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

2017

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Phase IV Monitoring Report 2017
Spatially Explicit Space Use and Activity

Principal Investigators
Dr. Bilal Habib
Sh. Mukul Trivedi
Dr. Parag Nigam
Dr. Vinay Sinha

Co-Investigators
Dr. Kishor Mankar
Sh. G. P. Narwane

Researchers
Madhura Davate
Nilanjan Chatterjee
Pallavi Ghaskadbi
Lynette Gomes

महाराष्ट्र वन विभाग

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

Further Contact:
Field Director
Tadoba – Andhari Tiger Reserve
Office of Field Director, Mul Road
Chandrapur – 442 401,
Maharashtra, India
Tell: 00 91 7172 251414
Fax: 00 91 7172 277116
Email: ccf_fdtatr@rediffmail.com

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

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Executive Summary

Annual monitoring of Tadoba-Andhari Tiger (TATR) Reserve was conducted in the Core and Buffer of TATR from February – July 2017 covering an area of 1727 sq. km. in compliance with the aim of the project- "Long Term Monitoring of Tigers, Co-Predators and Prey species in Tadoba- Andhari Tiger Reserve and Adjoining Landscape, Maharashtra India", Phase IV .The objective of the Phase IV Monitoring was to estimate the minimum number of tigers and leopards in the reserve using Capture-Recapture Sampling and density estimation of prey base using Distance Sampling.

334 camera traps were placed in the core and buffer areas of TATR following a sampling grid of 2.01 sq. km in four blocks. In each sampling block camera traps were active for 20 –25 days. During 120 days of camera trapping survey with sampling effort of 8016 trap nights, 50 adult individual tigers were photographed in the core area (exclusively) and 19 individuals in the buffer area (exclusively) of TATR. 6 individuals were seen to use both core and buffer area of TATR. Tiger density per 100 sq. km based on Spatially Explicit Capture-Recapture (SECR) model was 5.82 (± 0.68) in the Tadoba Andhari Tiger Reserve.

In order to estimate prey density, 50 line transects in core area and 63 line transects in buffer area were sampled 3 - 7 times during the sampling period in the month of January 2017, with a total walking effort of 700 km and 829 km in core and buffer respectively. Overall during the sampling, 834 animal/bird groups were sighted. The overall density of major prey species (Gaur 2.12/sq. km, Sambar 1.76/sq. km, Chital 6.69/sq. km, Wild pig 3.97/sq. km, Langur 11.09/sq. km, Barking-deer 1.12/sq. km, Nilgai 0.33/sq. km, Peafowl 3.45/sq. km, Hare 1.23/sq. km and Grey jungle fowl 2.93/sq.km) as estimated using distance sampling was 33.49/sq. km in the core area.

The minimum area used and daily activity pattern for each species was studied using camera-trapping data from both core and buffer of Tadoba-Andhari Tiger Reserve. Captures at each camera trap location were modelled in Geographic Information System (GIS) domain to understand the abundance distribution of animals using IDW (Inverse distance weighted) which is an interpolation technique that generates spatially explicit capture surfaces.

Each photograph obtained from the camera trap data contains time and date of capture. This information was used to evaluate the population activity of the species. Species active at the same periods may interact as predator and prey, or as competitors. Camera-trap capture data was used to plot 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.

Pallavi G.

1. Introduction

The tiger, the largest member of the felid family is found in about thirteen Asian countries with India being the most important one. India alone harbors almost 57% of the world's tiger population (http://tigers.panda.org/news/wild-tigers-numbers-increase-to-3890) with Central India being an important tiger conservation landscape (TCL) (Wikramanayake et al. 2011). Since times immemorial the tiger has been a part of the Indian culture representing power, beauty and magnificence and therefore there is no doubt that this regal animal has earned its rightful place as the National Animal of India. India has rendered full protection to the tiger as a Schedule I species in the 1972 Wildlife Protection Act. In spite of the textual glory that the animal enjoys the survival of the species is threatened by problems such as habitat fragmentation and poaching. The tiger is an important umbrella species and efforts to protect the animal and the landscape which it belongs to, have subsequently helped in conservation of other important species as well.

Tadoba - Andhari Tiger Reserve (TATR) located in the Vidarbha region of Chandrapur district, Maharashtra between 20° 04´ 53˝ to 20° 25´ 51˝ N and 79° 13´ 13˝ to 79° 33´34˝ E. is a pristine and a unique ecosystem. It became a national Park in 1955 and was declared a tiger reserve in 1995. It has gained popularity amongst tourists and nature enthusiasts because of its beautiful landscape and animal sightings. However, undoubtedly the biggest draw has always been the tigers of TATR. The tiger population in TATR is connected to other tiger populations in surrounding forests such as that of Indravati Tiger Reserve through the forests of Chandrapur-Gadchiroli districts. The Erai River in the west and the Andhari River in the east are the main rivers draining the region. The largest water bodies in the core area of TATR are Tadoba Lake and Kolsa Lake while the important water sources in the buffer regions are the Erai and Naleshar dam. The region experiences a wide range of temperature throughout the year with summers and winters being the most prominent seasons. The temperatures rise as high as 47°C during peak summers and falls to about 8°C in the winters (Accuweather, 2017). The summers are hot and long while winters are short and mild. The region receives about 1175 mm of annual rainfall between June and September (Kumbhar et al, 2013).

Tadoba-Andhari Tiger Reserve spreads across 1727 sq. km and comprises of Tadoba National Park and Andhari Wildlife Sanctuary. TATR is an interspersion of grasslands, dry tropical deciduous forests, mixed bamboo, riverine patches and water bodies. Amongst all land cover classes mixed bamboo forests is dominant and covers most of the area while riparian forests are least represented (Paliwal & Mathur, 2014). In accordance with

Champion and Seth's (1968) classification the vegetation is Southern Tropical Dry Deciduous Forest with Bamboo (*Dendocalamus strictus*) and Teak (*Tectona grandis*) being the dominant species. Other prominent tree species found here include Ain (*Terminalia elliptica*), Arjun (*Terminalia arjuna*), Bhera (*Chloroxylon swietenia*), Dhawada (*Anogeissus latifolia*), Mahua (*Madhuca indica*), Rohan (*Soymida febrifuga*), Salai (*Boswellia serrata*), Tendu (*Diospyros melanoxylon*) etc. A wide variety of grasses are also found in TATR and some of the prevalent species recorded here include *Heteropogon contortus, Themeda triandra, Aristida funicularis, Vitivera zizanioides, Aristida reducta* (Muratkar & Kokate, 2012).

This pristine landscape is 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.

As a part of the research project titled "Long term monitoring of tigers, co-predators and prey species in TATR, Maharashtra", the Wildlife Institute of India has been monitoring this landscape intensively for over 4 years. The following are the approved objectives of the project:

1. **Mapping of current landuse pattern, infrastructure, mining areas, villages, roads, power transmission lines, demographic profile, livestock population, dispersal corridors, prey and predator occupancy, within the 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 and 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 programme 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 out. Conflict report on annual basis and village survey report on 3-year basis will be prepared.

