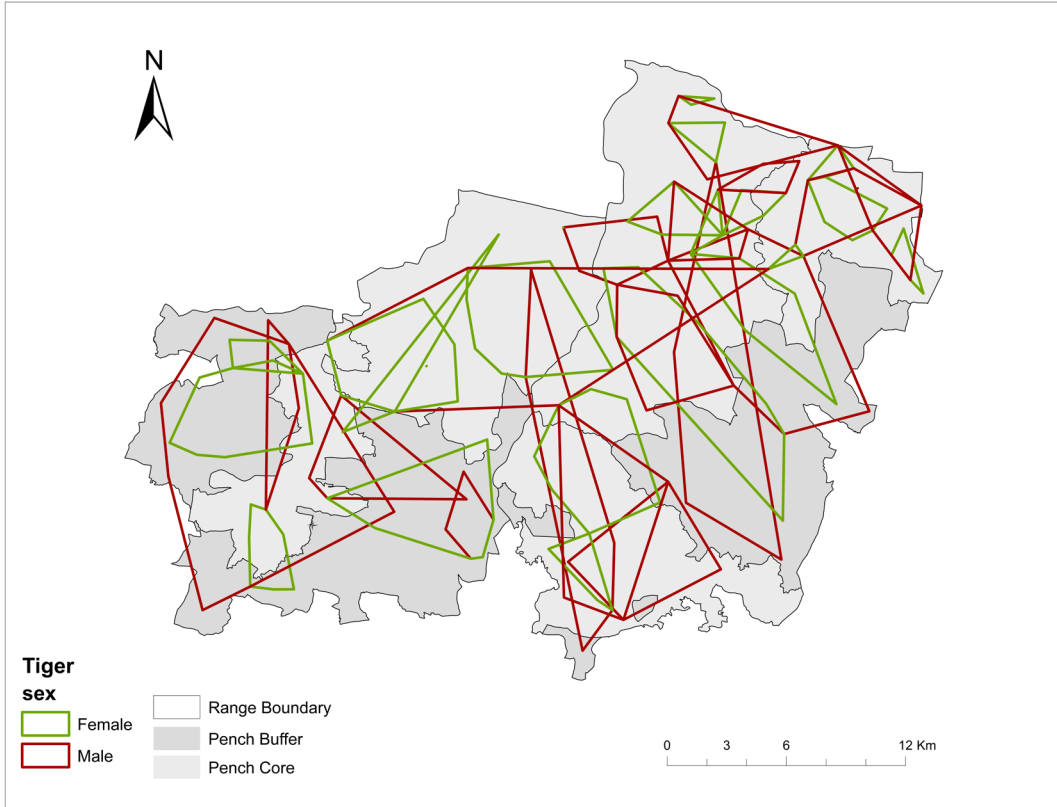


Figure 7(g): Minimum Convex Polygon of Tigers (Male - Female overlap) in Pench Tiger Reserve, Maharashtra, India during the year 2024

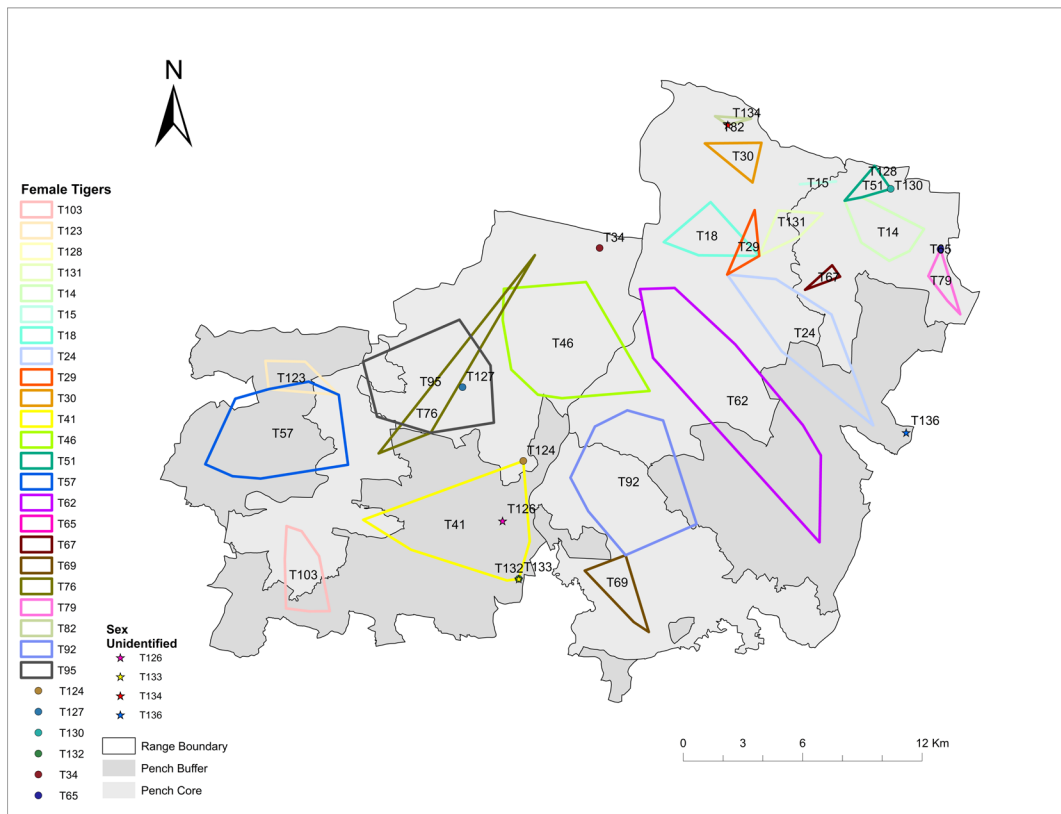


Figure 7(h): Minimum Convex Polygon of Tigers (Females) in Pench Tiger Reserve, Maharashtra, India during the year 2024

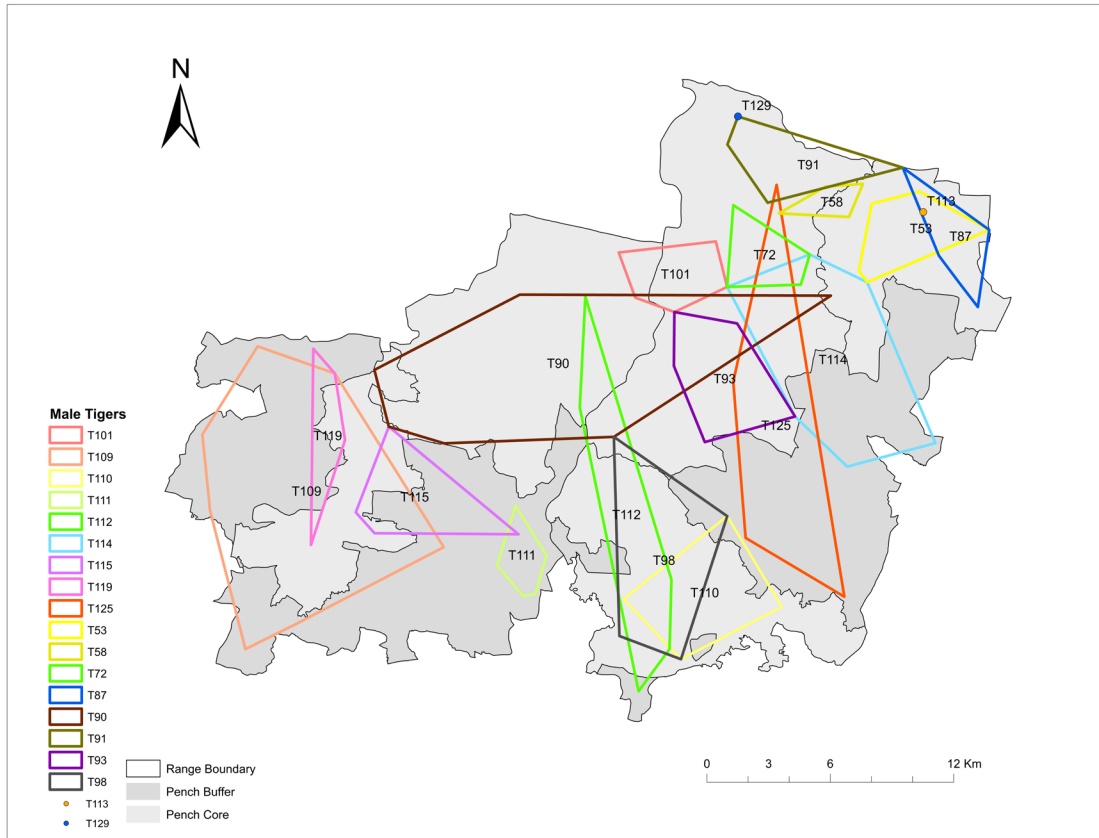


Figure 7(i): Minimum Convex Polygon of Tigers (Males) in Pench Tiger Reserve, Maharashtra, India during the year 2024

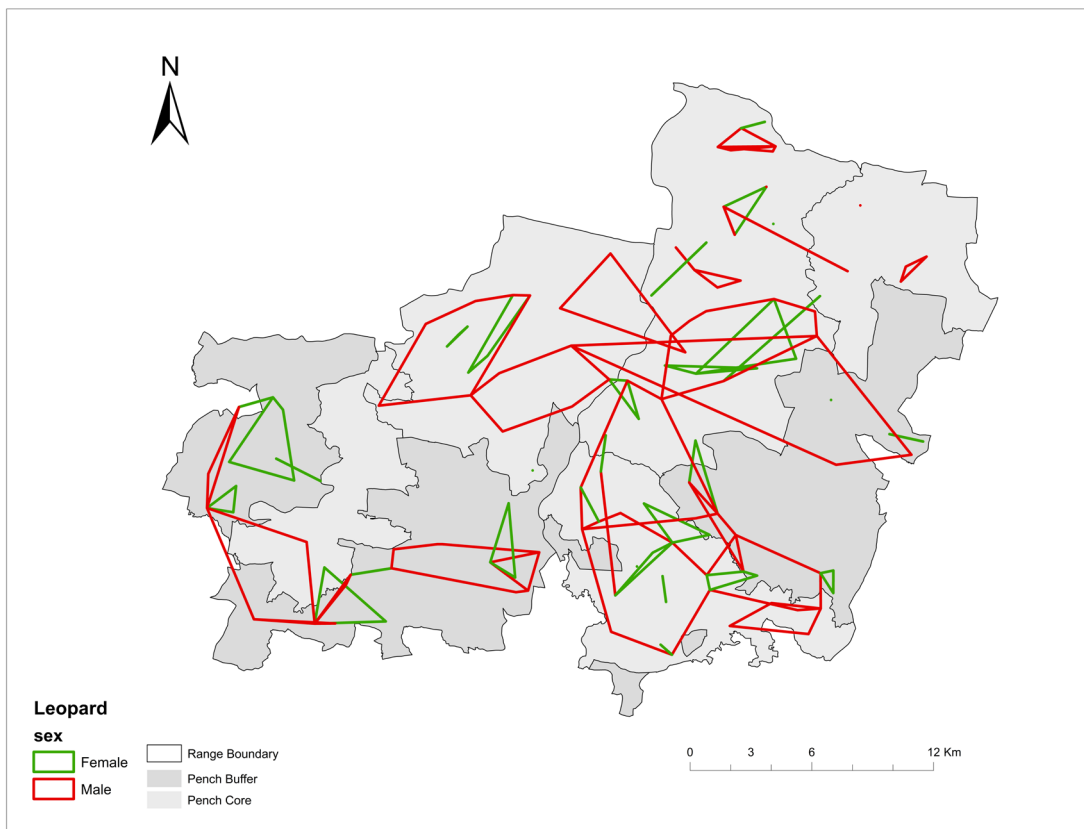


Figure 7(j): Minimum Convex Polygon of Leopards (Male - Female overlap) in Pench Tiger Reserve, Maharashtra, India during the year 2024

