Tadoba Andhari Tiger Reserve

Status of Tigers, Co-Predators & Prey

2021

Report Title:
Status of Tigers, Co-Predators and Prey in Tadoba Andhari Tiger Reserve - 2021

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

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Executive Summary

Phase IV monitoring for the Tadoba Andhari Tiger Reserve (TATR) core and buffer was conducted from February – May 2021 covering an area of 1315 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 Phase IV Monitoring is to estimate the minimum number of tigers in the reserve using Spatially Explicit Capture-Recapture Sampling and density estimation of prey base using Distance Sampling.

Camera traps were placed in 621 grids of 2.01 sq. km. area each in the core and buffer area of TATR in two blocks. In each sampling block, camera traps were active for 27 - 44 days. During 83 days of camera trapping survey with a sampling effort of 20,965 trap nights, 85 adult individual tigers were photographed in the sampled area of TATR. Estimated population (N) of tigers based on the best fit (SECR Heterogeneity) model was 86 (SE ± 0.71). Tiger density per 100 sq. km. based on the Spatially Explicit Capture-Recapture (SECR) model was 6.31 (SE ± 0.70). Along with tigers 114 adult individual leopards were photographed in the sampled area of TATR and estimated population (N) based on the best fit (SECR Heterogeneity) model was 118 (SE ± 2.17). Leopard density per 100 sq. km. based on the Spatially Explicit Capture-Recapture (SECR) model was 7.07 (SE ± 0.67).

To estimate prey density, 133 line transects in core and buffer of TATR were sampled 7 times during the sampling period, with a total walking effort of 1862 km. During the sampling, a total of 1163 animal/bird observations were made. The overall individual density per km^2 of major prey species in TATR was Gaur 2.16 (SE ± 0.39), Sambar 1.71 (SE ± 0.29), Chital 2.65 (SE ± 0.55), Wild Boar 3.73 (SE ± 0.84), Langur 3.35 (SE ± 0.71), Barking Deer 0.42 (SE ±0.08), Nilgai 1.04 (SE ± 0.25), Black-naped Hare 0.68 (SE ± 0.15) Peafowl 1.79 (SE ± 0.25) and Grey Jungle Fowl 8.19 (SE ± 1.02).

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 TATR. 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.

1. Introduction

Tigers are one of the most charismatic and awe-inspiring species in our world. India holds around 75% of the global tiger population. One of the major reasons for this is the conservation efforts put in place by our country to bring this species back from the brink of extinction under the Project Tiger. This includes providing inviolate spaces for the tigers to live and breed along with maintaining a healthy prey population in these forests. For this purpose, healthy tiger habitats were identified from across the country and were declared as tiger reserves to provide them with the highest level of conservation status. These reserves have been intensively monitored year-round to prevent all illegal activities like poaching, illegal grazing, encroachment, etc. to provide a haven for tigers and other wildlife.

Tadoba Andhari Tiger Reserve (TATR) is one of the 51 tiger reserves currently present in our country. It is located in the Chandrapur district of Maharashtra, between 20°04' 53" to 20°25' 51" N and 79°13' 13" to 79°33' 34" E. It consists of the Tadoba National Park with an area of 116.55 km^2 (declared in 1955) and the Andhari Wildlife Sanctuary with an area of 508.85 km^2 (declared in 1983) which together form the core area of the tiger reserve with a total area of 625.4 km^2 along with a buffer area of 1101.7 km^2 around the core which was added in the year 2012. With a total area of 1727 km^2 it is amongst the largest tiger reserves in the state.

TATR acts as a major source population of tigers and leopards not just for the adjoining forest divisions of Bramhapuri, Chandrapur and Central Chanda but also for other protected areas such as Umred Paoni Karhandala Wildlife Sanctuary, Navegaon-Nagzira Tiger Reserve, Bor Tiger Reserve, Pench Tiger Reserve and Kawal Tiger Reserve. The adjoining forests and other forest patches function as corridors and connect these protected areas with each other. Thereby helping in maintaining a healthy gene flow between these reserves.

Flora and Fauna of TATR

The tiger reserve harbours 61 species of mammals apart from tigers including leopard (Panthera pardus), dhole or asiatic wild dog (*Cuon alpinus*), sloth bear (*Melursus ursinus*), gaur (Bos gaurus), sambar deer (*Rusa unicolor*), chital or spotted deer (*Axis axis*), barking deer or Muntjacs (*Muntiacus muntjak*), chausingha or four-horned antelope (*Tetracerus quadricornis*), ratel or honey badger (*Mellivoora capensis*), jungle cat (*Felis chaus),* rusty-spotted cat (*Prionailurus rubiginosus*), etc. 34 species of reptiles are also found in the tiger reserve which includes mugger crocodile or marsh crocodile (*Crocodilus palustris*), Indian rock python (*Python molurus*), russell's viper (*Daboia russelii*), Indian cobra or spectacled cobra (*Naja naja*), etc. along with more than 250 species of birds and 174 species of butterflies.

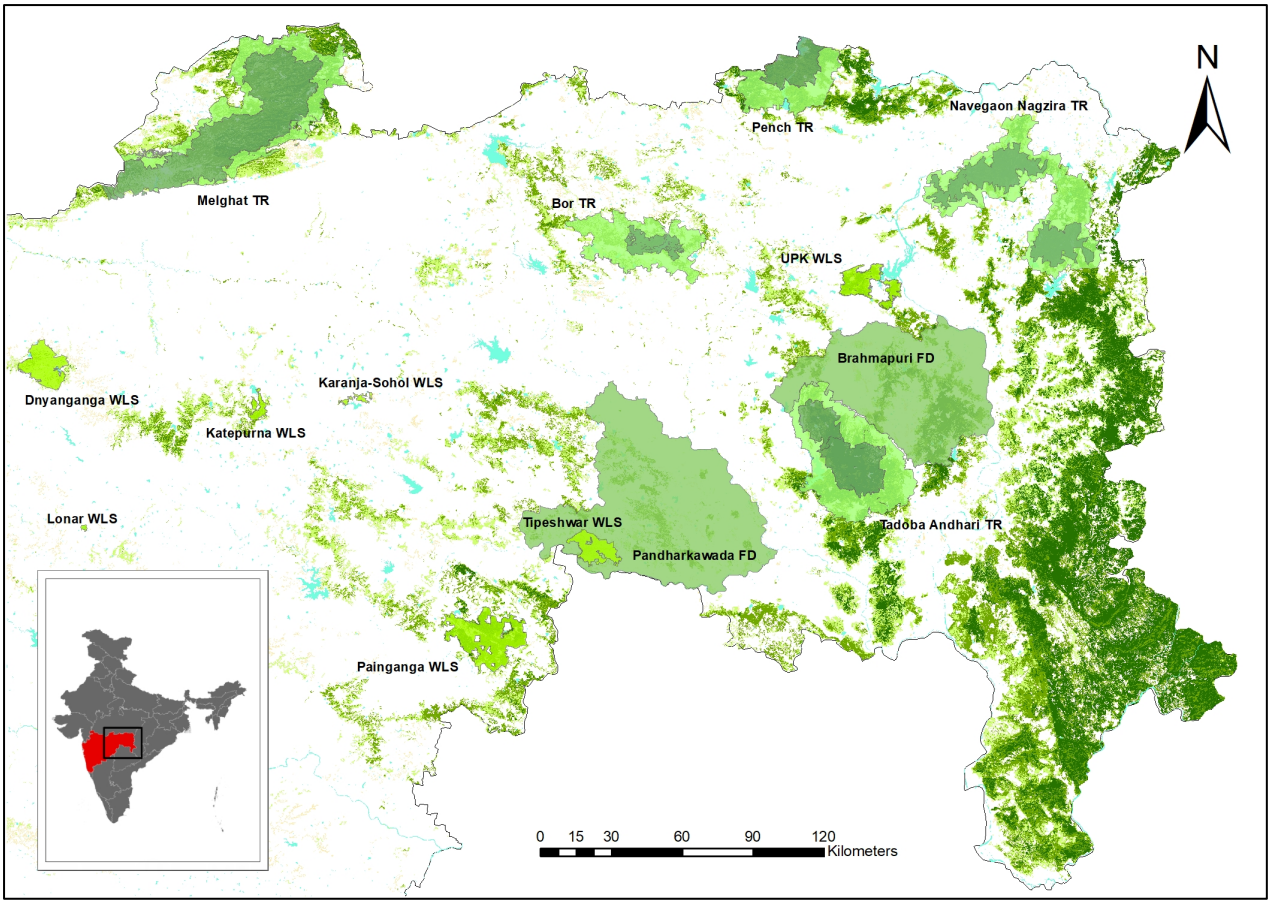

Figure 1: Map showing the location of Tadoba Andhari Tiger Reserve along with other tiger reserves and protected areas in the Vidarbha landscape of Maharashtra

According to Champion and Seth's classification (1968) the vegetation of TATR can be classified as Southern Tropical Dry Deciduous Forest. The vegetation of TATR can be further divided into dry deciduous forest, bamboo forest, open forest, riparian forest, and scrubland. The most dominant species of trees in TATR is Teak (*Tectona grandis*). Other dominant tree species include Ain (*Terminalia eliptica*), Arjun (*Terminalia arjuna*), Bhera (*Chloroxylon swietenia*), Dhawada (*Anogeissus latifolia*), Mahua (*Madhuca indica*), Salai (*Boswelia serrata*), Tendu (*Diospyros melanoxylon*), etc. Along with these species like Jamun (*Syzigium cumini*) and Mango (*Mamgifera indica*) can be seen in the riparian patches of the tiger reserve. According to a study by Paliwal & Mathur (2014), the tiger reserve is dominated by mixed bamboo forest which occupies 77.99% of the total area. Most dominant species of bamboo found in TATR is *Dendrocalamus strictus*.

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

a) 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

a) 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

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

2. Status of Prey in Tadoba Andhari Tiger Reserve

Introduction:

Prey-predator interactions play a major role in maintaining the health of an ecosystem. The large carnivore density in a forest largely depends on the abundance and diversity of the prey species inside it. Ungulates play an important role in maintaining ecosystems by influencing the vegetation structure, plant species composition and nutrient cycling (McNaughton 1979; Bagchi and Ritchie 2010). Therefore, effective management of prey species is essential for maintaining a healthy predator populations as well as a healthy ecosystem. For proper management of ungulates regular monitoring of their abundance, distribution and density is required.

Distance sampling:

Line transect sampling is the most widely used method for estimation of ungulate populations. Transects are laid randomly across the forest and all the vegetation types present in the forest are covered by them. Prey species sighted while walking on these transect lines are recorded along with habitat and terrain information.

In total 56 transects were walked upon in 60 beats of core division and 77 transects were walked upon in 77 beats of buffer division. Each transect had a total length of 2 km and was walked on 7 times between 21st and 27th of February 2021, to give a combined effort of 1862 km. Figure 2 shows the distribution of transect lines across the tiger reserve. A total of 1163 sightings were made in these transects in which 10 species of prey including Chital (Axis axis), Sambar (Rusa unicolor), Gaur (Bos gaurus), Wild boar (Sus scrofa), Nilgai (Boselaphus tragocamelus), langur (Semnopithecus sp.), barking deer (Muntiacus muntjak), Peafowl (Pavo cristatus), Grey jungle fowl (Gallus sonnerattii) and Black-naped hare (Lepus nigricollis) were observed. The details of prey species observed in line transects are provided in Table 1 – 6.

During the transect walk data on species, number of animals seen, group composition, bearing of the animal and angular sighting distance were recorded. To record the distances accurately Laser Range Finders were used and to give spatial reference to each and every observation Global Positioning System (GPS) was used. The GPS co-ordinates of transect were also recorded.

Grey Jungle Fowl was the most observed species in both core and buffer, followed by Sambar, Chital and Peafowl in core and Peafowl, Wild boar and Nilgai in buffer. Black-naped hare and Nilagi were the least sighted species in core, whereas Barking deer and Black-naped hare were the least sighted species in buffer.

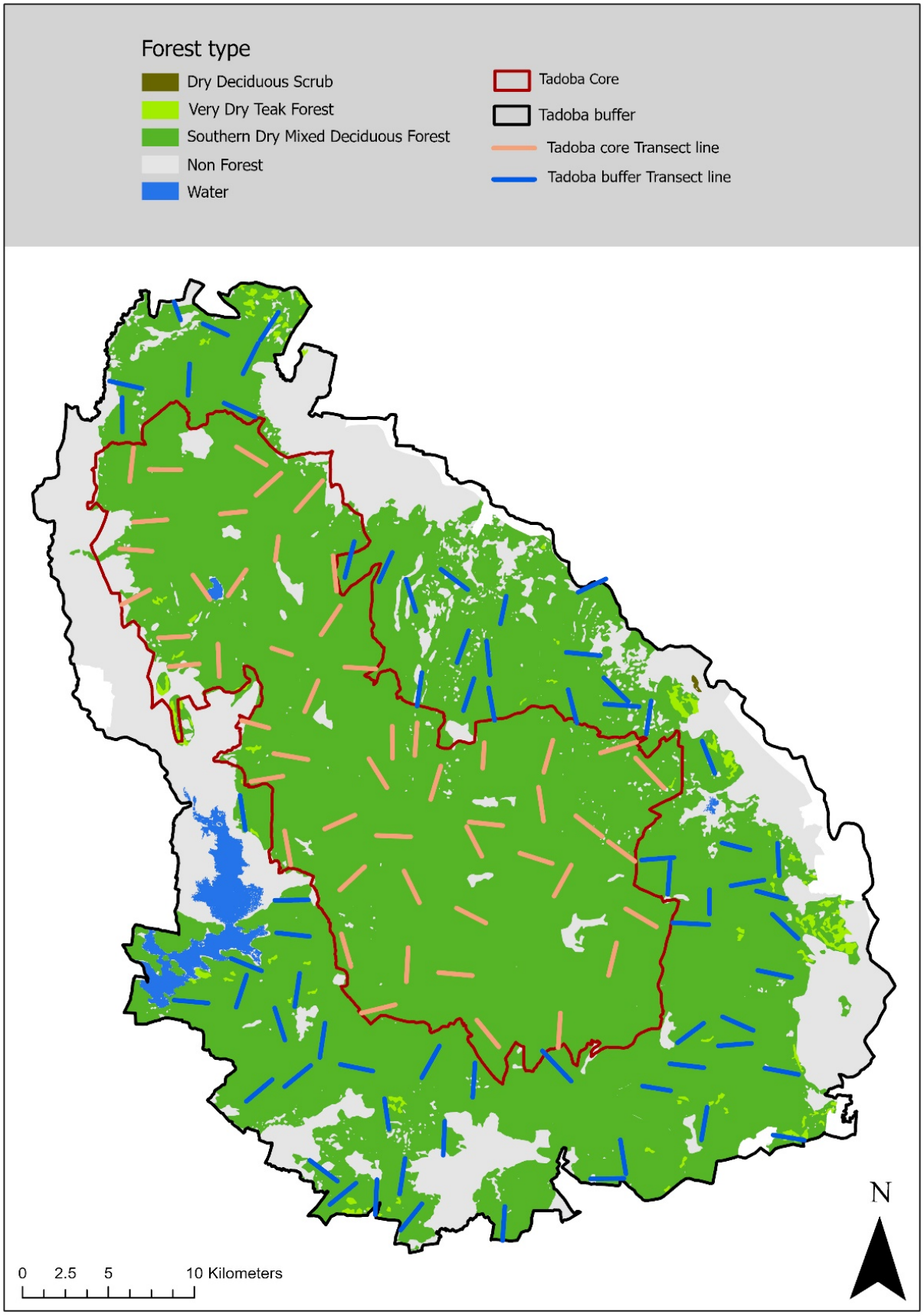

Figure 2: Distribution of line-transects in Core and Buffer area of Tadoba Andhari Tiger Reserve monitored during the year 2021

Table 1: Transect monitoring efforts and species reported from Core and Buffer Area of TATR during Phase IV Monitoring 2021

	Core	Buffer
Number of transects	56	77
Length of each transect	2 km	2 km
Number of replicates	7	7
Total distance covered	784	1078
Number of species recorded	10	10

	Core			Buffer		
Species	**Number of sightings**	**Individuals recorded**	**Average group size (min-max)**	**Number of sightings**	**Individuals recorded**	**Average group size (min-max)**
Sambar	76	140	1.84 (1-6)	43	78	1.71 (1-6)
Chital	74	348	4.58 (1-17)	48	207	4.09 (1-17)
Nilgai	24	52	2.17 (1-6)	53	139	2.63 (1-15)
Gaur	35	94	2.69 (1-16)	53	176	3.29 (1-17)
Wild boar	43	267	6.21 (1-20)	67	422	6.25 (1-35)
Langur	28	246	8.93 (3-16)	41	308	7.49 (1-15)
Barking deer	27	29	1.08 (1-2)	17	21	1.19 (1-2)
Hare	15	17	- (1-2)	26	28	1.08 (1-2)
Peafowl	59	115	1.96 (1-9)	63	115	1.82 (1-7)
Grey jungle fowl	173	279	1.62 (1-10)	154	273	1.77 (1-7)

