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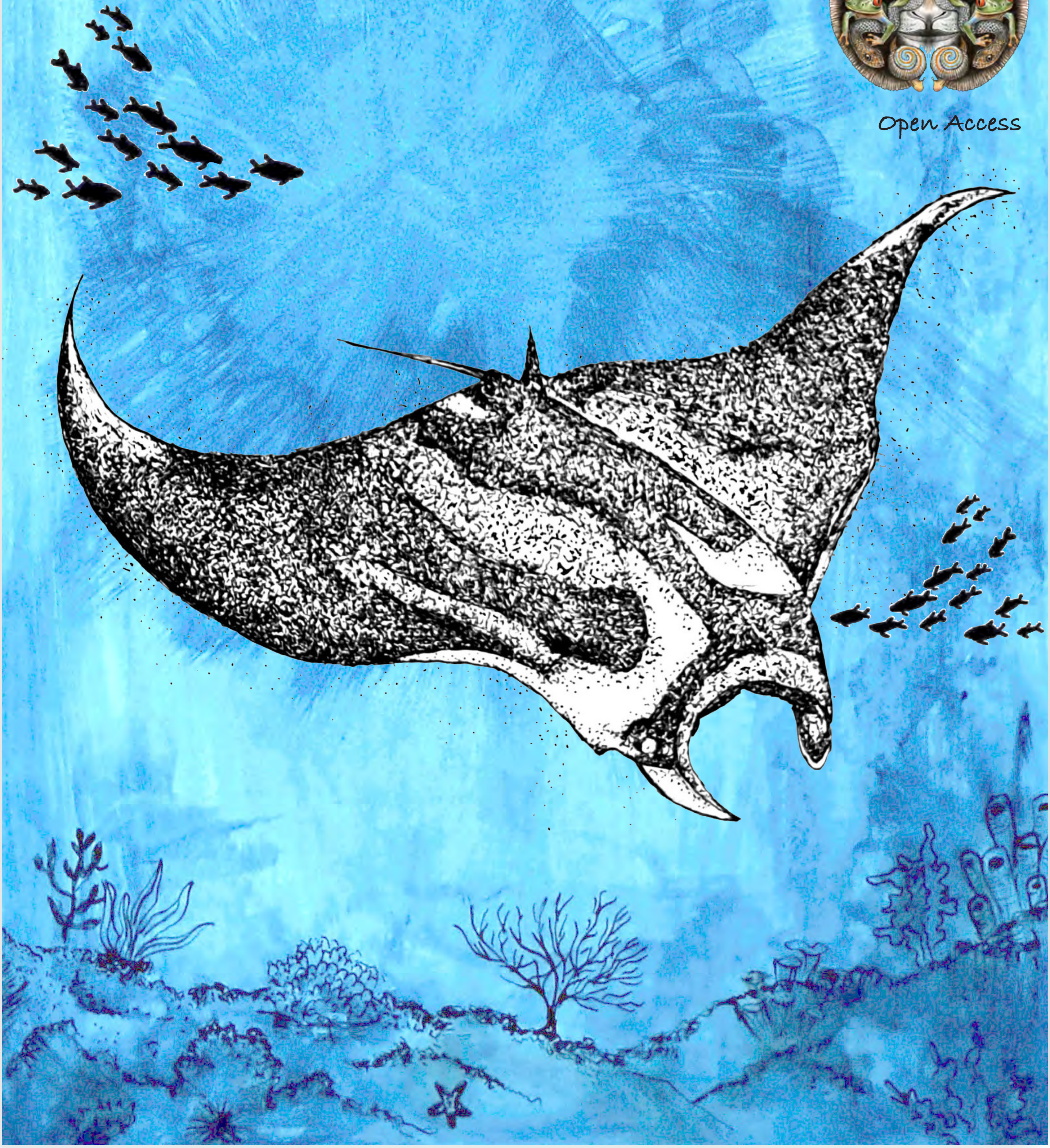

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Cover: Giant Oceanic Manta Ray *Mobula birostris* in ink on acrylic wash by Elakshi Mahika Molur adapted from scientific illustration by Roger Hall.

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ARTICLE

Impact of human activities on wild ungulates in Nagarjunsagar Srisailam Tiger Reserve, Andhra Pradesh, India

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Abstract: Human activities affect wildlife in several ways, ungulates tend to avoid areas of high human use and alter their behavior to avoid human activity. We used remote camera traps to quantify the relative abundance and activity of wild ungulates in high and low human use areas within Nagarjunasagar Srisailam Tiger Reserve (NSTR). Major human activity in NSTR included collection of forest produce and fuel wood, and livestock grazing. Poaching for bush-meat and the use of hunting dogs was also prevalent, but could not be quantified. The relative abundance of wild ungulates was high in low human-use areas except for chital and wild pigs, which require flat terrain and water found in prime areas for settlements. Diurnal ungulates like Chital and Nilgai substantially altered their activity in response to human activity, as did nocturnal species like Sambar and Mouse Deer. The demographic response of ungulates in NSTR has been poor compared to other tiger reserves that have been made free of human use. Our research highlights the importance of having human-free protected areas so as to achieve the desired conservation objectives of harbouring viable populations of large carnivores that require high prey abundance.

Keywords: Activity pattern, camera traps, human impacts, NSTR, relative abundance.

Telugu abstract: మానవులు అడవులలో చేసే కార్యకలాపాలు అనేక విధాలుగా వన్యప్రాణులను ప్రభావితం చేస్తాయి మరియు మానవ సంచారం ఎక్కువగా వుండే ప్రాంతాలలో వారికి ఎదురుపడకుండా శాఖాహార జంతువులు వాటి అలవాట్లను మరియు ప్రవర్తనను మార్చుకుంటున్నాయి. నాగార్జునసాగర్ శ్రీశైలం టైగర్ రిజర్వ్ (NSTR) పరిధిలోని ఎక్కువ మరియు తక్కువ మానవ సంచారం మరియు వినియోగం వుండే ప్రాంతాలలో అడవి జంతువుల లభ్యత, కదలికలు మరియు కార్యకలాపాలను లెక్కించడానికి మేము రిమోట్ కెమెరా ట్రాప్‌లను ఉపయోగించాము. (NSTR) లో అటవీ ఉత్పత్తులు మరియు వంటచెరుకు, కలప సేకరణ మరియు పశువులను మేపడం, మాంసం కోసం వేటాడటం మరియు వేట కుక్కల వాడకం లాంటి ప్రధానమైన మానవ కదలికలు. కానీ దీనికి సంభంధించి సరైన గణాంకాలు లెక్కించబడలేదు. తక్కువ మానవ సంచారం వున్న ప్రాంతాలలో చితల్ మరియు అడవి పందులను మినహాయించి ఇతర శాఖాహార వన్యప్రాణుల యొక్క లభ్యత ఎక్కువగా ఉంది, చితల్ మరియు అడవి పందుల వంటి జీవులకు చదునైన భూభాగం మరియు నివాస ప్రాంతాలలో నీరు అవసరం అవి మన నివాస ప్రాంతాలకు దగ్గరగా నివసిస్తుంటాయి . సాంబార్ మరియు మౌస్ డీర్ వంటి నిశాచర జాతుల మాదిరిగానే చితాల్ మరియు నీల్‌గాయ్ వంటి పగటి పూట సంచరించే జీవులు మానవ కార్యకలాపాలకు ప్రతిస్పందనగా తమ కదళికలను గణనీయంగా మార్చుకున్నాయి. మానవ కదళికలను నిషేదించిన ఇతర టైగర్ రిజర్వ్‌లతో పోలిస్తే NSTRలో శాఖాహార జీవుల జనాభా ప్రతిస్పందన పేలవంగా ఉంది. మా పరిశోధ పెద్ద మాంసాహారుల యొక్క జనాభాను కాపాడటం కోసం ఎంత మొత్తంలో వేటాడబడే జీవులు సమృధిగా వుండాలో తెలిపే అంశాలను గుర్తించడం మరియు మానవ-రహిత రక్షిత అటవీ ప్రాంతాలను కలిగి ఉండటం యొక్క ప్రాముఖ్యత లాంటి పరిరక్షణ అంశాలను స్పష్టంగా తెలియజేస్తుంది.

