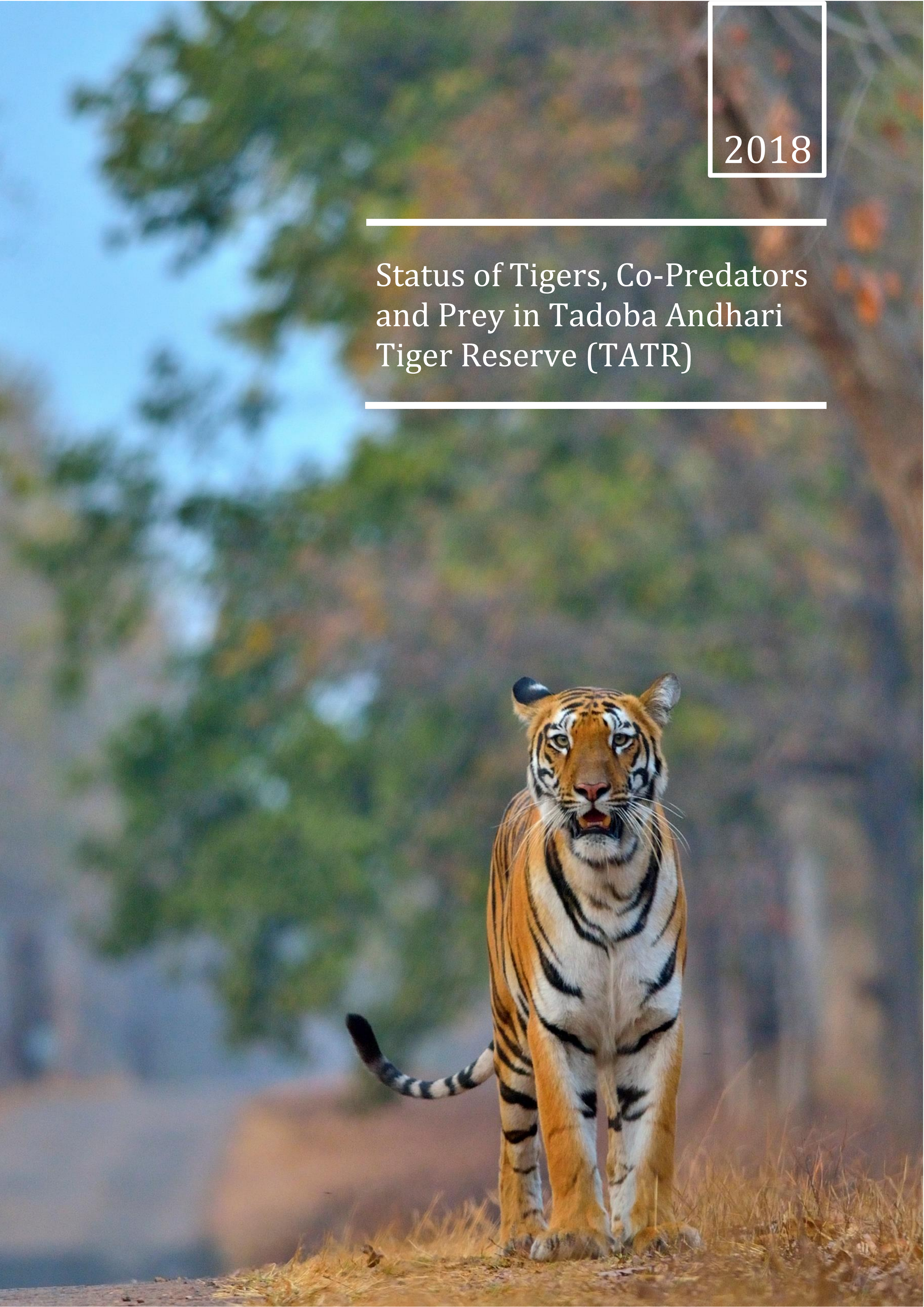
2018

Status of Tigers, Co-Predators and Prey in Tadoba Andhari Tiger Reserve (TATR)



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Status of Tigers, Co-Predators and Prey in Tadoba Andhari Tiger Reserve (TATR)

Phase IV Monitoring Report 2018
Spatially Explicit Space Use and Activity

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2018

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Citation: *Habib, B., Nigam P., Pallavi, G., Gomes, L., Praveen, N. R., Sinha, V., Ladkat, N. S., Guruprasad, G. and Bhagwat, S. (2019): Status of Tigers, Co-Predator and Prey in Tadoba Andhari Tiger Reserve (TATR) 2018 – Pp 41.*

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Acknowledgements

We acknowledge the support from the Field Staff of Tadoba Andhari Tiger Reserve – The unsung heroes of Tadoba. We thank all the Assistant Conservator of Forests, Range Forest Officers of 10 Ranges of Tadoba Core and Buffer, Foresters, Forest Guards and other Field Staff – including Special Tiger Protection Force (STPF). Our thanks are due to the National Tiger Conservation Authority and Maharashtra Forest Department for financial and all necessary logistic support including permits. We thank the Director, Dean and Research Coordinator WII for trust and all the support. Finally, we are grateful to the Principal Chief Conservator of Forests (Wildlife)/Chief Wildlife Warden, Additional Principal Chief Conservator of Forests (Wildlife) East, and Field Director Tadoba Andhari Tiger Reserve for their encouragement and support.

Pic: Pallavi Ghaskadbi

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Executive Summary

As a part of the project "Long Term Monitoring of Tigers, Co-Predators and Prey species in Tadoba-Andhari Tiger Reserve, Maharashtra India", Phase IV monitoring for the TATR core and buffer was conducted from November – March 2018 covering an area of 1700 km^2. 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. 390 camera traps were placed in the core and buffer area of TATR following a sampling grid of 2.01 sq. km in six blocks. In each sampling block camera traps were active for 23 – 27 days. During 150 days of camera trapping survey with sampling effort of 57,000 trap nights, 81 adult individual tigers were photographed. In the core area 39 individuals (exclusively) and in the buffer area 22 individuals (exclusively) were recorded. Tiger density per 100 km^2 based on Spatially Explicit Capture-Recapture (SECR) model was 5.51 (SE ± 0.59) in the Tadoba Andhari Tiger Reserve. In order to estimate prey density, 53 line-transects in core area and 74 line transects in buffer area were sampled 3 times during the sampling period, with a total walking effort of 318 km and 444 km in core and buffer area respectively. Overall during the sampling, 624 animal groups were sighted. The overall density of major prey species as estimated using distance sampling was 57.45 (±4.92) /sq. km whereas it was 45.57 (±5.63)/sq. km in buffer and 33.65 (±3.44)/sq. km in core respectively. The density of major prey species in core were Sambar 7.0 (±1.6) ; Chital 10.81 (±2.2); Gaur 6.6 (±2.0); Wild pig 6.58 (±2.0); Langur 11.81 (±2.8); Nilgai 2.0 (±0.6); Barking deer 1.26 (±0.4) ; Black-naped hare 2.62 (±0.6), Peafowl 6.87 (±1.5) ; Jungle fowl 0.82 (±0.4) per sq. km. The density of major prey species in buffer were Sambar 2.83 (±0.8) ; Chital 8.86 (±1.5); Gaur 1.65 (±0.5); Wild pig 16.29 (±4.9); Langur 18.9 (±5.1); Nilgai 4.37 (±1.3); Barking deer 1.42 (±0.8) ; Black-naped hare 1.73 (±0.4), Peafowl 2.37 (±0.6) ; Jungle fowl 0.69 (±0.5) per sq. km.

In order to study space use pattern and activity we used camera-trapping data from both core and buffer area of Tadoba-Andhari Tiger Reserve. Camera trap locations with number of captures of each species were modeled in a GIS domain using IDW (Inverse distance weighted) interpolation technique to generate spatially explicit capture surfaces. The times recorded on camera trap photos provide information on the period during the day that a species is most active. Species active at the same periods may interact as predator and prey, or as competitors. Sensors that record active animals (e.g. camera traps) build up a record of the distribution of activity over the course of the day. Records are more frequent when animals are more active and less frequent or absent when animals are inactive. The area under the distribution of records thus contains information on the overall level of activity in a sampled population.

Introduction

Tadoba Andhari Tiger Reserve is the largest Tiger Reserve in Maharashtra with a total area of 1,727 km^2. The total area consists of the Tadoba National Park and the Andhari Wildlife Sanctuary. With an area of 116.55 km^2. Tadoba was declared as a National Park as early as 1955. In 1986, the adjoining forested area of the Andhari river was declared as the Andhari Wildlife Sanctuary. Finally in 1993, a total area of about 625 km^2 was declared as the Tadoba Andhari Tiger Reserve (TATR). In 2012, an additional areas of 1127.17 km^2 was incorporated as the buffer area thereby making TATR one of the largest tiger reserve in the state of Maharashtra.

Situated in the Chandrapur district between 20º 04´ 53˝ to 20º 25´ 51˝ N and 79º 13´ 13˝ to 79º 33´ 34˝ E, TATR is not only one of the largest Tiger Reserve, but it also serves as one of the major source populations of large carnivores, especially tigers in the Central Indian Tiger Landscape and more specifically the Eastern Vidarbha Landscape of Maharashtra. This tiger population is vital for the metapopulation dynamics of the landscape connecting the adjoining tiger populations in the north such as Pench and Navegaon-Nagzira Tiger Reserve through Umred Karhandla Wildlife Sanctuary, Bor Tiger Reserve and Indravati and Kawal Tiger Reserves through the forests of Chandrapur - Gadchiroli districts in the south. This connectivity further extends till Kanha National Park in north-west (Figure 1).

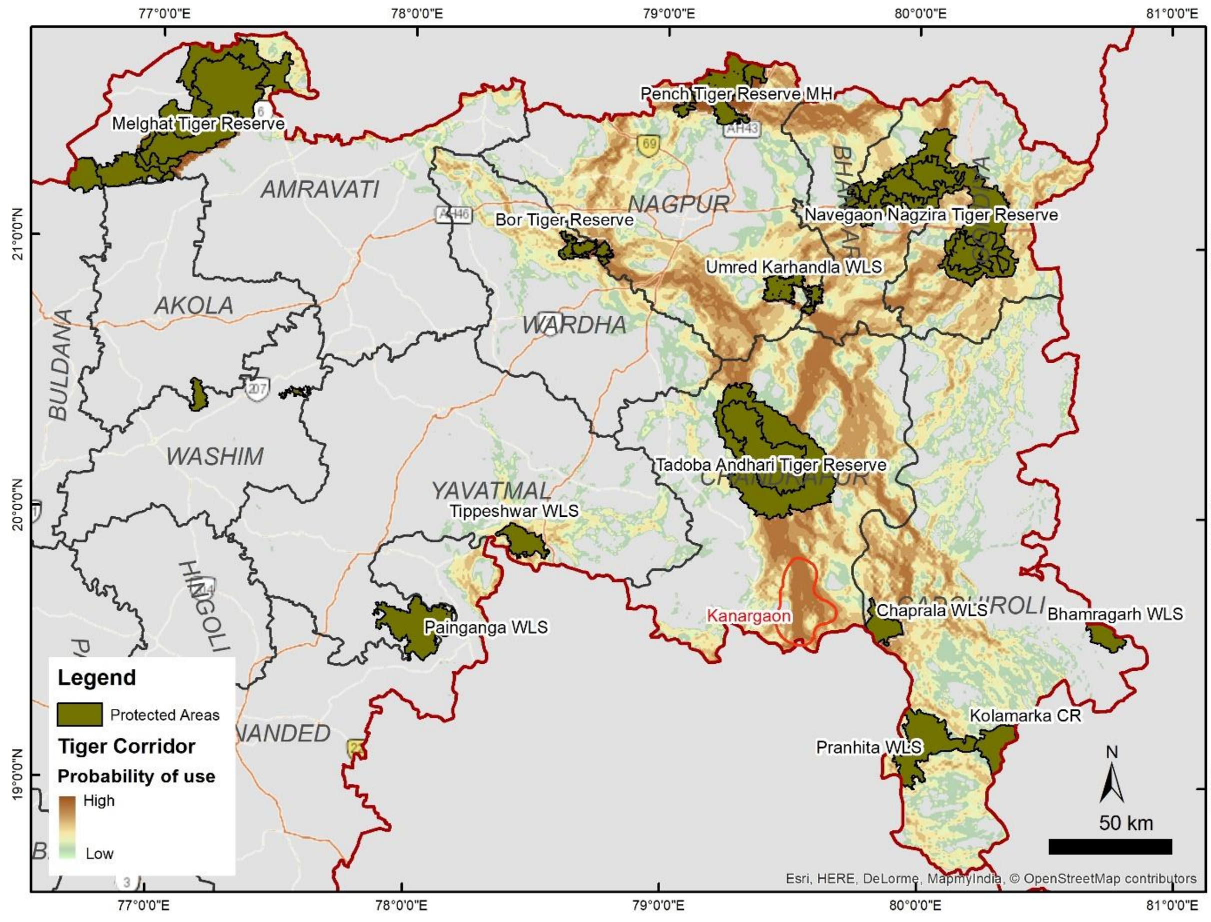


Figure 1: Map showing location of TATR with respect to other tiger reserves and connectivity in Eastern Vidarbha Landscape, Maharashtra, India