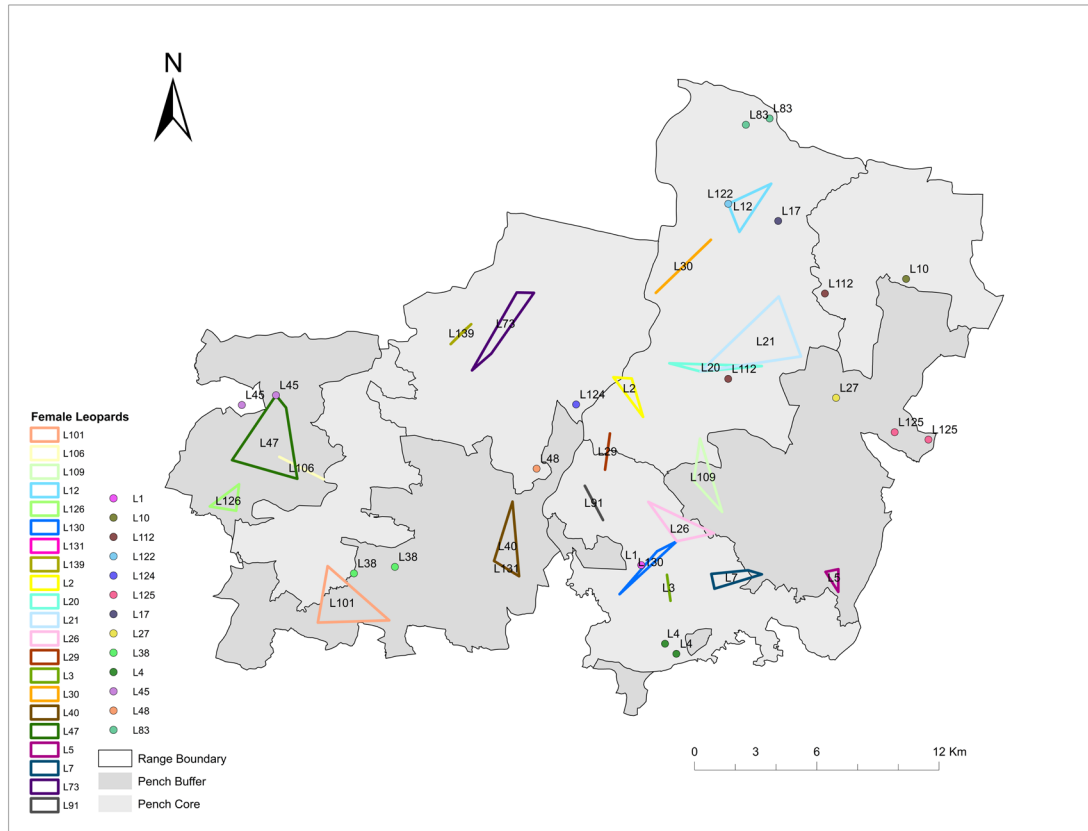


Figure 7(k): Minimum Convex Polygon of Leopards (Females) in Pench Tiger Reserve, Maharashtra, India during the year 2024

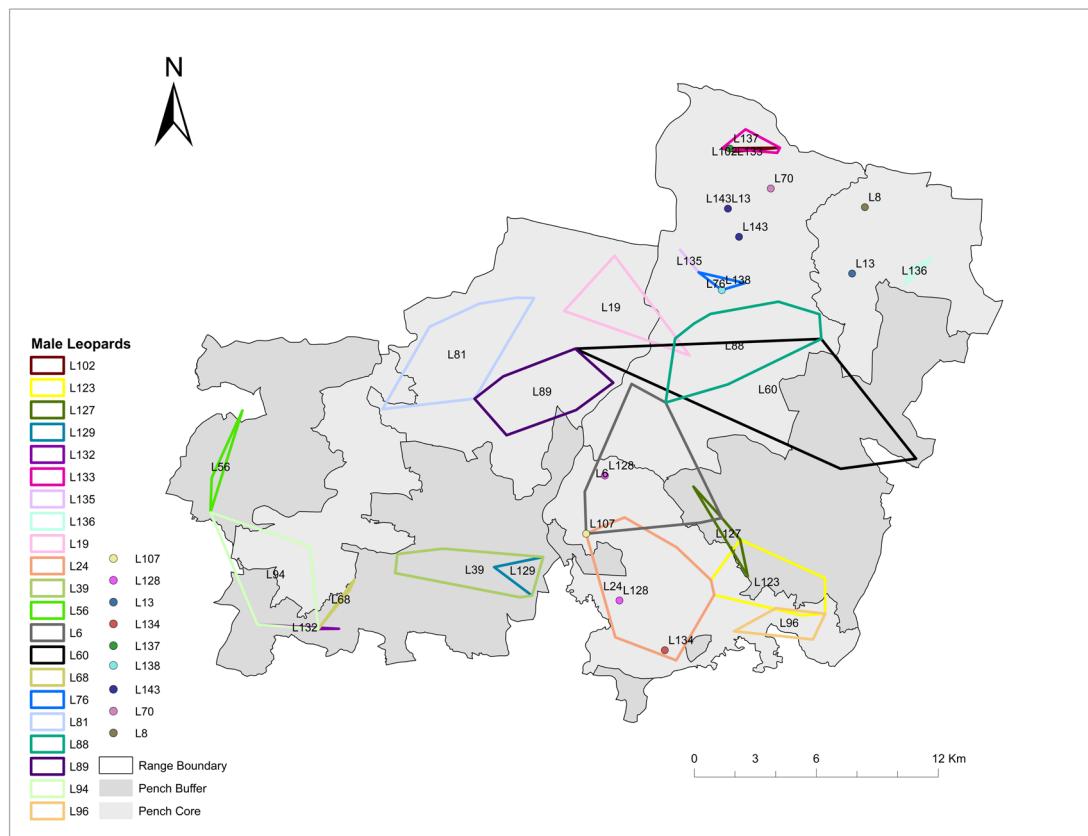


Figure 7(l): Minimum Convex Polygon of Leopards (Males) in Pench Tiger Reserve, Maharashtra, India during the year 2024

# Temporal Activity of Predators and Prey Species in Pench Tiger Reserve

The Kernel density estimates of daily temporal activity patterns of different predator species are shown in Figure 9.1 – 9.4. From the kernel density estimators, the tiger and leopard were observed to have a high degree of overlap *i.e.* 0.89 and 0.83 in 2023 and 2024 respectively as indicated by the estimated overlap coefficients in Table 8.1 and 8.2

Table 8.1: Temporal activity overlap of predator and prey species in Pench Tiger Reserve, Maharashtra, India during the year 2023

Species	Tiger	Leopard	Wild Dog
Sambar	0.8	0.85	0.54
Spotted Deer	0.48	0.49	0.71
Gaur	0.8	0.8	0.55
Wild Boar	0.47	0.48	0.82
Golden Jackal	0.65	0.65	0.66
Four Horned Antelope	0.34	0.33	0.5
Nilgai	0.48	0.49	0.71
Indian hare	-	0.78	0.3
Langur	-	0.28	0.63
Tiger	-	0.89	0.47
Leopard	0.89	-	0.49
Wild Dog	0.47	0.49	-

Table 8.2: Temporal activity overlap of predator and prey species in Pench Tiger Reserve, Maharashtra, India during the year 2024

Species	Tiger	Leopard	Wild Dog
Sambar	0.86	0.88	0.63
Spotted Deer	0.57	0.67	0.74
Gaur	0.88	0.83	0.7
Wild Boar	0.64	0.72	0.87
Four Horned Antelope	0.71	0.77	0.66
Barking Deer	0.52	0.42	0.57
Nilgai	0.59	0.67	0.76
Indian hare	0.61	0.65	0.6
Langur	0.51	0.44	0.63
Tiger	-	0.83	0.64
Leopard	0.83	-	0.71
Wild Dog	0.64	0.71	-