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INTRODUCTION

Global biodiversity declines are being driven by the direct and indirect effects of anthropogenic actions (Hooper et al. 2012). India supports an extremely high diversity of wildlife (inside and outside designated PAs); most of these species are found in higher densities here than elsewhere across their range (Srivathsa et al. 2023). Remarkable species richness can be found among herbivores, which are primary consumers at the base of many food chains (Putman 1989). Human activities including fuelwood extraction, fodder collection, cattle grazing, consumption of bush meat, and infrastructure development in natural areas can influence herbivore populations, habitat, behaviour, and relationships negatively (Meyer et al. 2013; Frey et al. 2017). In places where wild animals co-occur with humans and space is limiting, animals may minimize contact with humans by separating themselves in time and/or space (Kronfeld-Schor & Dayan 2003), often at a cost to their fitness. These activity shifts in wild animals have been studied using advanced monitoring tools such as GPS-satellite collars (Berger et al. 2003; Ungar et al. 2005) and camera traps (Edwards et al. 2020).

The time and activity budgets of species under different ecological conditions can provide insights into factors that influence predation, competition, metabolic requirements, and others (Aschoff 1989; Hayward & Hayward 2012; Kasiringua et al. 2017). Camera traps have been used as a tool for animal population estimation (Karanth & Nichols 1998; Rowcliffe & Carbone 2008), inventorying rare and elusive species (O'Brien et al. 2003), monitoring illegal activities (Jenks 2012; Hossain et al. 2016), and studying animal behaviour (Wegge et al. 2004). For species where direct observation is difficult, camera trap data has been used to study animal activity patterns (Rowcliffe & Carbone 2008; Frey et al. 2017). For species that cannot be individually recognized from coat patterns, camera trap-based encounter rates are used to compute a relative abundance index (RAI) that is often correlated with independent density estimates (Carbone et al. 2001; Rovero & Marshall 2009).

Nagarjunsagar Srisailam Tiger Reserve (NSTR) forms part of the Nallamala Hills of the Eastern Ghats in Andhra Pradesh. Despite being the largest tiger reserve in the country (area 3,728 km^2; Jhala et al. 2015), there is little ecological data available from the reserve (Srinivasulu 2001). Two forest-dwelling communities, the Lambadas and Chenchus, inhabit the core area of the Tiger Reserve. Impacts of humans and their animals on wild ungulates can be due to: 1) direct hunting, 2) hunting by free-ranging dogs, 3) competition with livestock, and 4) disturbance/competition caused by extraction of forest produce. These impacts may influence the demography of ungulates (decreased abundance and slow growth rates) changes in habitat use, and behavioural changes in time-activity patterns to avoid human activity periods (Madhusudan & Karanth 2002; Karanth et al. 2009; Dave & Jhala 2011; Ohashi et al. 2013; Ritchie at al. 2013).

Due to human-related activities, the animal density in NSTR seems to be low (Srinivasulu 2001). Yet, earlier studies from this site indicates that ungulate sightings were common in the early morning hours close to waterbodies (Bhargav et al. 2009). But due to livestock grazing and hunting pressure the detection of prey was very low and hence proper density estimates were not obtained (Bhargav et al. 2009; Jhala et al. 2011, 2015, 2020).

Due to the presence of armed militant groups in NSTR until recently, few studies could be conducted and therefore information on ungulate densities in this area were lacking. The objective of tiger reserves in India is to use the charismatic tiger as an umbrella species to protect ecosystems. A demographically viable tiger population requires space for a minimum of 20 breeding female tigers (Chapron et al. 2008; Bisht et al. 2019) which translates to an area of about 1,000 km^2 with an average of 50 km^2 as a female breeding territory in Indian forests. This area should support ~450 medium sized ungulates per tiger, and the minimum requirement for a breeding population of tigers is around 34,000 (Jhala et al. 2021). The All India Tiger Estimation Report (Jhala et al. 2020) reports that there were 38 unique tigers captured in the study area resulting in a density estimate of 0.91 tigers per 100 km^2 (SE ± 0.14) and due to low prey sighting on transects the prey density was not estimated (Jhala et al. 2020). NSTR is the only tiger reserve in the state of Andhra Pradesh that has a reasonable number of tigers, and when combined with the tiger reserve of Amrabad in the state of Telangana can potentially accommodate more tigers in the future.

High-density tiger populations and humans do not mix well. To create space for a source population of tigers while providing better livelihoods for forest-dwelling people, a scheme of incentivized voluntary relocation of human settlements from the core areas of tiger reserves is implemented by the National Tiger Conservation Authority (Jhala et al. 2021). The relocation incentive scheme (currently INR 15,00,000 or ~ 20,000 US$ per adult) was not applicable to the tribal communities of Lambadas and Chenchus since their presence in NSTR was not considered to be detrimental for tiger conservation due to the perception that tribal communities lived in harmony with nature and for the utilitarian reason that they were useful as labour for reserve maintenance and management (E.g., patrolling & protection, habitat management activities, and forest fire management activities) since bringing labour from outside is expensive. Also, owing to presence of armed militant groups, the implementation of human resettlement scheme was difficult as militants depended on local forest dwellers for resources and did not permit them to relocate. Now that militancy in the area has been subdued, the administration can initiate incentivized voluntary relocation of all interior settlements to outside of the tiger reserve for better livelihood options and for creating space for wildlife (Pandey et al. 2013; Jhala et al. 2021).

The present study is a first of its kind in the Eastern Ghats landscape that evaluates relative abundance of wild herbivores, their activity patterns, and their behavioural responses to human-related activities. Our study was constrained by the large size of the protected area and the low abundance of ungulates (Kothari et al. 1995; Karamsi 2010; Jhala et al. 2015), making traditional robust approaches like distance sampling impractical due to the large amount of effort required, compounded by low detections of skittish ungulates. Under conditions where ungulates are traditionally hunted, the use of line transect-based distance sampling can be biased, since wild ungulates are extremely vigilant and would likely detect the observer before they can be detected and flee, thus potentially be unavailable for sampling.