Table 2: Individual Density, Group Density, Effective Strip Width, Average Group Size and Encounter Rate of various prey species reported from Core area of Tadoba Andhari Tiger Reserve during Phase IV monitoring 2021

Parameters	Sambar	Chital	Gaur	Wild pig	Langur	Nilgai	Barking deer	Hare	Peafowl	Grey jungle fowl
Individual density (No of Animals/km²)	3.08	3.98	1.91	5.50	3.70	0.56	0.82	-	1.84	10.10
Standard error	0.69	1.21	0.57	1.87	1.22	0.21	0.22	-	0.38	1.74
Percent CV	22.56	30.46	29.90	34.00	32.90	36.95	26.74	-	20.60	17.20
95% confidence interval	1.98 - 4.79	2.20 - 7.18	1.07 - 3.40	2.85 - 10.60	1.96 - 7.00	0.28 - 1.14	0.49 - 1.38	-	1.23 - 2.75	7.20 - 14.17
Group density (No of groups/km²)	1.57	1.03	0.84	0.80	0.40	0.30	0.73	-	1.09	6.46
Standard error	0.34	0.28	0.21	0.19	0.12	0.10	0.19	-	0.20	1.08
Percent CV	21.33	27.03	25.14	23.49	31.03	33.92	26.47	-	18.42	16.77
95% confidence interval	1.03 - 2.39	0.61 - 1.74	0.52 - 1.38	0.51 - 1.27	0.22 - 0.72	0.15 - 0.57	0.44 - 1.22	-	0.76 - 1.56	4.64 - 9.00
Effective strip width	30.83	44.06	26.50	34.27	43.59	51.59	22.72	-	33.41	16.98
Standard error	2.99	4.19	4.77	4.12	8.46	8.51	3.80	-	3.70	1.36
Percent CV	9.70	9.51	17.99	12.02	19.40	16.49	16.73	-	11.09	7.98
95% confidence interval	25.43 - 37.38	36.46 - 53.23	18.43 - 38.11	26.91 - 43.63	29.36 - 64.71	36.76 - 72.40	16.14 - 32.00	-	26.77 - 41.69	14.51 - 19.87
Average group size	1.84	4.58	2.69	6.21	8.93	2.17	1.08	-	1.96	1.62
Standard error	0.15	0.48	0.53	0.90	0.71	0.30	0.05	-	0.24	0.09
Percent CV	8.14	10.57	19.59	14.49	7.93	13.80	4.95	-	12.02	5.50
95% confidence interval	1.57 - 2.17	3.71 - 5.65	1.81 - 3.98	4.64 - 8.31	7.59 - 10.50	1.63 - 2.88	1.00 - 1.19	-	1.55 - 2.50	1.45 - 1.80
Encounter rate	0.10	0.09	0.04	0.06	0.03	0.03	0.03	-	0.07	0.22
Percent CV	19.00	25.30	17.57	20.18	24.21	29.64	20.51	-	14.70	14.74
95% confidence interval	0.07 - 0.14	0.06 - 0.15	0.03 - 0.06	0.04 - 0.08	0.02 - 0.06	0.02 - 0.05	0.02 - 0.05	-	0.05 - 0.10	0.16 - 0.29
Probability of a greater chi-square value, P	0.86	0.95	1.00	0.99	0.89	0.84	0.91	-	0.70	0.97

Table 3: Individual Density, Group Density, Effective Strip Width, Average Group Size and Encounter Rate of various prey species reported from Buffer area of Tadoba Andhari Tiger Reserve during Phase IV monitoring 2021

Parameters	Sambar	Chital	Gaur	Wild pig	Langur	Nilgai	Barking deer	Hare	Peafowl	Grey jungle fowl
Individual density (No of Animals/km2)	0.73	1.69	2.98	2.70	2.96	0.20	0.93	1.11	1.81	4.99
Standard error	0.19	0.43	0.72	0.75	0.95	0.06	0.27	0.30	0.35	0.76
Percent CV	25.31	25.23	24.27	27.66	32.19	31.95	28.95	27.54	19.17	15.29
95% confidence interval	0.45 - 1.20	1.04 - 2.77	1.86 - 4.78	1.58 - 4.62	1.59 - 5.50	0.11 - 0.38	0.53 - 1.63	0.65 - 1.89	1.24 - 2.63	3.70 - 6.73
Group density (No of groups/km2)	0.53	0.64	0.72	0.70	0.42	0.19	0.94	0.47	0.98	2.89
Standard error	0.12	0.14	0.14	0.14	0.12	0.06	0.27	0.12	0.17	0.42
Percent CV	23.43	22.03	19.22	19.41	28.35	31.06	28.70	24.69	17.42	14.59
95% confidence interval	0.34 - 0.84	0.42 - 0.99	0.50 - 1.05	0.48 - 1.02	0.24 - 0.73	0.10 - 0.35	0.54 - 1.65	0.29 - 0.76	0.70 - 1.38	2.17 - 3.85
Effective strip width	36.62	33.91	32.81	41.85	42.94	39.09	12.31	51.45	29.78	24.74
Standard error	4.52	3.81	3.52	4.13	8.68	8.41	1.98	5.79	2.99	2.10
Percent CV	12.34	11.23	10.73	9.86	20.22	21.51	16.06	11.25	10.04	8.48
95% confidence interval	28.57 - 46.94	27.07 - 42.48	26.46 - 40.68	34.38 - 50.95	28.62 - 64.42	24.84 - 61.51	8.85 - 17.11	41.08 - 64.45	24.37 - 36.37	20.93 - 29.24
Average group size	1.71	4.09	3.29	6.25	7.49	1.19	1.08	2.63	1.82	1.77
Standard error	0.21	0.53	0.48	1.09	0.68	0.10	0.06	0.37	0.17	0.09
Percent CV	12.30	13.04	14.66	17.41	9.07	8.49	5.13	14.06	9.40	5.21
95% confidence interval	1.34 - 2.20	3.15 - 5.31	2.46 - 4.42	4.43 - 8.84	6.23 - 8.99	1.00 - 1.42	1.00 - 1.20	1.99 - 3.49	1.51 - 2.20	1.60 - 1.96
Encounter rate	0.04	0.04	0.05	0.06	0.04	0.02	0.02	0.05	0.06	0.14
Percent CV	19.92	18.95	15.94	16.72	19.87	22.40	23.78	21.98	14.24	11.87
95% confidence interval	0.03 - 0.06	0.03 - 0.06	0.03 - 0.06	0.04 - 0.08	0.02 - 0.05	0.10 - 0.02	0.01 - 0.04	0.03 - 0.07	0.04 - 0.08	0.11 - 0.18
Probability of a greater chi-square value, P	0.72	0.86	0.89	0.76	0.99	0.89	0.80	0.98	0.84	0.95

Table 4: Overall Individual Density, Group Density, Effective Strip Width, Average Group Size and Encounter Rate of various prey species in Tadoba Andhari Tiger Reserve during Phase IV monitoring 2021

Parameters	Sambar	Chital	Gaur	Wild pig	Langur	Nilgai	Barking deer	Hare	Peafowl	Grey jungle fowl
Individual density (No of Animals/km²)	1.71	2.65	2.16	3.73	3.35	1.04	0.42	0.68	1.79	8.19
Standard error	0.29	0.55	0.39	0.84	0.71	0.25	0.08	0.15	0.25	1.02
Percent CV	17.19	20.88	18.21	22.61	21.29	24.15	19.99	21.91	13.98	12.47
95% confidence interval	1.22 - 2.40	1.76 - 3.98	1.51 - 3.08	2.40 - 5.79	2.22 - 5.08	0.65 - 1.65	0.29 - 0.63	0.45 - 1.05	1.36 - 2.35	6.42 - 10.46
Group density (No of groups/km²)	0.99	0.79	0.69	0.72	0.50	0.48	0.39	0.64	1.03	5.03
Standard error	0.16	0.15	0.10	0.12	0.15	0.11	0.08	0.14	0.13	0.61
Percent CV	16.16	18.55	14.50	16.65	18.83	22.23	19.67	21.63	12.63	12.12
95% confidence interval	0.72 - 1.36	0.55 - 1.14	0.52 - 0.92	0.52 - 1.00	0.35 - 0.73	0.31 - 0.74	0.27 - 0.58	0.42 - 0.98	0.81 - 1.32	3.97 - 6.38
Effective strip width	31.87	40.32	33.29	39.63	35.27	42.02	29.37	16.77	31.22	16.86
Standard error	2.19	2.87	2.80	4.21	3.87	5.71	3.49	2.08	2.31	1.15
Percent CV	6.88	7.11	8.42	10.62	10.97	13.59	11.89	12.38	7.40	6.84
95% confidence interval	27.82 - 36.52	35.03 - 46.41	28.16 - 39.34	32.12 - 48.88	28.34 - 43.88	32.08 - 55.02	23.13 - 37.30	13.07 - 21.52	26.97 - 36.14	14.74 - 19.29
Average group size	1.80	4.46	3.05	6.24	8.08	2.51	1.12	1.10	1.89	1.67
Standard error	0.12	0.36	0.36	0.74	0.50	0.27	0.05	0.05	0.14	0.06
Percent CV	6.78	8.17	11.72	11.87	13.50	10.91	4.43	4.37	7.60	3.88
95% confidence interval	1.57 - 2.06	3.79 - 5.24	2.42 - 3.84	4.93 - 7.88	7.14 - 9.14	2.02 - 3.11	1.02 – 1.22	1.01- 1.20	1.63 - 2.20	1.55 - 1.80
Encounter rate	0.06	0.06	0.05	0.06	0.04	0.04	0.02	0.02	0.06	0.17
Percent CV	14.62	17.13	11.81	12.83	15.30	17.59	15.68	17.74	10.24	10.00
95% confidence interval	0.05 - 0.08	0.05 - 0.09	0.04 - 0.06	0.04 - 0.07	0.03 - 0.05	0.03 - 0.06	0.02 - 0.03	0.02 - 0.03	0.05 - 0.08	0.14 - 0.21
Probability of a greater chi-square value, P	0.96	0.84	0.96	0.96	0.89	0.93	0.96	0.82	0.97	0.91

Table 5: Comparison of prey density in Core area of TATR, Maharashtra, India (2002-2021). Standard errors are given in parentheses.

Species	2002	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Sambar	3.33	6.5 (±1.1)	3.9 (±1.1)	4.68 (±0.76)	5.27 (±1.16)	3.47 (±0.74)	1.76 (±0.58)	7.0 (±1.62)	8.23 (±1.89)	2.51 (±0.49)	3.08 (±0.69)
Chital	3.2	8.6 (±1.8)	6.3 (± 1.5)	5.10 (± 1.22)	7.42 (±2.36)	8.48 (± 2.03)	6.69 (±1.71)	10.81 (2.24)	13.82 (±3.23)	8.06 (±1.92)	3.98 (±1.21)
Gaur	1.8	6.6 (±1.4)	1.7 (± 0.3)	2.03 (± 0.56)	1.58 (±0.45)	2.64 (± 0.74)	2.12 (±0.46)	6.60 (±2.0)	7.30 (±2.43)	1.94 (±0.62)	1.91 (±0.57)
Langur	-	-	-	9.47 (± 1.90)	9.70 (±2.42)	10.32 (±2.86)	9.89 (±1.72)	11.81 (±2.80)	20 (±6.11)	3.70 (±1.52)	3.70 (±1.22)
Wild Pig	2.6	7.3 (±1.6)	3.7 (± 1.5)	5.42 (±2 .08)	4.49 (±1.73)	4.19 (±1.36)	3.97 (±0.46)	6.58 (±2.05)	7.23 (±2.87)	4.66 (±1.79)	5.50 (±1.87)
Nilgai	0.7	-	1.3 (± 0.5)	1.09 (± 0.36)	1.01 (±0.37)	0.42 (± 0.16)	0.33 (±0.12)	2.00 (±0.66)	3.25 (±0.89)	1.02 (±0.37)	0.56 (±0.21)
Barking Deer	0.9	5.2 (±1.2)	-	0.96 (± 0.23)	0.98 (±0.21)	1.16 (± 0.29)	1.12 (±0.45)	1.26 (±0.42)	1.43 (±0.53)	0.49 (±0.17)	0.82 (±0.22)
Hare	-	-	-	1.70 (± 0.36)	2.23 (±0.65)	0.49 (± 1.15)	1.23 (±0.54)	2.62 (±0.65)	3.4 (±0.34)	0.71 (±0.29)	-
Peafowl	-	-	-	3.92 (± 0.72)	3.36 (±0.81)	3.25 (± 0.67)	3.45 (±0.73)	6.87 (±1.59)	5.56 (±1.03)	2.38 (±0.67)	1.84 (±0.38)
Grey Jungle Fowl	-	-	-	1.43 (± 0.53)	2.58 (±0.78)	3.19 (± 0.9)	2.93 (±0.19)	0.82 (±0.40)	0.6 (±0.20)	1.60 (±0.33)	10.10 (±1.74)

Table 6: Comparison of prey density in Buffer area of TATR, Maharashtra, India (2015-2021). Standard errors are given in parentheses.

Species	2015	2016	2017	2018	2019	2020	2021
Sambar	1.88 (± 0.71)	1.22 (± 0.76)	1.58 (±0.40)	2.83 (±0.89)	3.44 (±0.96)	0.93 (±0.25)	0.73 (±0.19)
Chital	4.09 (± 0.92)	8.73 (± 1.93)	11.09 (±2.07)	8.86 (±1.58)	9.2 (±1.98)	3.39 (±0.74)	1.69 (±0.43)
Gaur	1.63 (± 0.59)	6.88 (± 1.87)	3.54 (1.07)	1.65 (±0.50)	1.98 (±0.80)	1.94 (±0.55)	2.98 (±0.72)
Langur	14.64 (± 5.98)	28.52 (±8.75)	11.10 (±3.75)	18.93 (±5.16)	20.22 (±5.22)	1.18 (±0.50)	2.96 (±0.95)
Wild Pig	4.56 (± 1.73)	9.82 (±6.23)	11.82 (±2.98)	16.29 (±4.93)	18.23 (±1.87)	3.43 (±0.99)	2.70 (±0.75)
Nilgai	0.74 (± 0.29)	5.91 (± 1.96)	5.22 (±1.66)	4.37 (±1.35)	5.67 (±1.87)	0.98 (±0.25)	1.11 (±0.30)
Barking Deer	0.68 (± 0.31)	3.62 (± 1.11)	2.82 (±0.31)	1.42 (0.80)	1.89 (±0.80)	0.22 (±0.08)	0.20 (±0.06)
Hare	0.99 (± 0.37)	1.51 (± 0.43)	1.02 (±0.31)	1.73 (±0.46)	1.91 (±0.67)	0.40 (±0.16)	0.93 (±0.27)
Peafowl	2.28 (± 0.79)	4.18 (± 0.9)	4.06 (±1.39)	2.37 (±0.69)	2.80 (±0.89)	0.92 (±0.24)	1.81 (±0.35)
Grey Jungle Fowl	0.59 (± 0.41)	1.03 (± 0.24)	1.43 (±0.54)	0.69 (±0.53)	0.98 (±0.98)	1.07 (±0.33)	4.99 (±0.76)

3. Status of Predators in Tadoba Andhari Tiger Reserve

Introduction:

Monitoring of large carnivore populations is important to guarantee their survival, to adapt management practices to changing situations, and to fulfil obligations for the conservation of habitat. It is also a very demanding exercise because of the large scales over which it must be conducted, often stretching across huge areas. The combination of biological characteristics of tigers - extensive distributional range, low densities, elusiveness, wide-ranging behaviors, low chances of detection of tiger sign in most situations – poses major challenges to the task of monitoring tiger populations. Typically, over large regions, even results of the mere presence or absence surveys tend to be equivocal or indeterminate. Particularly, it is difficult to infer the absence of tigers based on the absence of a tiger sign. The collection of quantitative data on the abundance of tigers or tiger signs is usually handicapped by small sample sizes, low detection probabilities, and numerous logistical and physical constraints. These species occur under a diversity of situations across TATR, and their monitoring hence represents a variety of challenges. The long-term monitoring projects are effective in understanding population trends in great details. The need for long term scientific monitoring of large carnivore populations arises from three considerations:

a) To objectively audit or evaluate success or failure of earlier management measures and conservation interventions to react adaptively and solve problems (Walters, 1986; Nichols et al., 1995).

b) To establish benchmark data that can serve as a basis for specific objectives for management and conservation efforts and

c) To improve our basic understanding of tiger, co-predator, and prey ecology through rigorous field studies, to develop a body of theoretical knowledge that can generate the predictive capacity to deal with new situations and contributes to the general advancement of scientific knowledge.