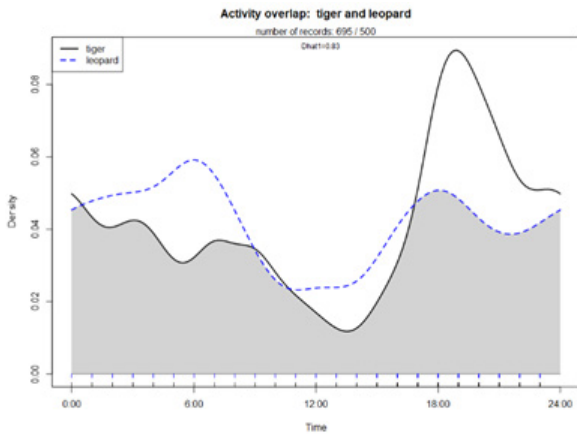


Figure 9.1(a): Tiger - Leopard

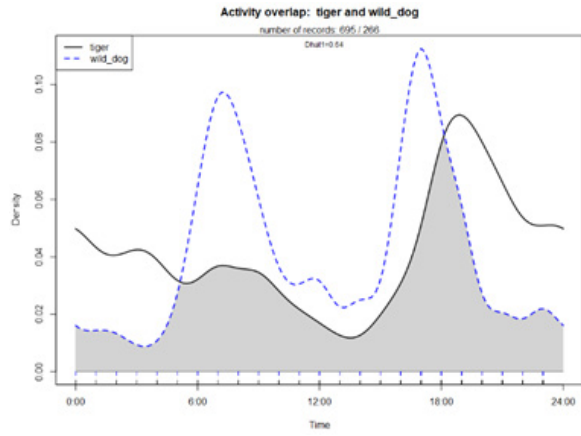


Figure 9.1(b): Tiger - Wild Dog

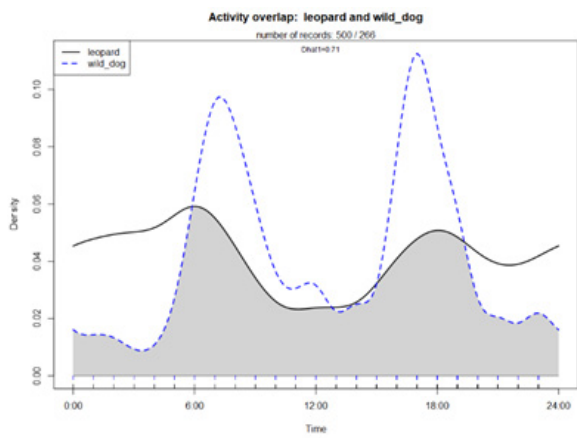


Figure 9.1(c): Leopard - Wild Dog

Figures 9.1 (a-c): Daily temporal activity pattern overlap between co-predators a) tiger vs. leopard; b) tiger vs. wild dog; c) leopard vs. wild dog in Pench Tiger Reserve, Maharashtra, India during the year 2024. The lines represent the kernel density estimates based on individual photograph times. The overlap is shown by the shaded area in each plot.

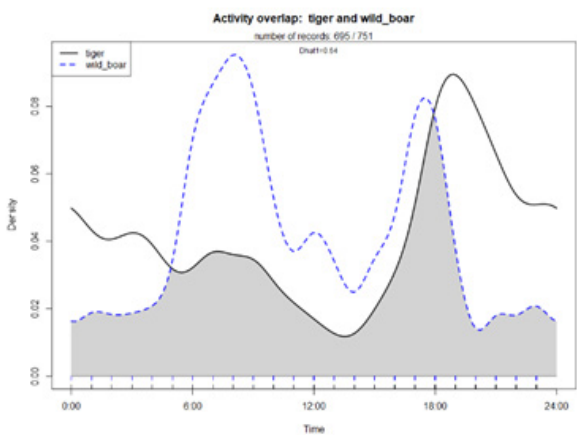


Figure 9.2(a): Tiger - Wild Boar

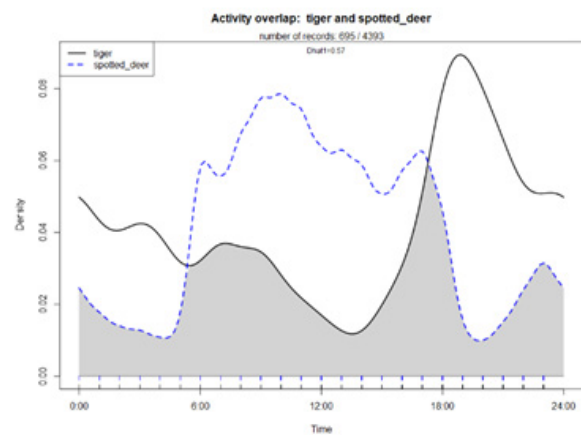


Figure 9.2(b): Tiger - Spotted Deer

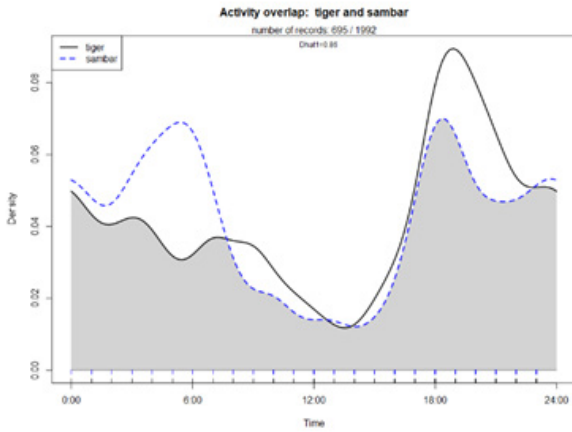


Figure 9.2(c): Tiger - Sambar

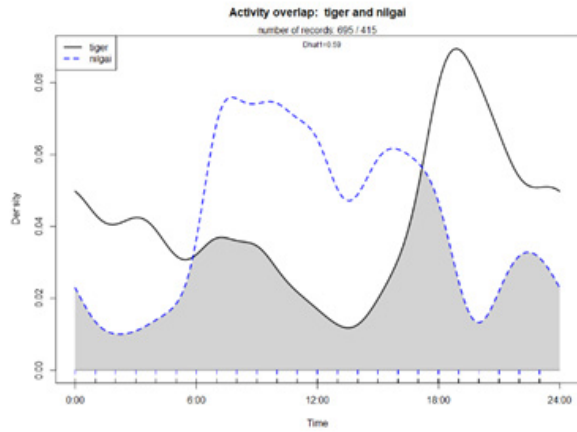


Figure 9.2(d): Tiger - Nilgai

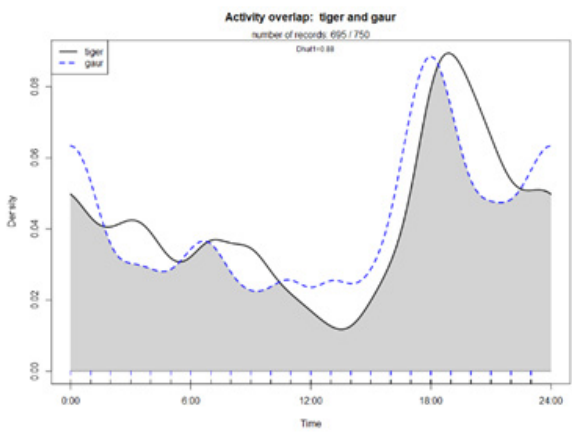


Figure 9.2(e): Tiger - Gaur

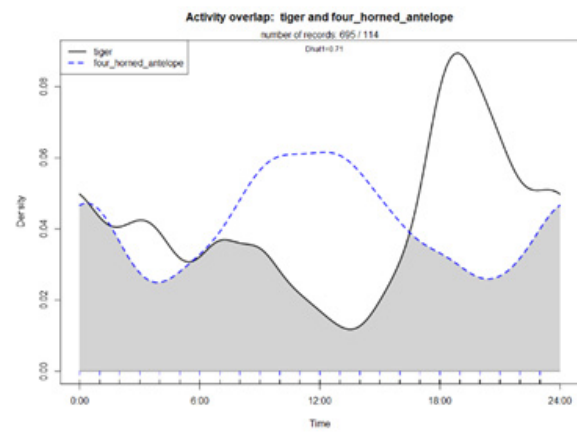


Figure 9.2(f): Tiger - Four Horned Antelope

Figures 9.2(a-f): Daily temporal activity patterns of the Tiger vs. prey species in Pench Tiger Reserve, Maharashtra, India during the year 2024. The lines represent the kernel density estimates based on individual photograph times. The overlap is shown by the shaded area in each plot.