To understand the ecology of a wild ungulate species, the factors that influence the dynamics of its population or the ecosystem it represents are crucial. Our a priori hypotheses were that ungulate abundances would be lower in areas of high human use, and that ungulates would adjust their activity to avoid periods of high human activity. With this ecological understanding in mind, our study aims to: a) estimate the relative abundance of wild ungulates in the park using camera traps and b) quantify the impact of human activities on the abundance & behaviour of wild ungulates. This study would help us to better understand the low densities and slow recovery of ungulate populations in NSTR and provide recommendations for management interventions.

MATERIALS AND METHODS

Study Area

NSTR is the largest tiger reserve in the country (3,728 km^2), demarcated as core and buffer administrative units of 2,444 km^2 and 1,284 km^2, respectively. It is located in the southern Eastern Ghats (15.88333-16.71666 N, 78.50000-79.46666 E) in the state of Andhra Pradesh. Our study area covered 2,500 km^2 within two administrative units, namely, Markapur and Atmakur divisions, including the extended Tiger Reserve core area constituted by Gundala Brahmeswaram Wildlife Sanctuary (GBM), Velgode, and Bairlutty ranges (Image 1).

The terrain of NSTR can broadly be classified as hills, plateaus, valleys, gorges, and escarpments. The vegetation type is southern tropical dry deciduous, tropical moist deciduous, and tropical thorn forests (Champion & Seth 1968). Forest contributed to (84%) of land cover in the study area which is mostly deciduous and scrub/degraded forest followed by agricultural land (1%), waste land (12%), water bodies (2%), and built up (1%). In total, forest covers 84% of the study area. These data were calculated using Arc GIS (v.10.1*)* (ESRI 2011).

The major portion of rainfall is received from the south-west monsoon that commences from the second half of June and continues up to the first week of October. Then there is a short dry spell for a month. The north-east monsoon is active from November to the first half of December, mainly on the eastern slopes of Nallamala Hills. The mean annual rainfall ranges from 590–760 mm (Jhala et al. 2020). NSTR supports large carnivores like the Tiger *Panthera tigris*, Leopard *Panthera pardus*, Dhole *Cuon alpinus*, Wolf *Canis lupus*, Striped Hyena *Hyena hyena*, Golden Jackal *Canis aureus*, and Sloth Bear *Melursus ursinus*. Wild ungulates found in NSTR are Chital *Axis axis*, Sambar *Rusa unicolor*, Blackbuck *Antelope cervicapra*, Mouse Deer *Moschiola meminna*, Nilgai *Boselaphus tragocamelus*, Chousingha *Tetracerus quadricornis*, and Wild Boar *Sus scrofa* (Pandey et al. 2013).

The study area encompasses 15 major villages that were home to two scheduled tribes (Subramanyachary 2013), the Chenchus and Lambadas, with few other scheduled castes and their livestock, mainly composed of cattle, buffalos, and goats & sheep. Location of human settlements is mostly determined by proximity to perennial water and productive flat lands, which are also prime habitat for wildlife (pers. obs.).

Andhra Pradesh is home to 12 primitive tribal groups (PTGs), with Chenchu being one of the PTGs recognized

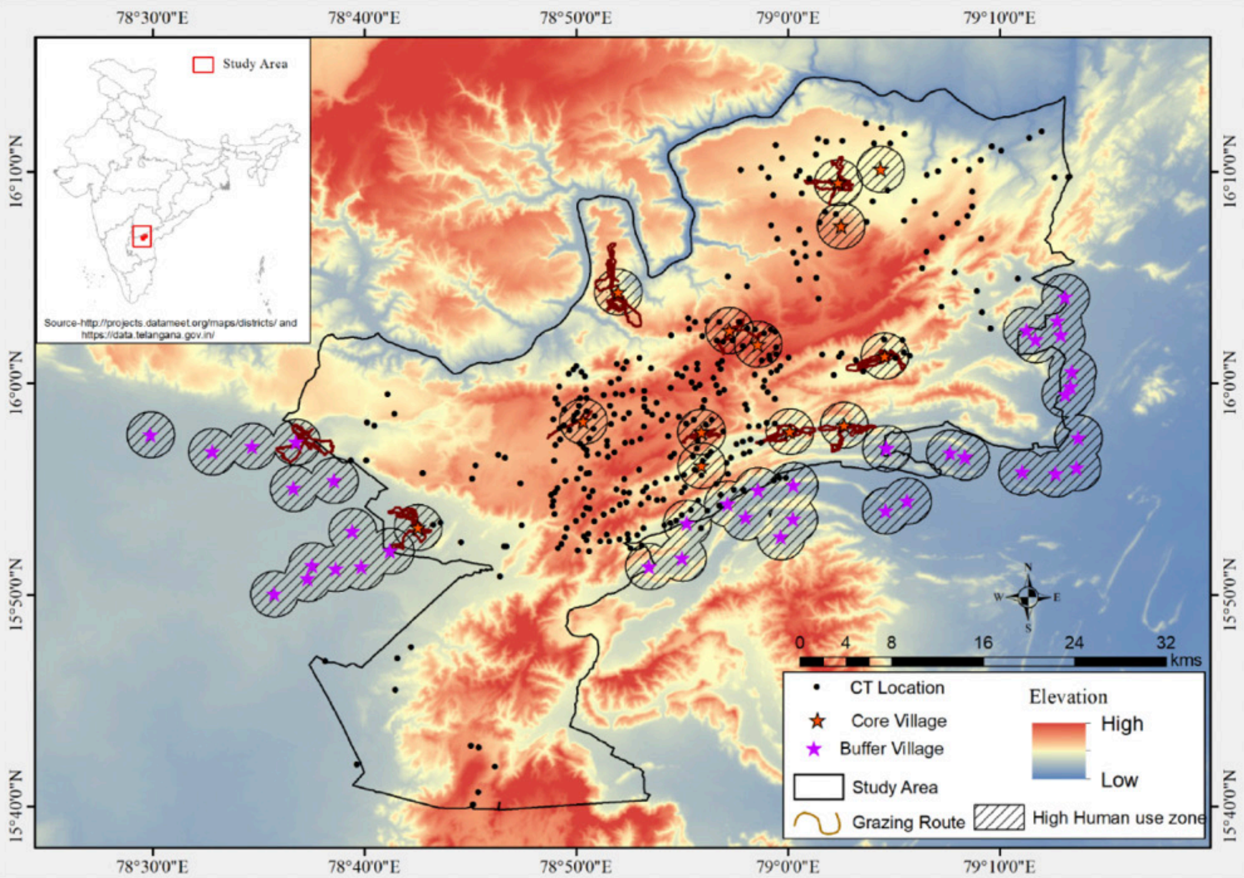


Image 1. Map showing camera trap locations within Nagarjunsagar Srisailam Tiger Reserve (NSTR). Cameras within the maximum grazing radius of livestock from villages/cattle sheds were considered to in the high human impact zone. DEM based on Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Global courtesy of the U.S. Geological Survey (https://earthexplorer.usgs.gov/ The map inset shows the location of NSTR within the state of Andhra Pradesh, India (http://projects.datameet.org/maps/districts) and (https://data.telangana.gov.in). The map was created by authors using Arc GIS 10.1.

by the Indian government. Later in 2006, the Indian government proposed renaming the primitive tribal group as primitive and vulnerable for 75 tribal groups in India based on their dependency on hunting, gathering food from the forest, growth of their population, and literacy level. The purpose of this classification was to provide assistance so as to uplift the tribal community in different sectors like education, health, livelihood, skilled labour, agriculture, housing, while retaining their culture (Ministry of Tribal Affairs 2015). These communities are mostly confined to the foothills and low-lying areas of Nallamalla Hills covering Prakasam, Kurnool, Mahaboobnagar, Rangareddy, Guntur Nalgonda districts of both Andhra Pradesh and Telangana states (Raju et al. 2009).