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 happened in 1975 followed by 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 2016 - 2017. As a part of the long term monitoring program the focus of the research during the said year was:

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

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

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

2. Status of Prey in Tadoba-Andhari Tiger Reserve

2.1: Introduction

The ungulate population in any landscape serves as an important regulator of different ecosystem processes (Hobbs, 1996). Terrestrial ungulate prey population serves as an important factor for maintaining large carnivore population (Wolf & Ripple, 2016). Availability of prey population also serves as a deterministic factor for carnivore density (Karanth et al, 2004). Therefore, it is pivotal to monitor the prey population. Monitoring techniques selected depends on environmental conditions, species, population size and distribution (Kaczensky et al, 2009). Depending on the topography and the vegetation of the region to be surveyed several ungulate and large herbivore population monitoring techniques are used (distance sampling using line transect or point counts, strip transect, track count and dung count). Low detection probability and low visibility are the main challenges in densely forested areas which hinders ungulate abundance estimation.

2.2: Distance Sampling

Distance sampling is a widely used technique to estimate the size or density of a biological population in any given area. The most common form of distance sampling is the line transect method. The region to be surveyed is sampled by placing random transect lines. An observer travels along the line and records the presence of any animals within a distance d of the transect line. Ideally, it is assumed that all animals on the transect line would be recorded and that the probability of detection decreases with increase in the distance from the line. Line transects are considered to be superior than other methods because it acknowledges that some individuals may be missed during survey and provides a method for controlling the number of individuals that may have been missed by the observer.

Transect sampling was carried out in Tadoba - Andhari Tiger Reserve in 2017. Transects were carefully laid across the entire 1700 sq. km. of the area of TATR which covered almost all the different types of vegetation and terrain in the area (Figure 1). A total of 50 transects across 34 beats in the core and another 63 transects in 58 beats of the buffer area were laid with each transect measuring 2 km. Each transect was walked 3-7 times during the period between 2nd - 8th January 2017 and prey species present in the area were recorded along with the habitat features.

During transect walks data on the prey species, number of animals, group composition, distance from transect line and angle bearing of sighted animal was recorded. Standard instruments were used to accurately record the data. Laser Range finders were used to measure the distance of the animals and compass was used to record the bearing. Global Positioning System (GPS) was used to give spatial reference to each animal cluster observed.

The major prey species recorded include 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 (*Gallus sonneratii*) and Black- naped Hare (L*epus nigricollis*).

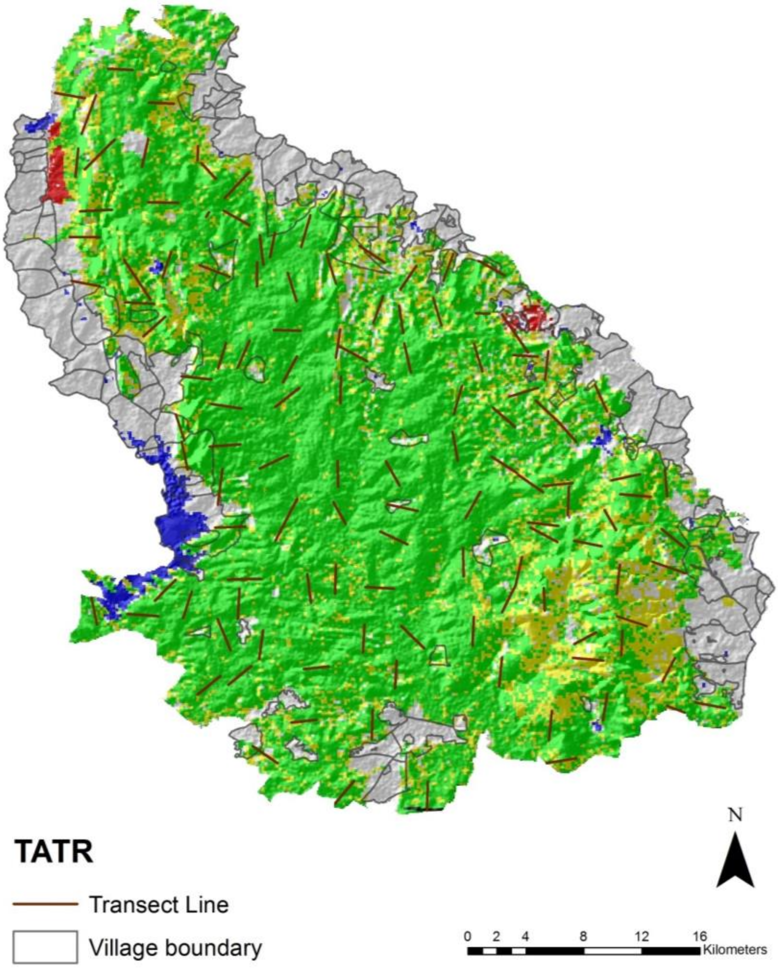


Figure 1: Distribution of line-transects in Core and Buffer area monitored during the year 2017 (Tadoba-Andhari Tiger Reserve, Maharashtra, India)

Total sightings of all prey species numbered to 383 and 306 in core area and buffer area respectively. Table 2.1 give 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 Gaur were the most sighted ungulates on transects of the buffer area of TATR. Sambar and Nilgai were the least sighted species on transects of core and buffer area respectively. It is worth the mentioning that species like Four-horned Antelope were not at all sighted in both core and buffer area of TATR.

Table 2.1: Transect monitoring efforts and species reported from Core and Buffer Area of TATR during Phase IV Monitoring 2017

			Core	Buffer		
Number of transect			50	63		
Length of each transect			2 km	2 km		
Number of replicates			7	3 – 7		
Total distance covered			700 km	829 km		
Number of species recorded			10	10		
	Core			**Buffer**		
Species Recorded	Number of sightings	Individuals recorded	Average group size (min-max)	Number of sightings	Individuals recorded	Average group size (min-max)
Sambar	49	132	2 (1-3)	17	34	2 (1-5)
Chital	56	435	4 (1-42)	55	187	3 (2-5)
Nilgai	19	38	3 (2-4)	19	40	2(1-4)
Gaur	40	132	3 (1-12)	28	125	3 (2-9)
Wild boar	31	108	4(1-18)	24	116	4 (2-7)
Langur	33	287	8 (2-19)	29	292	4(3-16)
Barking deer	28	30	1 (1-2)	23	28	1 (1-2)
Hare	30	49	2 (2-3)	39	42	1 (1-2)
Peafowl	58	102	2 (1-2)	43	56	2 (1-3)
Grey jungle fowl	39	40	1	29	35	1 (1-2)

The total prey density i.e. the total of the individual prey densities in the core area is 33.49 per km^2. In the core the density of langur was highest (9.89 ± 1.72), followed by chital (6.69 ± 1.71), wild pig (3.97 ± 0.46), peafowl (3.45 ± 0.73) and grey jungle fowl (2.93 ± 0.19). In the buffer region the density of wild pig (11.82 ± 2.98) was found to be highest and is followed by langur (11.10± 3.75), chital (11.09 ± 2.07) and nilgai (5.22 ± 1.66).

The Individual Density, Group Density, Effective Strip Width, Average Group Size and Encounter Rate of 10 species reported during the Phase IV Monitoring 2017 in the Core and Buffer Area of Tadoba Tiger Reserve, Maharashtra, India is given in Table 2.2 and 2.3. The comparison of ungulate density with previous estimates is given in Table 2.4 and 2.5. It is evident from Table 2.4 and 2.5 that the major prey species in the core area and buffer area are almost stable as compared to the last few years.