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 TATR. For Phase IV exercise camera traps were deployed in 621 grids of 2.01 km^2 area each in Tadoba Andhari Tiger Reserve (Figure 3). The total area was divided into two blocks due to limitation of camera traps. One pair of camera traps was deployed in each location for 27-44 days in the field that resulted in 20,965 trap nights. Cuddeback C1 and Professional Colour camera traps were used for the above exercise.

The cameras were active for the 24-h period that accounted for one sampling occasion. Each camera was assigned a unique identification number. Grid and the locations of each station were recorded for spatial analysis. Every tiger and leopard photograph were given a unique identification number after examining the stripe and rosette pattern on the flanks, limbs, and forequarters (Schaller 1967; McDougal 1977; Karanth 1995). Individual capture histories of tiger and leopard were developed in a standard "X-matrix format" (Otis et al., 1978; Nichols 1992). One critical assumption for closed population estimate is that the population should be demographically and geographically closed; (Otis et al., 1978; Rexstad and Burnham 1991) and to follow our closure assumption the sampling duration was kept as a minimum. Capture histories were analyzed using the software R package 'SECR' (Efford M.G. 2015) using a model developed for closed populations. The appropriate model was selected based on the Akaike Information Criterion. The density was estimated with the maximum likelihood obtained from the model fitted with 'SECR'.

Population Estimation of Tigers and Leopards:

During 83 days of camera trapping, with a sampling effort of 20,965 trap nights a total of 85 adult individual tigers were photographed within the core and buffer area of TATR along with 114 adult leopards. For estimating the density and population, "SECR" instead of the conventional capture-recapture model was used.

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 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. The key additional data that SECR analyses require, over and above the data used in non-spatial capture-recapture studies, are the locations of traps at which individuals were captured. Hence, to develop SECR models, some notation for trap location was needed.

Tiger density per 100 sq. km. based on the SECR Heterogeneity model was estimated to be 6.31 (SE ± 0.70) and that of Leopard was estimated to be 7.07 (SE ± 0.67). The best model for the density estimate was chosen based on the AIC (Akaike Information Criterion). The details for tigers and leopards are provided in Table 8 - 12. g_0 is the detection probability for the species, it is assumed to be constant or variable depending on the distribution. Sigma is the distribution of the average movement of the animal. It increases if the individuals are captured at very far away locations.

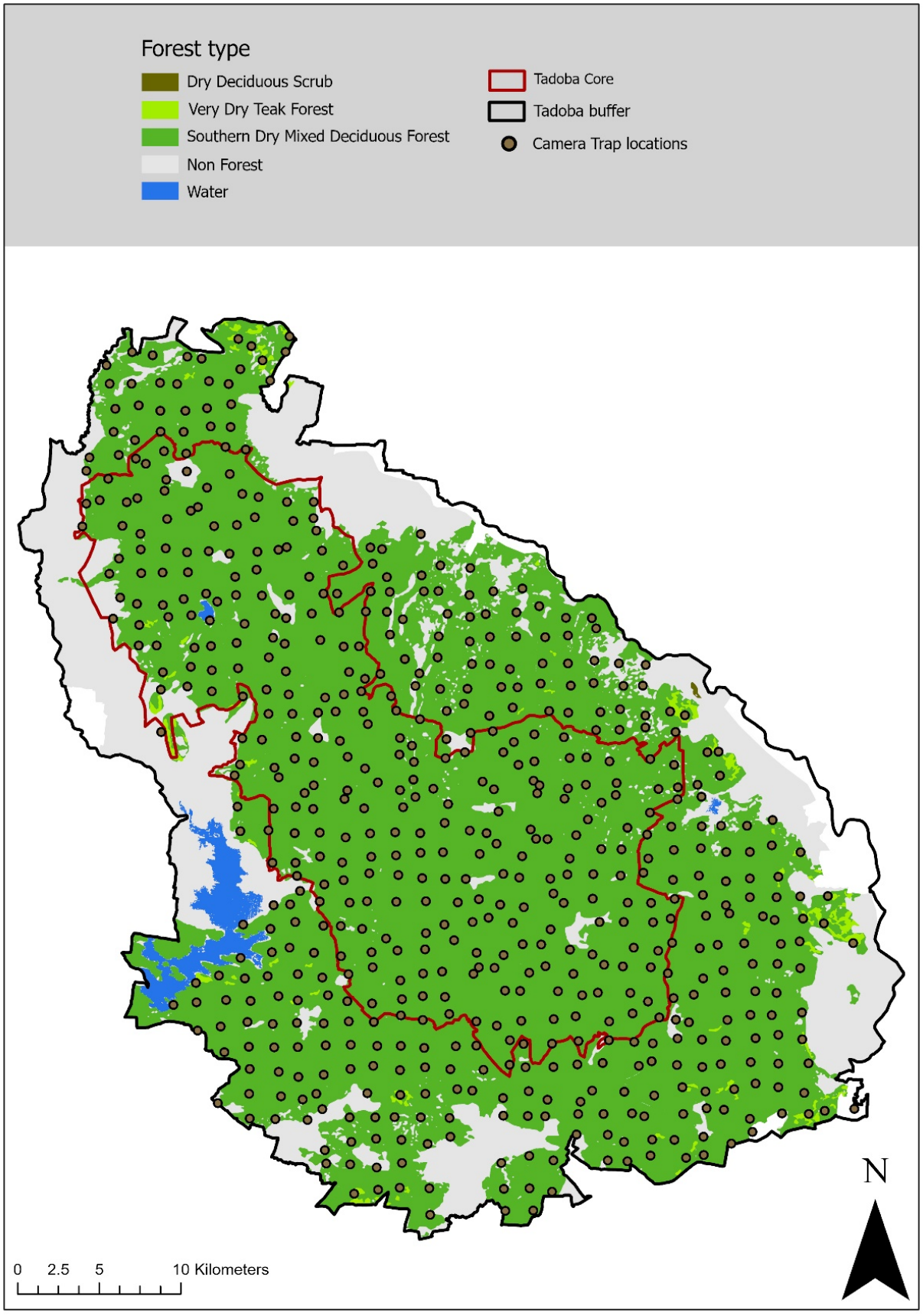

Figure 3: Camera trapping locations for the year 2021 in Core and Buffer area of Tadoba Andhari Tiger Reserve, Maharashtra, India

Table 7: Density estimates of tigers using Spatially Explicit Capture-Recapture Models in Tadoba Andhari Tiger Reserve, Maharashtra, India for the year 2014 – 2021.

Parameters	2014	2015	2016	2017	2018	2019	2020	2021
Model	Heterogeneity	Heterogeneity	Heterogeneity	Heterogeneity	Heterogeneity	Heterogeneity	Heterogeneity	Heterogeneity
Detection function	Half Normal	Half Normal	Half Normal	Half Normal	Half Normal	Half Normal	Half Normal	Half Normal
Density Estimate	5.609	5.673	5.648	5.823	5.51	5.23	6.58	6.31
Density SE	0.773	0.698	0.713	0.683	0.598	0.564	0.716	0.70
Density CI	4.28 - 7.34	4.46 - 7.21	4.93 -6.36	4.79 - 7.12	4.46 - 6.81	4.24 - 6.46	5.32 - 8.14	5.08 – 7.82
g0 Estimate	0.305	0.499	0.407	0.512	0.607	0.392	0.636	0.482
g0 SE	0.022	0.098	0.091	0.056	0.050	0.027	0.041	0.043
g0 CI	0.264-0.352	0.340-0.731	0.313-0.689	0.40-0.624	0.51–0.71	0.34-0.45	0.56-0.72	0.40-0.58
Sigma Estimate	4.283	3.309	3.354	3.237	2.07	3.83	2.36	2.4
Sigma SE	0.305	0.239	0.431	0.318	0.533	0.988	0.77	0.06
Sigma CI	3.725-4.925	2.871-3.814	2.716-3.972	2.659-3.946	0.974-2.184	3.64-4.03	2.22-2.52	2.28-2.54

Table 8: Population estimates of tigers using Spatially Explicit Capture-Recapture Models in Tadoba Andhari Tiger Reserve, Maharashtra, India for the year 2010 - 2021.

Year	Effective trapping area (km^2)	No of individuals captured	Estimate	Density per 100 km^2
2010	321	15	17 (± 3.6)	5.29 (± 1.12)
2012	603	47	49 (± 4.6)	5.40 (± 0.60)
2013	603	50	51 (± 7.5)	5.62 (± 0.82)
2014	1170	65	72 (± 5.37)	5.60 (± 0.77)
2015	1310	71	88 (± 4.91)	5.67 (± 0.69)
2016	1310	69	86 (± 8.7)	5.64 (± 0.71)
2017	1310	75	86 (± 4.42)	5.82 (± 0.68)
2018	1310	81	86 (± 3.5)	5.51 (± 0.59)
2019	1682	88	115 (± 12.42)	5.23 (± 0.56)
2020	1301	85	85 (± 0.94)	6.58 (± 0.72)
2021	1315	85	86 (± 0.71)	6.31 (± 0.70)

Table 9: Comparison of number of tigers utilizing core and buffer of Tadoba Andhari Tiger Reserve, Maharashtra, India across the years 2013 – 2021.

Details	2013	2014	2015	2016	2017	2018	2019	2020	2021
Tigers (Exclusively Core)	50	51	51	48	50	39	44	27	15
Tigers (Exclusively Buffer)	NA	10	14	17	19	22	23	34	37
Tigers (Core and Buffer)	NA	04	06	04	06	20	21	24	31

Table 10: Density estimates of leopards using Spatially Explicit Capture-Recapture Models in Tadoba Andhari Tiger Reserve, Maharashtra, India for the year 2019 - 2021.

Parameters	2019	2020	2021
Model	Heterogeneity	Heterogeneity	Heterogeneity
Detection function	Half Normal	Half Normal	Half Normal
Density Estimate	6.86	8.39	7.07
Density SE	0.689	0.812	0.666
Density CI	5.65-8.33	6.94-10.14	5.89-8.50
g0 Estimate	0.25	0.31	0.31
g0 SE	0.014	0.016	0.019
g0 CI	0.21-0.27	0.28-0.34	0.28-0.35
Sigma Estimate	5.41	2.14	2.23
Sigma SE	0.15	0.56	0.06
Sigma CI	5.12-5.72	2.03-2.25	2.11-2.35

Table 11: Population estimate for leopards using Spatially Explicit Capture-Recapture Models in Tadoba Andhari Tiger Reserve, Maharashtra, India for the years 2019 - 2021.

Year	Effective trapping Area (km^2)	No. of individuals captured	Estimate	Density per 100 km^2
2019	1682	106	151 (± 15.29)	6.86 (± 0.68)
2020	1301	106	109 (± 1.64)	8.39 (± 0.81)
2021	1667	114	118 (± 2.17)	7.07 (± 0.67)

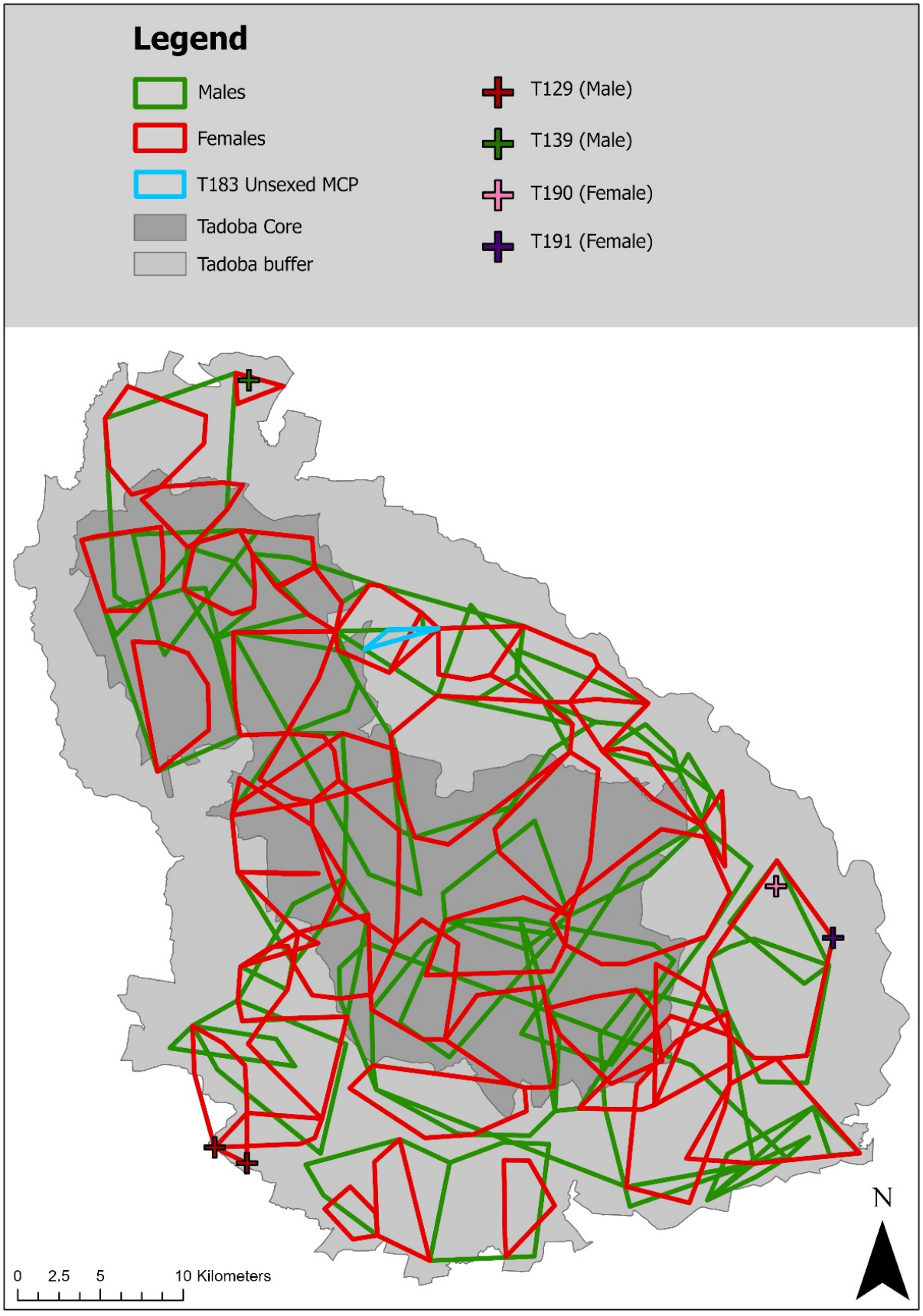

Figure 4: Minimum Convex Polygon of Tigers (Males & Females) Tadoba Andhari Tiger Reserve during the year 2021

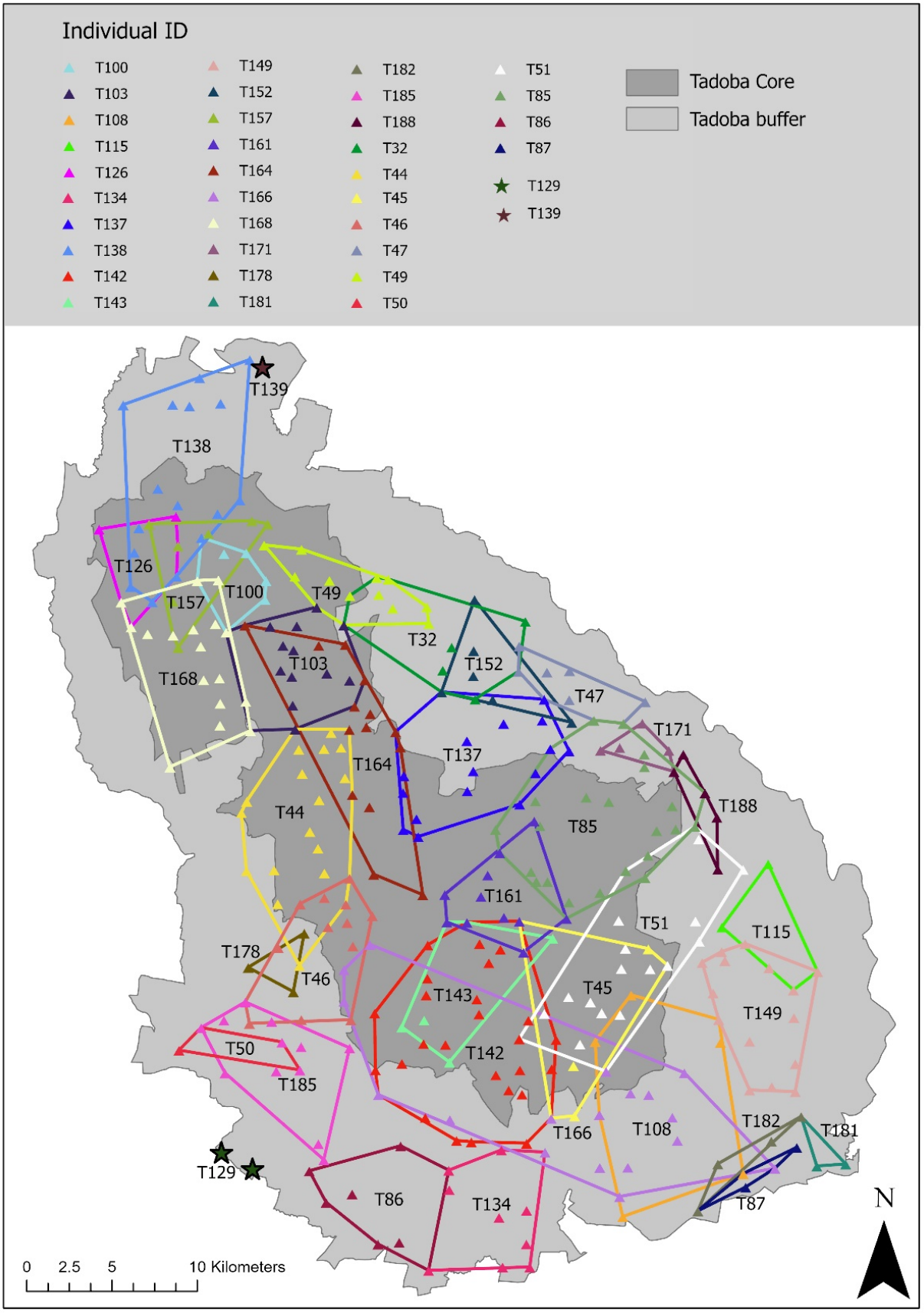

Figure 5: Minimum Convex Polygon of Male Tigers Tadoba Andhari Tiger Reserve during the year 2021