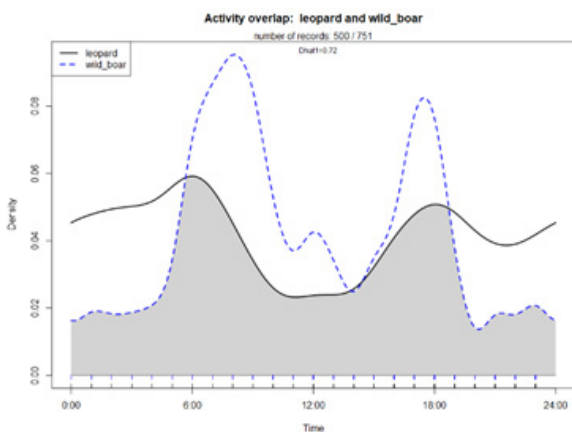


Figure 9.3(a): Leopard - Wild Boar

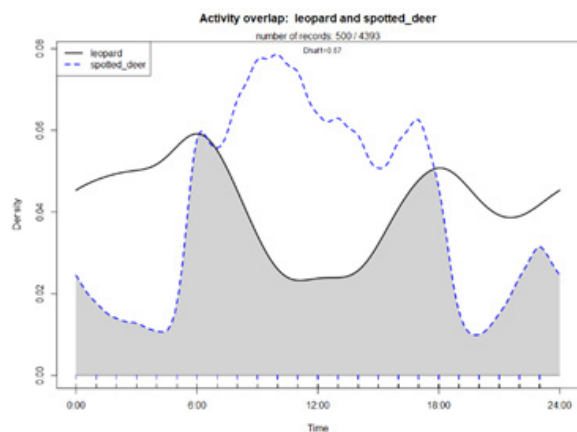


Figure 9.3(b): Leopard - Spotted Deer

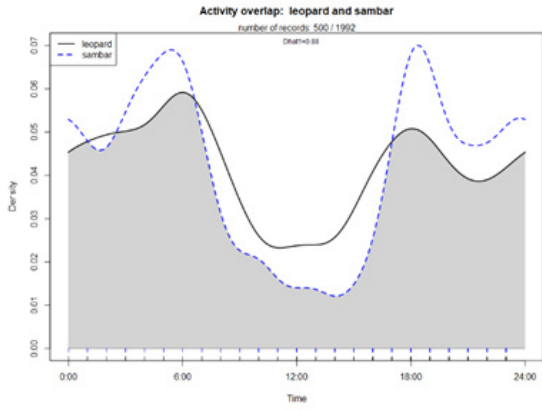


Figure 9.3(c): Leopard - Sambar

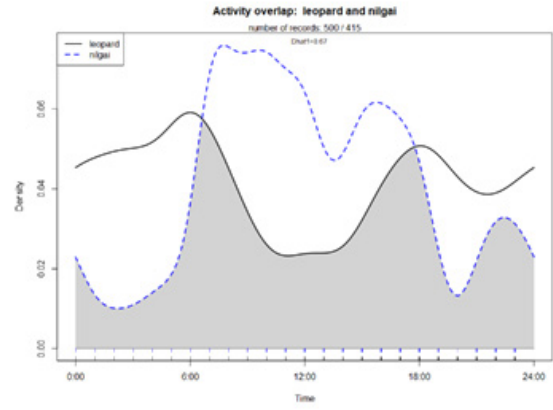


Figure 9.3(d): Leopard - Nilgai

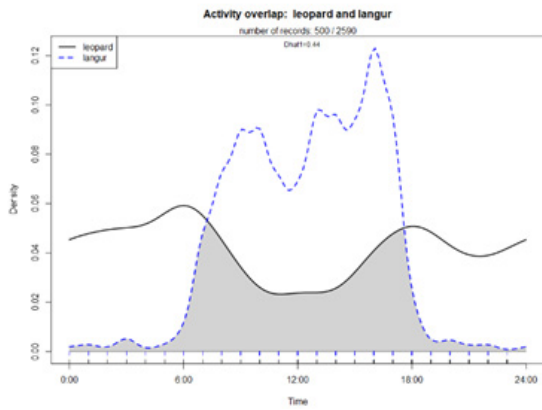


Figure 9.3(e): Leopard - Langur

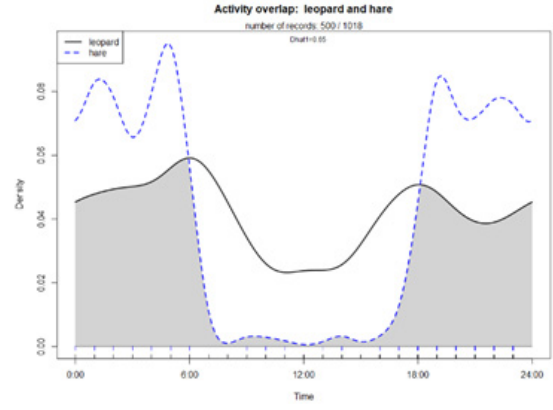


Figure 9.3(f): Leopard - Indian Hare

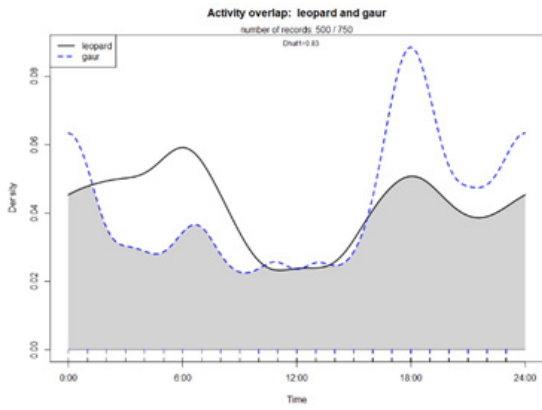


Figure 9.3(g): Leopard - Gaur

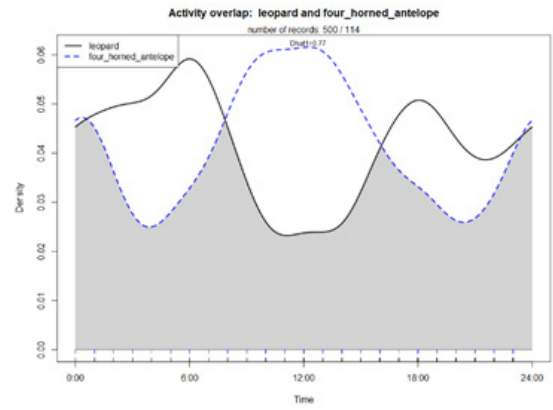


Figure 9.3(h): Leopard - Four Horned Antelope

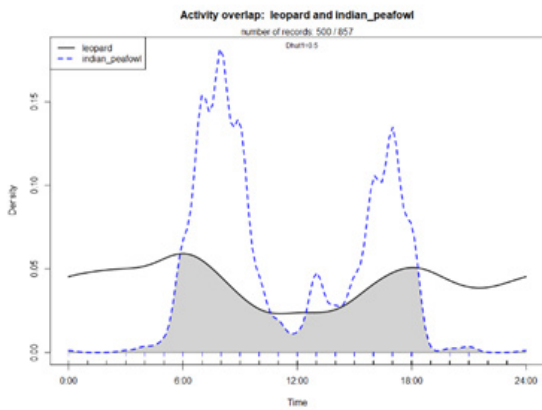


Figure 9.3(i): Leopard - Peafowl

Figures 9.3(a-i): Daily temporal activity patterns of the Leopard vs. prey species in Pench Tiger Reserve, Maharashtra, India during the year 2024. The lines represent the kernel density estimates based on individual photograph times. The overlap is shown by the shaded area in each plot.



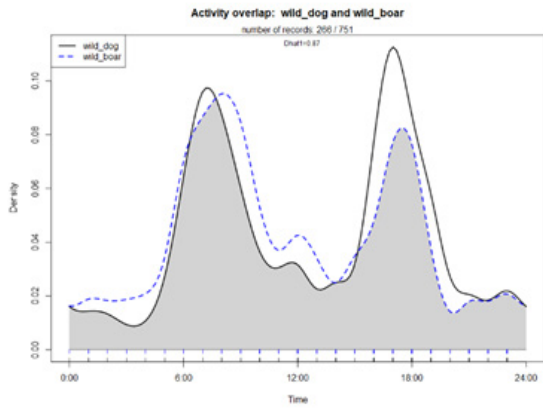


Figure 9.4(a): Wild Dog - Wild Boar

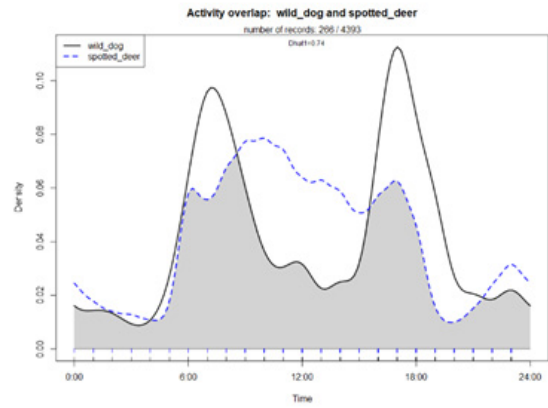


Figure 9.4(b): Wild Dog - Spotted Deer

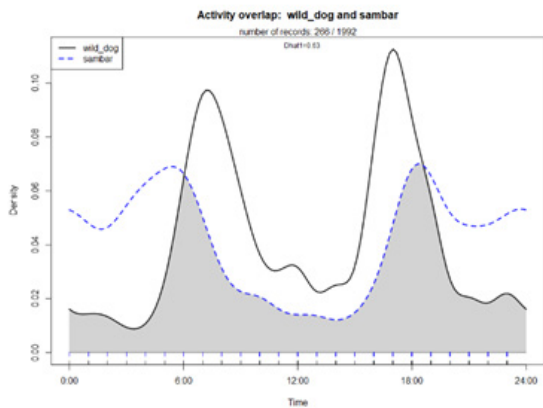


Figure 9.4(c): Wild Dog - Sambar

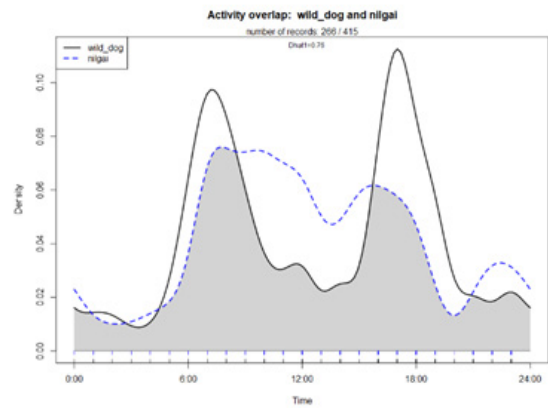


Figure 9.4(d): Wild Dog - Nilgai

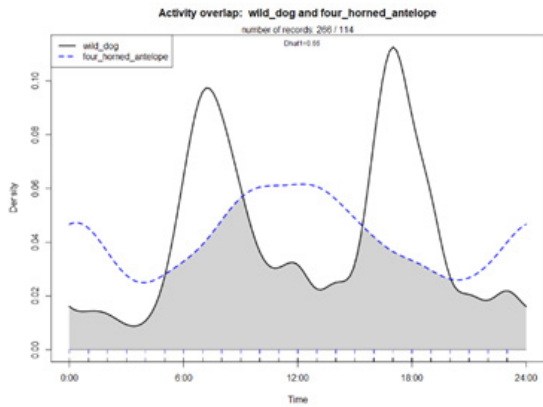


Figure 9.4(e): Wild Dog - Four Horned Antelope

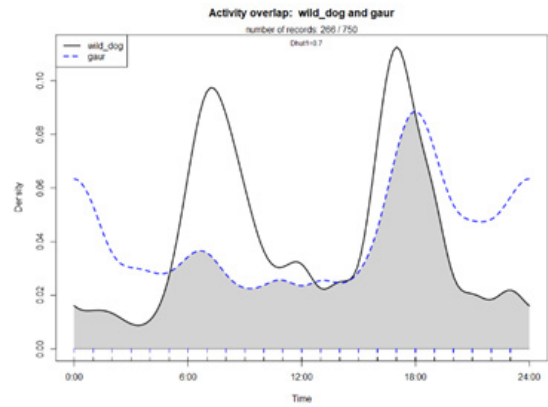


Figure 9.4(f): Wild Dog - Gaur

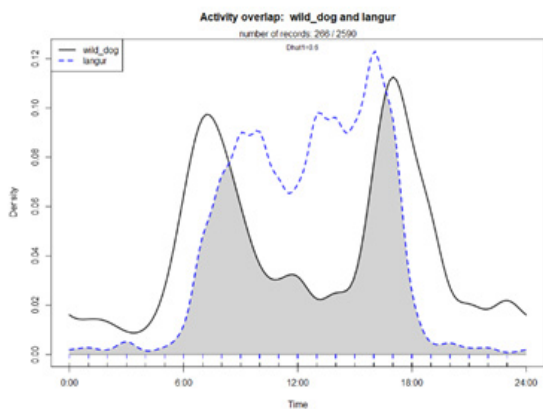


Figure 9.4(g): Wild Dog - Langur

Figures 9.4 (a-g): Daily temporal activity pattern of the Wild Dog vs. prey species in Pench Tiger Reserve, Maharashtra, India during the year 2024. The lines represent the kernel density estimates based on individual photograph times. The overlap is shown by the shaded area in each plot.