Historically, Chenchus were nomadic hunters and food gatherers inhabiting forested areas, where they ate honey and tubers, and hunted wildlife for food (Murty 1981). Most Chenchus now live in permanent settlements called gudem or pentas, which are a cluster of huts made from bamboo and grass, however, they continue to engage in collecting honey, grass, fruits, nuts, and leaves as supplements to their livelihood (Suryakumari et al. 2008). Chenchus still carry traditional bows and arrows when they move inside the forest that can be used for hunting.

Lambada tribes are called by different names, such as Sugalis and Banjaras in other parts (Lal 2015). These tribes spread across Andhra Pradesh and Telangana states in southern India (Vaditya 2019). They live in exclusive settlements of their own called 'Thandas' (Shankar 2016). Present day occupation of majority of Lambadas in general is cultivation and pastoralism (Karamsi 2010).

Inside the core area of NSTR, there are around 5,650 households, with a total population of more than 25,000 people and 2,977 cattle, while another 69 villages with 1,26,000 cattle are present in the buffer zone of the tiger reserve (Bhargav et al. 2009; Mathur et al. 2018). The entire tribal population within the tiger reserve depends on forest resources for survival, which are shared with wildlife (Srinivasulu 2001; Sudeesh & Sudhakar 2012).

Data Collection

Estimation of wild ungulate density

The smallest administrative unit, i.e., forest beats, were used to systematically distribute line transects (n = 142) to survey the study area. The length of each line transect was between 1.5 to 3 km. Each transect was walked once during the early morning (0600–0800 h) between December to February of 2014 and 2016. All sightings of animals, the group size, radial distance to the centre of the group and bearing were manually recorded on a datasheet**.** Radial distances to animals were measured using a hand-held range finder (Bushnell RX1000). Bearings were recorded using a hand-held compass (Suunto KB 20).

Relative Abundance of Wild ungulates

Sampling using camera traps was done across the study area between January to July 2014 in an area covering 713 km^2. A total of 345 camera locations were sampled, with a double camera unit (Cuddeback attack 1149, Cuddeback ambush 1194) deployed at each location for about 40 days. Since this exercise's primary objective was to obtain a population estimate of tigers, camera placement was mostly on game trails, dry stream beds, and dirt roads to maximize photo captures of carnivores. However, we believe that the photo capture data on ungulates to address our study's objectives and comparisons with other sites would remain unbiased as placement locations were similarly selected across the study area and in other tiger reserves across India (Jhala et al. 2021). We checked cameras every 3–7 days to download data and check battery status. All photographs were segregated to species, and information on time, date, and coordinates, recorded for each image.

Livestock were not free-ranging in NSTR, but taken out to graze by herders from corrals in each settlement every morning and brought back by dusk. Herders were often accompanied by dogs. Since livestock movement was constrained by the distance they could move from their corrals and from water sources, human, dog, and livestock activity was mostly concentrated within a certain radius from settlements. Cattle, buffalo, goat, and sheep escorted by herders were accompanied by the first author from early morning when they left the corrals to late evening when they returned to their corrals. A hand-held GPS unit was used by the first author to record the daily grazing circuit from villages in the winter and summer of 2014 and 2015. The grazing circuit was mapped using ArcGIS (v. 9.3), the average displacement distance of livestock herds from settlements/villages was computed, and each settlement was buffered by the 95% upper bound of this distance to delineate a zone of high human use. A total count of all livestock in each season was done for each village and cattle shed across NSTR at a time when livestock were corralled to determine the total livestock population.

Data analysis

Wild ungulate density estimation

Analysis was done using the conventional distance sampling approach in Program DISTANCE (v. 6.0) (Buckland et al. 2004). Due to low detection of ungulate species in NSTR on line transects we pooled observations from three sampling periods (Jhala et al. 2011 & 2015 and sampled by first author in 2016) from NSTR and used line transect observation data from seven other sites in the country (Table S1, S2) which have the similar habitat type to NSTR for fitting species detection functions in program DISTANCE to estimate effective strip width. Shape criteria were examined for heaping, and any outliers were right-hand truncated where necessary (Buckland et al. 2004). Three key functions (Half normal and hazard rate all with cosine and Hermite polynomial series adjustment) were considered for analysis. Model selection was evaluated using Akaike's information criteria (AIC), while Kolmogorov–Smirnov statistics were used to assess the goodness of fit of each model (Buckland et al. 2004). Subsequently, this pooled effective strip width was used to obtain year wise density estimates of ungulate species in NSTR.

Relative Abundance of Wild ungulates

Relative abundances of the wild ungulates in the study area were estimated from 2014 camera trap data, as photo capture rates which were computed by summing independent photo-captures of each species and dividing this sum by the camera trap operational days. We defined an independent photo-capture event as follows 1) consecutive photographs of different species or different individuals of the same species; 2) Consecutive photographs of individuals of the same species taken more than 30 minutes apart (O'Brien et al. 2003); and, 3) non-consecutive photos of individuals of the same species.

We used independent photographs of species to calculate relative abundance index (RAI) from camera trap images. RAI was computed as the number of independent photo captures of a species in 100 trap nights (Carbone et al. 2001). The total effort invested was determined by multiplying total camera operation day. Camera traps were segregated into two strata based on their location as i) within the high human - use areas and ii) those outside this zone as low human impact areas. RAI of ungulates was also computed separately for these two zones. We hypothesised that RAI values of ungulates would be lower in high human impact areas and RAI values of human disturbances (photocaptures of humans, domestic dogs, and livestock) would be higher in high human impact areas.

The RAI was computed for each camera trap location for each species in both high and low human use zones, for testing if RAI differed between high and low human use zones we used non-parametric Mann-Whitney U-test (Zar 2022).

Camera trap-based data collection overcomes biases induced by the skittish nature of wild ungulates which can result in non-availability for sampling on line transects, but unfortunately RAI does not allow for rigorous inference on absolute abundance. To test the hypothesis that RAI is a reliable index of absolute density we regressed the RAI values of Chital and Sambar (species with a reasonable sample size of observations) with absolute density estimates of these species obtained from line transect distance sampling from other similar forest types where absolute density estimates from distance sampling were also available (Jhala et al. 2020). A significant positive relationship between RAI and absolute density would lend support to the hypothesis.