Forest Patch Characteristics of EVL

In order to understand issues of fragmentation in corridor areas to inform the forest management of the magnitude of fragmentation in the landscape to enable them to draw better informed policies to aid long term tiger conservation in the landscape, the analysis was carried on three major forest categories: very dense, moderately dense and open. Forest cover data for the year 2014 at a spatial resolution of 23.5 m was obtained from Forest Survey of India. Three classes (very dense, moderately dense and open forest) were segregated from this dataset. Individual patches measuring 1 km^2 and above in area were identified and their patch statistics were calculated (area, perimeter and area-perimeter ratio). The daily average movement of a tiger in this landscape, as calculated from data on tiger movement from radio collars, is 302.33 m. Therefore, we considered patches which are more than 300m away from their nearest neighbor, as isolated, thus adding to fragmentation of the habitat in the landscape. We identified such isolated patches in three forest classes (very dense, moderately dense and open forest) and provided descriptive patch statistics (range: minimum and maximum, mean and standard deviation). The spatial distribution of these fragments is shown in Figure 2.

Very dense forest (VDF)

VDF is present in 28,340 patches covering a total area of 9351.92 km^2 (Range: 0.005 – 1157.5; $\bar{x}$ = 0.33, SD = 11.89) in the study area. Only 406 of these patches are larger than 1 km^2 and cover an areas of 8,115.2 km^2, with a mean area of $\bar{x}$ = 19.99 (SD = 97.13). Among these patches, 70 are more than 300 m (Range: 312.92 – 12,265.86, $\bar{x}$ = 3681.93, SD = 2740.21) from the nearest forest patch and have been considered as fragmented due to isolation with respect to tiger movement. These isolated patches cover an area of 159.03 km^2.

Moderately dense forest (MDF)

MDF is present in 78,833 patches covering a total area of 10,895.54 km^2 (Range: 0.005 – 240.11; $\bar{x}$ = 0.13, SD = 2.29) in the study area. Only 1189 of these patches are larger than 1 km^2 and cover an areas of 7070.13 km^2, with a mean area of $\bar{x}$ = 5.95 (SD = 17.71). Among these patches 306 are more than 300 m (Range: 360 – 29,348.42, $\bar{x}$ = 7256.62, SD = 5180.08) from the nearest forest patch and have been considered as fragmented due to isolation with respect to tiger movement. These isolated patches cover an area of 641.97 km^2.

Open forest (OPF)

OPF is present in 70,236 patches covering a total area of 10,895.54 km^2 (Range: 0.005 – 106.03; $\bar{x}$ = 0.11, SD = 1.01) in the study area. Only 1017 of these patches are larger than 1 km^2 and cover an area of 4099.47 km^2, with a mean area of $\bar{x}$ = 4.03 (SD = 7.38). Among these patches 315 are more than 300 m (Range: 312 – 117,646.08, $\bar{x}$ = 30,674.57, SD = 27,642.06) from the nearest forest patch and have been considered as fragmented due to isolation with respect to tiger movement. These isolated patches cover an area of 779.07 km^2.

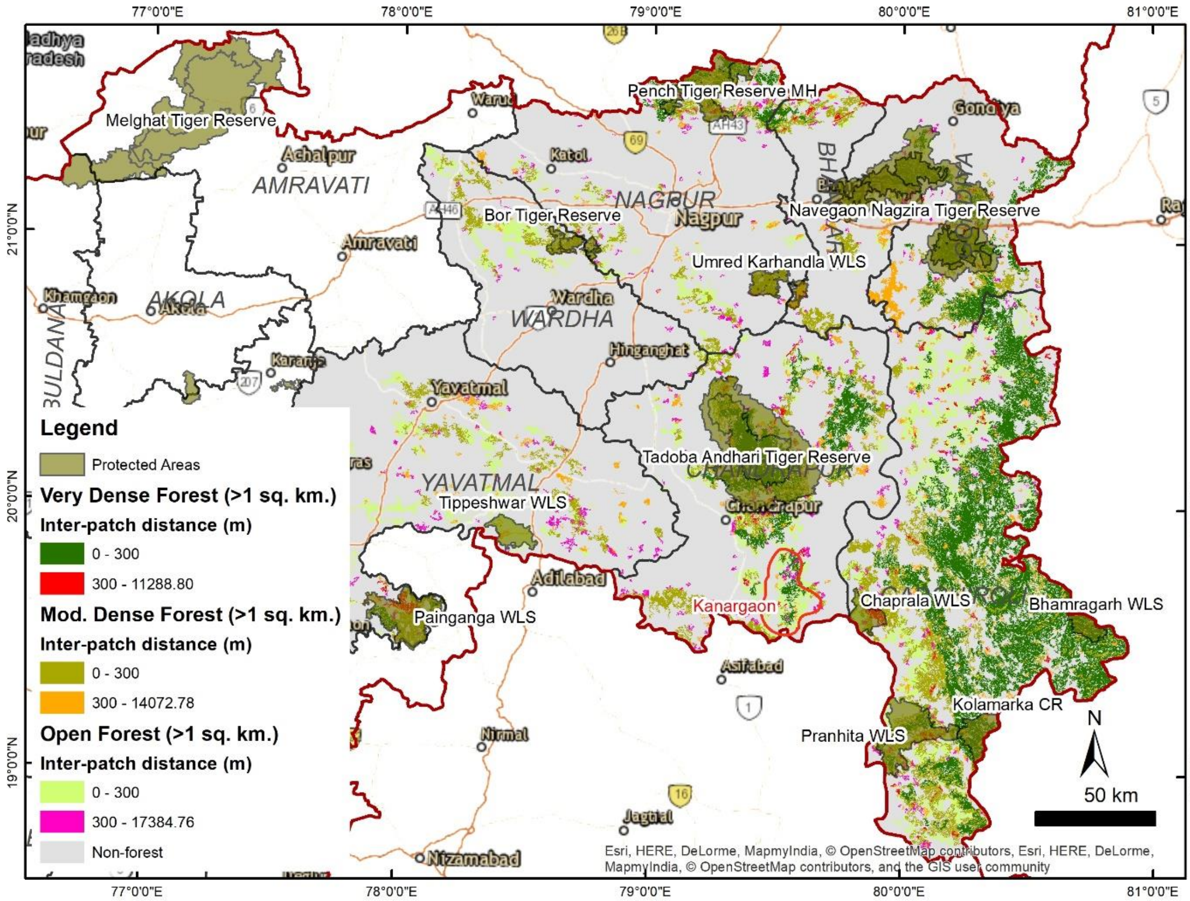


Figure 2: Forest fragments in Eastern Vidarbha Landscape, Maharashtra

Characteristics of Flora and Fauna of Tadoba Andhari Tiger Reserve

The vegetation of TATR can be classified as Southern Tropical Dry Deciduous (Champion and Seth1968) and typifies the class of ecosystem it represents. Dominated by the dry flora species like Teak (*Tectona grandis*), Bhera (*Chloroxylon swietenia*), Dhawada (*Anogeissus latifolia*), Mahua (*Madhuca indica*), Rohan (*Soymida febrifuga*), Salai (*Boswellia serrata*), Tendu (*Diospyros melanoxylon*) etc., the ecosystem also has highly contrasting tracts of riparian vegetation at the numerous perennial and non-perennial streams that are interspersed throughout the forest. Species like Jamun (*Syzygium cumini*), Arjun (*Terminalia arjuna*) and Mango (*Mangifera indica*) can be found in these riparian tracts which serve as a refuge to the fauna during the harsh and dry summers that the forest experiences. The average annual rainfall in TATR is recorded at 1,175m from the months of July to September. The temperature varies from 3° C in December to 50° C in April (Khawarey & Karnat, 1997; Marathe, Goel, Ranade, Jog, & Watve, 2002). Majority of TATR harbours bamboo (*Dendrocalamus strictus*), a species which plays an important role in the life cycle of Tadoba. It has also been called as the "keystone" species for the Reserve. In absence of extensive meadows, bamboo forms an important food source for the herbivores in the forest. The thicket-like aggressive growth of bamboo has also halted the spread of weeds throughout the tiger reserve. In TATR, the bamboo flowering occurs every 40 years after which the bamboo dies off. The next mass flowering event is expected to occur in 2020-2021. In this regard, the next couple of years are crucial for the ecosystem and vegetation in TATR and would require close monitoring for research as well as management.

The terrain in TATR is predominantly flat with a mildly hilly region in the west and Chimur hills in the north reaching elevations up-to 315 msl. Several streams drain rainwater into the Irai and Andhari rivers that run through the reserve. Large reservoirs like the Irai and Nalleshwar are located at the western and eastern boundaries of the reserve respectively. Along with several lakes inside the Reserve, these water sources support the ecosystem of the landscape in the unforgiving dry season. Geologically, the different types of parent rock found in TATR include quartz, quartzite, granite and sandstone, shale and clay in the south. The soil type that emerges from the erosion of these rocks are ruddy ferruginous soil and alluvial soil with clay and sand.

The tiger (*Panthera tigris*) is undoubtedly the umbrella species and the top predator in the pristine landscape of TATR. However, the forest is also home to several other species besides the tiger such as leopard (*Panthera pardus*), dhole (*Cuon alpinus*), gaur (*Bos gaurus*), sambar (*Rusa unicolor*), chital (*Axis axis*), chausingha (*Tetracerus quadricornis*), sloth bear (*Melursus ursinus*), honey badger (*Mellivora capensis*), rusty-spotted cat (*Prionailurus rubiginosus*) etc. TATR harbours a rich diversity of fauna comprising a total of 62 species of mammals, over 300 species of birds, 174 species of butterflies and 34 species of reptiles.

For the last decade, TATR has shown tremendous improvement in terms of habitat and population of the striped predator. The challenge which would be faced in the future is that of the tigers moving out of TATR via corridors which are lifelines of maintaining a healthy gene flow in the landscape.

As a part of the research project titled "**Long term monitoring of tigers, co-predators and prey species in Tadoba-Andhari Tiger Reserve, Maharashtra**", the Wildlife Institute of India has been monitoring this landscape intensively for over 5 years. The objectives of the project as approved were as follows:

1. Mapping of current land use pattern, infrastructure, mining areas, villages, roads, power transmission lines, demographic profile, livestock population, dispersal corridors, prey and predator occupancy etc, within landscape surrounding TATR. TATR has been extensively mapped. The landscape surrounding TATR will be mapped during the first year of the project to evaluate land use pattern, infrastructure development and other impacts which will provide crucial information about the surrounding landscape in term of capability to sustain tiger dispersal or act as corridor for tigers dispersing from TATR.

2. Spatial distribution and temporal dynamics of habitat occupancy of tigers, co-predators and prey species. Relationship of these parameters to habitat related variables. Occupancy based sampling approaches will be followed to achieve this objective. This exercise will be conducted on biannual basis.

3. Population density, abundance and demographic structure of Tigers and co-predators in landscape. Capture –recapture sampling method and spatially explicit CR approaches will be used to achieve this objective. This exercise will be carried on annual basis. Once this exercise is carried on annual basis there is no need to carry out the Phase IV of regular tiger monitoring during the duration of the project.

4. Population density and abundance estimation of key prey species in landscape. Distance sampling method will be used to achieve this objective. This exercise will be carried on annual basis.

5. Estimation of vital rates (survival, recruitment, temporal emigration, dispersal, etc) of tigers and co-predators. For this exercise Five Tigers and Five Leopards will be fixed with Satellite collars within one study cycle. As discussed with FD not more than 5 tigers and 5 leopards will be radio-collared at one time within TATR. During the entire monitoring program, 2 – 3 such cycles will be carried which will produce valid sample size for statistical considerations. Open model capture – recapture methods and spatially explicit CR approaches will also be used to achieve this objective.