## Modelling Spatially Explicit Intensive Use Areas: Predator & Prey Species

Using IDW technique spatially explicit intensive use area maps (based on camera trap location and number of photographs at each location) have been developed for predator and prey species. Figure 10 (a-o) shows intensive use areas by different wild species of Pench Tiger Reserve.

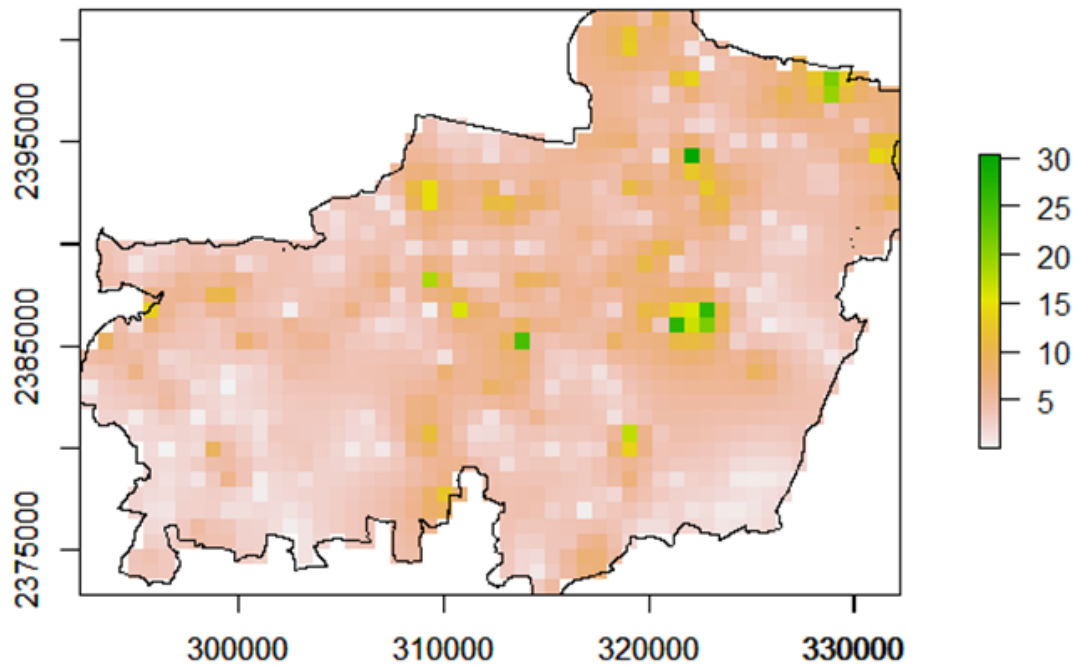


Figure 10(a): Intensive use area map for Tiger at PTR

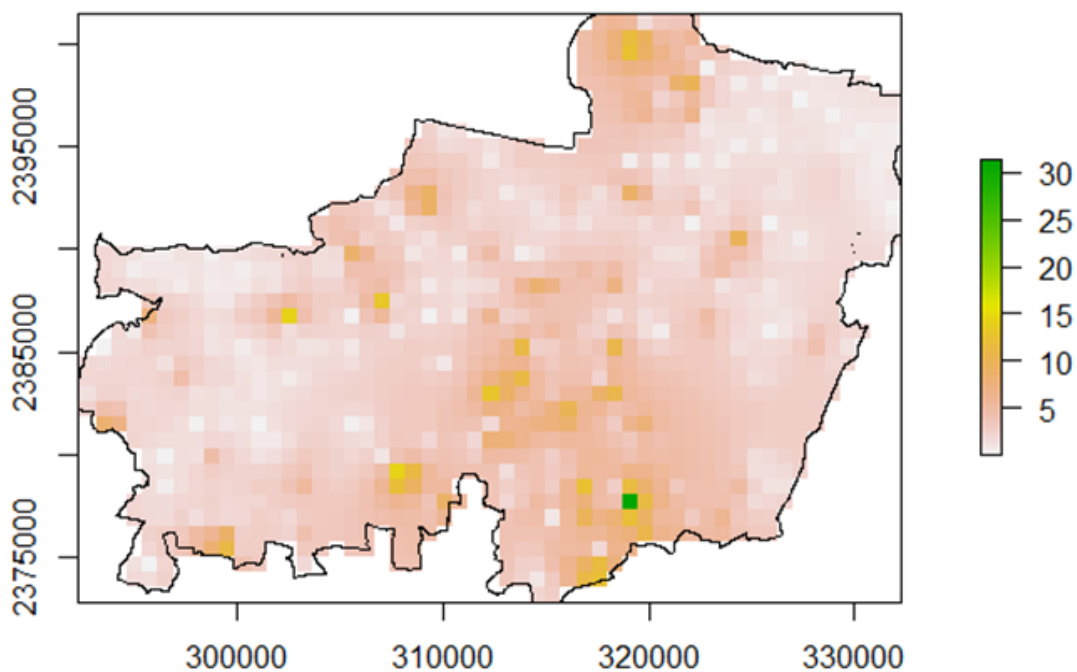