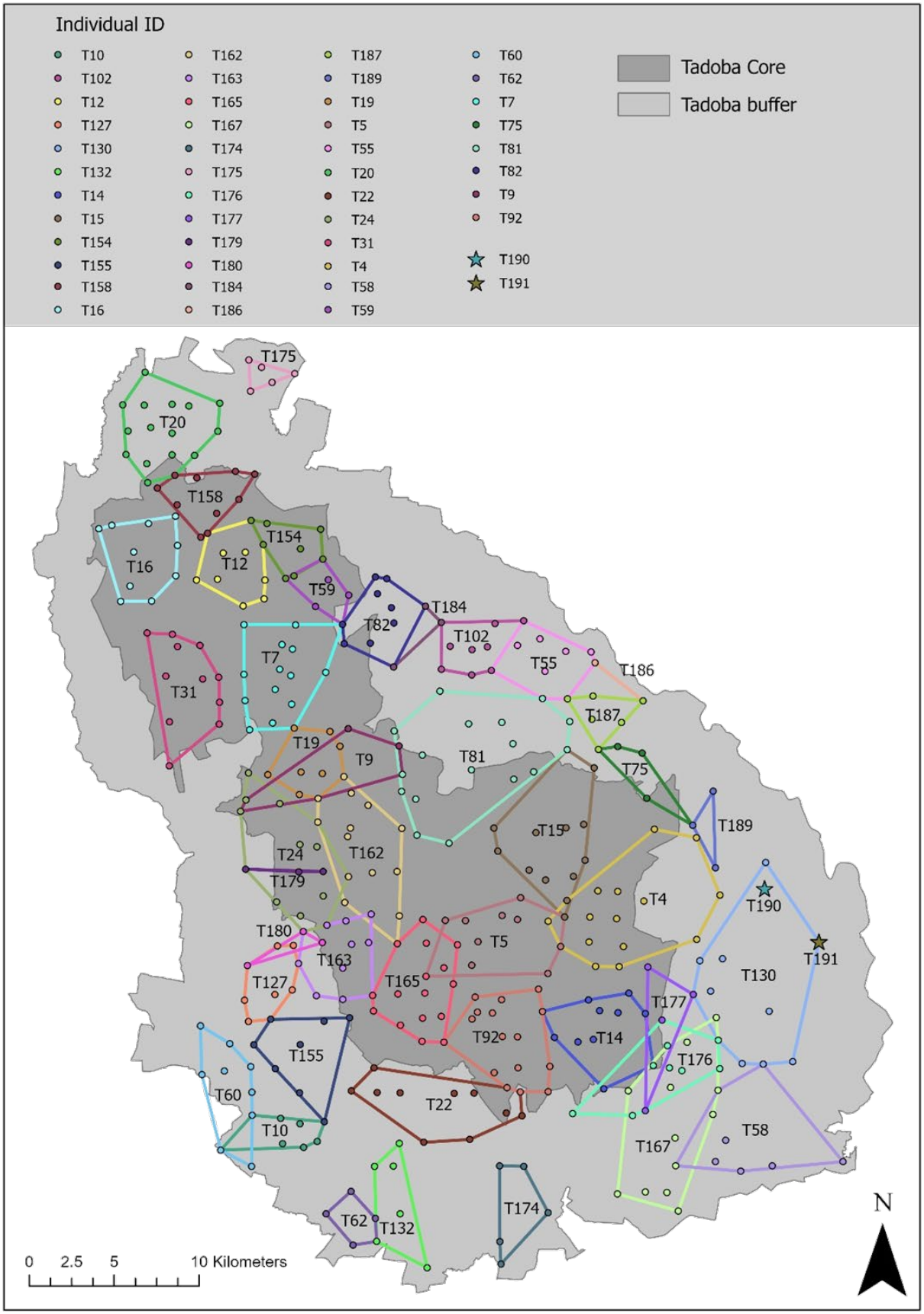

Figure 6: Minimum Convex Polygon of Female Tigers Tadoba Andhari Tiger Reserve during the year 2021

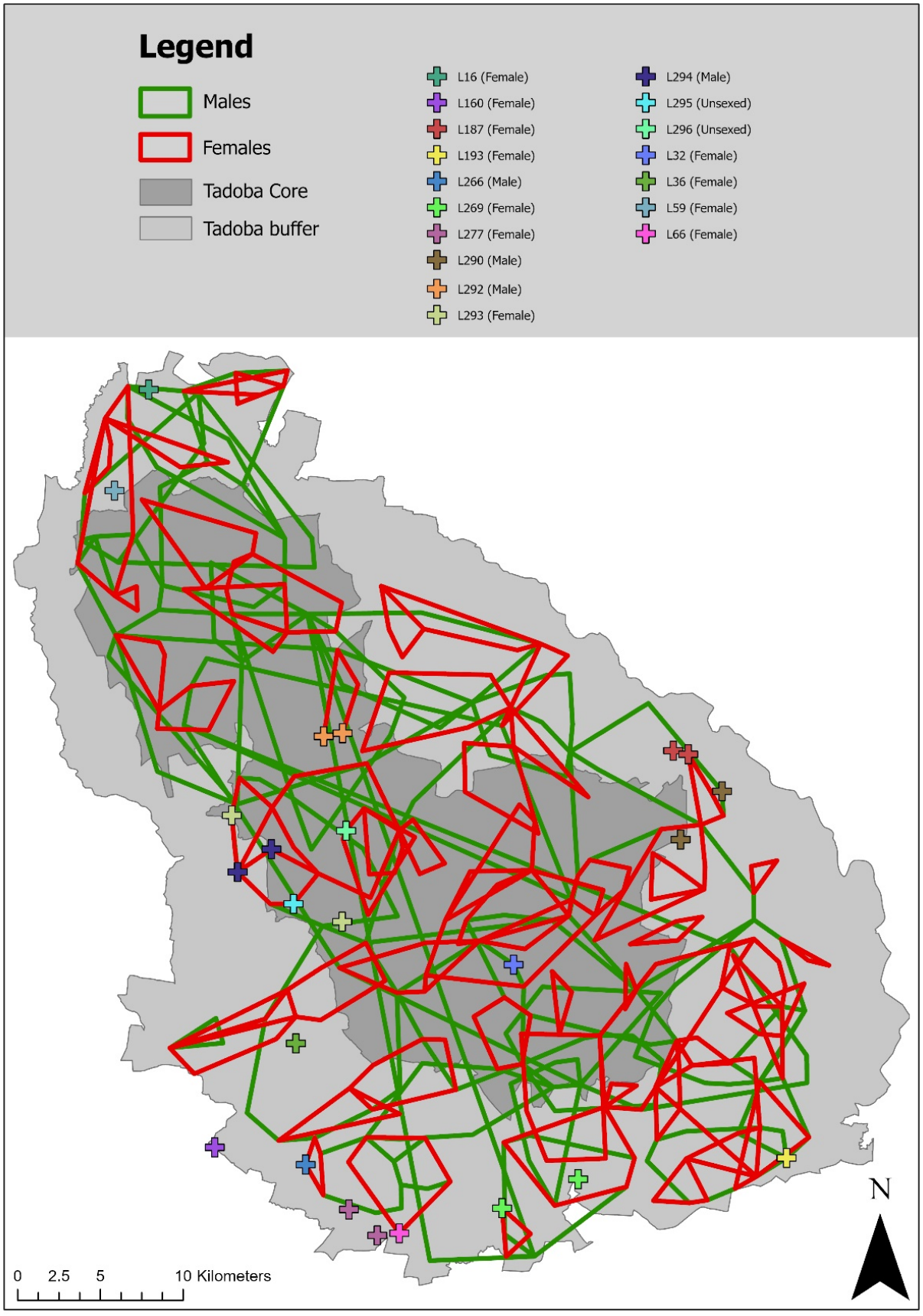

Figure 7: Minimum Convex Polygon of Leopards (Males & Females) Tadoba Andhari Tiger Reserve during the year 2021

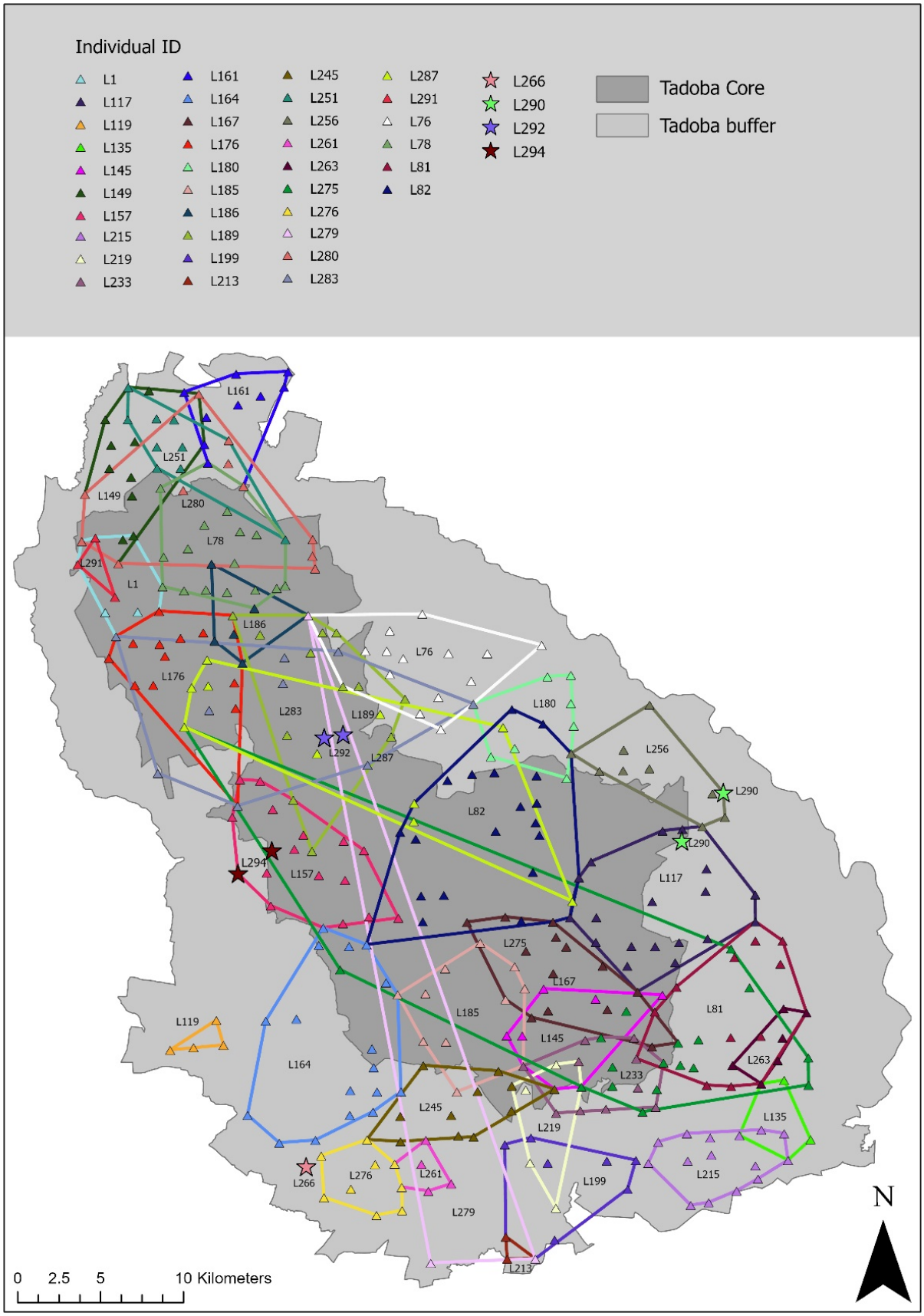

Figure 8: Minimum Convex Polygon of Male Leopards Tadoba Andhari Tiger Reserve during the year 2021

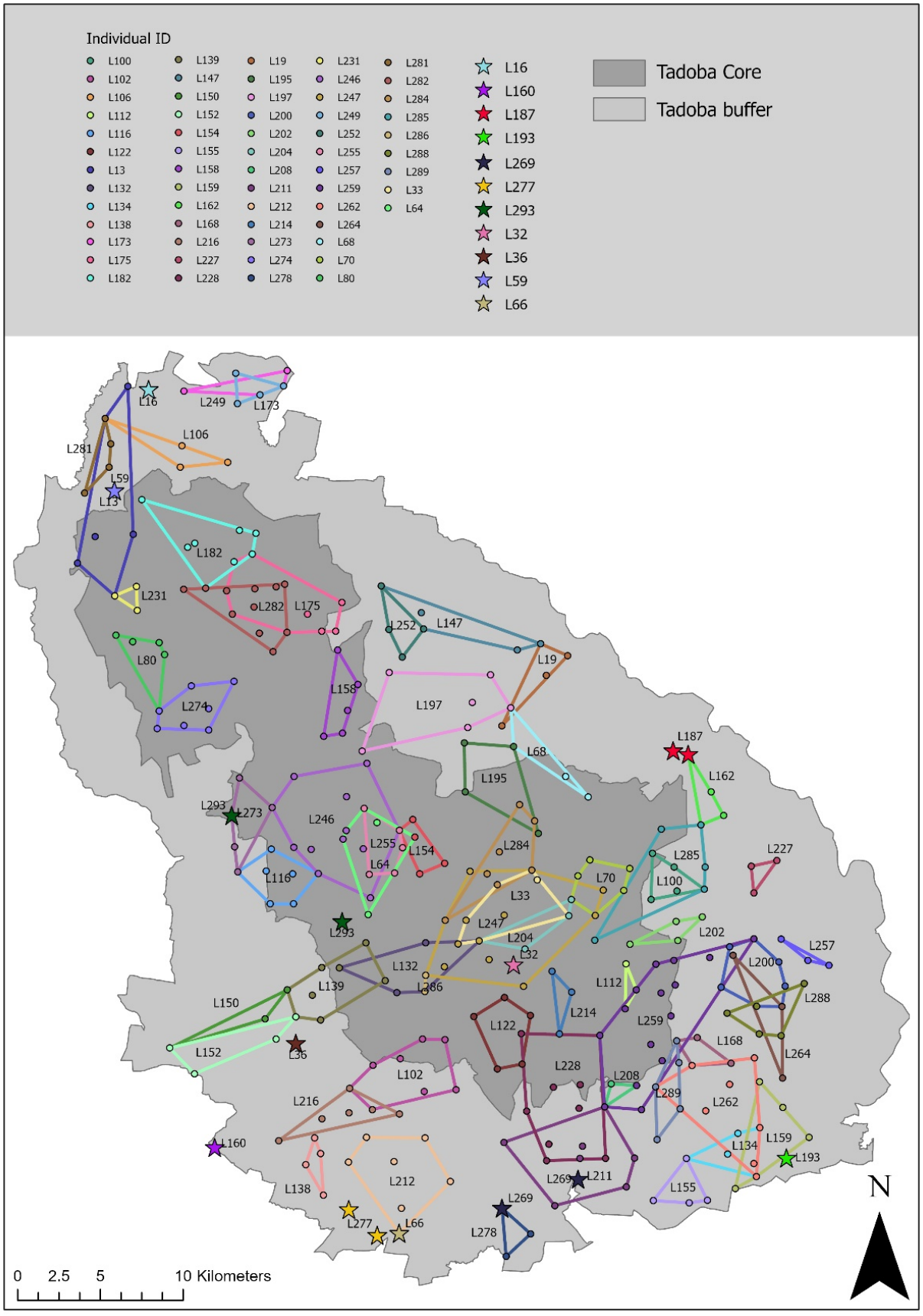

Figure 9: Minimum Convex Polygon of Female Leopards Tadoba Andhari Tiger Reserve during the year 2021

4. Temporal Activity of Predators and Prey Species in TATR

Introduction:

To know how prey species, interact with each other over time and space, it is imperative to study their activity patterns as well as their overlap. Camera trap being an excellent tool provides capture timings that have been used to determine the peak activity period among sympatric predators and prey of the study area.