6. Study Tiger/Leopard Conflict and socio-economic aspects. Village surveys once in three years and conflict survey on annual basis will be carried. Conflict report on annual basis and village survey report on 3-year basis.

7. Monitoring of village translocation sites. Tadoba provides an opportunity to study the impact of village translocation. Sites of different time scales are available in TATR to monitor the change. First relocation in TATR happened in 1975 followed by relocation in 1993 and 2012.

8. To investigate food habits of Tigers and Co-predators in TATR landscape complex.

9. Training of field staff for managing human-wildlife conflict and emergency situations.

This report details the progress of work carried out during the year 2018. As a part of the long-term monitoring program the focus of the research during the said year was:

I. Population density and abundance estimation of key prey species in landscape.

II. Population density, abundance and demographic structure of tigers in TATR landscape.

III. Activity pattern of tigers, co-predators & prey species in Tadoba-Andhari Tiger Reserve.

IV. Modeling Spatially Explicit Intensive Use Areas by Predator and Prey Species

Status of Prey Species in TATR

Introduction

Knowledge of animal abundance is critical to the ecological theory and practice of studies in both population biology (Krebs 1985; SouleÂ 1986) and wildlife resource monitoring (Parmenter et al., 1989; Sinnary and Hebrand 1991; Conroy et al., 1995). Availability of wild ungulate prey is one of the most important determinants of large carnivore density (Karanth et al. 2004). Ungulates also play an important role in maintaining ecosystems by influencing the vegetation structure, plant species composition and nutrient cycling (McNaughton 1979; Bagchi and Ritchie 2010). Maintaining and monitoring ungulate populations is therefore an important objective of conservation management. Estimating ungulate abundance in dense forested areas especially remains a challenge due to their low visibility and low detection probability.

Distance Sampling

The most common form of distance sampling is the line transect method. Line transects are laid randomly over the total forest area considering that all vegetation types existing in the area are represented while marking these lines. Sightings of prey species observed while walking on these lines are recorded along with habitat and terrain features.

A total of 53 transects in core –zone and 78 transects in buffer-zone of 2 km length were marked in Tadoba-Andhari Tiger Reserve. Figure 3 shows the distribution of line transect across TATR. Transects are well spread over an area of 1700 sq. km. of the area of Tadoba – Andhari Tiger Reserve covering almost all the vegetation types in the area. Each line transect was walked 3 times during the period from 18th February 2018 to 23rd February 2015 to record prey species across the whole area of TATR. Thus a total of 762 km effort have been invested on line transect surveys which generated a total of 624 observations of all types of prey species. This includes the major prey species like Gaur (*Bos gaurus*), Sambar (*Rusa unicolor*), Chital (*Axis axis*), Wild Pig (*Sus scrofa*), Nilgai (*Boselaphus tragocamelus*), Barking Deer (*Muntiacus muntjak*), Langur (*Semnopithecus sp.*), Peafowl (*Pavo cristatus*), Grey Jungle Fowl (G*allus sonneratii*) and Black-naped Hare (*Lepus nigricollis*). 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 observation Global Positioning System (GPS) was used. The GPS co-ordinates of transect were also recorded.

Some limitations of the data:

The numbers of detections were generally very low and some species were well below the minimum of 40 recommended by Burnham et al. (1980) and Buckland et al. (1993). To avoid resulting biases in future surveys, data collection protocols need improvement. Moreover, the fact that the data was collected in a time when there was a state-wide strike by the Forest guards must be considered before trying to extrapolate from our results of 2018. However, despite these drawbacks, we believe these density estimates are some of the most rigorously derived and defensible results after cleaning the dataset.

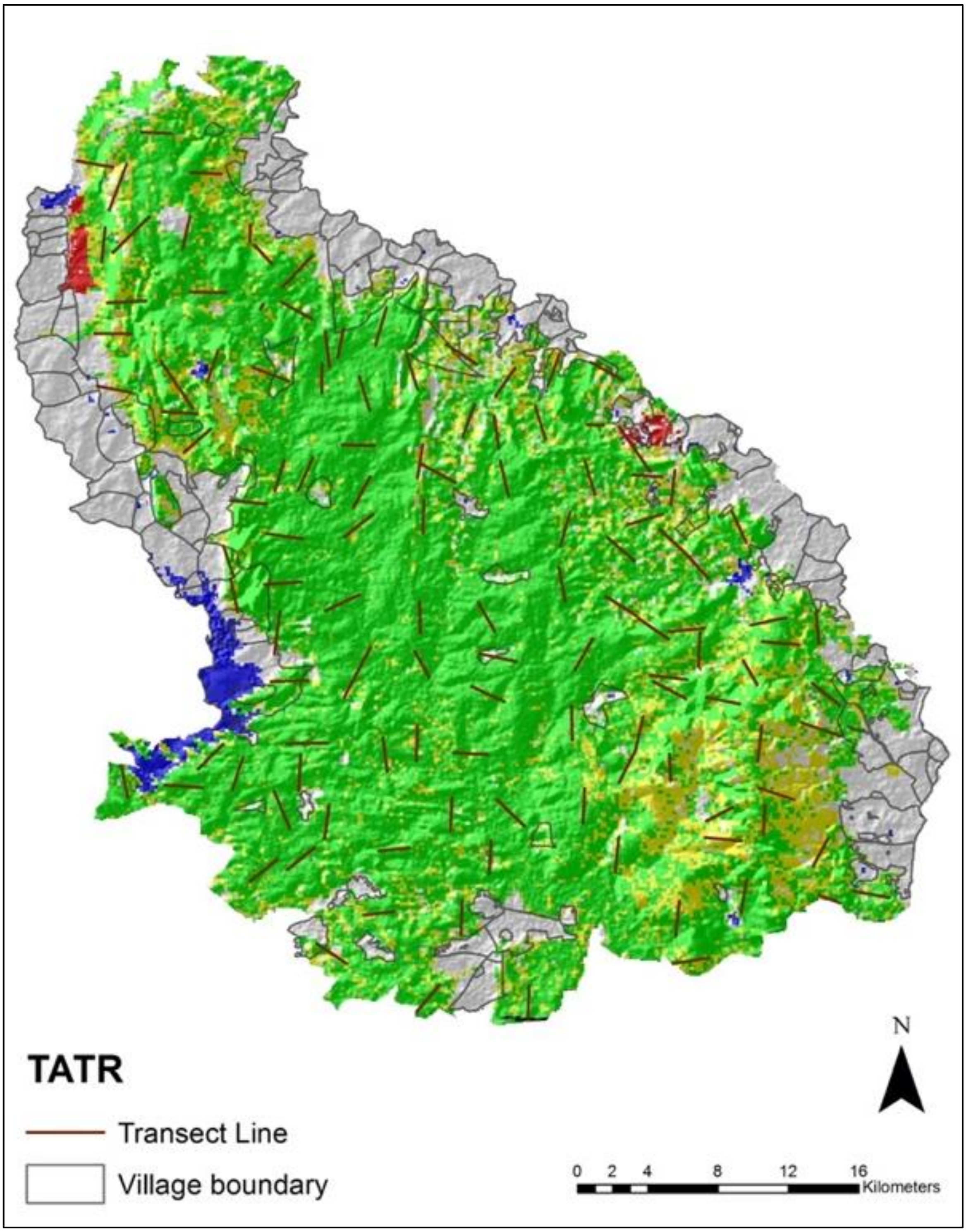


Figure 3: Distribution of line-transects in Core and Buffer area monitored during the year 2018 (Tadoba-Andhari Tiger Reserve, Maharashtra, India).

Total sightings of all prey species numbered to 309 and 287 in core area and buffer area respectively. Table1 gives details of line transect and species reported during the survey period. Sambar and Chital were the most sighted ungulates in the core and Chital and Wild Pig were the most sighted ungulates on transects of the buffer area of TATR. Grey jungle fowl was the least sighted species on transects of core and buffer area. It is worth the mentioning that species like Four-horned Antelope were not at all sighted in both core and buffer area of TATR but where recorded in camera traps.

Table 1: Transect monitoring efforts and species reported from Core and Buffer Area of TATR during Phase IV Monitoring 2018

	Core			Buffer		
Number of transect	53			74		
Length of each transect	2 km			2 km		
Number of replicates	3			3		
Total distance covered	318 km			444 km		
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	49	120	2.4 (1-10)	24	58	2.4(1-7)
Chital	55	328	5.9 (1-13)	53	324	6.1(1-23)
Nilgai	21	64	3 (1-7)	31	113	3.6(1-16)
Gaur	36	147	4(1-13)	27	68	2.5(1-10)
Wild boar	24	108	4.5(1-14)	38	307	8(1-23)
Langur	29	240	8.2(1-25)	32	352	11(1-22)
Barking deer	21	28	1.3(1-3)	17	17	1
Hare	25	29	1.1(1-2)	29	32	1.1(1-2)
Peafowl	39	93	2.4(1-6)	31	45	1.4(1-4)
Grey jungle fowl	10	18	1.8(1-5)	5	10	2(1-4)

The total prey density i.e. the total of the individual prey densities in the core area is 33.65 (±3.44)/sq. km. In the core the density of langur was highest (11.81 ± 2.80), followed by chital (10.81 ± 2.2), sambar (7.0 ± 1.6), gaur (6.6 ± 2.0) and wild pig (6.58 ± 2.00). In the buffer region the density of langur was found to be highest (18.90 ± 5.1) and is followed by wild pig (16.29 ± 4.9), chital (8.86 ± 1.5) and nilgai (4.37 ± 1.30).

The Individual Density, Group Density, Effective Strip Width, Average Group Size and Encounter Rate of 10 species reported during the Phase IV Monitoring 2018 in the Core and Buffer Area of Tadoba Tiger Reserve, Maharashtra, India is given in Table 2 and 3. The comparison of ungulate density with previous estimates is given in Table 4 and 5.

Table 2: Individual Density, Group Density, Effective Strip Width, Average Group Size and Encounter Rate of all Prey Species Reported during the Phase IV Monitoring 2018 in the **Core Area of Tadoba - Andhari Tiger Reserve, India**

Parameters	Sambar	Chital	Gaur	Wild Pig	Langur	Nilgai	Barking Deer	Hare	Peafowl	Grey Jungle Fowl
Individual density (No of Animals/Km^2)	7.0	10.81	6.60	6.58	11.81	2.00	1.26	2.62	6.87	0.82
Standard error	1.62	2.24	2.0	2.05	2.8	0.66	0.42	0.65	1.59	0.40
Percent CV	22.97	20.76	30.29	31.28	23.75	33.35	33.53	24.99	23.14	49.45
95% confidence interval	4.52-11.10	7.19-16.27	3.67-11.88	3.57-12.12	7.41-18.83	1.04-3.81	0.65-2.43	1.61-2.28	4.37-10.8	0.32-2.12
Group density (No of groups/Km^2)	2.80	1.95	1.65	1.96	1.29	0.78	0.98	2.41	2.97	0.43
Standard error	0.56	0.35	0.41	0.42	0.22	0.22	0.31	0.58	0.62	0.19
Percent CV	20.75	18.32	25.03	21.34	17.73	28.63	32.39	24.40	20.96	45.39
95% confidence interval	1.90-4.30	1.35-2.81	1.01-2.69	1.29-3.00	0.91-1.84	0.45-1.38	0.51-1.85	1.49-3.90	1.97-4.49	0.17-1.03
Effective strip width	27.00	44.50	34.48	19.20	35.4	42.09	33.88	16.36	20.73	36.64
Standard error	3.61	1.54	6.40	1.76	2.12	7.25	8.43	2.02	2.81	10.54
Percent CV	13.30	3.47	18.59	9.13	6.00	17.24	24.89	12.40	13.6	28.78
95% confidence interval	20.68-35.36	41.51-47.71	23.71-50.10	15.96-23.28	31.31-40.02	29.45-60.16	20.28-56.59	12.67-21.11	15.73-27.28	19.12-70.23
Average group size	2.44	5.96	4.08	4.5	8.27	3.04	1.33	1.16	2.38	1.8
Standard error	0.25	0.44	0.54	0.79	0.96	0.45	0.12	0.07	0.20	0.38
Percent CV	10.38	7.49	13.28	17.70	11.61	14.93	9.45	6.45	8.66	19.62
95% confidence interval	1.98-3.00	5.13-6.92	3.12-5.34	3.12-6.47	6.52-10.49	2.23-4.15	1.09-1.62	1.01-1.32	2.00-2.84	1.22-3.0
Encounter rate	0.15	0.17	0.11	0.07	0.09	0.06	0.06	0.07	0.12	0.03
Percent CV	15.86	17.99	16.77	19.28	16.68	22.85	20.73	21.02	15.96	35.11
95% confidence interval	0.11-0.21	0.12-0.24	0.08-0.15	0.05-0.11	0.06-0.12	0.04-0.1	0.04-0.1	0.05-0.12	0.08-0.16	0.01-0.06
Probability of a greater chi-square value, P	0.15	0.07	0.92	0.87	0.06	0.36	0.40	0.33	0.30	0.92