Table 2.2: Individual Density, Group Density, Effective Strip Width, Average Group Size and Encounter Rate of all Prey Species Reported during the Phase IV Monitoring 2017 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/Km2)	1.76	6.69	2.12	3.97	9.89	0.33	1.12	1.23	3.45	2.93
Standard error	0.58	1.71	0.46	0.46	1.72	0.12	0.45	0.54	0.73	0.19
Percent CV	33.01	30.56	26.36	42.46	17.42	35.89	4.03	29.87	19.85	10.03
95% confidence interval	0.93-3.33	4.10-10.09	1.03-2.95	2.48-4.89	6.89-14.21	0.16-0.67	1.03-1.21	0.68-1.84	2.76-5.14	1.57-3.54
Group density (No of groups/Km2)	1.09	1.10	0.69	0.74	0.89	0.22	0.56	0.86	1.90	1.55
Standard error	0.35	0.28	0.11	0.11	0.14	0.16	0.18	0.43	0.16	0.38
Percent CV	32.12	27.98	22.58	35.38	29.82	30.00	32.89	28.87	8.53	25.07
95% confidence interval	0.93-3.33	0.58-1.73	0.33-0.80	0.32-0.93	0.27-0.87	0.12-0.40	0.29-1.05	0.52-1.43	1.60-2.26	0.95-2.53
Effective strip width	15.43	14.75	28.52	17.73	20.87	42.43	18.93	12.98	27.89	14.10
Standard error	2.30	1.66	2.59	3.26	2.30	4.82	2.84	1.76	2.23	1.51
Percent CV	14.94	11.27	9.11	18.39	15.29	19.20	18.03	18.43	11.38	10.72
95% confidence interval	11.45-20.81	11.75-18.50	23.74-34.72	12.05-26.10	15.67-24.89	34.18-51.23	12.29-25.64	7.84-16.33	19.23-30.27	11.34-17.54
Average group size	1.94	6.68	2.92	3.94	8.23	2.06	1.08	1.54	1.93	1.96
Standard error	0.15	0.70	0.37	0.63	2.30	0.50	0.55	0.93	0.16	0.18
Percent CV	7.85	11.27	12.87	21.71	10.72	24.43	5.13	8.12	8.34	9.26
95% confidence interval	1.65-2.27	11.75-18.50	2.26-3.79	2.34-4.83	6.59-10.29	1.23-3.44	1.05-1.17	11.03-1.85	1.63-2.28	1.63-2.37
Encounter rate	0.03	0.02	0.02	0.03	0.04	0.02	0.03	0.03	0.03	0.02
Percent CV	28.09	25.61	20.66	30.22	25.61	23.05	27.50	29.65	19.37	20.32
95% confidence interval	0.02-0.06	0.01-0.04	0.01-0.04	0.01-0.04	0.02-0.06	0.009-0.19	0.01-0.05	0.01-0.05	0.02-0.04	0.01-0.03
Probability of a greater chi-square value, P	0.34	0.51	0.70	0.62	0.56	0.74	0.62	0.70	0.55	0.76

Table 2.3: Individual density Group Density, Effective Strip Width, Average Group Size and Encounter Rate of all Prey Species Reported during the Phase IV Monitoring 2017, 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/Km2)	1.58	11.09	3.54	11.82	11.10	5.22	2.82	2.26	4.06	1.43
Standard error	0.40	2.07	1.07	2.98	3.75	1.66	0.31	0.60	1.39	0.54
Percent CV	25.56	18.67	30.42	25.23	33.81	31.83	38.22	26.65	34.18	38.32
95% confidence interval	0.96-2.61	7.70-15.98	1.96-6.38	7.24-19.30	5.78-21.29	2.82-9.65	1.39-3.70	1.35-3.80	2.11-7.84	0.68-2.98
Group density (No of groups/Km2)	0.71	1.84	1.14	1.33	0.92	1.25	1.74	2.08	1.56	0.77
Standard error	0.16	0.30	0.26	0.26	0.25	0.35	0.27	0.54	0.49	0.28
Percent CV	22.64	16.61	23.46	19.69	27.40	28.59	37.60	26.27	31.69	36.41
95% confidence interval	0.45-1.10	1.33-2.55	0.72-1.81	0.90-1.96	0.54-1.56	0.72-2.19	1.36-2.52	1.25-3.47	0.84-2.88	0.38-1.55
Effective strip width	14.92	12.11	10.52	14.53	10.347	7.86	7.40	6.32	8.19	9.48
Standard error	1.64	1.00	1.59	1.37	1.67	1.42	1.46	0.69	1.02	1.63
Percent CV	11.01	8.31	15.15	9.44	16.22	18.09	19.85	10.97	12.54	17.24
95% confidence interval	11.91-18.68	10.26-14.30	7.73-14.31	12.03-17.56	7.42-14.40	5.43-11.39	4.85-11.28	5.06-7.90	6.35-10.56	6.62-13.56
Average group size	2.13	5.45	3.84	7.24	11.38	3.40	1.13	1.13	2.48	1.85
Standard error	0.31	0.39	0.67	0.78	1.60	0.54	0.09	0.07	0.31	0.19
Percent CV	14.81	7.21	15.15	15.77	14.13	16.07	19.85	10.97	12.81	17.24
95% confidence interval	1.58-2.89	4.72-6.30	7.73-14.31	6.46-12.12	8.52-15.20	2.45-4.73	4.8-11.28	5.06-7.90	1.91-3.22	6.62-13.52
Encounter rate	0.22	0.43	0.27	0.36	0.14	0.17	0.13	0.28	0.26	0.18
Percent CV	19.78	14.39	17.91	17.28	22.08	22.14	31.93	23.87	29.11	32.07
95% confidence interval	0.1-0.3	0.3-0.5	0.17-0.34	0.2-0.5	0.1-0.2	0.1-0.3	0.5-0.2	0.1-0.4	0.1-0.4	0.07-0.2
Probability of a greater chi-square value, P	0.52	0.54	0.35	0.54	0.72	0.40	0.74	0.43	0.29	0.61

Table 2.4: Comparison of prey density of Core area of TATR, Maharashtra, India (2002-2017).Standard errors are given in parenthesis.

Species	2002	2012	2013	2014	2015	2016	2017
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)
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)
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)
Langur	-	-	-	9.47 (± 1.90)	9.70 (±2.42)	10.32 (±2.86)	9.89 (±1.72)
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)
Nilgai	0.7	-	1.3 (± 0.5)	1.09 (± 0.36)	1.01 (±0.37)	0.42 (± 0.16)	0.33 (±0.12)
Barking Deer	0.9	5.2 (±1.2)	-	0.96 (± 0.23)	0.98 (±0.21)	1.16 (± 0.29)	1.12 (±0.45)
Hare	-	-	-	1.70 (± 0.36)	2.23 (±0.65)	0.49 (± 1.15)	1.23 (±0.54)
Peafowl	-	-	-	3.92 (± 0.72)	3.36 (±0.81)	3.25 (± 0.67)	3.45 (±0.73)
Grey Jungle Fowl	-	-	-	1.43 (± 0.53)	2.58 (±0.78)	3.19 (± 0.9)	2.93 (±0.19)

Table 2.5: Comparison of prey density of Buffer Area of TATR, Maharashtra, India (2015-2017)

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

3. Status of Tigers in Tadoba - Andhari Tiger Reserve

3.1: Introduction:

Monitoring large carnivore population contributes significantly towards understanding their behavior, tailor management practices to safeguard their survival and ensure long term conservation. However, given huge stretches of area and the elusiveness of large carnivores and their low densities, monitoring exercises pose to be difficult and challenging.