Temporal peak activity pattern

We used camera trap images and their associated information from the metadata of the images like date, time of the photograph to understand the temporal activity of six wild ungulate species in NSTR. The time of the photo capture was used to create a 24-hour activity pattern graph as well as analysis using Oriana software (v. 4.0). Oriana uses circular statistics to enumerate the dispersions such as mean vector length (r) along with confidence intervals. The mean vector has two properties: direction and length of the mean or angle, and the mean vector length (r) denotes the clusters of observation around the mean, which ranges from 0 to 1, where 1 is the frequency of observations very close to the mean and 0 is when observations are scattered across the study. In the rose plot the arc on the outer edge extending to either side of the mean represents the 95% confidence limits Oriana software (v.4). The output provided activity clustering along with mean peak activity time for wild ungulates and human related activities factors within a 24-hour cycle, facilitating a quantitative statistical comparison of their temporal activity.

Activity pattern and temporal overlap

We estimated the proportion of time active and activity pattern of ungulates across the day from camera trap data using the Activity package (v1.3.1) (Rowcliffe 2022) in Program R (v. 1.4). This provided information on how much time an ungulate species remains active in a day while the activity pattern describes the distribution of activity across the 24-hour period. Analysis of data was done separately for the two human impact strata. We hypothesised that ungulates in high human impact zones would alter their active behaviour and activity to avoid peak human associated activity periods (human, dog, and livestock activity peaks). Temporal overlap of ungulate activity with anthropogenic disturbances using different packages like Overlap (v. 0.3.3) (Ridout & Linkie 2009) and ggplot2 (v 3.3.3) in Program R (v 1.4.) software was estimated. We used the overlap coefficient (Δ), ranging from 0 – no overlap to 1 – complete overlap (Ridout & Linkie 2009) to estimate the overlap for each wild ungulate species in both high and low human-use areas with human related activities. Since samples used for overlap analysis were more than 75 independent photo-captures for most of the wild ungulate species in both high and low human impact areas we used D-hat 4 estimator for all species (Ridout & Linkie 2009).

RESULTS

Livestock Population and Grazing radius

The total livestock population in NSTR was 4,403 in summer and 3,934 in winter. The livestock population comprised of 44.5% goats, 31.4% cattle, & 24.0% buffalo during summer and 35.8% goats, 35.4% cattle, & 28.8% buffalo during winter. Average livestock grazing circuit was 4.0 (SE ± 0.12) km. Livestock ranged more in summer 4.6 (SE ± 0.22) km than in winter 3.5 (SE ± 0.23) km. The average foraging radius combined for both seasons was 1.8 (SE ± 0.07) km. The 99% upper bound on the foraging radius was 2.01 km. Camera traps within a buffer of this maximum foraging radius (2.01 km) around each human settlement / cattle shed were considered to be within high human activity zone (Image 1).

Wild ungulate density

Detection of all ungulates was low in NSTR. Density estimation for Chousingha, Mouse Deer, and Nilgai was not meaningful to report due to very few detections on transect surveys, and therefore density estimates of Chital at 1.8 (SE ± 0.0.52) individuals / km^2, Sambar at 0.72 (SE ± 0.24) / km^2, and Wild Boar at 0.48 (SE ± 0.15) / km^2, are reported (Table 1).

Relative Abundance Indices

We obtained 35,306 usable photographs with an effort of 10,681 trap nights. Humans were photo-captured the most (Table 2). Wild ungulates constituted 37% of this data. The highest number of captures were of Sambar (38%) followed by Chital (26%), Wild Boar (18%), Chousingha (9%), Mouse Deer (5%), and Nilgai (4%). RAI was highest for Wild Boar (10.0), while it was lowest was for Nilgai (1.5) (Table 2). Human impact was recorded throughout NSTR (in the form of human, livestock, and domestic dog photo-captures), and was similar across the reserve for humans and domestic dogs since RAIs of humans and domestic dogs were not significantly different near settlements and away from settlements (Table 2, Figure S1). Livestock RAI was significantly higher in the proximity of settlements (Figure S1). Amongst wild ungulates only Chousingha and Nilgai had significantly higher RAI in low human use areas while Wild Boars had significantly higher RAI in high human use areas (Table 2, Figure S1).

In support of our hypothesis, the regression between absolute density and RAI was asymptotically linear with a reasonably good fit for both Chital (Table S1, Figure S2; R^2 = 0.86; P = <0.001) and Sambar (Table S2, Figure S6; R^2 = 0.69; P = <0.01).

Temporal Activity Patterns

All wild ungulates except Chousingha showed bimodal activity. Chousingha were diurnal, Chital and Nilgai were

Table 1. Density estimates of ungulates in Nagarjunsagar Srisailam Tiger Reserve based on line transect distance sampling.

Species	Observations	Model	Density (SE)	%CV	Group density (DS)- (S.E)	%CV	ESW	Detection probability (P^)	Chi P-value
Chital	22	Hazard rate/Hermite polynomial	1.80 (0.52)	29	0.52 (0.13)	26.46	50.9	0.42	0.66
Sambar	17	Hazard rate/Hermite polynomial	0.72 (0.24)	33	0.49 (0.15)	31.82	41.9	0.41	0.72
Wild Boar	13	Uniform/Cosine	0.48 (0.15)	33	0.37 (0.10)	28.36	41.7	0.41	0.90

DS—Group density | ESW—Effective strip width | SE—Standard error | %CV—Coefficient of variation.

Table 2. Relative abundance of wild ungulates, livestock, domestic dogs, and humans in Nagarjunasagar Srisailam Tiger Reserve as estimated from relative abundance index (RAI) from camera trap data.

Species	Total number of photographs	Total number of independent photographs	Overall RAI	RAI in the high human-use zone	RAI in the low human-use zone	Overall % time active	% Time active in high human- use zone	% Time active in low human- use zone
Sambar	5003	923	8.6	6.7	9.2	45	37	47
Chital	3443	859	8.0	12.1	6.9	29	28	28
Wild Boar	2356	1073	10.0	14.4	8.7	47	53	41
Chousingha	1152	383	3.6	1.9	4.1	30	31	30
Mouse Deer	665	380	3.6	1.5	4.1	36	23	35
Nilgai	387	158	1.5	0.5	1.8	43	28	36
Humans	14033	4117	38.5	50.1	35.2	38	34	36
Livestock	7127	821	7.7	13.3	6.1	36	28	27
Domestic dog	1140	264	2.5	2.4	2.5	39	41	34