Figure 10(b): Intensive use area map for Leopard at PTR

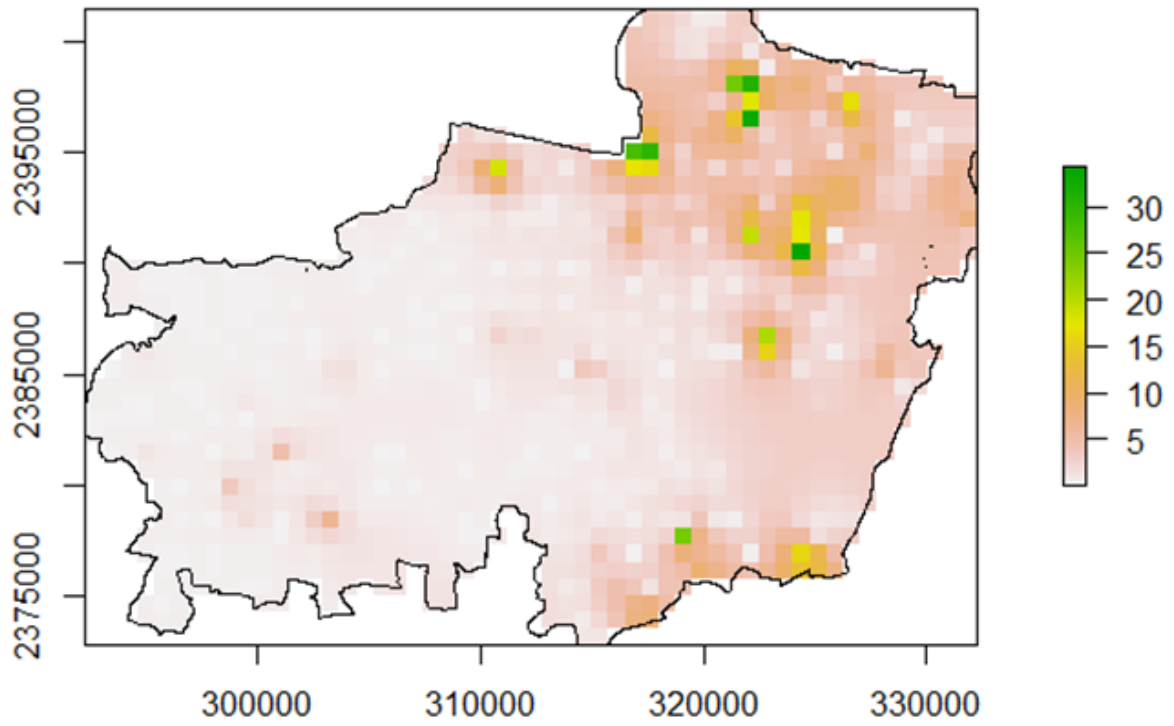


Figure 10(c): Intensive use area map for Wild Dog at PTR

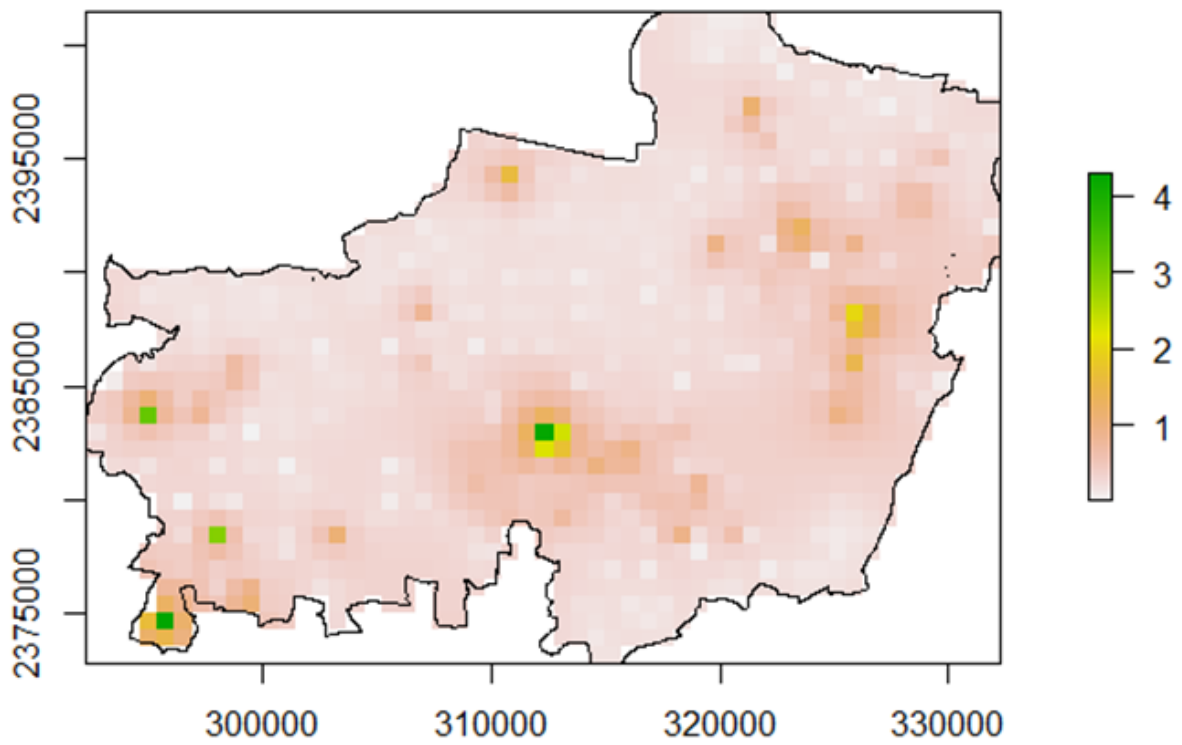


Figure 10(d): Intensive use area map for Sloth Bear at PTR

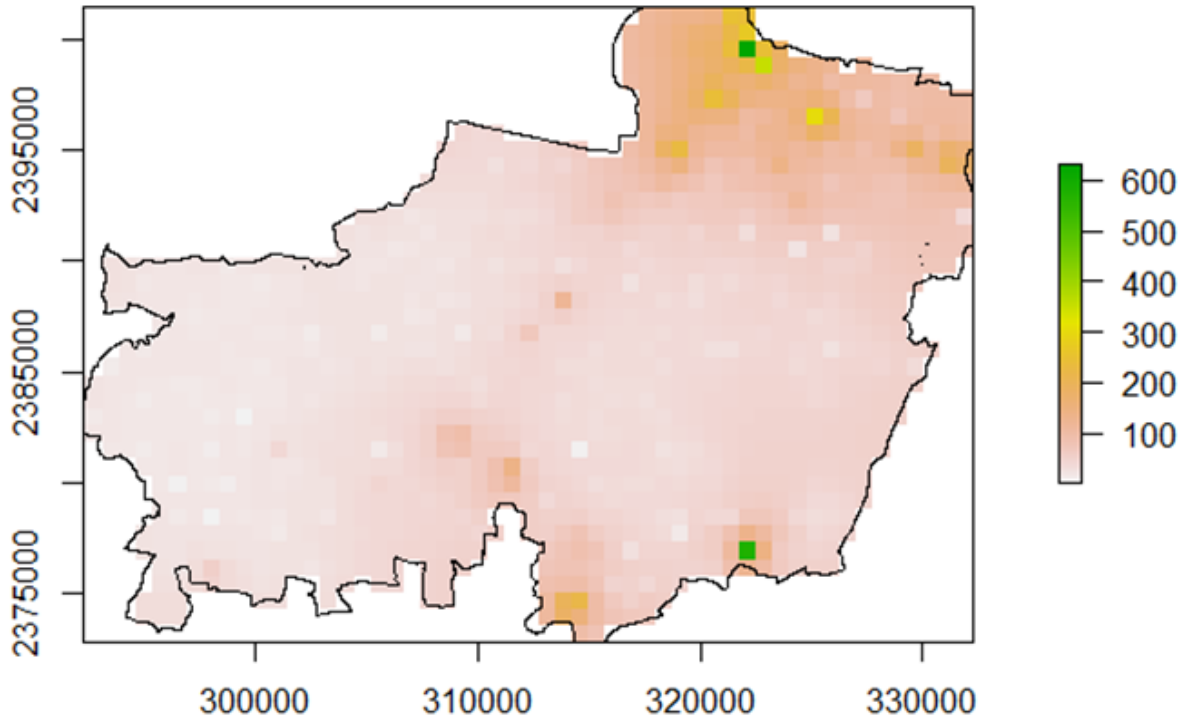


Figure 10(e): Intensive use area map for Spotted Deer at PTR

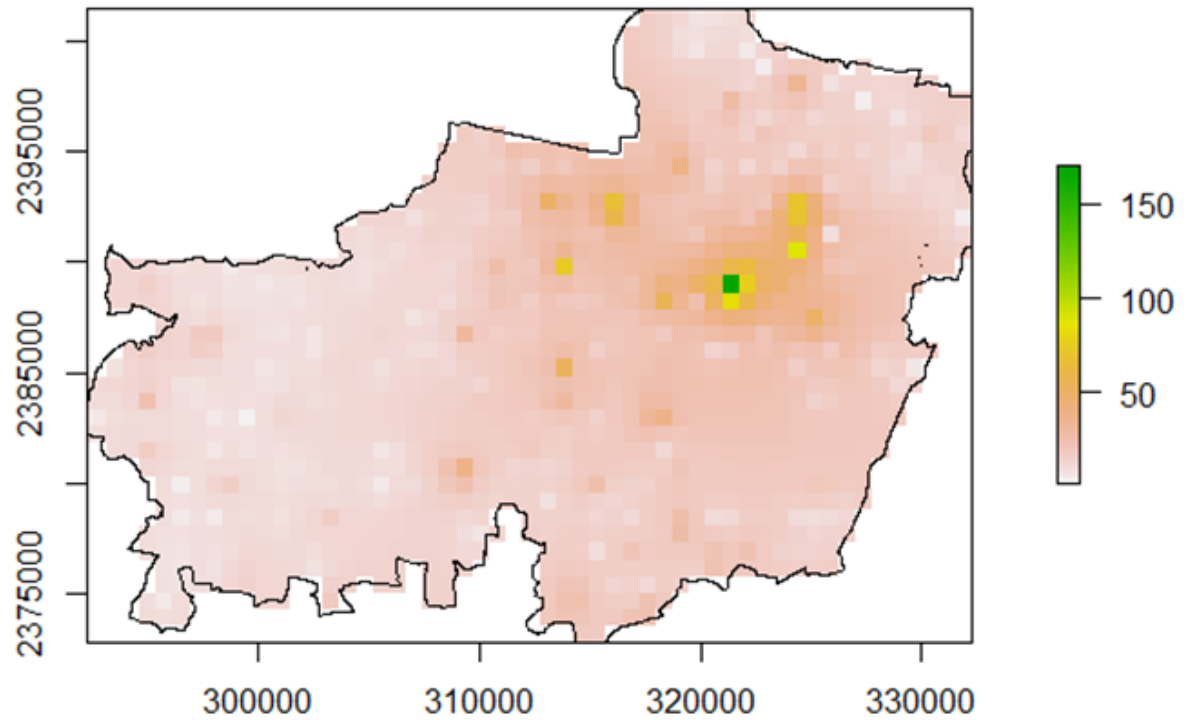


Figure 10(f): Intensive use area map for Sambar at PTR

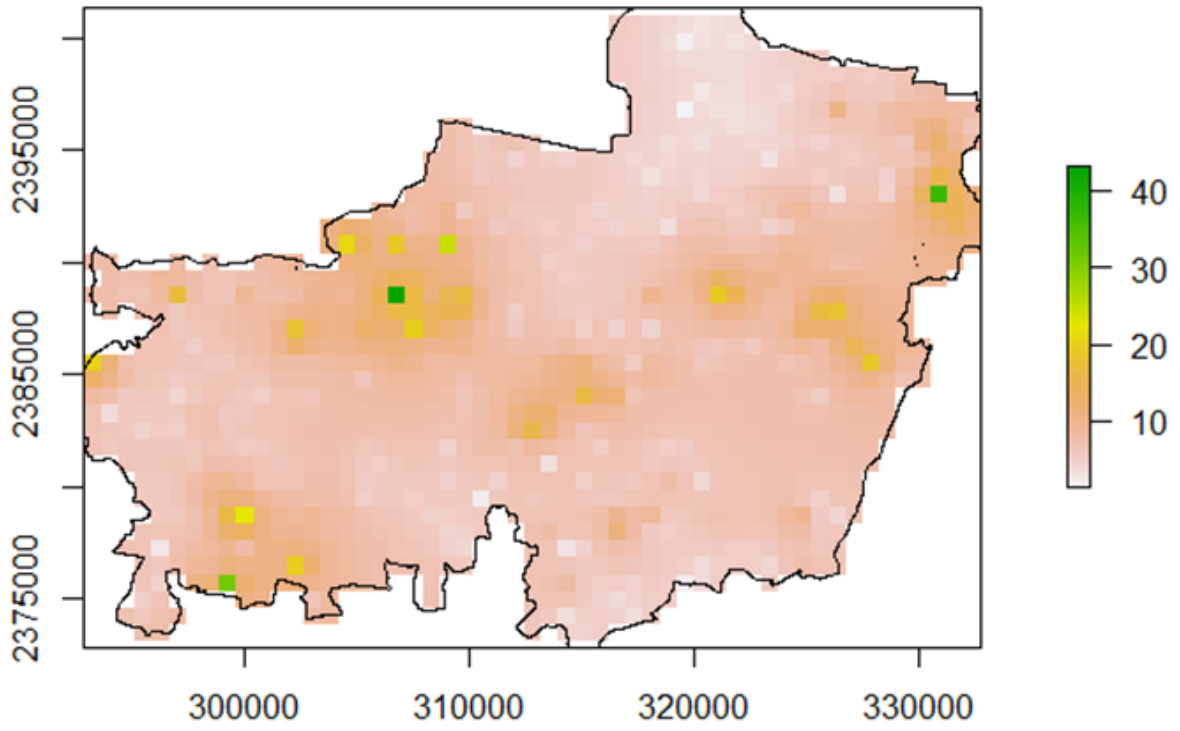