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).

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.

The dearth of baseline monitoring data on tigers and their co-predators in India has made it difficult to understand the effect that factors such as environmental degradation, fragmentation, disturbance and genetic factors have on these animal communities. The aim of conservation is not limited to only a single species but also includes conserving their habitats and their ecological interactions. The major problem that one faces while engaging in tiger monitoring is the large distribution range, low density, elusive behavior, wide ranging behavior and low detection probability of tiger signs. The combination of all these factors make the collection of quantitative data problematic (Kranth & Nichols, 2017). In large distribution areas, signs of tiger presence or absence are quite indeterminate such that the absence of tiger signs does not necessarily mean that the animal is absent. Long term projects of monitoring help to understand population trends over a long period of time in great details.

3.2: Camera Trapping

Camera trapping is a widely used non-invasive method to identify elusive species and obtain basic ecological information about them (Rowcliffe et al, 2008). The success of a camera trap exercise depends on deployment of the cameras at optimal sites to maximize the number of captures. Prior to site selection for cameras, a survey is conducted along forest paths, animal trails, dirt-tracks and dried water beds to record carnivore presence using signs such as pugmarks, tracks, rake marks, fecal deposits, scent and kills. TATR already has a routine patrolling system in place and hence information about animal movement in each beat was available. Even so, the trap locations used in the previous years (2014-2016) were referred to and revised if change in the existing animal movement pattern was reported.

The camera trapping exercise followed the protocols established by Karanth and Nichols (2002) and Jhala et al. (2010). The potential camera locations were first mapped using ArcGIS 9.3 (ESRI, Redlands, CA, USA). Each sampling grid for the camera trapping exercise was 2.0164 sq. km (1.42 km x 1.42 km). 381 sites comprising of sites in both core and buffer area of TATR were finally selected for trap camera deployment. A pair of Moultrie D-55 (www.moultriefeeders.com/gamespy-d55) or Cuddeback C1, Ambush (http://cuddeback.com/cameras) camera traps was placed opposite to each other so as to photograph both flanks of tiger and leopard simultaneously during the camera-trap exercise. Each camera deployed at the sites was set in multi-shot mode with a delay of 5 seconds. At each site a pair of cameras was set up by tying them to tree trunks, poles or bamboo at a height of about 25-30 cm from ground. Care was taken to not exactly align the opposite facing cameras to avoid the problem of missing an animal sighting in the photographs in case flashes of both cameras triggered at the same time leading to over-illumination of the captured photos. The cameras were monitored to replace battery. We used the flank which yielded maximum unique individuals for abundance estimation.

The entire camera trapping exercise was carried on between the periods of February-July for a period of 120 days. The total area was divided into four blocks and the sampling period was 22-24 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 were recorded for every capture. The location of camera traps is shown in Figure 3.1

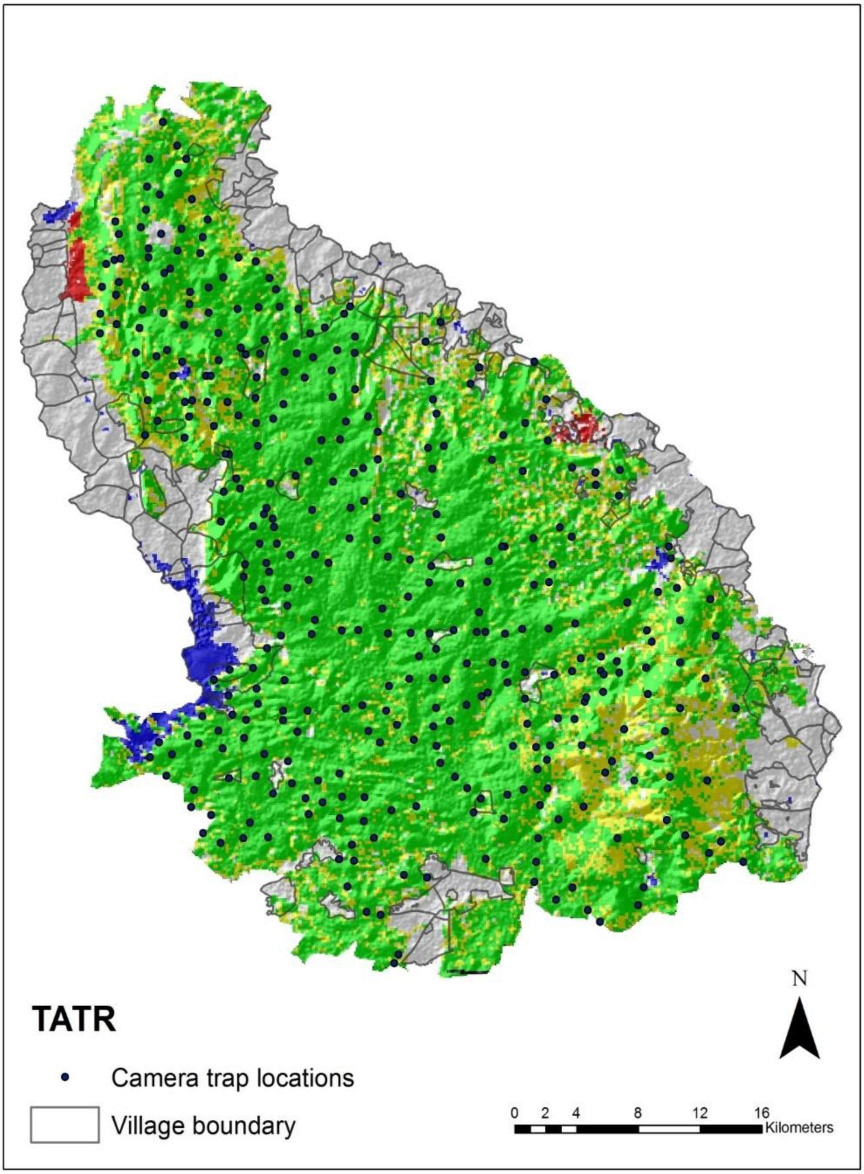


Figure 3.1: Camera trapping locations for 2017 in Core and Buffer area of Tadoba - Andhari Tiger Reserve, Maharashtra, India

Every tiger and leopard photographed was 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 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’.

3.3: Large Carnivore Population Estimation:

Spatially explicit capture–recapture (SECR) method to estimate population is much advanced and advantageous compared to non-spatial methods when the goal is to estimate population size. The primary aim of SECR is to estimate the population density of free ranging animals (Efford, 2004). SECR models the spatial relationship between animals and detectors and overcomes the edge effect which is not considered in the conventional capture-recapture method.