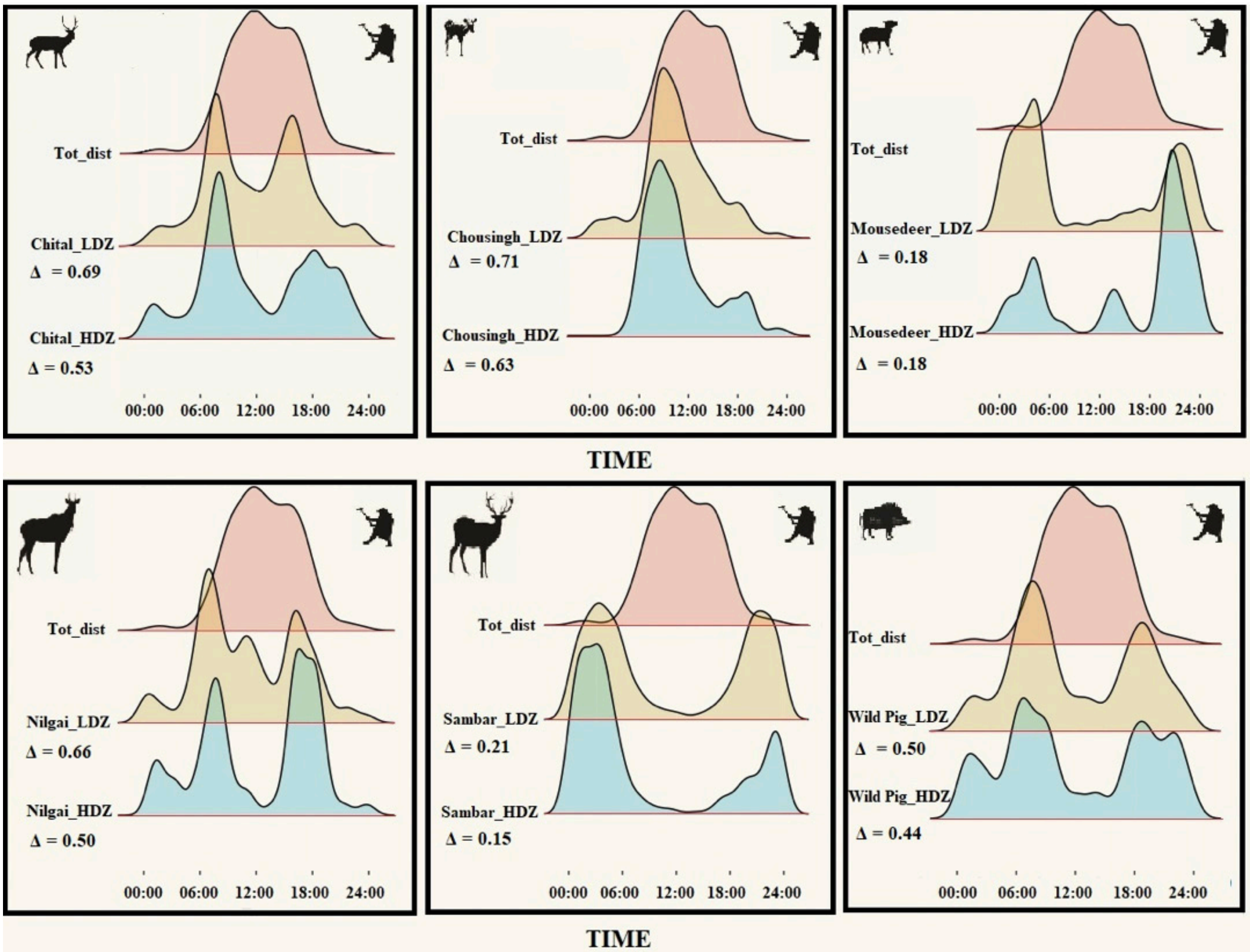


Figure 1. Temporal overlap depicted as kernel density functions of wild ungulate activity with combined anthropogenic disturbances ((Tot_dist= photo captures of humans, livestock, and domestic dogs) in areas of high human impacts (HDZ, in proximity to settlements) and low human impacts (LDZ, away from settlements). Δ – is the coefficient of overlap between human activity and ungulate activity in Nagarjunsagar Srisailam Tiger Reserve.

crepuscular and diurnal, Sambar and Mouse Deer were primarily nocturnal, while Wild Boars showed activity at night and in the forenoon (Figure S3). All human related activity (humans, domestic dogs, and livestock) were diurnal, beginning late mornings and extending into late evening (Figure 1, Figure S3). In agreement with our a priori hypothesis, within the constraints of some ungulates being diurnal, wild ungulates avoided all forms of human activities (Figure 1; Figure S3). The 95% confidence intervals of wild ungulate activities (except Chital) did not overlap any of the human related activities (humans, livestock, and domestic dogs; Figure S3). Chital activity in low human use areas overlapped only with the 95% confidence intervals of livestock active periods (Table 3, Figure S3). Overlap of ungulate activity with anthropogenic activities within the high-human impact zone was found to be higher for Chousingha (63%) and the lowest for Sambar (15%) (Figure S4). For species like Chital, Chousingha, and Nilgai in the low human impact zone, the overlap with various anthropogenic disturbance factors, such as humans, dogs, and livestock activities combined, was found to be more than (60%) for Chital and least for Mouse Deer (18%), respectively (Figure 1).

DISCUSSION

In the Anthropocene, exclusive space for biodiversity is one of the most limiting factors for conservation (Kipkeu 2014). Many protected areas set aside for wildlife conservation have people residing within them (Kothari et al. 1995). NSTR has 15 villages with human population of 5,650 families with a population of ~18,000 (Lal 2015), and a livestock population of ~4,500 within the tiger reserve. In addition to the resident settlements, NSTR is

Table 3. Temporal activity pattern of wild ungulates, livestock, domestic dogs, and humans in Nagarjun Sagar Srisailam Tiger Reserve. Mean vector length (r) denotes the clusters of observation around the mean, which ranges from 0 and 1 where 1 is the frequency of observations very close to the mean and 0 is when observations are scattered. The 95% confidence limit of the mean, overlap between HDZ (high human use zone) and LDZ (low human use zone) 95% CI signifies no statistical shift in peak activity between the two zones.

Species/zone	No. of observations	Mean vector (μ)	Length of mean vector (r)	SE mean	95% C.I
Chital HDZ	1569	10:37	0.143	00:28	09:41–11:32
Chital LDZ	1881	11:57	0.343	00:10	11:36–12:18
Sambar HDZ	664	01:38	0.659	00:08	01:22–01:54
Sambar LDZ	4085	00:47	0.51	00:04	00:38– 00:56
Chousingha HDZ	121	09:45	0.601	00:21	09:02– 10:27
Chousingha LDZ	981	10:27	0.581	00:08	10:11–10:42
Mouse Deer HDZ	50	22:19	0.612	00:33	21:14– 23:24
Mouse Deer LDZ	615	00:51	0.556	00:10	00:30–01:12
Wild Boar HDZ	839	02:12	0.134	00:41	00:50– 03:33
Wild Boar LDZ	1515	08:41	0.115	00:36	07:30– 09:52
Livestock HDZ	3257	12:14	0.697	00:03	12:07– 12:21
Livestock LDZ	3863	12:22	0.624	00:03	12:15– 12:29
Humans HDZ	4096	13:22	0.689	00:03	13:16– 13:28
Humans LDZ	9597	13:04	0.619	00:02	12:59– 13:08
Domestic dogs HDZ	469	12:34	0.597	00:11	12:12–12:56
Domestic dogs LDZ	668	13:48	0.693	00:07	13:33– 14:03

also used by humans and their livestock from peripheral villages (Image 1). Human and livestock photo-captures outnumber all other species in NSTR (Table 2), which should be reason for concern.

Human-related activities contributed 63% of total independent photo-captures. Photo-captures of humans were high, followed by livestock and domestic dogs which were all primarily restricted to daylight hours. However, except for livestock, the presence of humans and domestic dogs was recorded across the protected area, suggestive of high impacts of human activities within NSTR and not limited to near the settlements. Though we found that wild ungulates avoided active periods of humans we found no statistical differences in relative abundance or activity for most wild ungulates between areas closer to human settlements (high human use) and further from settlements (low human use) suggesting a pernicious impact of humans across NSTR.