Methods and Results:

The temporal pattern of the predators and their prey was analyzed using R Studio in R statistical software (version 3.6.2). 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 photographed at all times 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, favoring the coefficient of overlapping, Δ (Weitzman 1970), which ranges from 0 (no overlap, eg. 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 during the day the proportion of activity that occurs during that period differs between the two distributions by <1–Δ. 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:

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

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:

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

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

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 daily temporal activity patterns of different predator species are shown in Figures 10 - 16. From the kernel density estimators, the tiger and leopard were observed to have a high degree (0.91) of overlap as indicated by the estimated overlap coefficients in Table 13:

Table 12: Temporal activity overlap of predator and prey species.

Species	Tiger	Leopard	Dhole
Barking Deer	0.62	0.57	0.86
Chital	0.54	0.46	0.80
Four-horned Antelope	0.45	0.38	0.59
Gaur	0.84	0.80	0.69
Indian Hare	0.66	0.72	0.30
Langur	0.33	0.25	0.63
Nilgai	0.47	0.39	0.70
Rusty-spotted cat	0.69	0.76	0.31
Ratel	0.68	0.75	0.30
Porcupine	0.60	0.66	0.24
Sambar	0.88	0.82	0.68
Wild Boar	0.55	0.48	0.85
Sloth Bear	0.93	0.92	0.60
Jungle Cat	0.74	0.79	0.35
Tiger	-	0.91	0.60
Leopard	0.91	-	0.53
Dhole	0.60	0.53	-
Peafowl	0.36	0.30	0.62
Grey Jungle Fowl	0.40	0.30	0.75

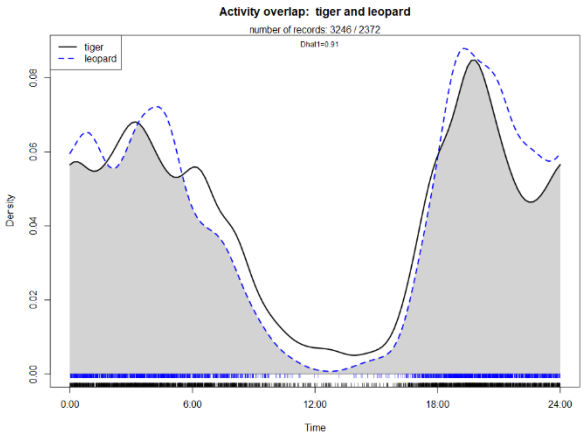

Figure 10 (a): Tiger - Leopard

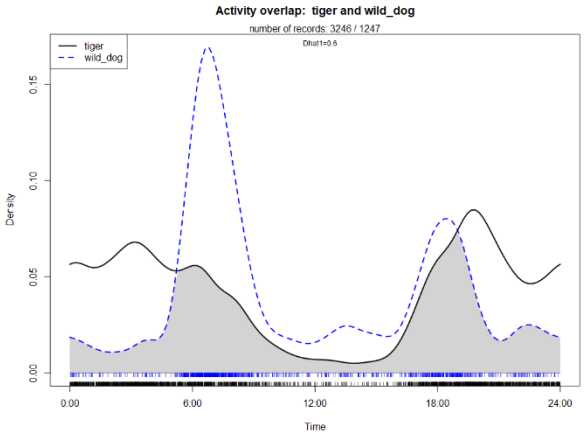

Figure 10 (b): Tiger - Dhole

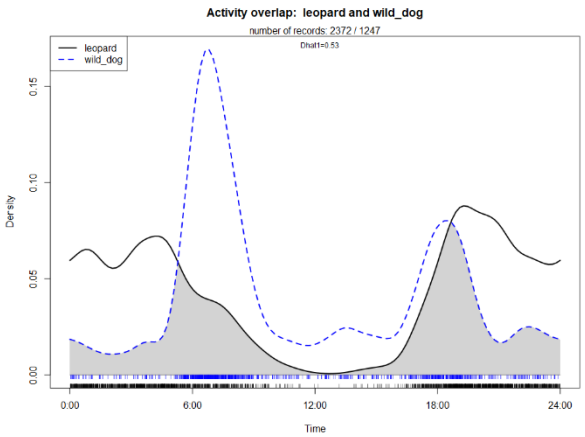

Figure 10 (c): Leopard - Dhole

Figure 10 (a-c): Daily temporal activity pattern overlap between co-predators. (a) Tiger vs. Leopard; (b) Tiger vs. Dhole; (c) Leopard vs. Dhole in TATR, India India during the year 2021. The lines represent the kernel density estimates based on individual photograph times. The overlap is shown by the shaded area in each plot.

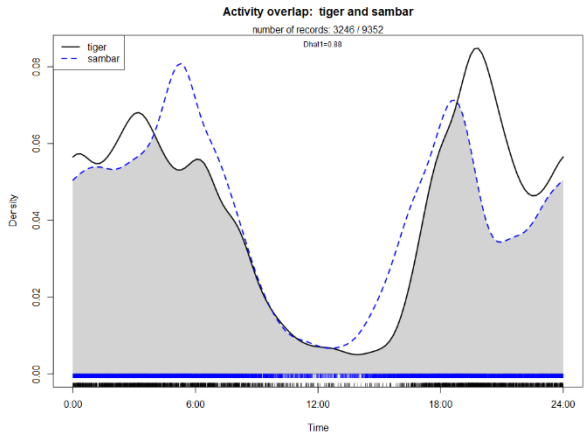

Figure 11 (a): Tiger - Sambar

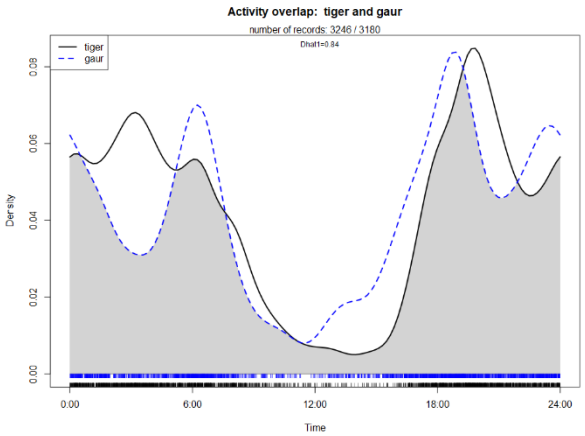

Figure 11 (b): Tiger - Gaur

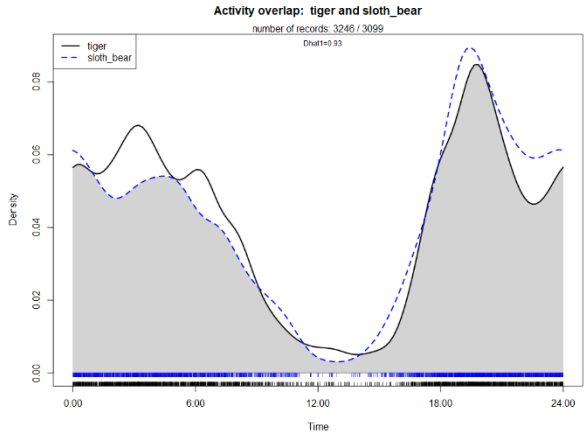

Figure 11 (c): Tiger – Sloth bear

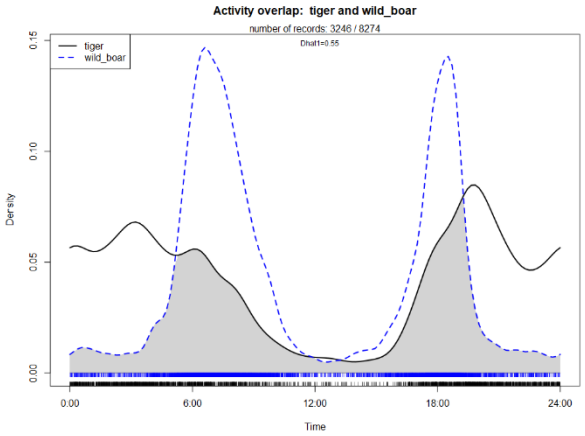

Figure 11 (d): Tiger – Wild boar

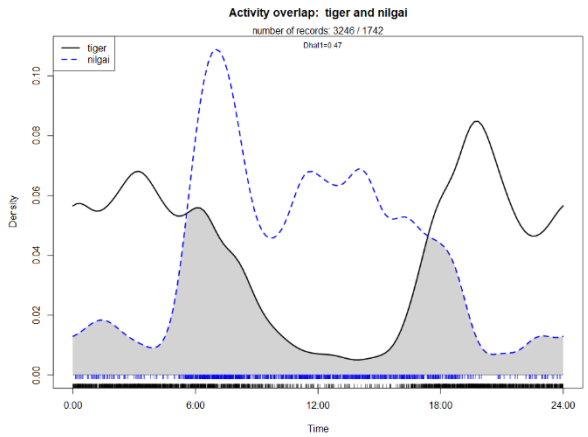

Figure 11 (e): Tiger - Nilgai

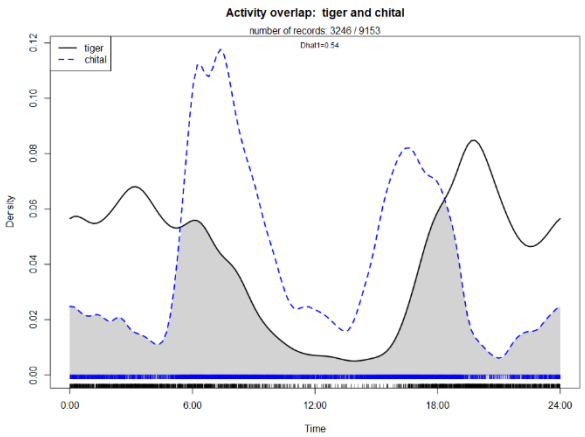

Figure 11 (f): Tiger - Chital

Figure 11 (a-f): Daily temporal activity patterns of Tiger vs. prey species in TATR, India during the year 2021. The lines represent the kernel density estimates based on individual photograph times. The overlap is shown by the shaded area in each plot.

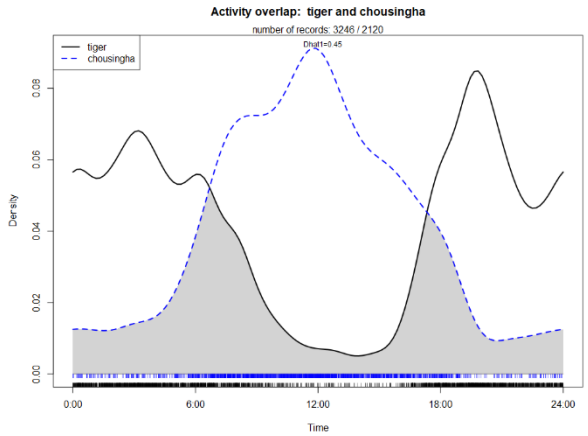

Figure 12 (a): Tiger - Chousingha

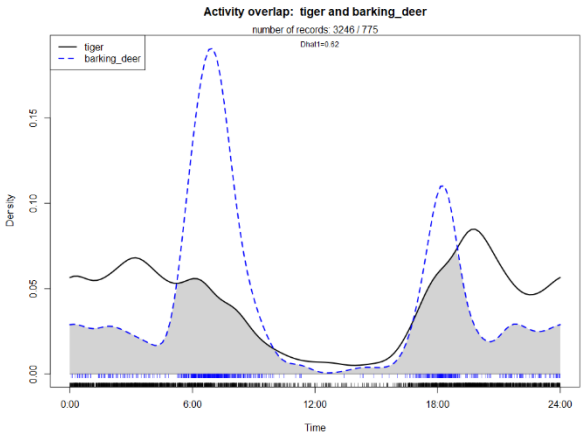

Figure 12 (b): Tiger - Barking deer

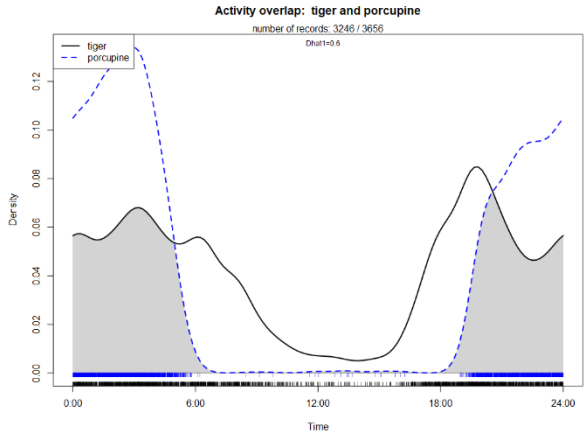

Figure 12 (c): Tiger - Porcupine

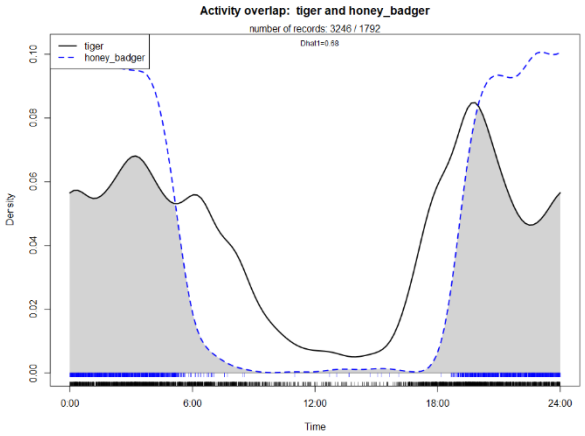

Figure 12 (d): Tiger - Ratel

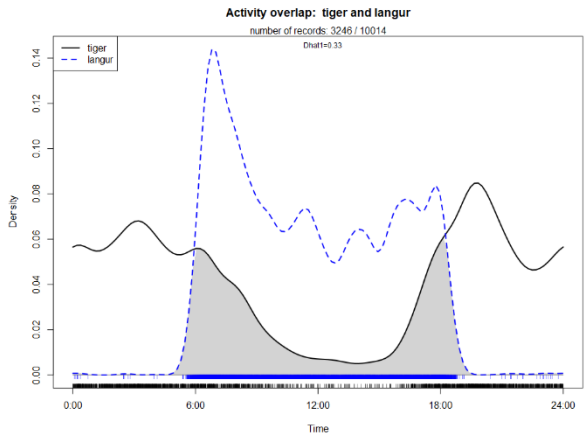

Figure 12 (e): Tiger - Langur

Figure 12 (a-e): Daily temporal activity patterns of Tiger vs. prey species in TATR, India during the year 2021. The lines represent the kernel density estimates based on individual photograph times. The overlap is shown by the shaded area in each plot.