Here the detectors are the trap cameras which photograph tigers and leopards which are then individually identified by comparison of their natural stripes and rosettes. Trap cameras are an example of proximity detectors since they act independent of each other and do not “capture” animals but merely stores the record of an animal visiting the camera site (Efford, 2017). The key additional data that Spatially Explicit Capture Recapture (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.

Tiger and Leopard density per 100 km^2 based on secr Heterogeneity model was estimated to be 5.83 (± 0.68) and 6.13 (± 0.84) respectively for TATR. Best model for the density estimate are chosen according to the AIC (Alkaike Information Criterion). The details are provided in Table 3.1 and Table 3.2 along with the comparison of capture and density estimate from previous years. Table 3.3. and Table 3.4 give the details of tigers captured within core and buffer area of tiger reserve. 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 3.1: Density estimates of tigers using Spatially Explicit Capture-Recapture Models in Tadoba - Andhari Tiger Reserve, Maharashtra, India for the year 2014 – 2017

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

Table 3.2: Density estimates of leopards using Spatially Explicit Capture-Recapture Models in Tadoba - Andhari Tiger Reserve, Maharashtra, India for the year 2017

Parameters	2017
Model	Heterogeneity
Detection function	Half normal
Density estimate	6.134
Density standard error	0.942
Density confidence interval	4.573-7.528
g0 estimate	0.48
g0 standard error	0.074
g0 confidence interval	0.36-0.65
Sigma estimate	5.266
Sigma standard error	0.231
Sigma confidence interval	4.833-5.738

Table 3.3: Comparison of density of tigers across the years 2010 – 2017 for Tadoba-Andhari Tiger Reserve, Maharashtra, India.

Year	Effective trapping area	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)

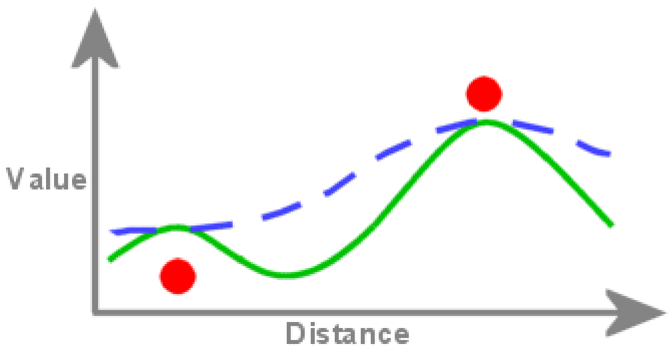
Table 3.4: Number of individual tigers captured from core and buffer area of Tadoba-Andhari Tiger Reserve, Maharashtra, India during the 2017 Phase IV Monitoring

Details	No. of Tigers (2013)	No. of Tigers (2014)	No. of Tigers (2015)	No. of Tigers (2016)	No. of Tigers (2017)
Tigers captured exclusively from Core Area of Tadoba-Andhari Tiger Reserve	50	51	51	48	50
Tigers captured exclusively from Buffer Area of Tadoba-Andhari Tiger Reserve	NA	10	14	17	19
Tigers sharing boundary across the Core and Buffer Area of Tadoba-Andhari Tiger Reserve	NA	04	06	04	6

4. Modelling Spatially Explicit Intensive Use Areas by Predators in Tadoba - Andhari Tiger Reserve

The location of camera traps with number of captures for each species was modeled in GIS domain using the IDW (Inverse distance weighted). IDW is a deterministic method for multivariate interpolation with a known scattered set of points. The assigned values to unknown points are calculated with a *weighted* average of the values available at the known points. 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. It is best if sample points are evenly distributed throughout the area and if they are not clustered.

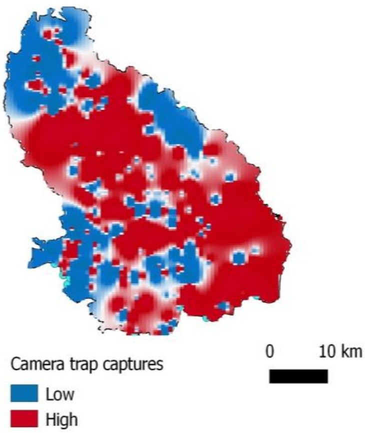
A surface calculated using IDW depends on the selection of the power value (*p*) and the search neighborhood strategy. IDW is an exact interpolator, where the maximum and minimum values (see diagram below) in the interpolated surface can only occur at sample points. The output surface is sensitive to 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. Since IDW does not provide prediction standard errors, justifying the use of this model may be problematic.



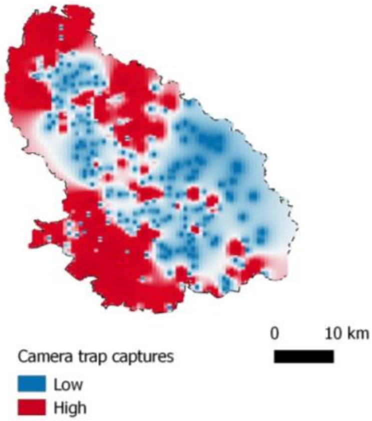
Based on camera trap location and number of photographs at each location for six predator species namely Tiger, Leopard, Dhole, Jungle cat, Rusty-spotted cat and Honey badger for the core and buffer area of TATR (Table 4.1), we developed spatially explicit intensive use area maps with the help of IDW. The maps are shown in Figure 4.1.

Table 4.1: Number of camera-trap stations and photographs of different species captured from core and buffer area of Tadoba-Andhari Tiger Reserve, Maharashtra, India during the 2017 Phase IV Monitoring

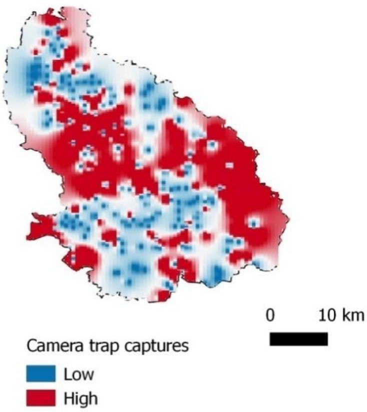
Area	Species	Tiger	Leopard	Dhole	Honey badger	Rusty-spotted cat	Jungle cat
Core TATR	Number of trap stations where photographed	156	68	70	97	32	52
	Maximum number of photographs at a trap station	11	10	22	15	3	5
	Average number of photographs at a trap station	3	3	6	9	2	2
Buffer TATR	Number of trap stations where photographed	45	50	42	31	12	10
	Maximum number of photographs at a trap station	12	8	17	7	2	4
	Average number of photographs at a trap station	3	3	5	5	1	2