Figure 10(g): Intensive use area map for Gaur at PTRt

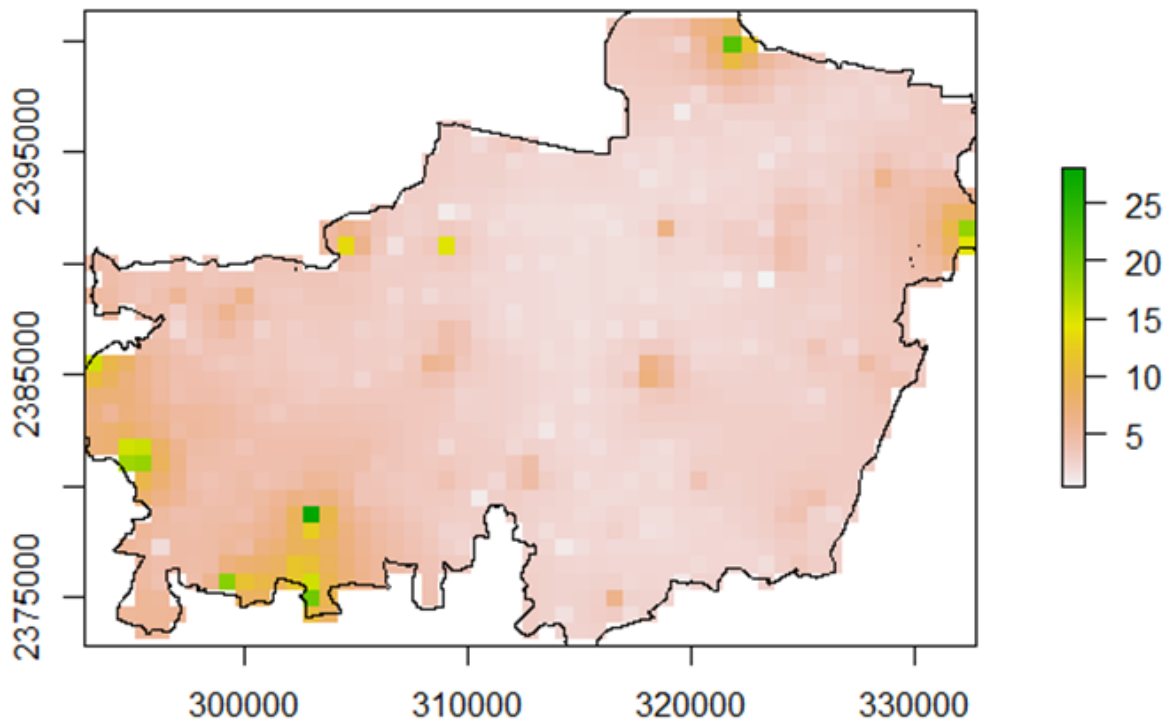


Figure 10(h): Intensive use area map for Nilgai at PTR

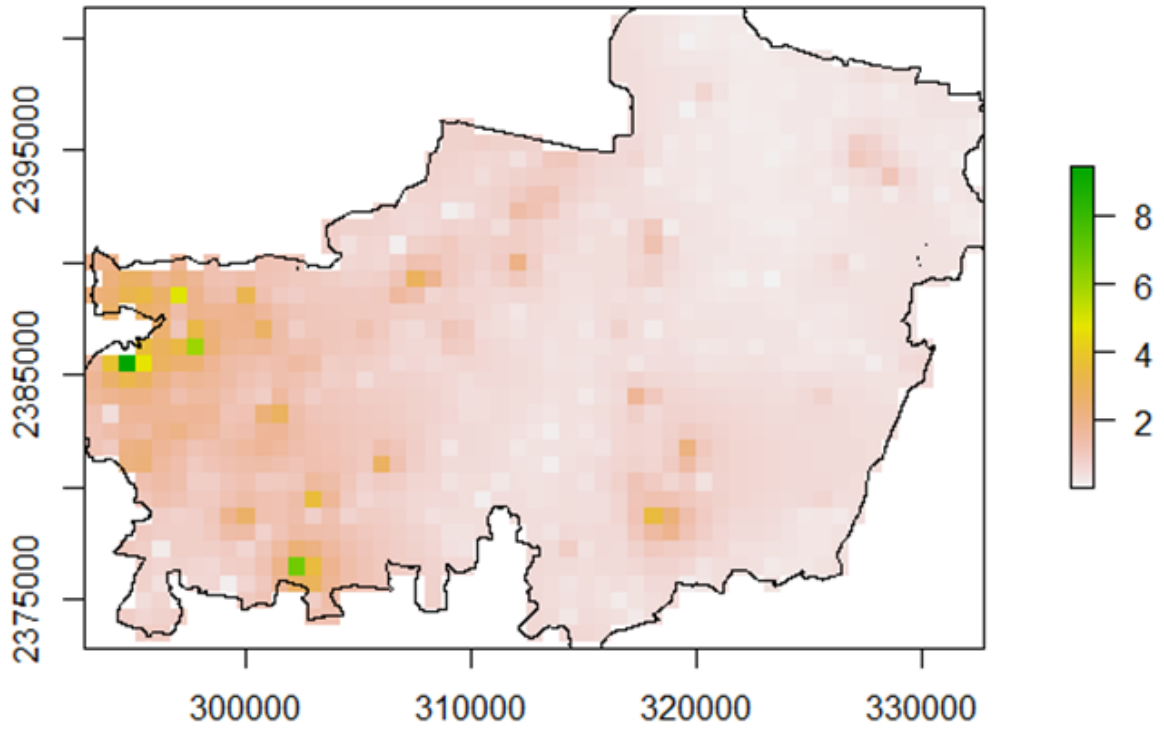


Figure 10(i): Intensive use area map for Four Horned Antelope at PTR

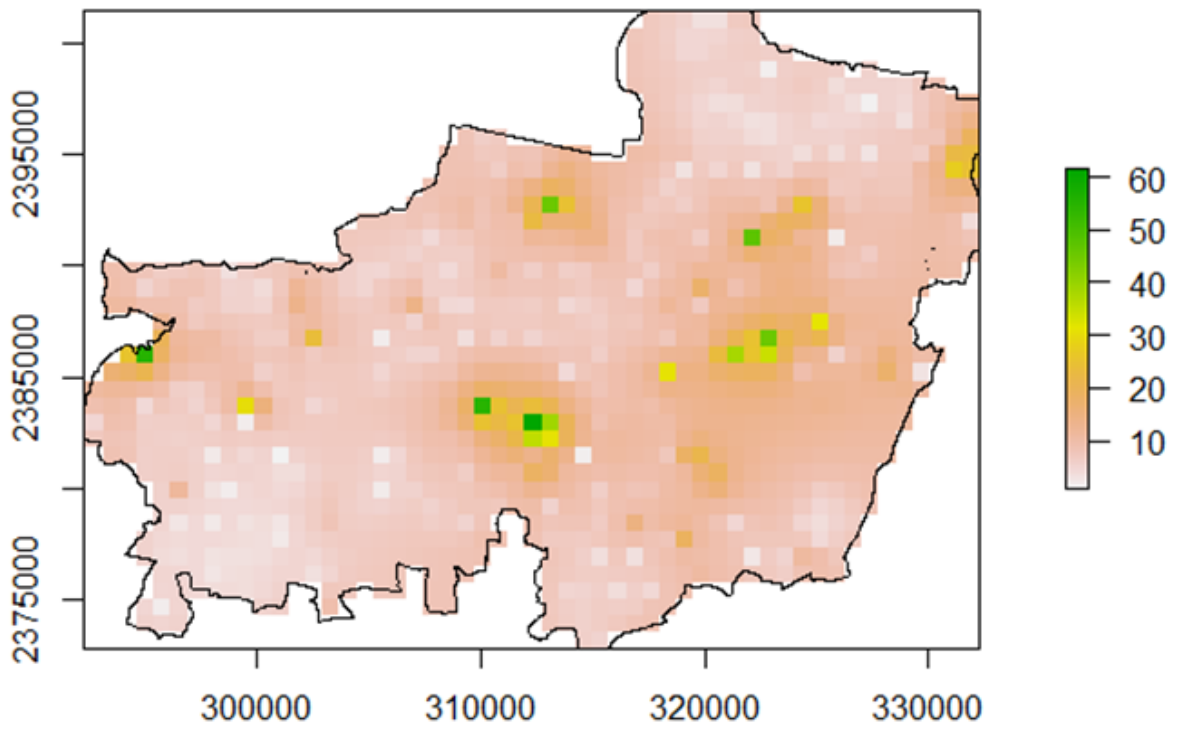


Figure 10(j): Intensive use area map for Wild Boar at PTR

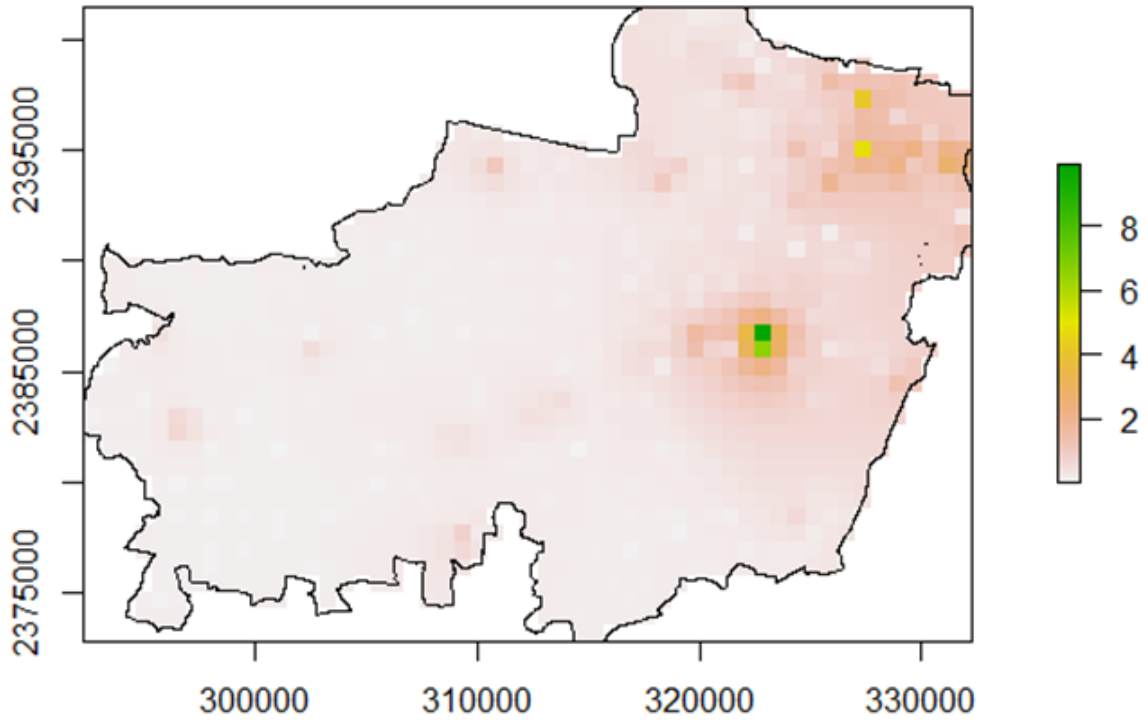


Figure 10(k): Intensive use area map for Jungle cat at PTR

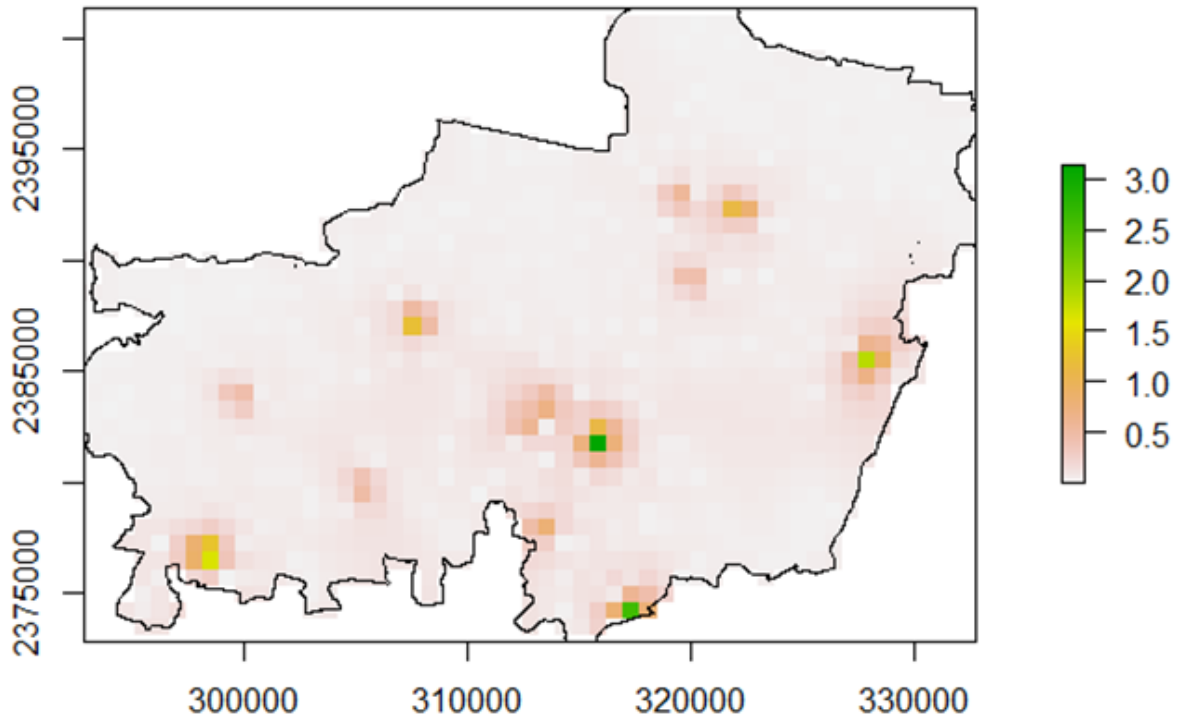