In a comparative scenario, in Kuno Wildlife Sanctuary with similar dry deciduous forest like NSTR, the Chital population was found to recover from a density of 4.6 km^{-2} (Banerjee 2005) to ~40 km^{-2} (Jhala et al. 2015) after human habitations were relocated from Kuno and protection from poaching enhanced. Subsequent to the data collection for this study, we obtained photo-capture of local communities indulging in hunting activities (Image S1). Wild Boar abundance was not in agreement with our a priori predictions since they had higher abundance in high human use areas. This was likely since human habitations were located in flatter productive terrain (Image 1) which is also the only habitat for Chital and Wild Boars as these species tend to avoid hilly areas.

Earlier studies on temporal activity of sambar in India (Schaller 1967; Shea et al. 1990; Lahkar et al. 2020) and on greater mousedeer from Borneo (Ross et al. 2013) report these species to be nocturnal. Our data confirm these inherent biological patterns of Sambar and Mouse Deer becoming active well after darkness and continuing their activity into dawn hours (Lahkar et al. 2020). By being nocturnal, both species avoid periods of high human activities. However, in human-free areas, Sambar are recorded to show activity during daylight hours as well (Griffiths & Schaik 1993). Though there were no totally human free areas in NSTR, we did observe greater daytime activity for Sambar in low human impact zone (Figure 1).

More significantly, the overall active period of Sambar reduced in high human use areas (Table 2), thereby reducing the duration available for foraging and other vital activities. At NSTR, chital were reported to be widely dispersed and to form small herds (Srinivasulu

2001), which contrasts with our observations, since we found all ungulates to be very skittish, Chital in particular, were at very low densities and mostly observed as solitary or in very small groups, a major deviation from observations in other protected areas where chital tend to be the most abundant wild ungulate, often occurring in large herds. Chital have been reported as being diurnal with a bimodal activity at dawn and dusk (Schaller 1967) our results conform to this pattern.

A shift in the activity of Chital (though not statistically significant) was observed between high and low human-use areas of NSTR (Figure 1), with the evening peak of activity being less pronounced and more spread out into the late evening and early night in high human-use areas. High and low human-use areas actually differed only in terms of livestock use, with human and domestic dog usage being recorded across NSTR with no statistical difference across zones.

Livestock is sympatric with wild ungulates in most forested areas of India (Kothari et al. 1989), where they potentially compete for essential resources like food and water. Even though livestock grazes Indian forests to varying extents, their impact on wild native ungulates is less understood (Madhusudan 2004). Understanding the interaction between wild ungulates and livestock is complex and varied under different ecological conditions (Sankar 1994; Dave & Jhala 2011). Though we segregate our camera traps into high and low human impact zones we caution that human activity was recorded across NSTR and therefore we find little differences between low and high human impact zones in terms of timing of activity as well as active duration, these differences would likely have been more pronounced if compared between total human impact free areas and human use areas.

More importantly, our data show that all ungulates across NSTR avoided time periods having high human activities. Often diseases like foot and mouth can get transmitted between livestock and sambar (Johnsingh & Manjrekar 2015). NSTR has a large resident cattle population and during the monsoon an additional large number of cattle migrate from nearby villages to graze (Bhargav et al. 2009).

Presence of domestic dogs in protected areas shifts wildlife temporally or permanently from the available space they have (Banks & Bryant 2007). Our results show that domestic dogs were very active (41%) in high human use areas and domestic dogs usually accompanied humans (Table 2). Domestic dogs have been traditionally used by forest dwelling communities to hunt bushmeat. Even the odour of dog urine or faeces can trigger wild animals to avoid an area (Hennings 2016). Since domestic dogs occur at densities higher than natural predators, the frequency of attacks on wild prey species is also likely high, especially in and around protected areas (Ritchie et al. 2013).

We found that free-ranging dogs often accompany tribesmen armed with bow and arrows who move around unhindered inside the protected area on the pretext of collecting non-timber forest products. While conducting fieldwork AK witnessed incidents where dogs accompanied by local tribal communities chased Chital. Temporal activity pattern revealed that activity of dog's overlap more than 60% of the activity of Chital, Nilgai, and Chousingha. These ungulates being diurnal are limited in their ability to change their activity to avoid dog activity periods (that are only diurnal). Thus human impacts and predation through dogs would affect these diurnal species the most. Domestic dogs were often used for hunting wildlife by local tribal communities and their impact were likely significant in depressing ungulate densities as also reported (Madhusudan & Karanth 2002).

Many wildlife species face extinction because of human impacts; therefore, a prevailing belief is that many species cannot co-exist with people (Carter et al. 2012). Any human-related activity can disturb wildlife; one such significant depressant is hunting. Carnivore assemblages may be affected by direct poaching or through poaching of their prey. Diverse methods, including domestic dogs, bow and arrows, traps, and smoking of fossorial mammals, were traditionally used for hunting (Datta & Naniwadekar 2019). It is recognized that continued overhunting lowers animal densities and subsequently leads to local, regional, and overall species extinction (Diamond 1989; Rabinowitz 1995). A study from Nagarahole Tiger Reserve mentions that 78% of local communities interviewed preferred to hunt Mouse Deer by using domestic dogs (Madhusudan & Karanth 2002).

In NSTR mousedeer has the least overlap with domestic dog activity (Figure S5) possibly to avoid predation. Hunting also changes the behaviour of wildlife as seen in Sika Deer in Bialowieza National Park where they became more diurnal once the park management restricted tourism and hunting (Kamler et al. 2007). Hunting influenced Wild Boar activity patterns where it was more diurnal during the non-hunting season in central Japan (Ohashi et al. 2013). The NSTR management acknowledges that the resident Chenchu tribals, who always carry a bow and arrows and are accompanied by domestic dogs whenever they move inside the forest, do hunt birds and monitor lizards (Pandey et al. 2013). The Lambada tribe, are reported to occasionally hunt small mammals during festive season (Bhargav et al. 2009). Despite the fact that we were unable to quantify ungulate poaching as a cause of their low densities, based on observations and camera trap photographs of such actions, poaching, combined with high livestock densities, and domestic dog related stress was most likely to be responsible for NSTR's low wild ungulate densities.

CONCLUSIONS

Our findings suggest that RAI estimates can help index abundance and can be used to estimate trends in wild ungulate populations. Our data and inferences show that impacts of human activities alter wild ungulate abundance and behaviour, as also demonstrated previously (Gaynor et al. 2018) The tropical dry deciduous forests are among the most impacted habitats by anthropogenic activities and are vulnerable to degradation (Chundawat et al. 1999). The forests near human settlements were more disturbed than those away from settlements. In the short-term, we recommend active removal of free-ranging dogs, control of poaching, and minimizing livestock grazing, for wildlife population revival.