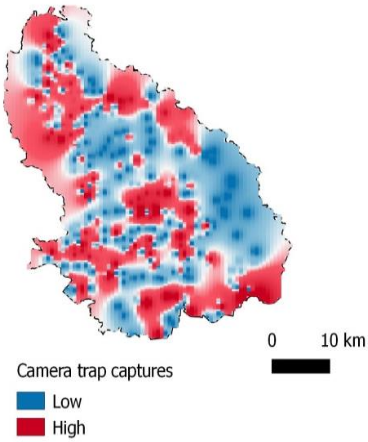
Tiger



Leopard



Rusty-spotted Cat



Honey-Badger

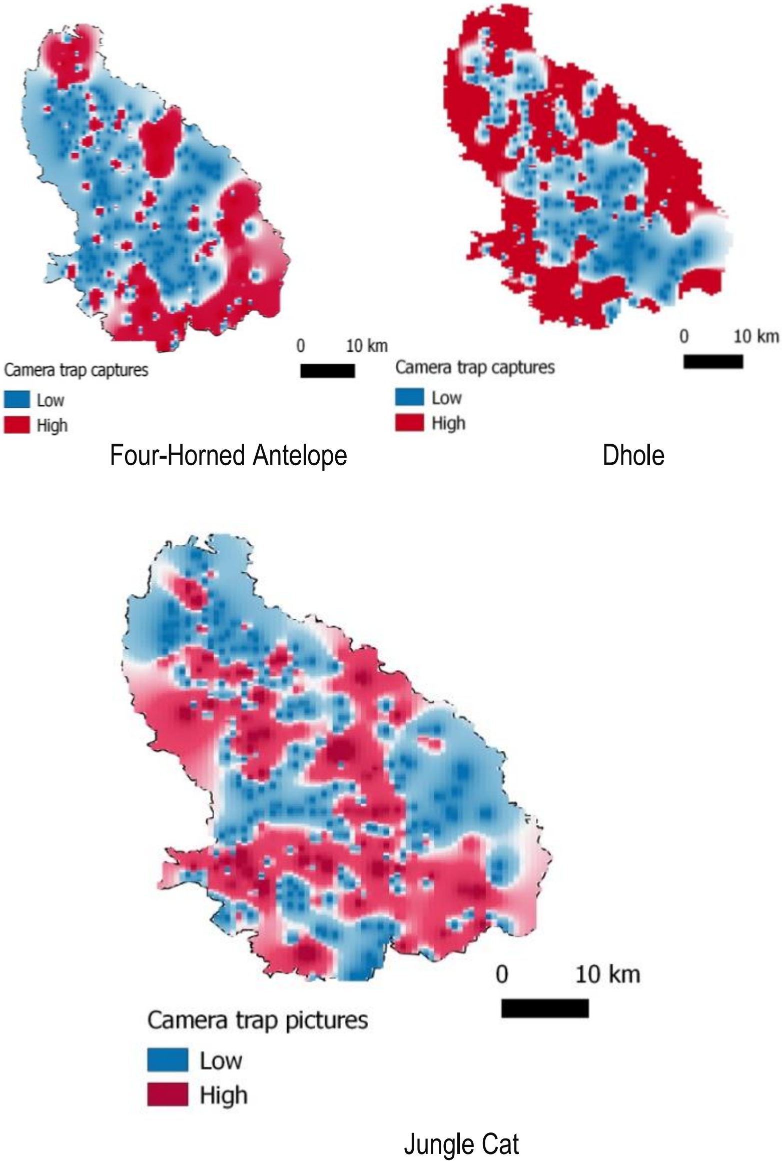


Figure 4.1: Intensive area use Tiger, Leopard, Dhole, Jungle cat, Rusty-spotted cat, four-horned antelope and Honey badger at Tadoba-Andhari Tiger Reserve, Maharashtra, India during the 2017 Phase IV Monitoring.

5. Temporal activity pattern overlap between predator and prey species

In any given predator-prey system a continuous arms race exists (Dawkins & Krebs, 1979). Both are continuously adapting and developing traits for their survival. The selection pressure on the predator enhances their traits which assist in detecting and capturing prey while prey adapt their features which help them in avoiding detection and escape. This coevolution has resulted in development and constant evolution of various predator and anti-predator adaptations (Stephens & Peterson, 1984). As one such adaptation, prey may adjust their activity pattern to that of their predator, and vice versa. The predator may increase its access to prey by being active in periods when prey is active. Conversely, the prey may avoid its predator by being more active in periods when the predator is less active. Furthermore, other behavior of prey such as foraging and movement may also be molded in a multi-predator system such as that of TATR.

Data acquired from camera trapping has been extensively used for estimation of animal densities and spatial ecology of animals. However only a few deal with comparison of activity patterns of large sympatric carnivores with respect to their prey in India. The camera trap photographs have a record of the time during which the species is most active. Number of records are more frequent when the species is up and active while it will lesser when they are not. Species that are active during the same time period in a day may be predator-prey or competitors.

The temporal pattern of the three 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 2013 (Table 5.1). The approach established by Linkie and Ridout (2009) was used to study temporal activity pattern where package “overlap” which estimates the coefficient of temporal overlap non-parametrically using kernel density estimates, was used. The package provides functions to fit kernel density functions to data on temporal activity patterns of animals; estimate coefficients of overlapping of densities for two species; and calculate bootstrap estimates of confidence intervals.

The process occurs in two stages. In the first stage, kernel density estimation is employed to non-parametrically estimate the kernel density (Fernandez-Duran, 2004). In the next stage pair-wise comparison was conducted where the overlap in the calculated density was calculated. Dhat4 is recommended if both samples are larger then 50, otherwise use Dhat1.
Dhat1 is from density vectors calculated at T, equally-spaced times, t, between 0 and 2π:

$$\hat{\Delta}_1 = \frac{2\pi}{T}\sum_{i=1}^{T}\min\{\hat{f}(t_i), \hat{g}(t_i)\}$$

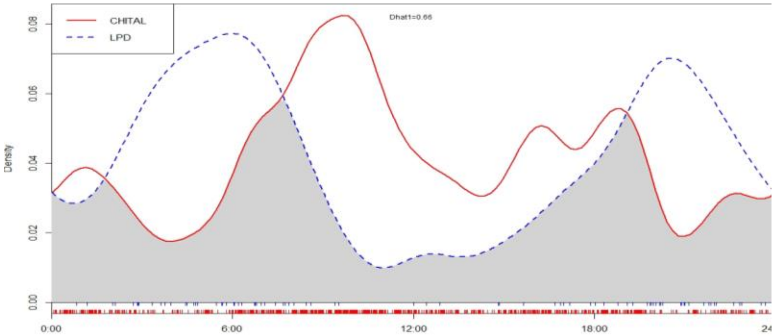
Comparing curves at times of actual observations works well if there are enough observations of each species. Simulations show that Dhat4 is best when the smallest sample has at least 50 observations. Dhat1 compares curves at n. grid equally spaced points, and is best for small samples (Schimd & Schmidt, 2006)

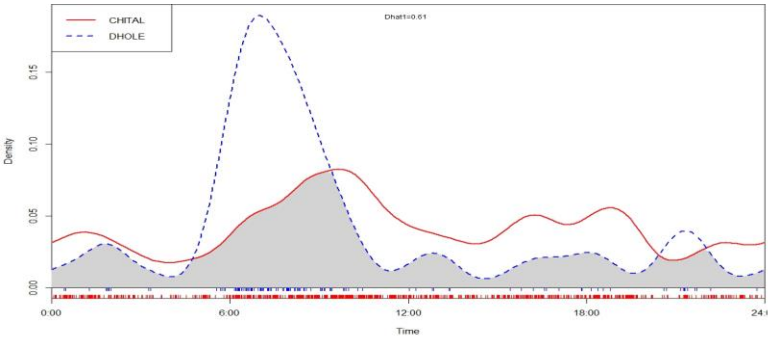
Table 5.1: Activity Overlap of Other Prey Species of Tadoba-Andhari Tiger Reserve with the three sympatric Species