Figure 10(l): Intensive use area map for Rusty Spotted Cat at PTR

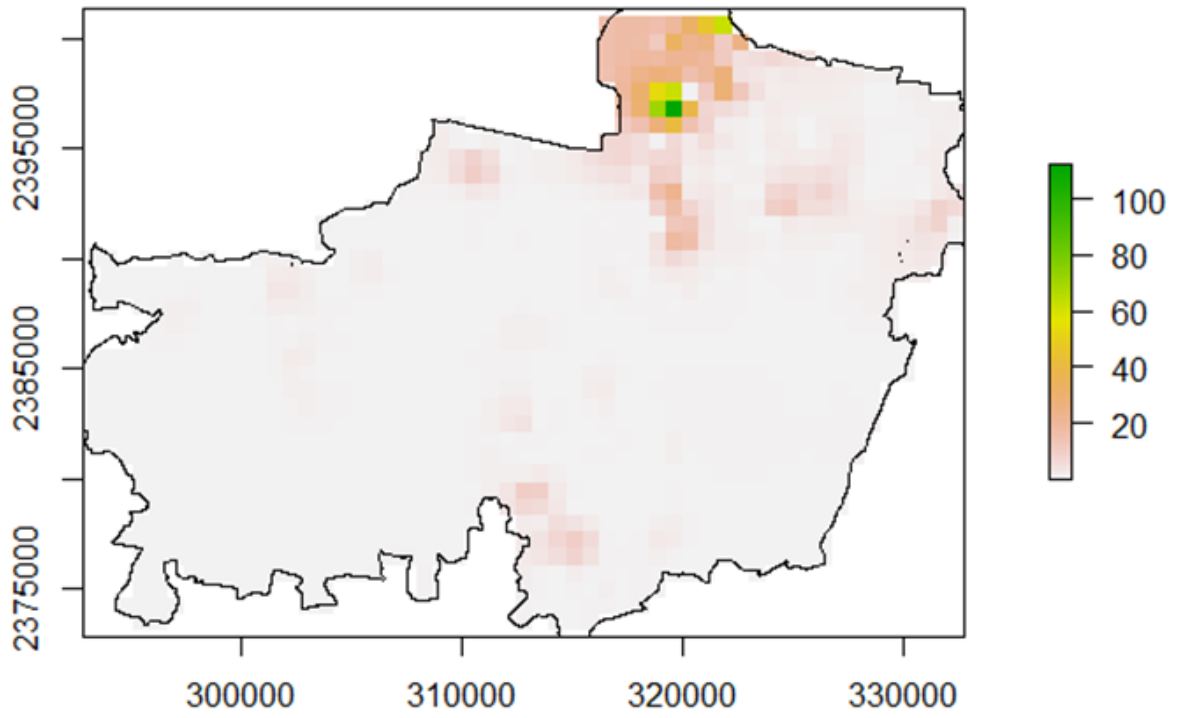


Figure 10(m): Intensive use area map for Golden Jackal at PTR

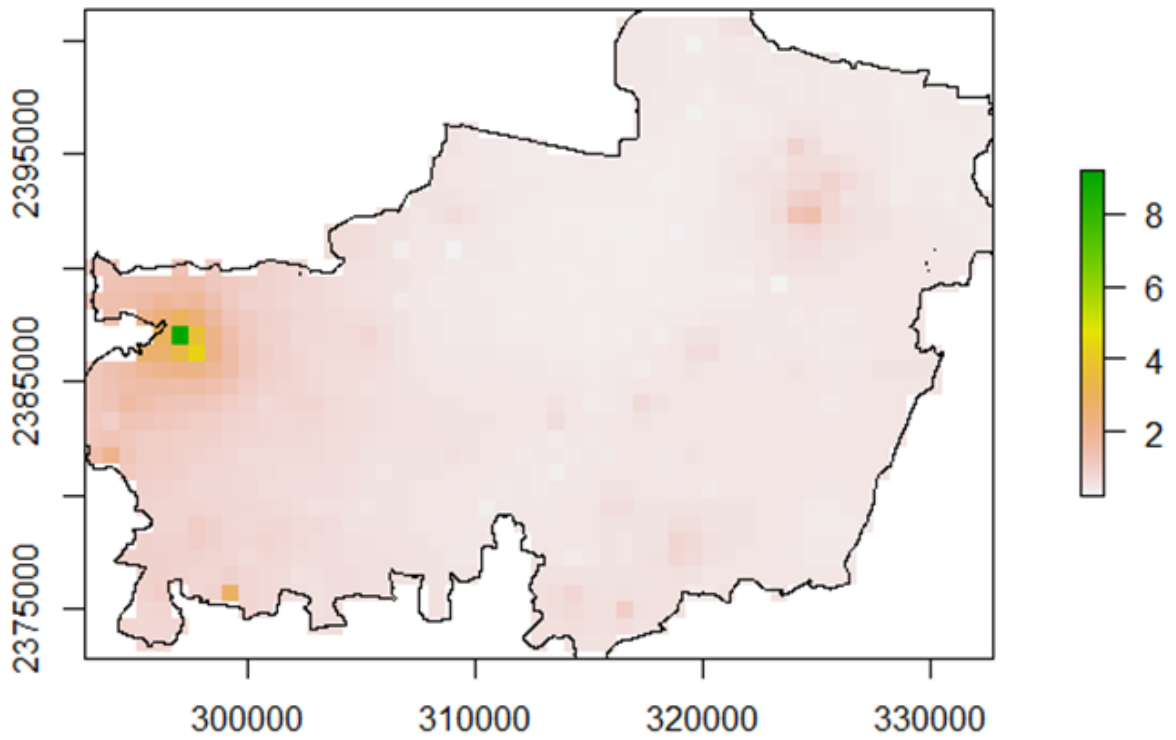


Figure 10(n): Intensive use area map for Ratel at PTR



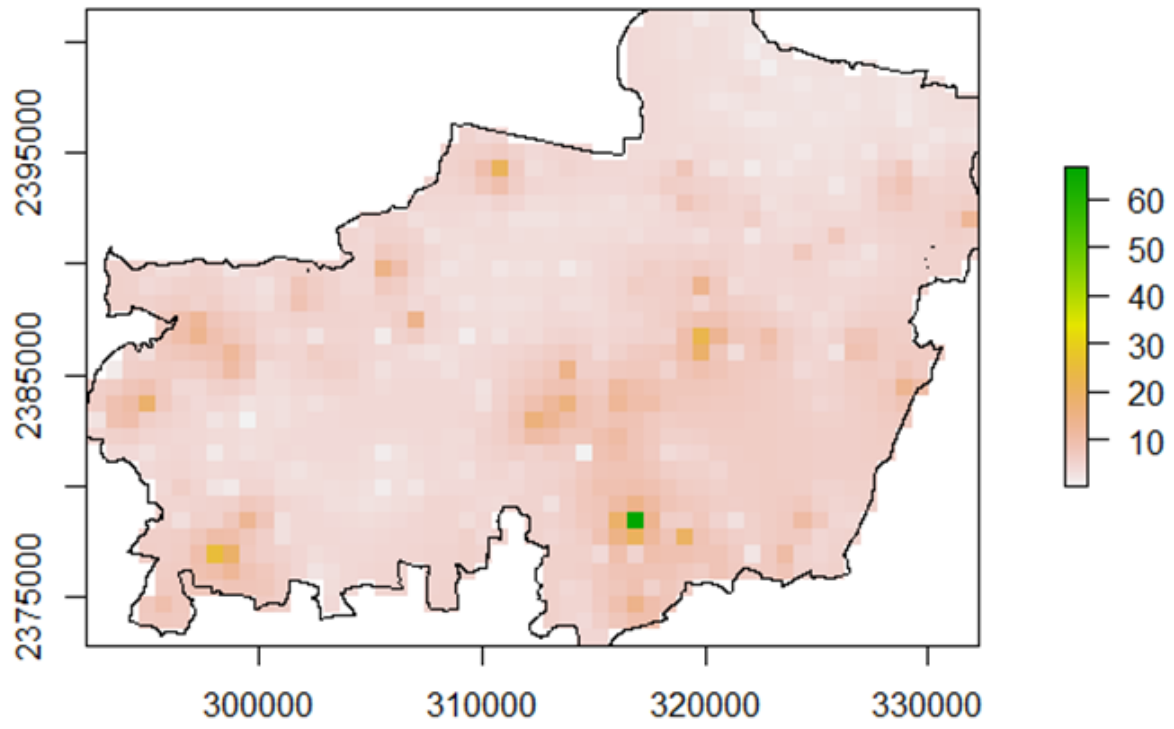


Figure 10(o): Intensive use area map for Indian Hare at PTR

Figures 10 (a-o): Intensive use area of various species in Pench Tiger Reserve, Maharashtra, India during the 2024

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