Table 3: Individual Density, Group Density, Effective Strip Width, Average Group Size and Encounter Rate of all Prey Species Reported during the Phase IV Monitoring 2018 in the **Buffer Area of Tadoba - Andhari Tiger Reserve, India**

Parameters	Sambar	Chital	Gaur	Wild Pig	Langur	Nilgai	Barking Deer	Hare	Peafowl	Grey Jungle Fowl
Individual density (No of Animals/Km^2)	2.83	8.86	1.65	16.29	18.93	4.37	1.42	1.73	2.37	0.69
Standard error	0.89	1.58	0.50	4.93	5.16	1.35	0.80	0.46	0.69	0.53
Percent CV	31.53	17.84	30.57	30.30	27.26	30.99	56.72	26.55	29.40	77.53
95% confidence interval	1.53-5.22	6.24-12.58	0.91-2.98	9.04-29.35	11.14-32.17	2.40-7.98	0.84-4.21	1.03-2.92	1.34-4.21	0.17-2.80
Group density (No of groups/Km^2)	1.02	1.33	0.80	1.29	1.80	1.27	0.73	1.61	1.53	0.26
Standard error	0.29	0.17	0.19	0.25	0.45	0.30	0.39	0.42	0.43	0.18
Percent CV	28.48	13.45	24.25	19.96	24.99	23.96	53.57	26.22	28.67	69.21
95% confidence interval	0.58-1.79	1.02-1.73	0.50-1.29	0.87-1.91	1.10-2.94	0.79-2.04	0.25-2.07	0.96-2.69	0.87-2.67	0.07-0.92
Effective strip width	29.0	49.4	40.0	36.48	22.01	30.20	28.86	22.39	24.37	23.72
Standard error	5.79	3.86	6.45	3.65	3.26	4.56	14.03	4.15	4.79	8.52
Percent CV	19.96	7.83	16.09	10.01	14.85	15.13	48.52	18.55	19.67	35.88
95% confidence interval	19.25-43.70	42.24-57.81	28.84-55.73	29.80-44.65	16.24-29.75	22.20-41.08	10.83-76.90	15.37-32.66	16.35-36.34	9.04-62.44
Average group size	2.41	6.11	2.57	8.07	11	3.64	1.82	1.10	1.36	2.00
Standard error	0.30	0.64	0.51	1.03	1.01	0.69	0.82	0.05	0.12	0.54
Percent CV	12.43	10.49	20.33	12.76	9.18	19.02	18.64	4.18	6.50	17.39
95% confidence interval	1.87-3.12	4.95-7.94	1.70-3.90	6.24-10.45	9.12-13.26	2.48-5.35	1.31-2.88	1.00-1.22	1.13-1.64	1.00-4.21
Encounter rate	0.05	0.13	0.06	0.09	0.07	0.07	0.04	0.07	0.07	0.01
Percent CV	20.31	10.93	18.14	17.27	20.09	18.57	22.71	18.53	20.86	59.19
95% confidence interval	0.03-0.08	0.10-0.16	0.04-0.09	0.06-0.13	0.05-0.11	0.05-0.11	0.02-0.06	0.04-0.10	0.04-0.10	0.004-0.03
Probability of a greater chi-square value, P	0.27	0.05	0.45	0.27	0.13	0.19	0.98	0.92	0.88	1

Table 4: Comparison of prey density of **Core** area of TATR, Maharashtra, India (2002-2018). Standard errors are given in parentheses.

Species	2002	2012	2013	2014	2015	2016	2017	2018
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)
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)
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)
Langur	-	-	-	9.47 (± 1.90)	9.70 (±2.42)	10.32 (±2.86)	9.89 (±1.72)	11.81 (±2.80)
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)
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)
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)
Hare	-	-	-	1.70 (± 0.36)	2.23 (±0.65)	0.49 (± 1.15)	1.23 (±0.54)	2.62 (±0.65)
Peafowl	-	-	-	3.92 (± 0.72)	3.36 (±0.81)	3.25 (± 0.67)	3.45 (±0.73)	6.87 (±1.59)
Grey Jungle Fowl	-	-	-	1.43 (± 0.53)	2.58 (±0.78)	3.19 (± 0.9)	2.93 (±0.19)	0.82 (±0.40)

Table 5: Comparison of prey density of **Buffer** area of TATR, Maharashtra, India (2015-2018). Standard errors are given in parentheses.

Species	2015	2016	2017	2018
Sambar	1.88 (± 0.71)	1.22 (± 0.76)	1.58 (±0.40)	2.83(±0.89)
Chital	4.09 (± 0.92)	8.73 (± 1.93)	11.09 (±2.07)	8.86(±1.58)
Gaur	1.63 (± 0.59)	6.88 (± 1.87)	3.54 (1.07)	1.65(±0.50)
Langur	14.64 (± 5.98)	28.52 (±8.75)	11.10(±3.75)	18.93(±5.16)
Wild Pig	4.56 (± 1.73)	9.82 (±6.23)	11.82 (±2.98)	16.29(±4.93)
Nilgai	0.74 (± 0.29)	5.91 (± 1.96)	5.22 (±1.66)	4.37(±1.35)
Barking Deer	0.68 (± 0.31)	3.62 (± 1.11)	2.82 (±0.31)	1.42(0.80)
Hare	0.99 (± 0.37)	1.51 (± 0.43)	1.02 (±0.31)	1.73(±0.46)
Peafowl	2.28 (± 0.79)	4.18 (± 0.9)	4.06 (±1.39)	2.37(±0.69)
Grey Jungle Fowl	0.59 (± 0.41)	1.03 (± 0.24)	1.43 (±0.54)	0.69(±0.53)

Status of Tigers in TATR

Introduction

The combination of biological characteristics of tigers - extensive distributional range, low densities, elusiveness, wide ranging behaviors, low detectability of tiger signs – poses major challenges to the task of monitoring tiger populations. Typically, over large regions, even results of mere presence or absence surveys tend to be indeterminate. In particular, it is difficult to infer absence of tigers based on absence of tiger sign. Collection of quantitative data on abundance of tigers or tiger sign is usually handicapped by small sample sizes, low detection probabilities and numerous logistical and physical constraints.

Camera traps (i.e. cameras that are remotely activated via an active or passive sensor) offer a reliable, minimally invasive, visual means of surveying wildlife that substantially reduces survey effort. Camera traps are increasingly popular in ecological studies (Burton et al. 2015) and provide a wealth of information that is often of considerable conservation value (Caravaggi et al. 2017). Continued technological improvements and decreasing equipment costs combined with their demonstrated versatility mean that the use of camera traps will only continue to grow in ecological studies.

Monitoring of large carnivore populations is important to guarantee their survival, to adapt management practices to changing situations and for the conservation of habitat in the long run. The need for long term scientific monitoring of large carnivore populations arises from three considerations:

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

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

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

Camera Trapping:

The success of camera-trapping depends on the selection of ideal locations to deploy the camera traps so as to maximize the number of captures. Prior to camera placement, a survey is done along the forest paths, animal trails, dirt-tracks, dried stream bed to record carnivore presence through indirect signs (pugmarks, tracks, scat, scraps, rake mark, scent deposits and kills). Since there is a system of routine patrolling already in place in TATR, there is a record of animal movements for each beat in TATR. However, locations followed for the camera trapping in the year 2012, 2013, 2014, 2015, 2016 and 2017 were again referred and revised if there was any change in the existing movement pattern of animals. This exercise followed the protocol prescribed by Karanth and Nichols (2002) and Jhala et al., (2010).

Potential locations of camera trap stations were then mapped using ArcGIS 9.3 (ESRI, Redlands, CA, USA). This year we have chosen a sampling grid of 2.0164 sq km (1.42 km x 1.42 km) for camera trapping. A total of 390 sites were selected for deployment of camera traps in the core area and buffer area of TATR. The location of the camera traps overlaid on the forest cover map of TATR has been shown in the Figure 4. A pair of Moultrie D-55 (www.moultriefeeders.com/gamespy-d55) and Cuddeback Ambush camera traps (http://cuddeback.com/cameras/ambush.aspx) was placed opposite to each other so as to photograph both flanks of tiger and leopard simultaneously during the camera-trap exercise. The camera delay was set at multi-shot mode with delay of 15 seconds. Cameras were tied up on tree trunks or poles at the height of 25-35 cm opposite to each other. It is advised not to put the cameras facing each other exactly so as to miss the animal sight in photograph in case of over illumination of flashes if triggered at the same time. We used the flank which yielded maximum unique individuals for abundance estimation. For the present analysis all photographs of the right flank have been used to identify the individual tigers. Camera trapping exercise extended from 11th October to 30th May for around 120 days. The total area was divided into six blocks and the sampling period was 25 days for each block.

The cameras were active for 24-h period that accounted for one sampling occasion. Each camera was assigned a unique identification number. Date, time, temperature and camera-ID was recorded for every capture. An effort of 9528 camera trap nights was used during the 2018 Phase IV monitoring in Tadoba Andhari Tiger Reserve. 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 "Xmatrix 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) to follow our closure assumption the sampling duration was kept as minimum. Capture histories were analyzed using the software R package 'secr' (Efford M.G. 2015) using 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'.

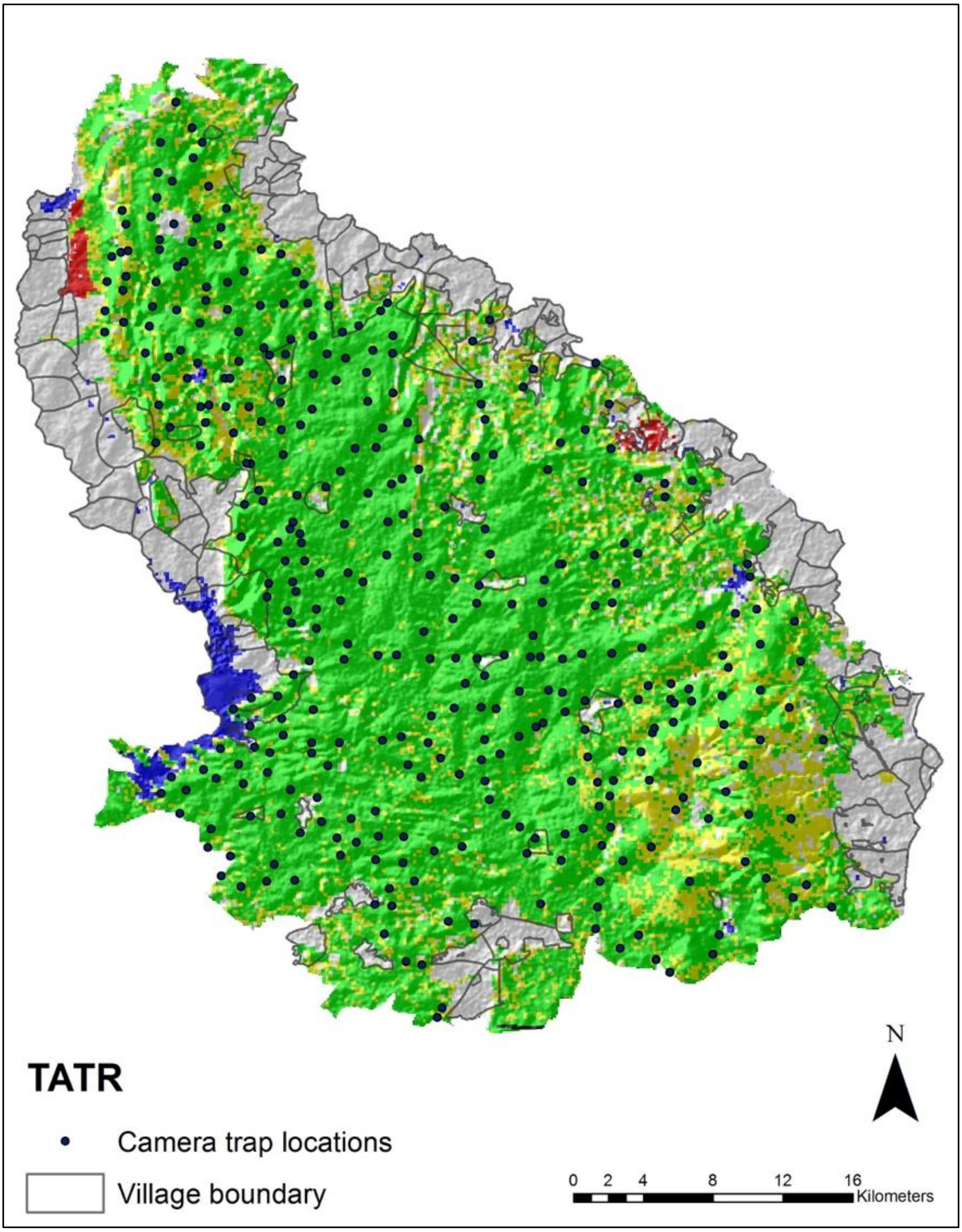


Figure 4: Camera trapping locations for 2018 in Core and Buffer area of Tadoba - Andhari Tiger Reserve, Maharashtra, India