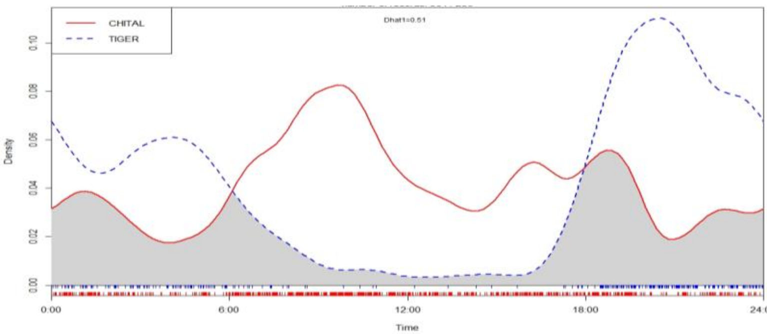
Predator/Prey Species	Tiger	Leopard	Dhole
Wild Pig	0.50	0.69	0.66
Nilgai	0.52	0.71	0.65
Barking Deer	0.64	0.81	0.66
Four Horned Antelope	0.35	0.50	0.54
Langur	0.20	0.38	0.48

Temporal activity overlap among various species at Tadoba-Andhari Tiger Reserve, Maharashtra, India during the 2017 Phase IV Monitoring

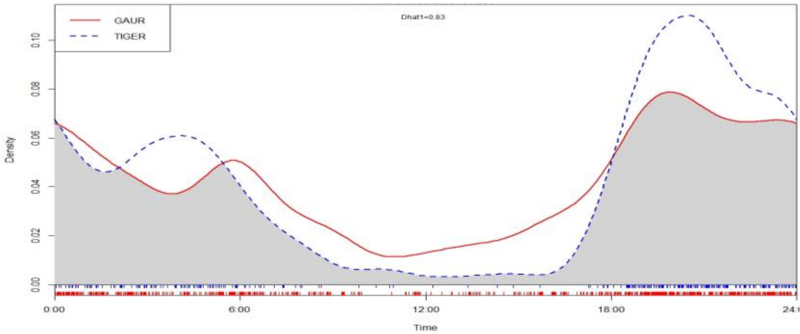
<u>Activity Overlap of Chital with sympatric carnivores</u>

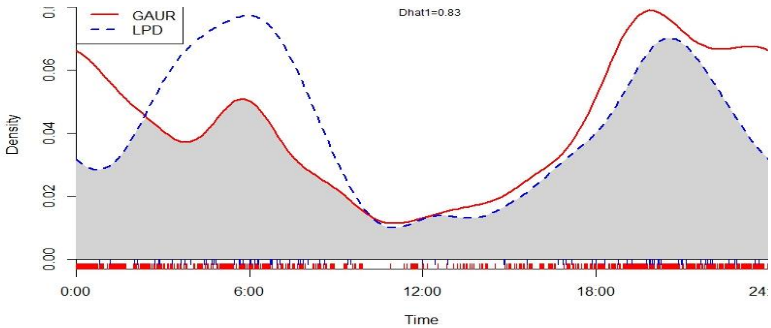


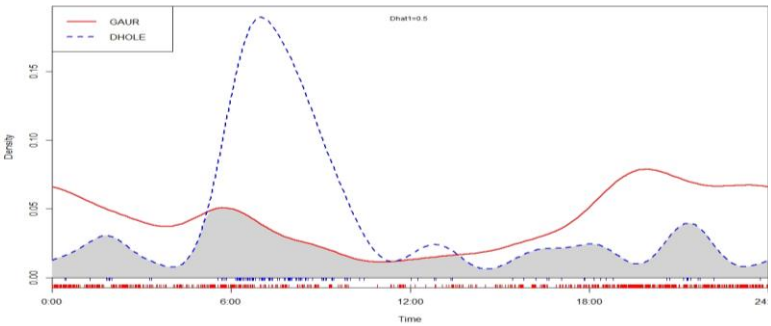




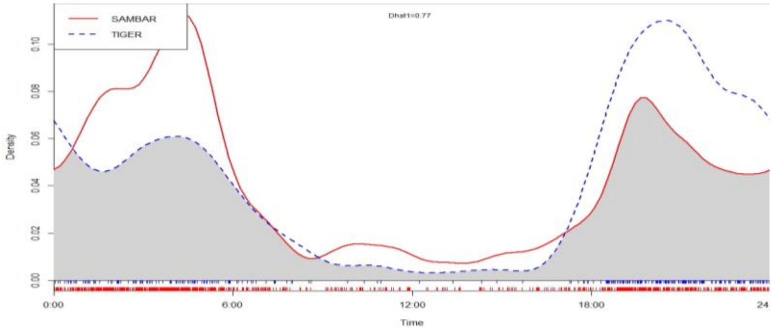
Activity overlap of Gaur with Sympatric Carnivores

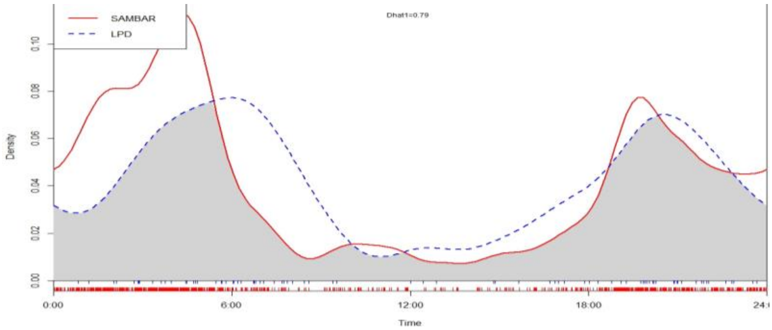


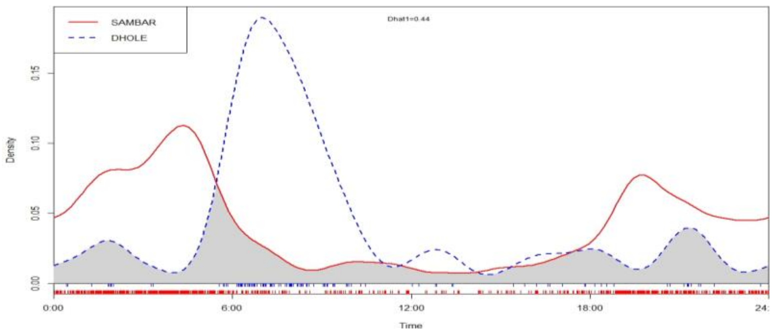




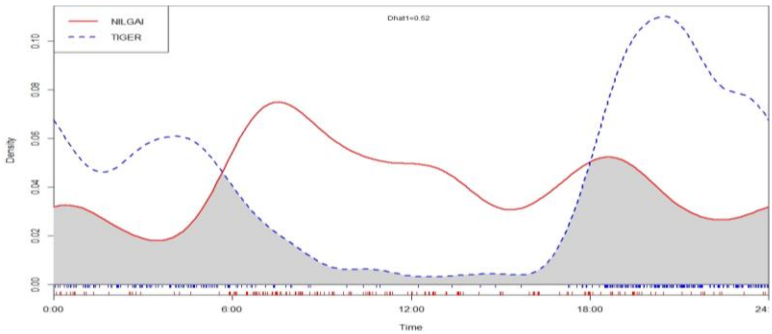
Activity Overlap of Sambar with Sympatric Carnivores