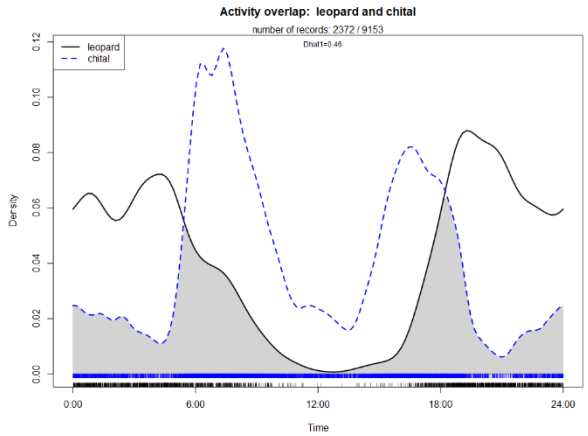

Figure 13 (a): Leopard - Chital

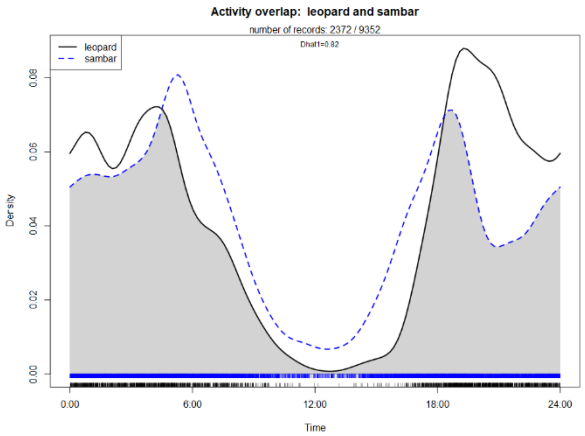

Figure 13 (b): Leopard - Sambar

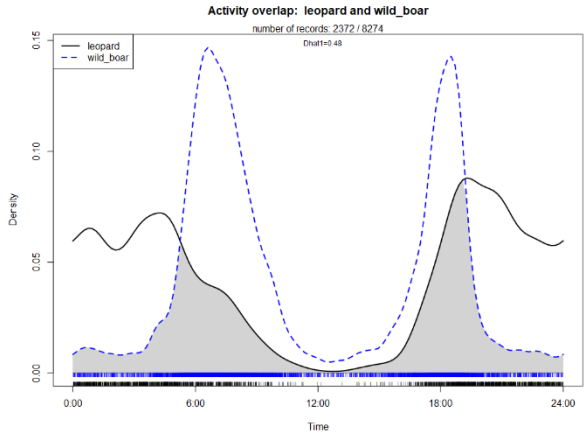

Figure 13 (c): Leopard - Wild boar

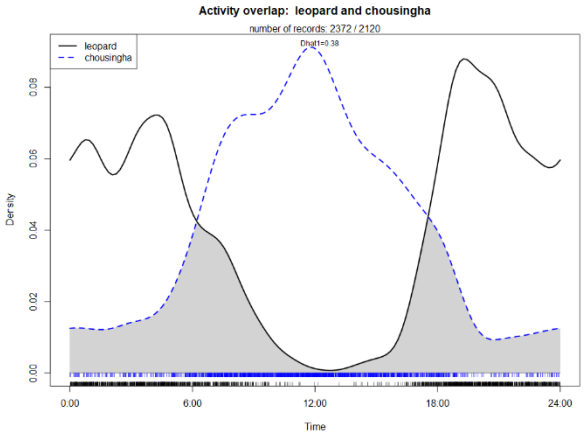

Figure 13 (d): Leopard - Chousingha

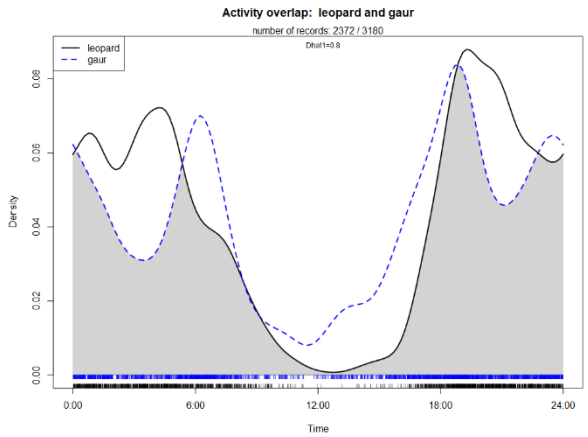

Figure 13 (e): Leopard - Gaur

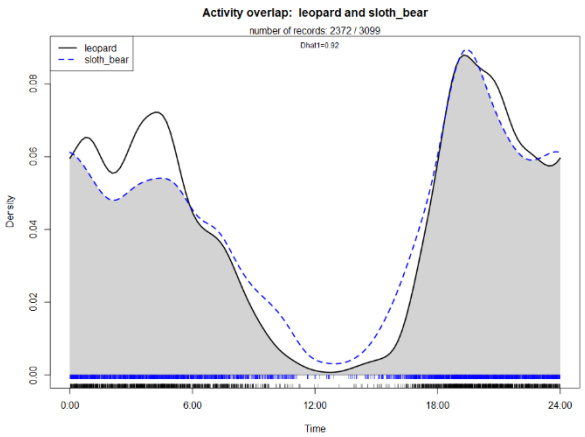

Figure 13 (f): Leopard - Sloth bear

Figure 13 (a-f): Daily temporal activity patterns of Leopard vs. prey species in TATR, India during the year 2021. The lines represent the kernel density estimates based on individual photograph times. The overlap is shown by the shaded area in each plot.

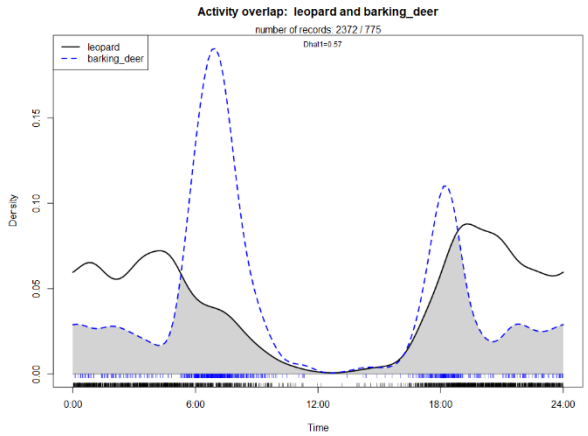

Figure 14 (a): Leopard - Barking deer

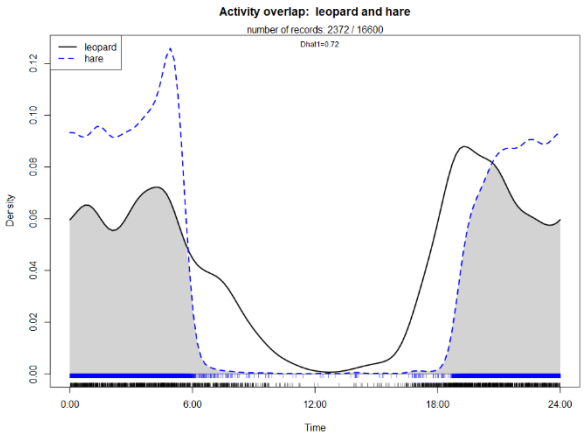

Figure 14 (b): Leopard - Hare

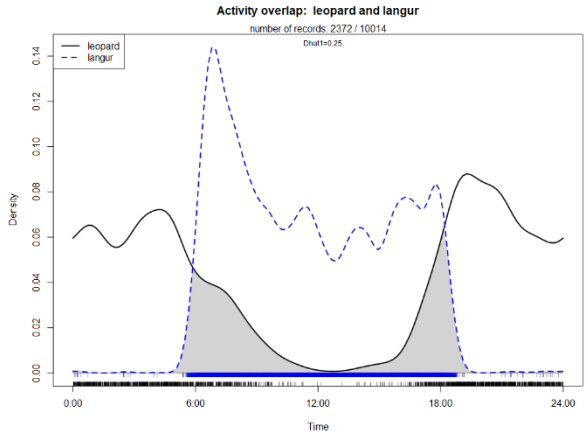

Figure 14 (c): Leopard - Langur

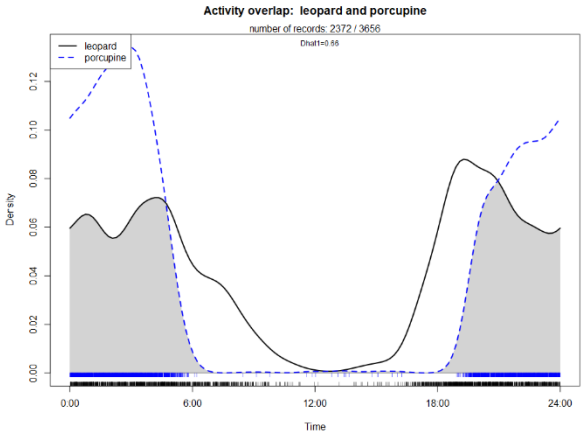

Figure 14 (d): Leopard - Porcupine

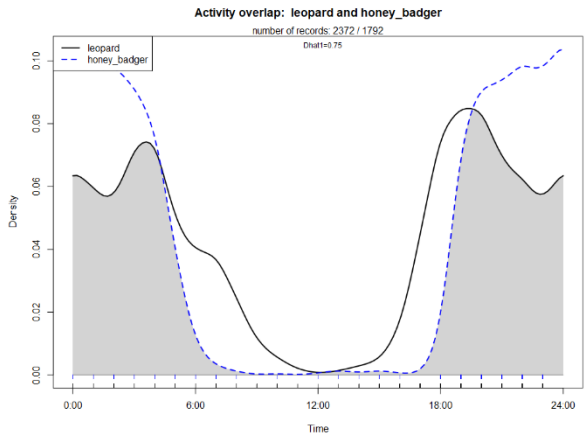

Figure 14 (e): Leopard - Ratel

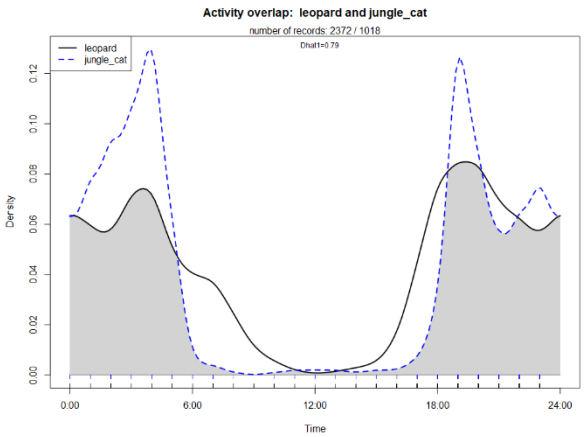

Figure 14 (f): Leopard - Jungle cat

Figure 14 (a-f): Daily temporal activity patterns of Leopard vs. prey species in TATR, India during the year 2021. The lines represent the kernel density estimates based on individual photograph times. The overlap is shown by the shaded area in each plot.

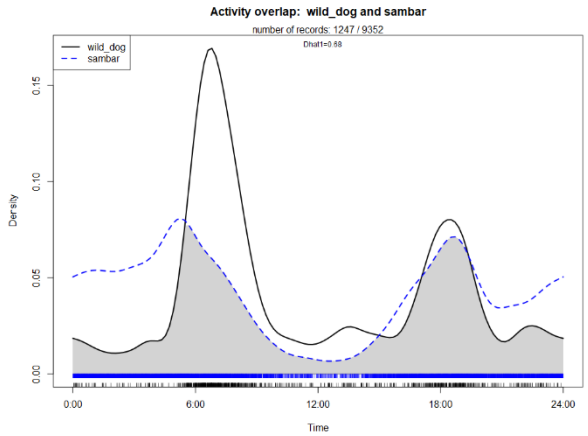

Figure 15 (a): Dhole - Sambar

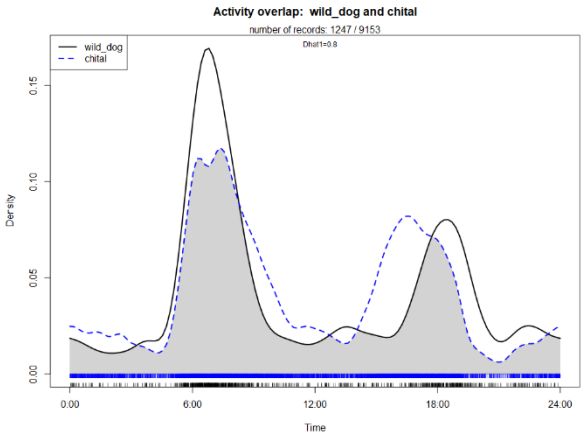

Figure 15 (b): Dhole - Chital

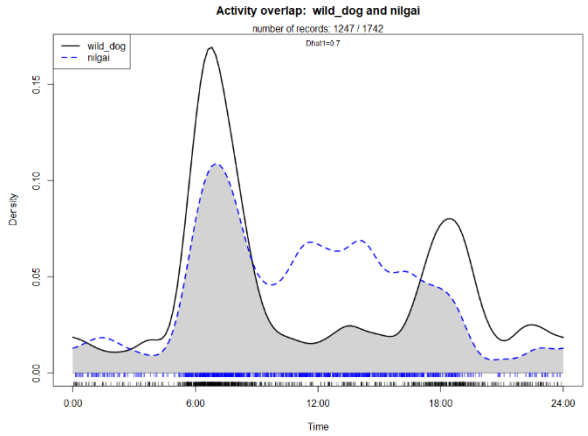

Figure 15 (c): Dhole - Nilgai

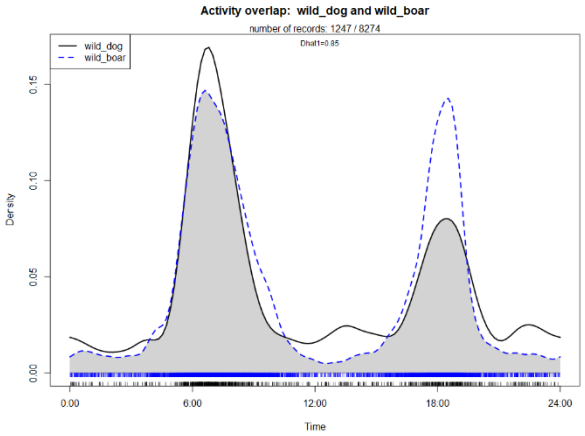

Figure 15 (d): Dhole - Wild boar

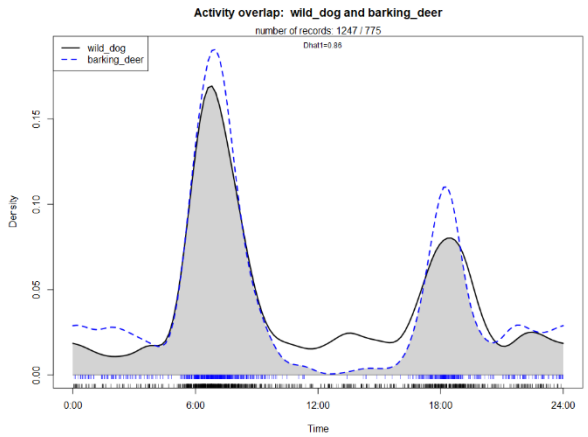

Figure 15 (e): Dhole - Barking deer

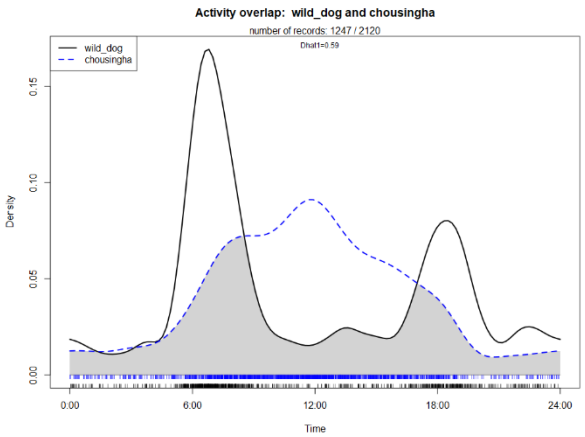

Figure 15 (f): Dhole - Chousingha

Figure 15 (a-f): Daily temporal activity patterns of Dhole vs. prey species in TATR, India during the year 2021. The lines represent the kernel density estimates based on individual photograph times. The overlap is shown by the shaded area in each plot.

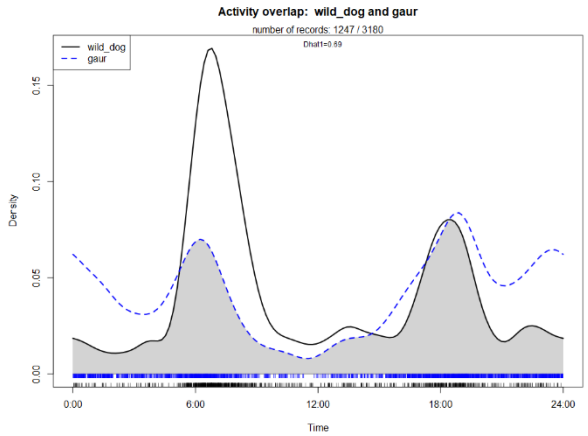

Figure 16 (a): Dhole - Gaur

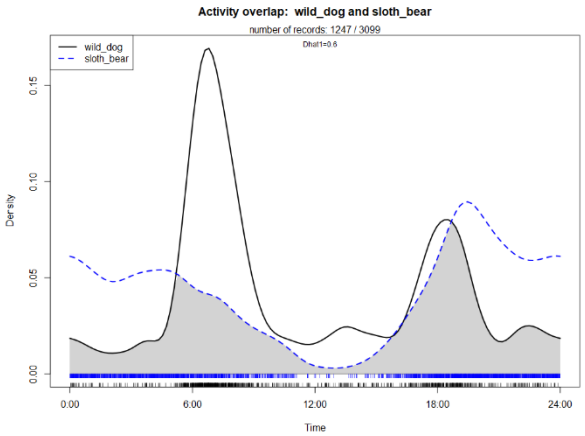

Figure 16 (b): Dhole - Sloth bear

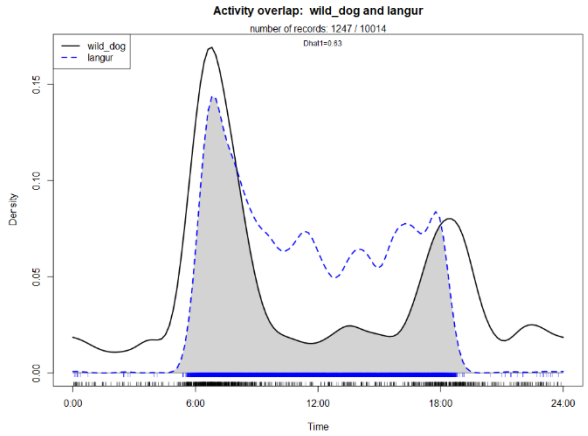

Figure 16 (c): Dhole - Langur

Figure 16 (a-c): Daily temporal activity patterns of Dhole vs. prey species in TATR, India during the year 2021. The lines represent the kernel density estimates based on individual photograph times. The overlap is shown by the shaded area in each plot.