Population Estimation of Tigers:

During 150 days of camera trapping for tigers i.e., a total sampling effort of 57,000 trap nights 81 adult individual tigers where photographed within the core and buffer area of TATR. For estimating the density and population we used “SECR” instead of conventional capture-recapture model. 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, we need some notation for trap location. Tiger density per 100 km^2 based on SECR. Heterogeneity model was estimated to be 5.51 (SE ±0.59) for TATR. Best model for the density estimate is chosen according to the AIC (Alkaike Information Criterion). The details are provided in Table 6 and Table 7 along with the comparison of capture and density estimate from previous years. g0 is the detection probability for the species, it is assumed to be constant or variable depending on the distribution. Sigma is the distribution of average movement of the animal. It increases if the individuals are captured at very far away locations. Table 8 give details of tigers captured within core and buffer area of tiger reserve.

We also mapped the home range polygons (Minimum area use) of Tigers for which we have captures at 3 or more than 3 camera trap sites. The spatial distribution maps of various individual tigers are shown in Figures 5, 6 and 7.

Table 6: Density estimates of tigers using Spatially Explicit Capture-Recapture Models in Tadoba - Andhari Tiger Reserve, Maharashtra, India for the year 2014 – 2018.

Parameters	2014	2015	2016	2017	2018
Model	Heterogeneity	Heterogeneity	Heterogeneity	Heterogeneity	Heterogeneity
Detection function	Half normal	Half normal	Half normal	Half normal	Half normal
Density estimate	5.609	5.673	5.648	5.823	5.51
Density standard error	0.773	0.698	0.713	0.683	0.598
Density confidence interval	4.285-7.340	4.461-7.214	4.935-6.361	4.791-7.125	4.46-6.81
g0 estimate	0.305	0.499	0.407	0.512	0.607
g0 standard error	0.022	0.098	0.091	0.056	0.050
g0 confidence interval	0.264-0.352	0.340-0.731	0.313-0.689	0.40-0.624	0.51 – 0.71
Sigma estimate	4.283	3.309	3.354	3.237	2.07
Sigma standard error	0.305	0.239	0.431	0.318	0.533
Sigma confidence interval	3.725-4.925	2.871-3.814	2.716-3.972	2.659-3.946	0.974 – 2.184

Table 7: Comparative density estimates of tigers using Spatially Explicit Capture-Recapture Models in Tadoba - Andhari Tiger Reserve, Maharashtra, India.

Year	Effective trapping area	No of individuals captured	Estimate	Density per 100 km2
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	5.51 (±0.59)

Table 8: Comparison of density of tigers across the years 2010 – 2018 for Tadoba-Andhari Tiger Reserve, Maharashtra, India.

Details	2013	2014	2015	2016	2017	2018
Tigers captured exclusively in Core of TATR	50	51	51	48	50	39
Tigers captured exclusively in Buffer of TATR	NA	10	14	17	19	22
Tigers sharing boundary across the Core and Buffer of TATR	NA	04	06	04	6	20

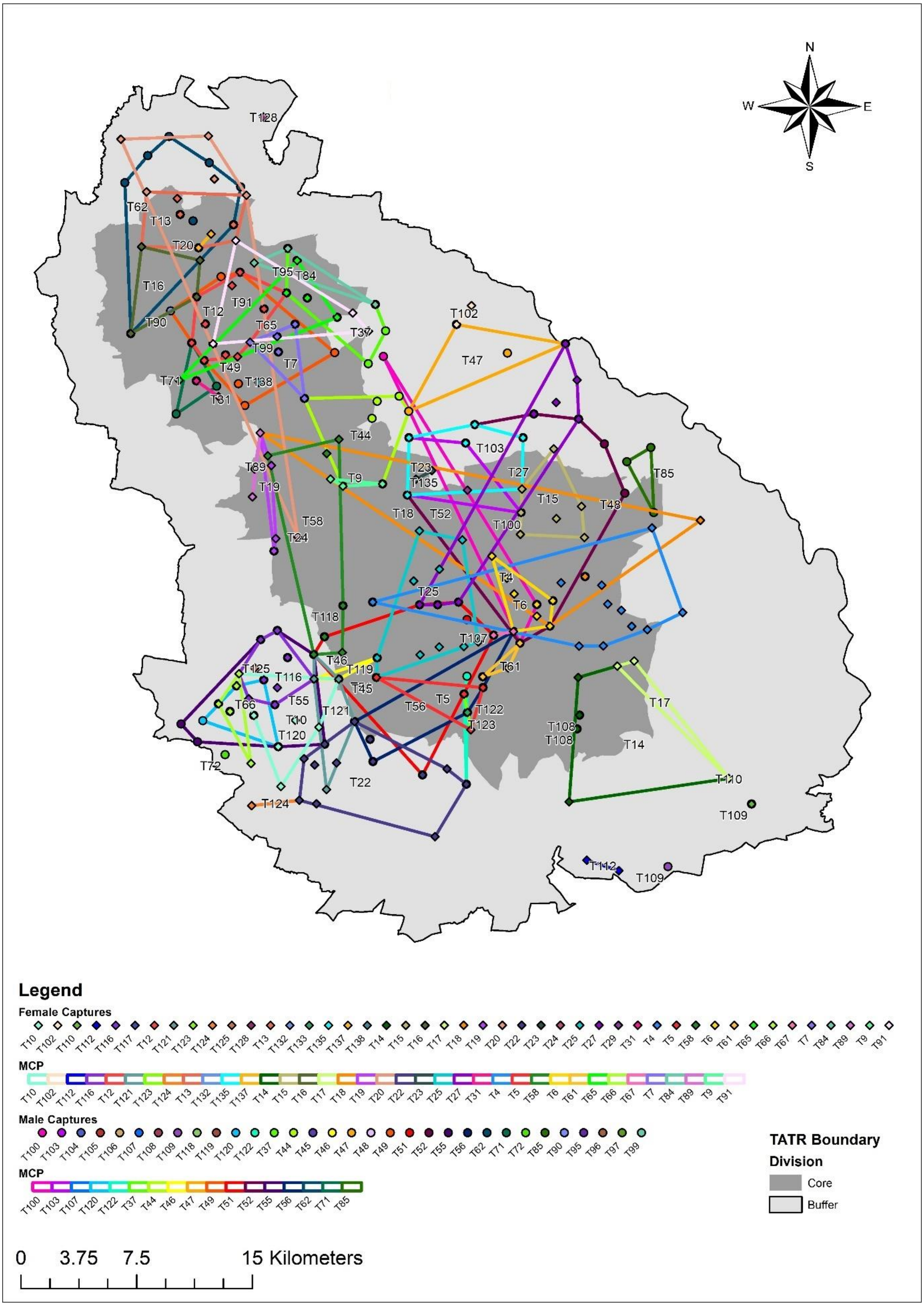


Figure 5: Minimum convex polygons or area used by tigers in TATR, Maharashtra during the year 2018. (Out of 81 (Min. No.) tigers on 77 tigers have been mapped as four tigers where not sexed)

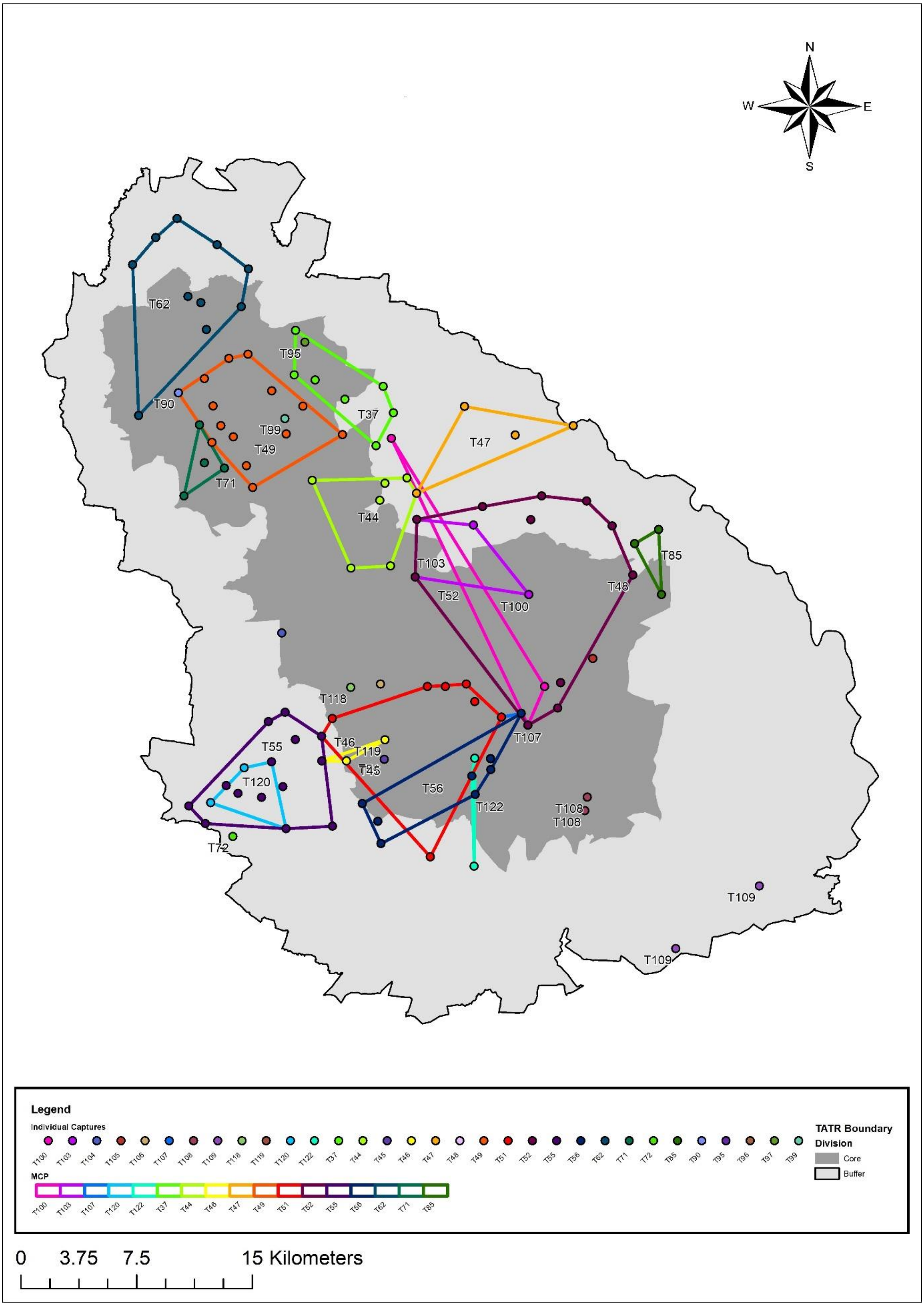


Figure 6: Minimum convex polygons or area used by male tigers in TATR, Maharashtra during the year 2018.