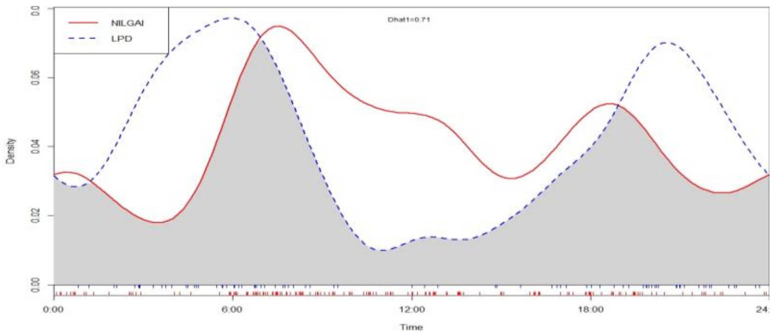


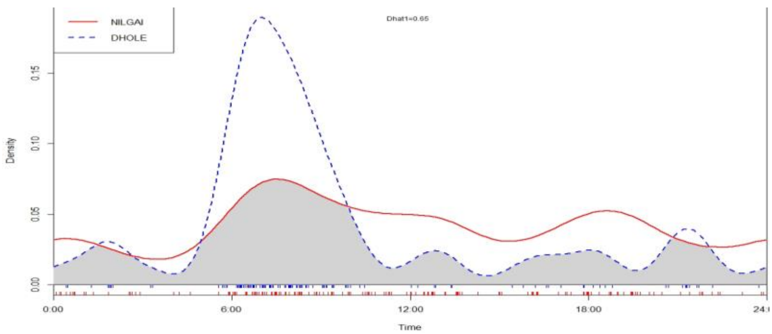




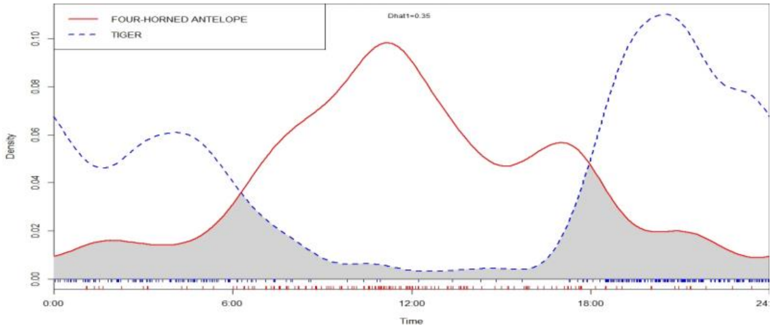
Activity Overlap of Nilgai with Sympatric Carnivores

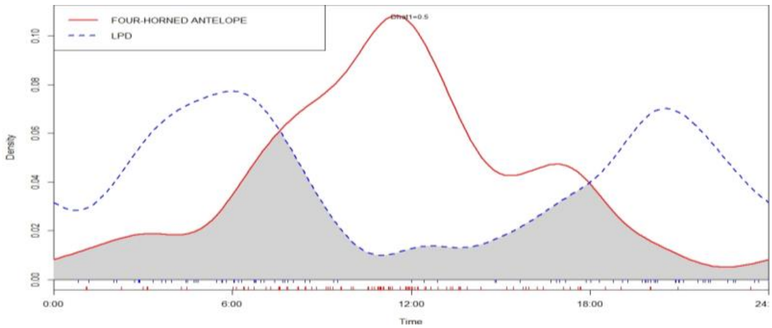


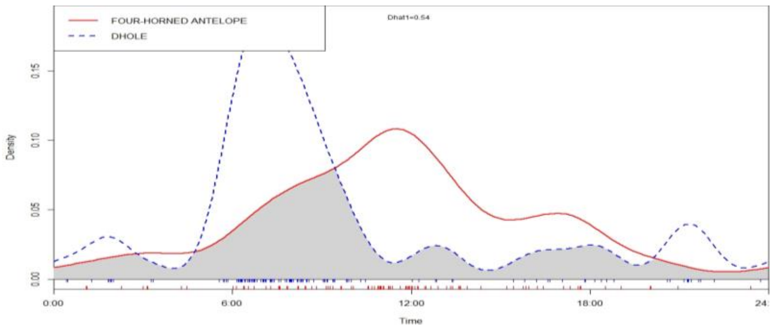




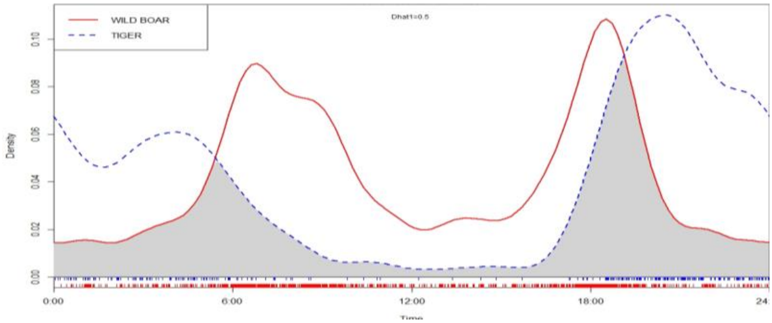
Activity Overlap of Four Horned Antelope with Sympatric Carnivores

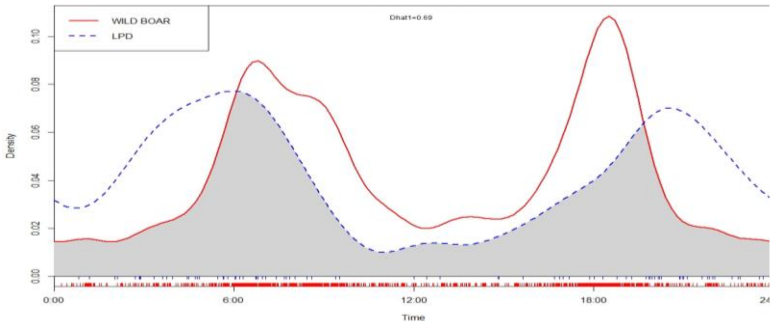


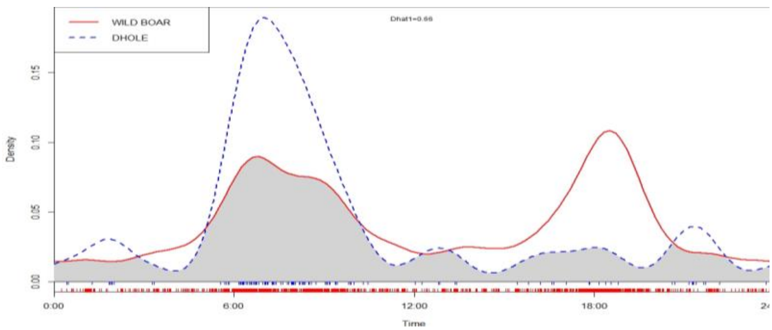




<u>Activity Overlap of Wild Pig with Sympatric Carnivores</u>







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

भारतीय वन्यजीव संस्थान
Wildlife Institute of India