5. 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 (Figure 17) in the interpolated surface can only occur at sample points. The output surface is sensitive to clustering and the presence of outliers. IDW assumes that the phenomenon being modelled is driven by local variation, which can be captured (modelled) by defining an adequate search neighbourhood.

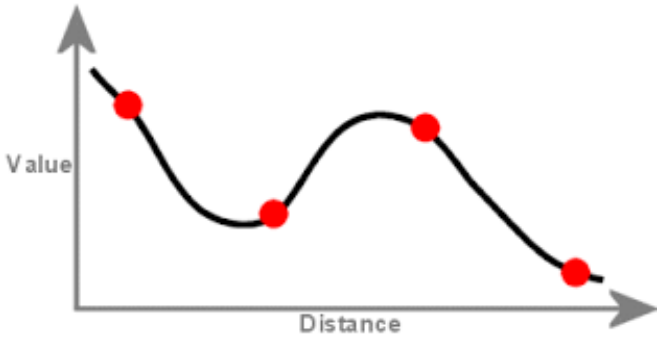

Figure 17: IDW (Inverse distance weighted) interpolation

Using IDW technique spatially explicit intensive use area maps (Based on camera trap location and number of photographs at each location) has been developed for predator and prey species. Figures 18 (a - n) show intensive use areas of different species in Tadoba Andhari Tiger Reserve.