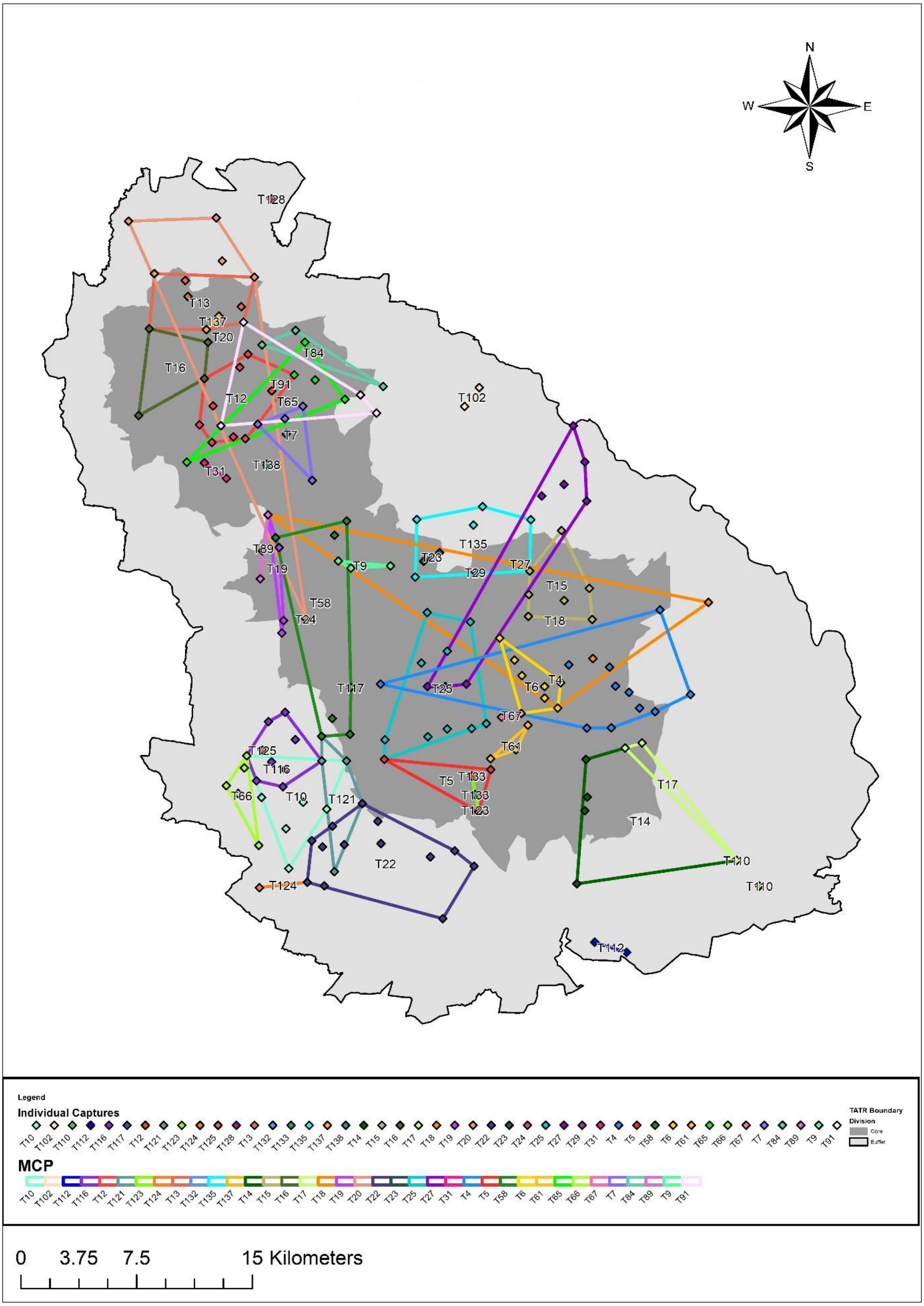


Figure 7: Minimum convex polygons or area used by female tigers in TATR, Maharashtra during the year 2018.

Temporal Activity of Predators and Prey species in TATR

Introduction

Activity time for an animal is a tradeoff between risk of starvation and predation risk (Lima 1988; Bednekoff 2007). Depending on the intensity of competition among predators and predator-prey interactions, activity peaks may be dynamic (Lima 1988) and sitespecific conditions may force animals to change their conventional activity patterns (Monterroso et al. 2013). The presence of multiple predators in a system can influence behavioural decisions of both the prey as well as amongst predators themselves to optimize their activity times. Most activity of animals is dedicated to acquisition of food (Suselbeek et al. 2014). Thus it makes sense to study the activity patterns of prey and predators both spatially and temporally complimenting it with an understanding of their actual diet through scat analysis. Data acquired from camera trapping has been extensively used for estimation of animal densities and spatial ecology of animals. However studies which deal with comparison of activity patterns of large sympatric carnivores with respect to their prey are few in India. The camera trap photographs have a record of the time during which the species is most active. Number of photographic records of a species are more frequent when the species is active. Species that are active during the same time period in a day may be predator-prey or competitors.

Methods and Results

The temporal pattern of the predators and their prey was analyzed using R statistical software (version 3.4) (R Development Core Team 2017 http://www.R-project.org) and Microsoft Office Excel 2018. The approach established by Linkie and Ridout (2009) was used to study temporal activity pattern 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 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 (Fernandez-Duran 2004). The kernel density estimates used a bandwidth parameter, which is selected following the procedure developed by Taylor (2008). For the second step, a measure of overlap between the two estimated distributions was calculated. Ridout and Linkie (2009) reviewed several alternative measures of overlap between two probability distributions, favouring the coefficient of overlapping, Δ (Weitzman 1970), which ranges from 0 (no overlap, e.g. one species entirely diurnal, the other entirely nocturnal) to 1 (complete overlap). This is defined as the area under the curve that is formed by taking the minimum of the two density functions at each time point. A useful interpretation of the coefficient of overlapping is that for any time period during the day the proportion of activity that occurs during that period differs between the two distributions by <1–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 Figure 8. From the kernel density estimators, the tiger and leopard were observed to have a high degree (0.94) of overlap as indicated by the estimated overlap coefficients in Table 9.

Table 9: Activity Overlap of Other Prey Species of Tadoba-Andhari Tiger Reserve with the three sympatric Species during the year 2018.

Predator/Prey Species	Tiger	Leopard	Dhole
Sambar	0.9	0.91	0.63
Chital	0.67	0.74	0.73
Gaur	0.84	0.84	0.72
Wild Pig	0.66	0.72	0.89
Black naped hare	0.72	0.67	0.37
Barking Deer	0.71	0.77	0.69
Four Horned Antelope	0.57	0.65	0.67
Hanuman Langur	0.31	0.37	0.51
Tiger	NA	0.92	0.64
Leopard	0.92	NA	0.69
Dhole	0.64	0.69	NA

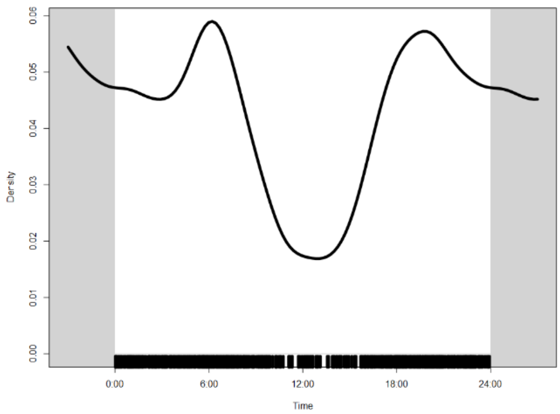


Figure 8 (a)

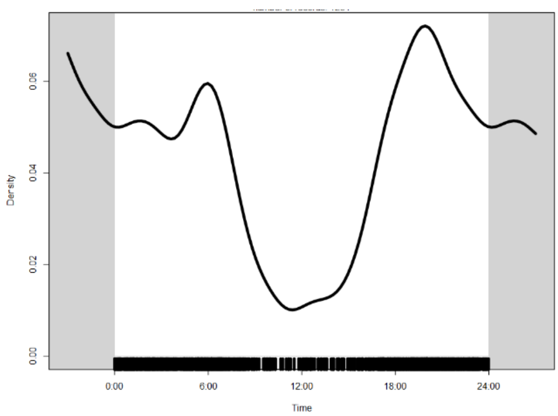


Figure 8 (b)

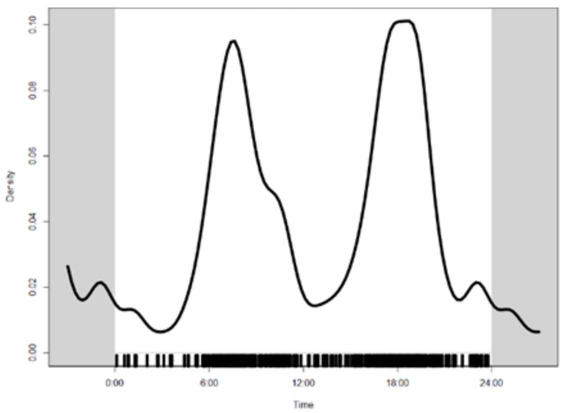


Figure 8 (c)

Figures 8 (a-c): Kernel density estimates of daily temporal activity patterns of (a) tiger, (b) leopard and (c) dhole - 3 sympatric carnivores in TATR, Maharashtra during the year 2018.

The Kernel density estimates of daily temporal activity patterns of different predator species are shown in Figure 8. The details of the co-efficient of overlaps of predator-predator species and predator-prey species are given in Table 9 and figures 9, 10, 11 and 12. From the kernel density estimators, the tiger and leopard were observed to have a high degree of temporal activity overlap (92%) whereas tiger and dhole were observed to have the least (64%) amongst predator-predator overlaps. This is easily explained as dholes are ecologically a diurnal species whereas tigers are active in the crepuscular hours. In prey-predator overlaps, tiger has maximum overlap with sambar (90%) which is considered as its main prey species. Leopards also show a high degree of temporal overlap with sambar (91%) as sambar are active in the night hours as well. It is worth mentioning that although dholes show maximum overlap with wild pigs (89%) followed by gaur (82%); it is mainly due to their diurnal habits and not related to diet preferences.

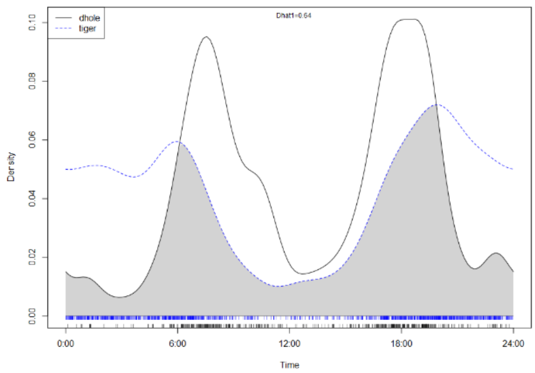


Figure 9(a): Dhole - Tiger

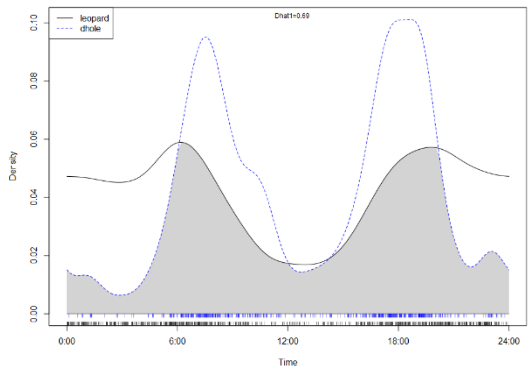


Figure 9(b): Leopard - Dhole

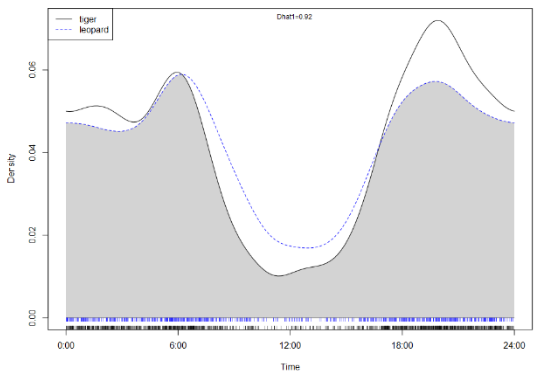


Figure 9(c): Tiger - Leopard

Figures 9 (a-c): Daily temporal activity pattern overlap between co-predators. a) dhole vs. tiger; b) dhole vs. leopard; c) tiger vs. leopard in TATR, India. The lines represent the kernel density estimates based on individual photograph times. The overlap is shown by the shaded area in each plot.

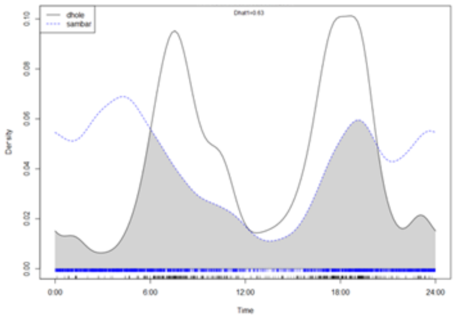


Figure 10(a): Dhole - Sambar

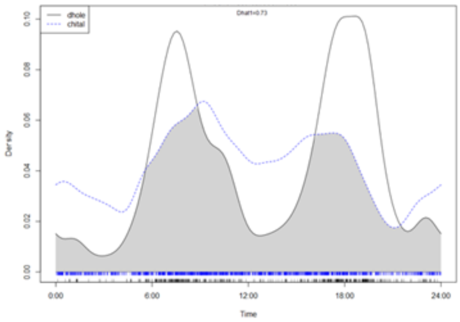


Figure 10(b): Dhole - Chital

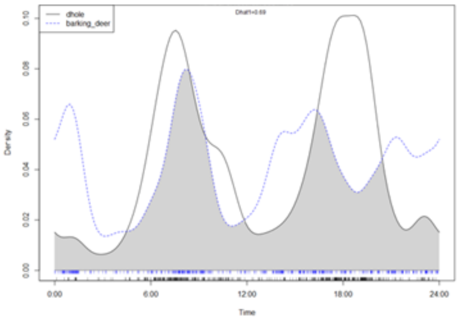


Figure 10(c): Dhole – Barking Deer

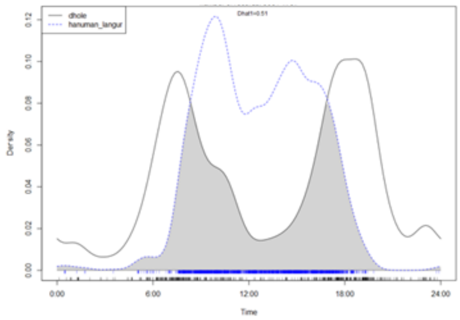


Figure 10(d): Dhole - Langur

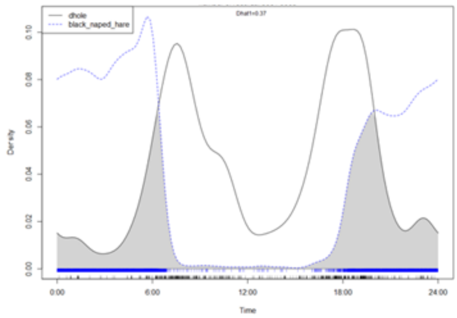


Figure 10(e): Dhole - Hare

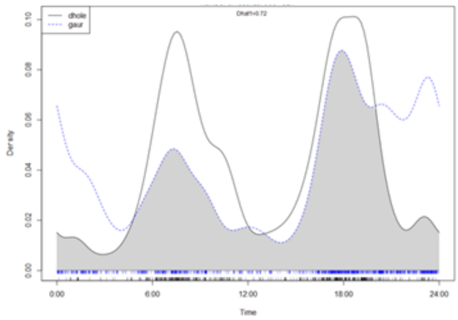


Figure 10(f): Dhole - Gaur

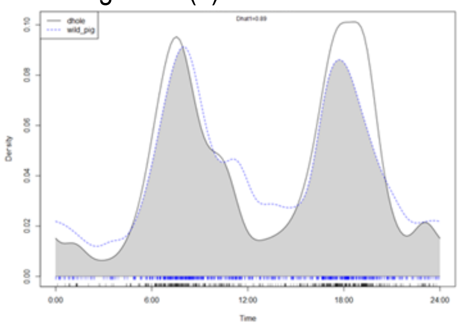


Figure 10(g): Dhole – Wild Pig

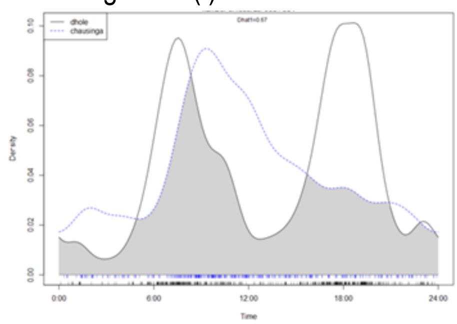


Figure 10(h): Dhole - Chausingha

Figures 10 (a-h): Daily temporal activity pattern of the Dhole vs. prey species in TATR, India during the year 2018. The lines represent the kernel density estimates based on individual photograph times. The overlap is shown by the shaded area in each plot.

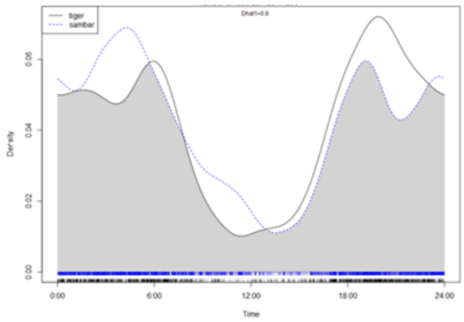


Figure 11(a): Tiger - Sambar

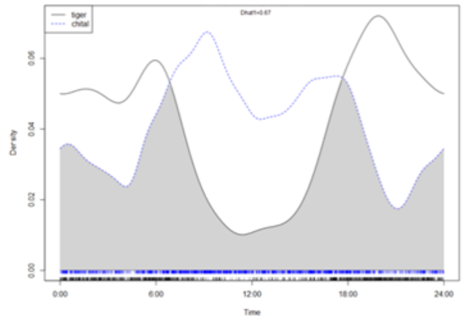


Figure 11(b): Tiger - Chital

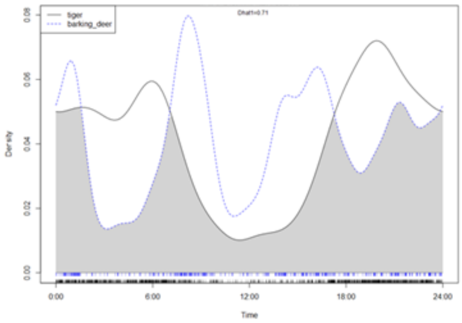


Figure 11(c): Tiger – Barking Deer

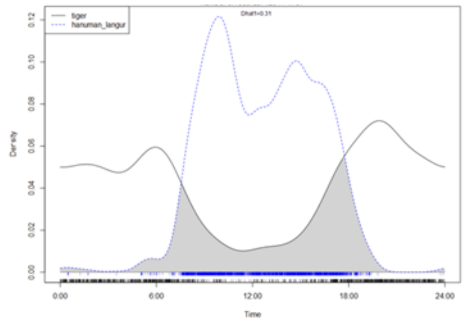


Figure 11(d): Tiger - Langur

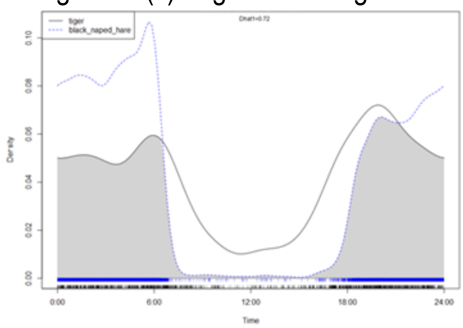


Figure 11(e): Tiger - Hare

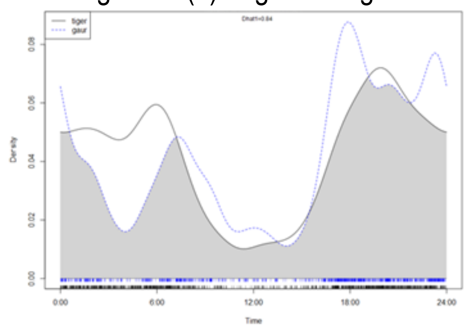


Figure 11(f): Tiger - Gaur

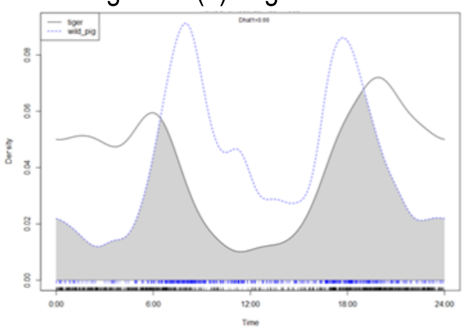


Figure 11(g): Tiger – Wild Pig

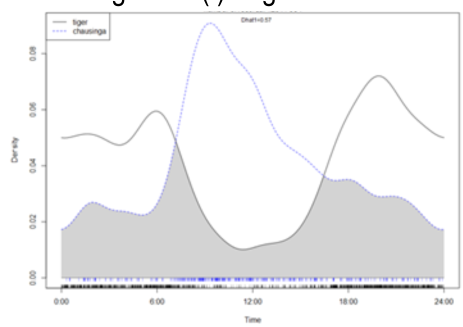


Figure 11(h): Tiger - Chausingha

Figures 11 (a-h): Daily temporal activity patterns of the Tiger vs. prey species in TATR, India during the year 2018. The lines represent the kernel density estimates based on individual photograph times. The overlap is shown by the shaded area in each plot.