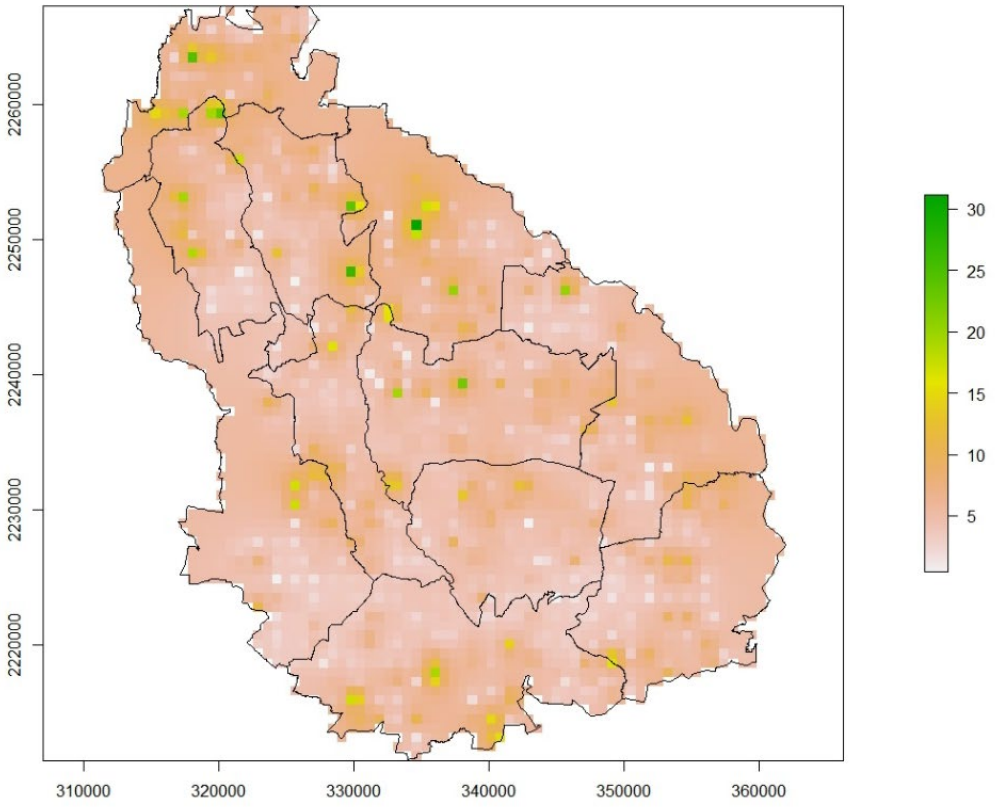

Figure 18 (a): Intensive use area map of Tiger in TATR

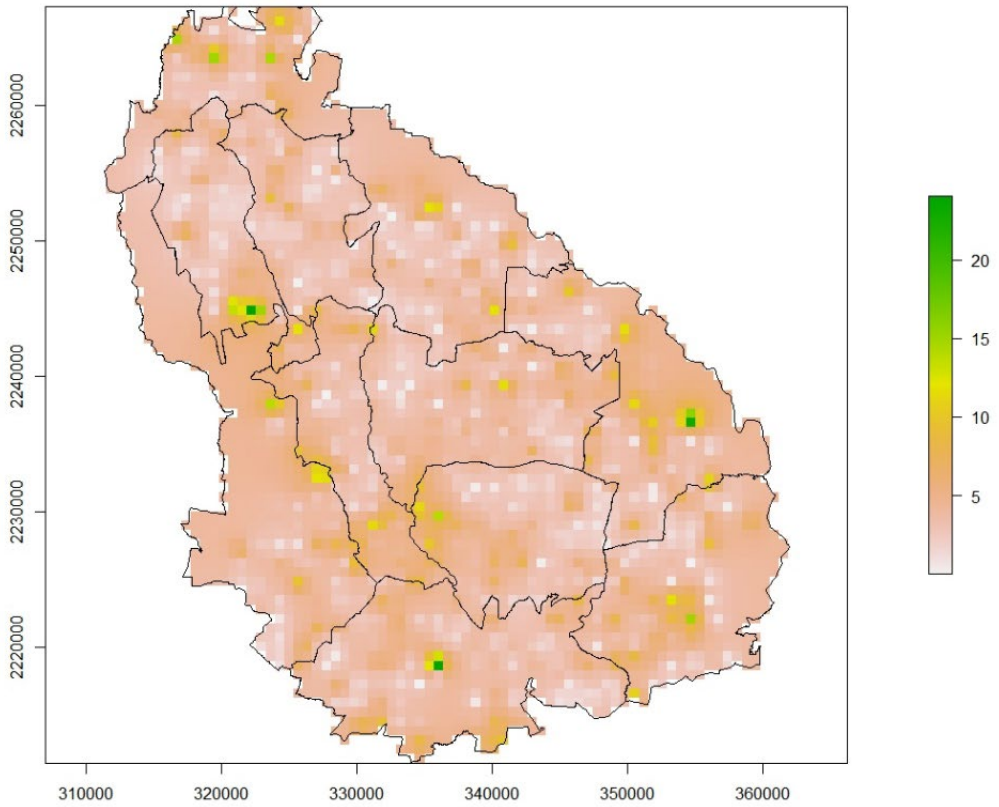

Figure 18 (b): Intensive use area map of Leopard in TATR

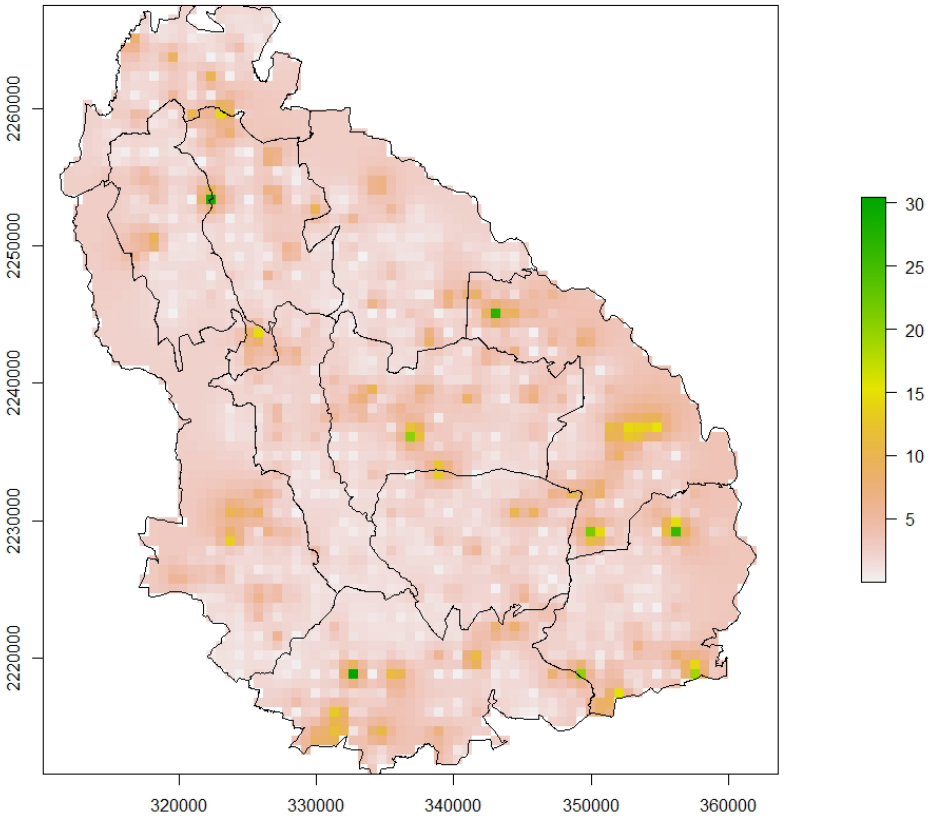

Figure 18 (a): Intensive use area map of Dhole in TATR

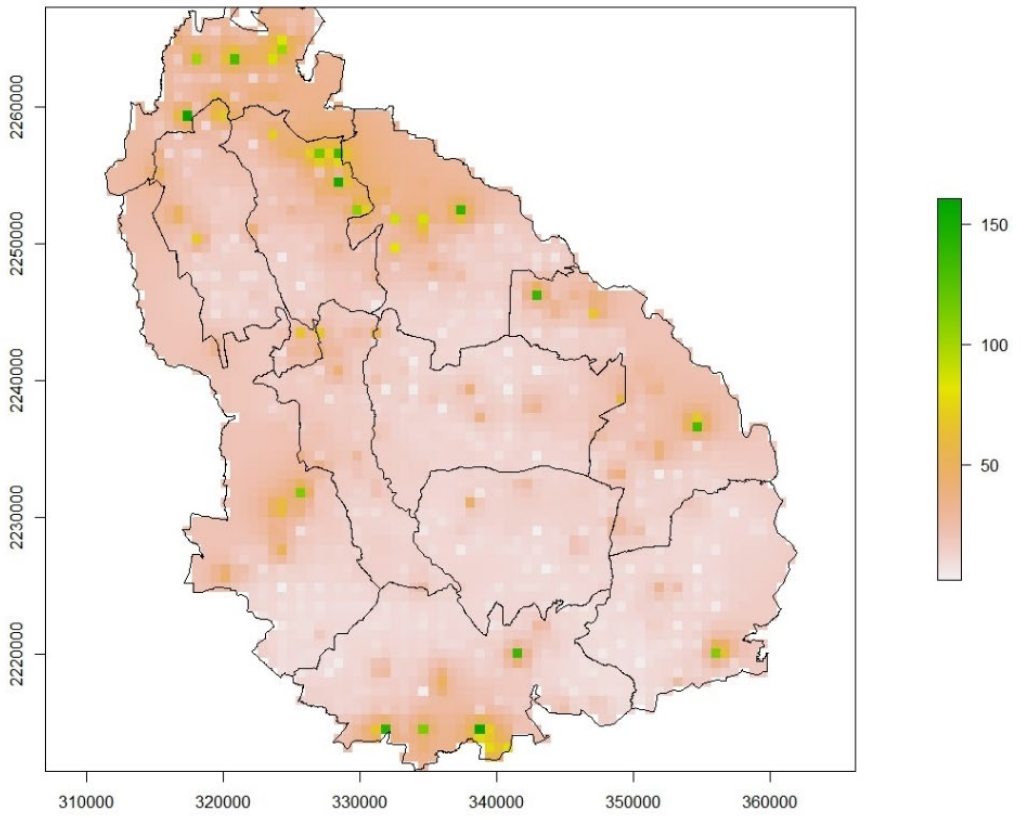

Figure 18 (b): Intensive use area map of Sambar in TATR

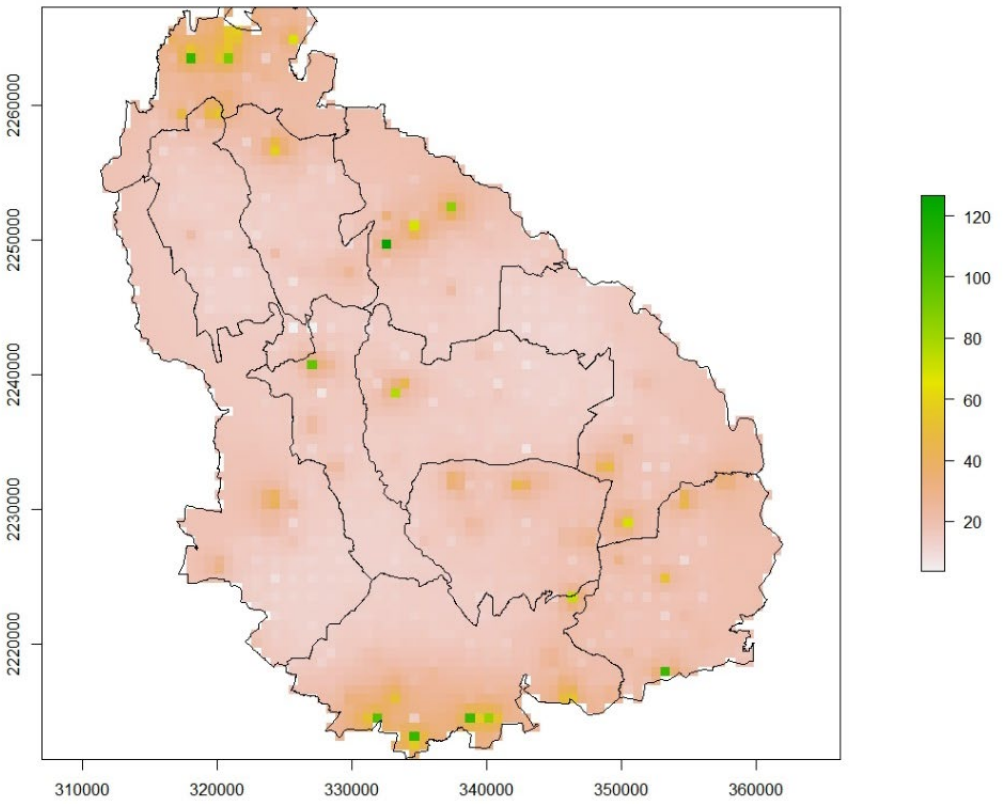

Figure 18 (e): Intensive use area map of Chital in TATR

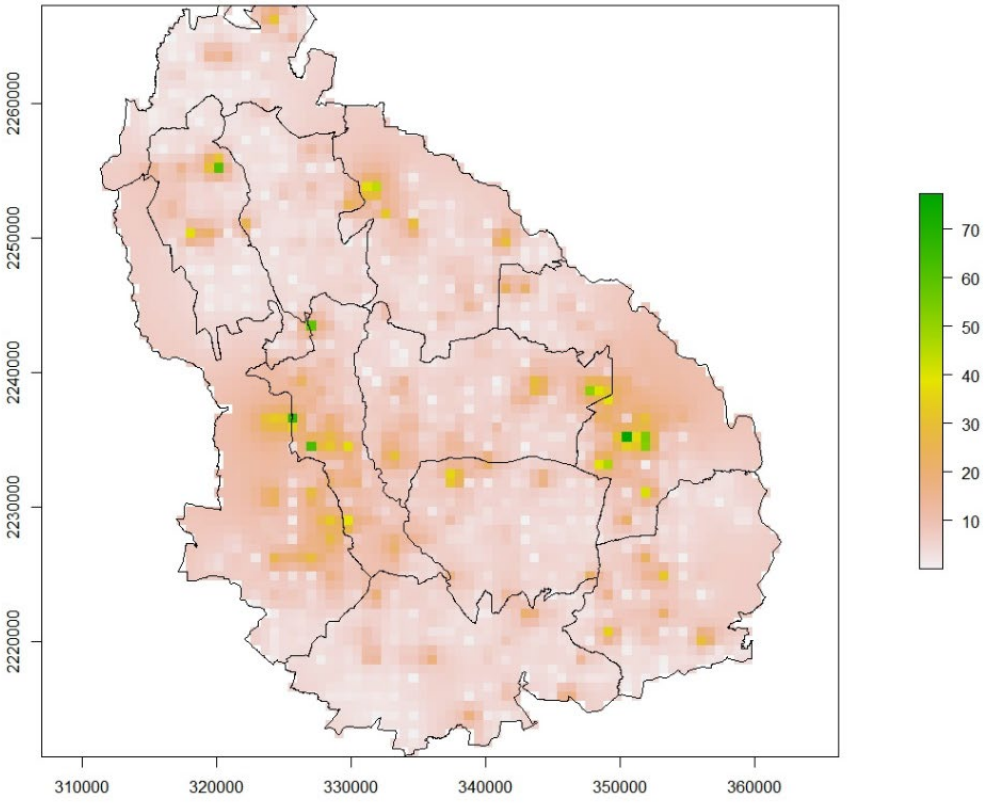

Figure 18 (f): Intensive use area map of Gaur in TATR

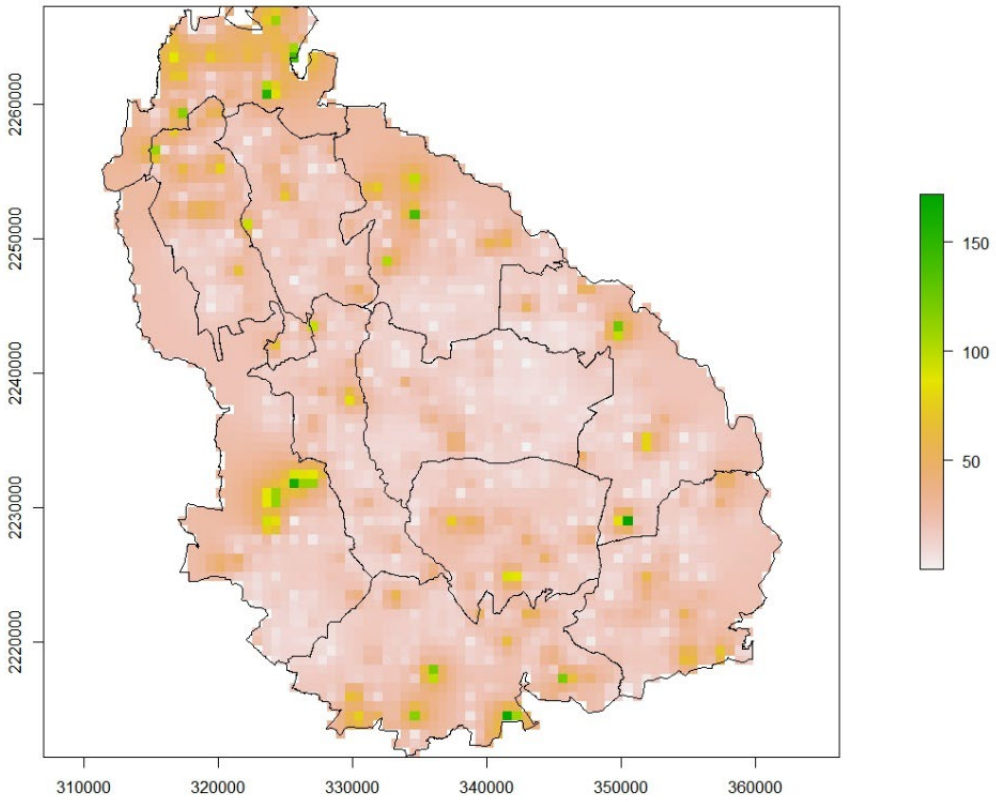

Figure 18 (g): Intensive use area map of Wild boar in TATR

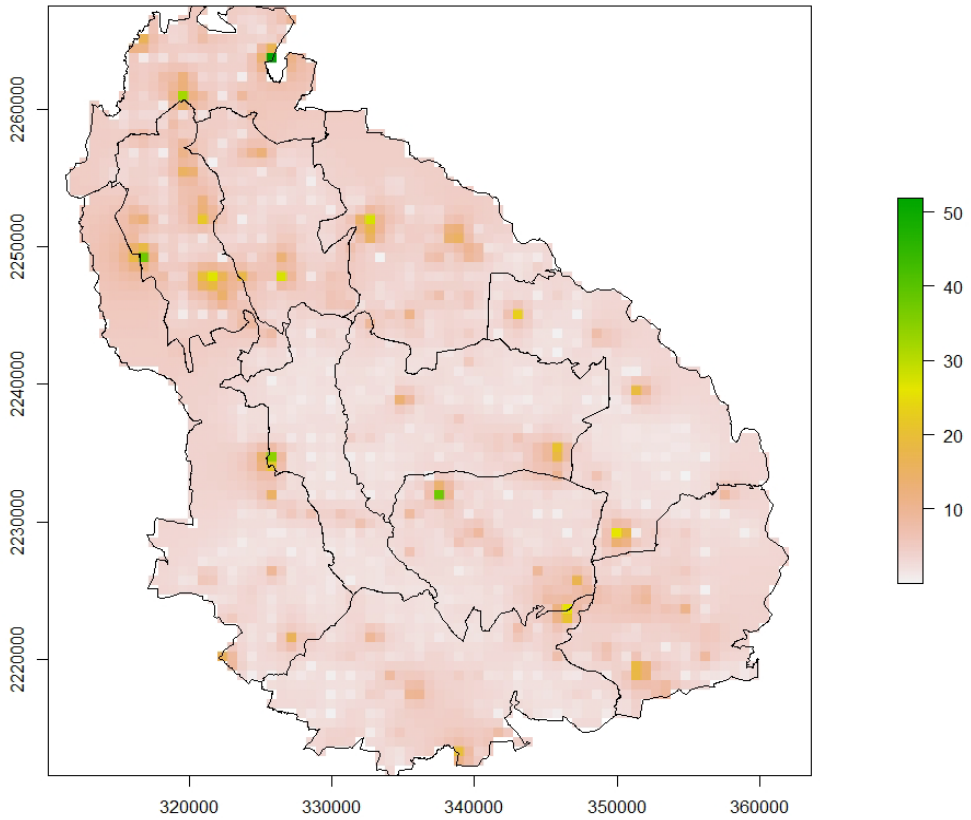

Figure 18 (h): Intensive use area map of Nilgai in TATR

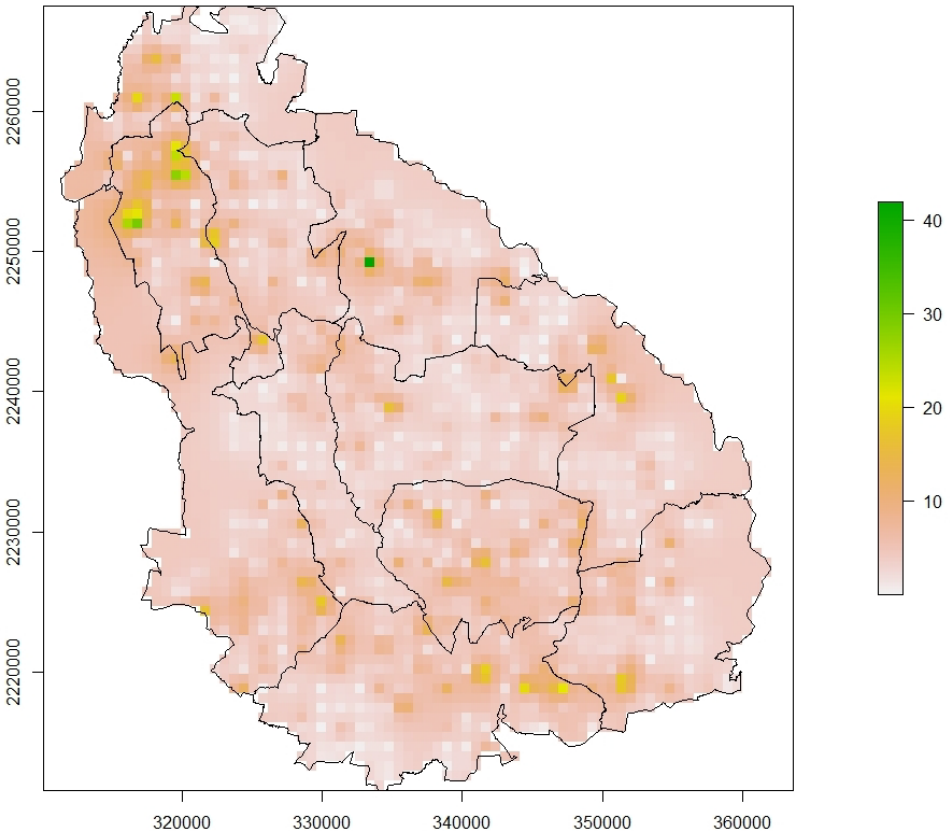

Figure 18 (i): Intensive use area map of Chousingha or Four-horned antelope in TATR

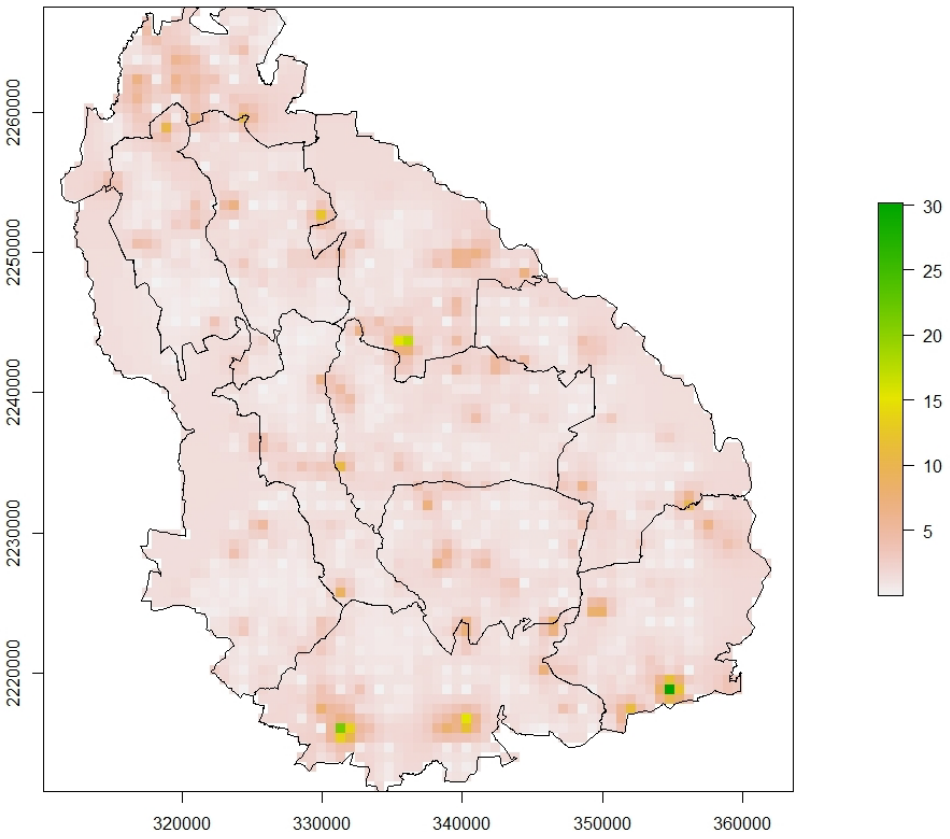

Figure 18 (j): Intensive use area map of Jungle cat in TATR

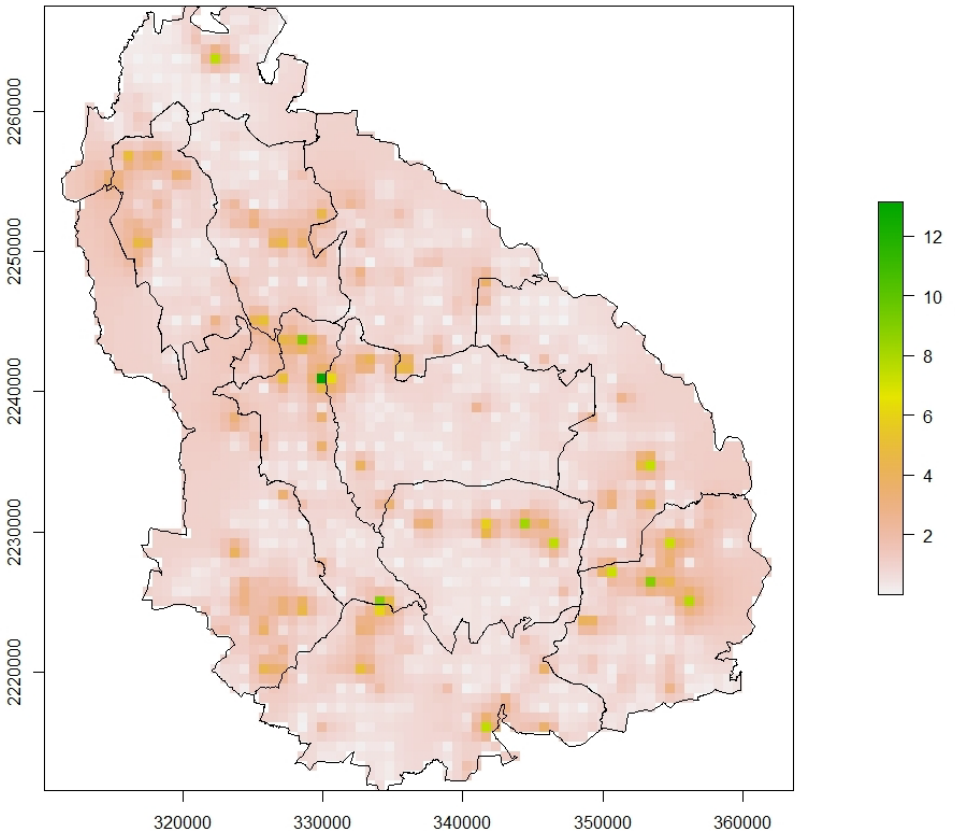

Figure 18 (m): Intensive use area map of Rusty-spotted cat in TATR

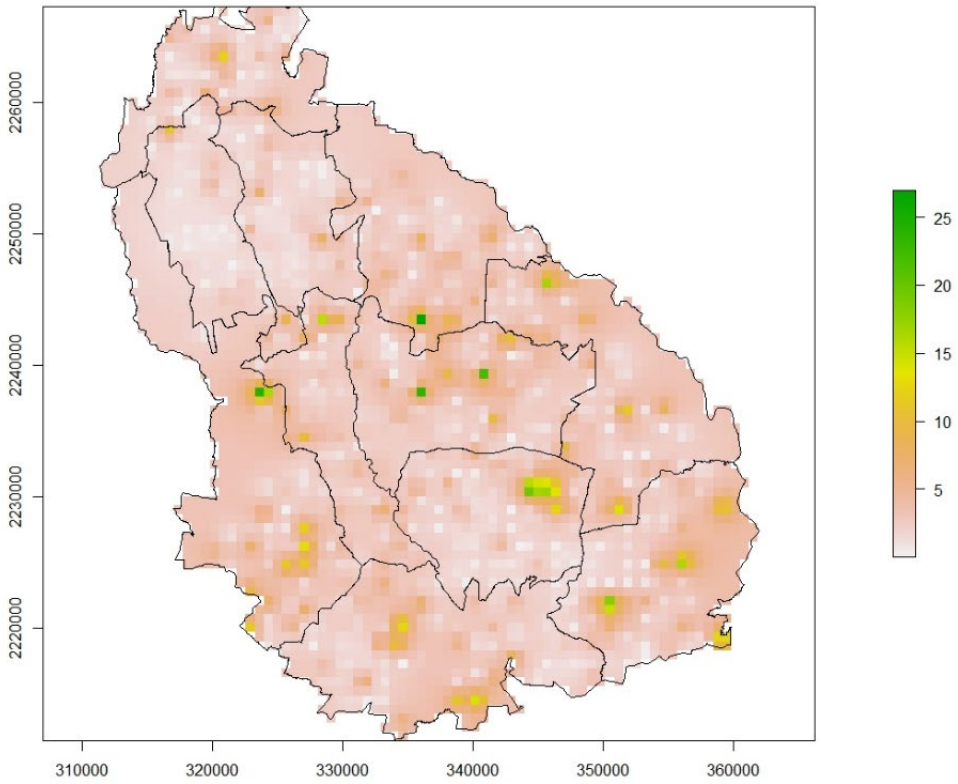

Figure 18 (n): Intensive use area map of Ratel or Honey badger in TATR

Figures 18 (a – n): Intensive use area maps of various species in Tadoba Andhari Tiger Reserve, Maharashtra, India during the 2021 Phase IV Monitoring.

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