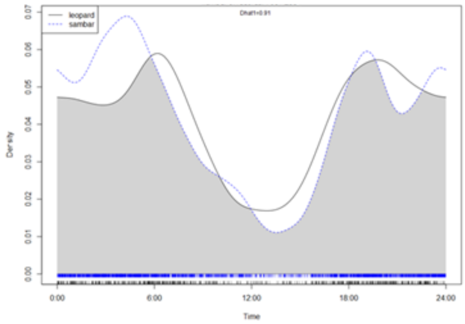


Figure 12(a): Leopard - Sambar

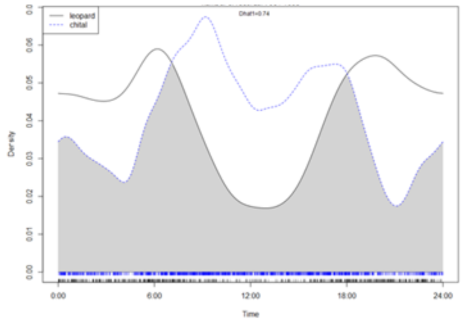


Figure 12(b): Leopard - Chital

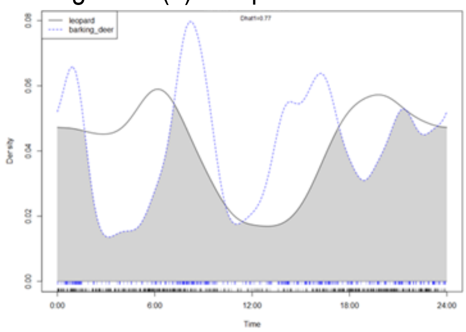


Figure 12(c): Leopard– Barking Deer

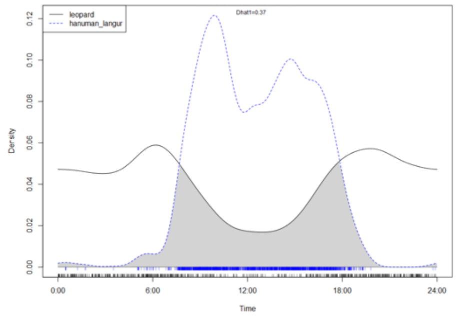


Figure 12(d): Leopard - Langur

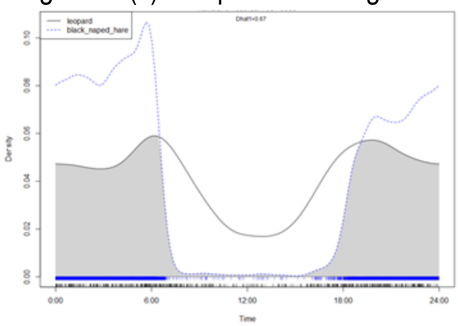


Figure 12(e): Leopard - Hare

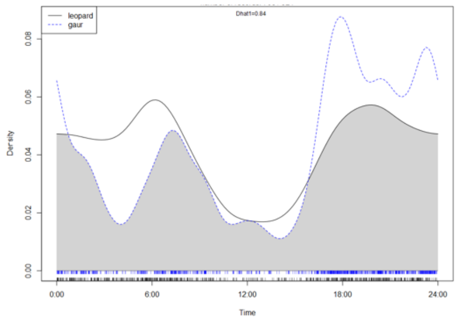


Figure 12(f): Leopard - Gaur

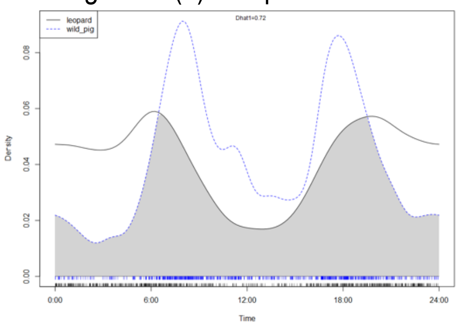


Figure 12(g): Leopard – Wild Pig

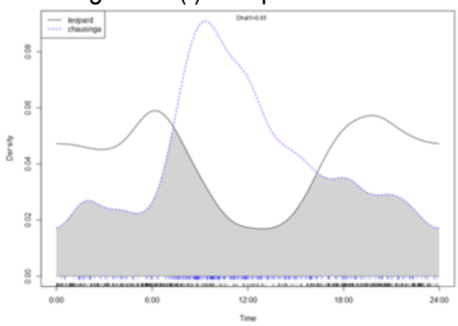


Figure 12(h): Leopard - Chausingha

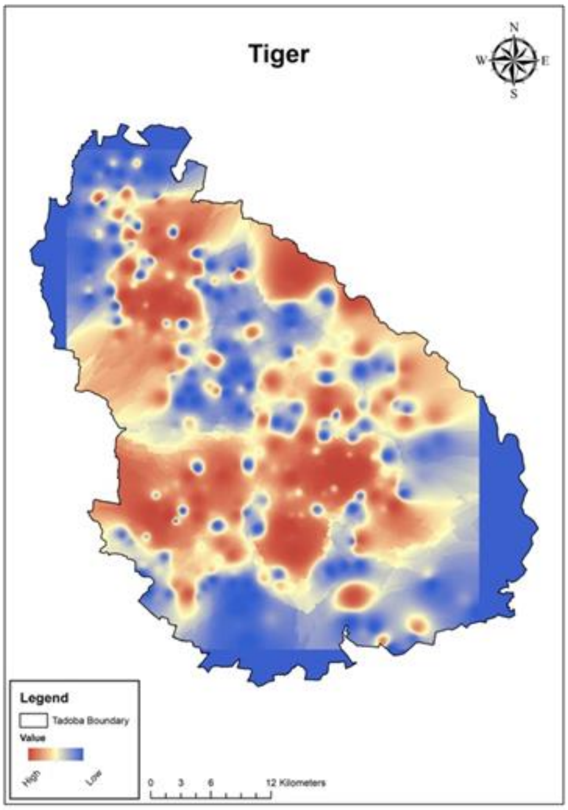
Figures 12 (a-h): Daily temporal activity patterns of the Leopard vs. prey species in TATR, India during the year 2018. The lines represent the kernel density estimates based on individual photograph times. The overlap is shown by the shaded area in each plot.

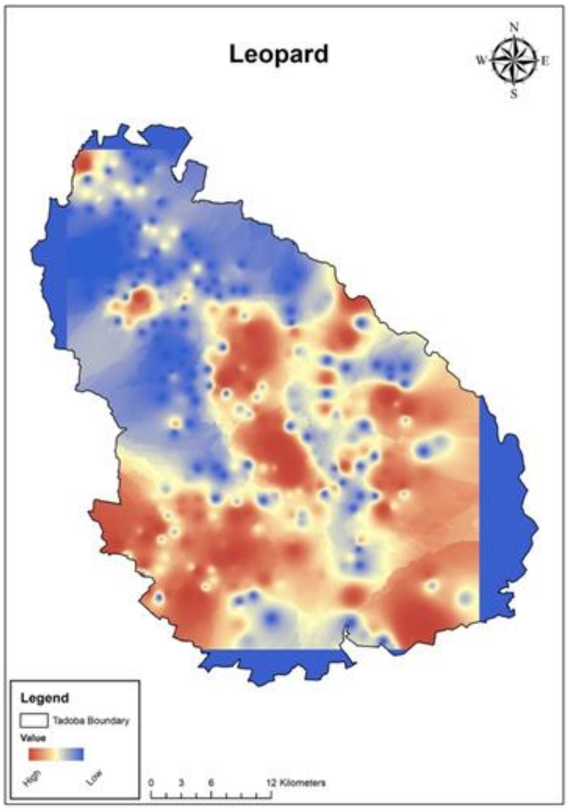
Modeling Spatially Explicit Intensive Use Areas by Predator and Prey Species:

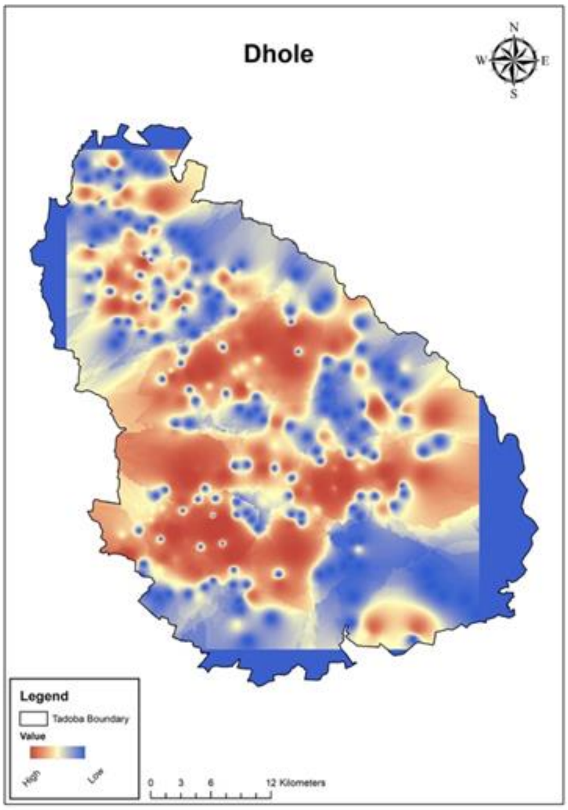
Camera trap locations with number of captures of each species were modeled in a GIS domain using IDW (Inverse distance weighted) interpolation technique to generate spatially explicit capture surfaces. IDW interpolation explicitly implements the assumption that things that are close to one another are more alike than those that are farther apart. To predict a value for any unmeasured location, IDW uses the measured values surrounding the prediction location. The measured values closest to the prediction location have more influence on the predicted value than those farther away. 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 (see Figure 13 below) 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 modeled is driven by local variation, which can be captured (modeled) by defining an adequate search neighborhood.

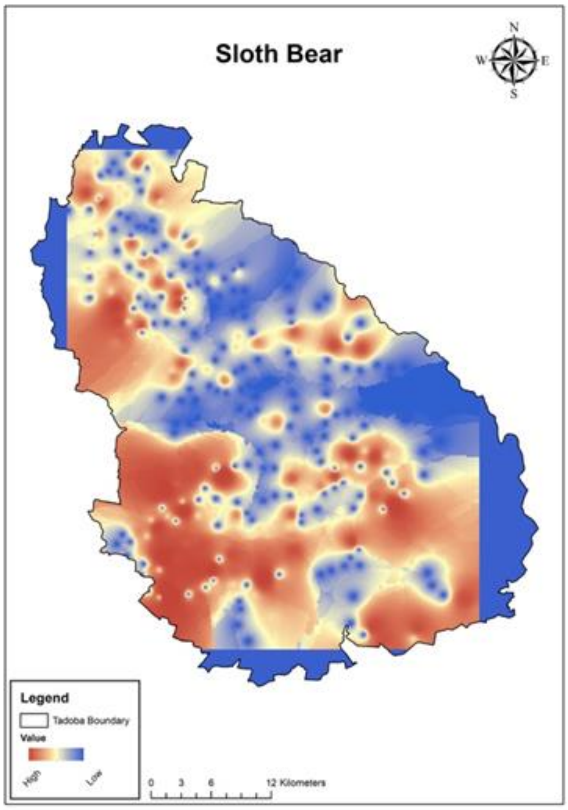
Figure 13: An example of IDW surface from points.

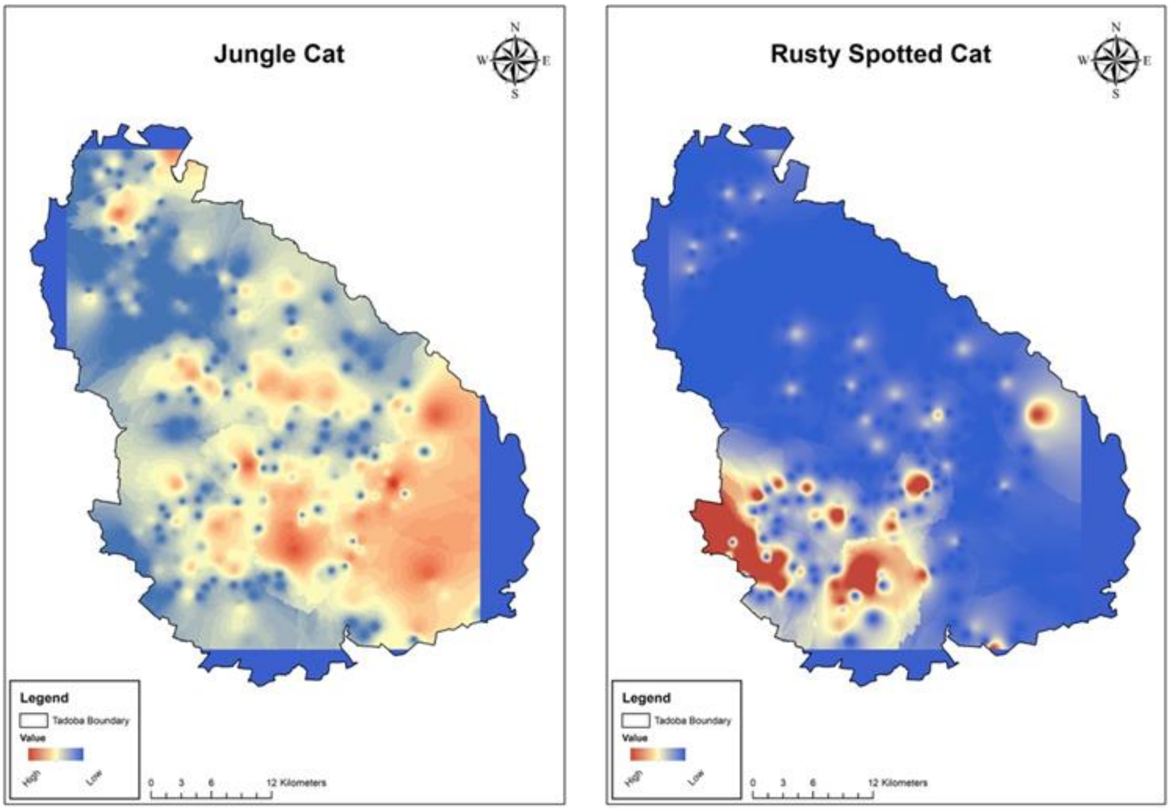
Using IDW technique we developed spatially explicit intensive use area maps (Based on camera trap location and number of photographs at each location) for four predator species namely Tiger, Leopard, Dhole, Sloth Bear, Jungle cat and Rusty-spotted cat core area of TATR. Figures 14 (a-f) show intensive use areas by six predator species Tiger, Leopard, Dhole, Sloth Bear, Jungle cat, and Rusty spotted cat.


Tiger
N
W
E
S
Legend
Tadoba Boundary
Value
High
Low
0 3 6 12 Kilometers


Leopard
N
W
E
S
Legend
Tadoba Boundary
Value
High
Low
0 3 6 12 Kilometers


Dhole
N
W
E
S
Legend
Tadoba Boundary
Value
High
Low
0 3 6 12 Kilometers


Sloth Bear
N
W
E
S
Legend
Tadoba Boundary
Value
High
Low
0 3 6 12 Kilometers



Figures 14: Intensive area use of Tiger, Leopard, Dhole, Sloth bear, Jungle cat and Rusty-spotted cat at Tadoba-Andhari Tiger Reserve, Maharashtra, India during the 2018 Phase IV Monitoring.

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Notes:

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Wildlife Institute of India