Most forest dwellers prefer to relocate when given a genuine opportunity, since living within protected areas is difficult due to limited access to basic amenities like electricity, roads, health care, education, and markets. While within protected areas, their crops are raided by wild ungulates, and large carnivores often kill their livestock and sometimes humans (Madhusudan & Mishra 2003; Chapron et al. 2008). However, people rights activists argue that human resettlement from protected areas is unethical and is not required since forest-dwelling communities live in harmony with nature and forest resource use by them is sustainable (Rangarajan & Shahabuddin 2006; Dattatri 2010). In certain instances, relocation results in transformation of the 'way of living' since relocation usually results in changing nomadic hunter-gatherer or pastoral communities to a more settled livelihood based on agriculture or labour.

Several communities such as Gujjars in Uttarakhand, Sahariyas in Madhya Pradesh, and Maldharis in Gujarat face a challenging transition that is often difficult to make (Rangarajan & Shahabuddin 2006). In line with this argument, the forest-dwelling tribes of NSTR (Chenchus and Lambadas) have not been offered the NTCA incentive of voluntary relocation. Thus, without any genuine feasible option to move out of the core area of NSTR, human settlements continue to grow within the tiger reserve, and their impact on forest resources remains unabated and increasing with time. To achieve the conservation objectives of the tiger reserve, i.e., to establish a long-term viable population of tigers that act as a flagship and umbrella species for the conservation of the ecosystem, higher abundance of wild ungulates is required, for this it seems important to mitigate the current human impacts in NSTR.

We propose that the incentivized voluntary relocation package of INR 1.5 million per adult (~ USD 20,000) (NTCA 2021) be made available to the forest-dwelling communities of NSTR. This would open an option for potentially better livelihoods and lifestyles to these people outside of the tiger reserve and benefit both people and wildlife simultaneously. Future studies should be carried out by camera trap based monitoring each year, keeping the present study as a baseline, to understand the status and trends of carnivore and herbivore abundance after human impacts are reduced/removed within NSTR. Such monitoring should conclusively prove the depressant effects of humans on wildlife and document the recovery of the wild ungulate populations (Anonymous 2009).

REFERENCES

Anonymous (2009). The state of forest report, forest survey of India, Ministry of Environment and Forests, Government of India. New Delhi 54–57.

Aschoff, J. (1989). Temporal orientation: circadian clocks in animals and humans. *Animal Behaviour* 37 (4): 881–896. https://doi.org/10.1016/0003-3472(89)90132-2

Banerjee, K. (2005). Estimating the ungulate abundance and developing the habitat-specific effective strip width models in Kuno Wildlife Sanctuary, Madhya Pradesh. M.Sc. Thesis. Forest Research Institute, Dehradun.

Banks, P., & J. Bryant (2007). Four-legged friend or foe? Dog walking displaces native birds from natural areas. *Biology Letters* 3: 611-613. https://doi.org/10.1098/rsbl.0374:1–4

Berger, A., K.M. Scheibe, S. Michaelis & W. Streich (2003). Evaluation of living conditions of free-ranging animals by automated chronobiological analysis of behavior. *Behavior Research Methods, Instruments, & Computers* 35(3): 458–466.

Bhargav, P., S. Dattatri & A. Desai (2009). A Rapid Appraisal report on Nagarjunasagar Srisailam Tiger Reserve-Andhra Pradesh. National Tiger Conservation Authority, 31 pp.

Bisht, S., S. Banerjee, Q. Qureshi & Y. Jhala (2019). Demography of a high-density tiger population and its implications for tiger recovery. *Journal of Applied Ecology* 56(7): 1725–1740. https://doi.org/10.1111/1365-2664.13410

Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers & L. Thomas (2004). Advance Distance Sampling*: Estimating abundance of biological populations,* Oxford, Oxford University Press, 33–47 pp.

Carbone, C., S. Christie, K. Conforti, T. Coulson, N. Franklin, J.R. Ginsberg & W.N. Shahruddin (2001). The use of photographic rates to estimate densities of tigers and other cryptic mammals. *Animal Conservation* 4(1): 75–79. https://doi.org/10.1017/S1367943001001081

Carter, N.H., B.K. Shrestha, J.B. Karki, N.M.B. Pradhan & J. Liu (2012). Coexistence between wildlife and humans at fine spatial scales. *Proceedings of the National Academy of Sciences* 109(38): 15360–15365. https://doi.org/10.1073/pnas.1210490109

Champion, H.G., & S.K. Seth (1968). *A Revised Survey of Forest Types of India*. Natraj Publishers, Dehradun, 404 pp.

Chapron, G., D.G. Miquelle, A. Lambert, J.M. Goodrich, S. Legendre & J. Clobert (2008). The impact on tigers of poaching versus prey depletion. *Journal of Applied Ecology* 45(6): 1667–1674. https://doi.org/10.1111/j.1365-2664.2008.01538.x

Chundawat, R.S., N. Gogate & A.J.T. Johnsingh (1999). Tigers in Panna: preliminary results from an Indian tropical dry forest. *Riding the Tiger: Tiger Conservation in Human-Dominated Landscapes.* Cambridge University Press, 378 pp.

Cumming, D.H.M. & G.S. Cumming. (2003). Ungulate community structure and ecological processes: body size, hoof area and trampling in African Savannas. *Oecologia* (134): 560–568.

Datta, A. & R. Naniwadekar (2019). Hunting for answers: the scale and impacts of hunting, and the importance of listening to hunters. *Mongabay* (Electronic Version) https://india.mongabay.com/2019/11/commentary-hunting-for-answers-the-scale-and-impacts-of-hunting-and-the-importance-of-listening-to-hunters/ Accessed on 21 January 2021.

Dattatri, S. (2010). The Myth of Harmonious Co-existence. *Conservation India.* https://www.conservationindia.org/articles/the-tribal-bill-the-myth-of-harmonious-co-existence-2 Electronic Version accessed on 21 January 2021

Dave, C. & Y. Jhala, (2011). Is competition with livestock detrimental for native wild ungulates? A case study of chital (Axis axis) in Gir Forest, India. *Journal of Tropical Ecology* 27(03): 239–247. https://doi.org/10.1017/S0266467410000738

Diamond, J.M. (1989). The present, past and future of human-caused extinctions. *Philosophical Transactions of the Royal Society of London. Biological Sciences* 325(1228): 469–477.

Edwards, S., J. Noack, L. Heyns & D. Rodenwold. (2020). Are camera traps a reliable method for estimating activity patterns? A case study comparing technologies for estimating brown hyaena activity curves. *Remote Sensing in Ecology and Conservation* 7(2): 129–138. https://doi.org/10.1002/rse2.175

ESRI (2011). ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute.

Frey, S., J.T. Fisher, A.C. Burton & J.P. Volpe (2017). Investigating animal activity patterns and temporal niche partitioning using camera-trap data: challenges and opportunities. *Remote Sensing in Ecology and Conservation* 3(3): 123–132. https://doi.org/10.1002/rse2.60

Gaynor, K.M., C.E. Hojnowski, N.H. Carter & J.S. Brashares (2018). The influence of human disturbance on wildlife nocturnality. *Science* 360(6394): 1232–1235. https://doi.org/10.1126/science.aar7121

Gompper, M.E. (2013). The dog-human-wildlife interface: assessing the scope of the problem. *Free-Ranging Dogs and Wildlife Conservation*. Oxford University Press, 342–351 pp.

Griffiths., M. & C.P.V. Schaik (1993). The Impact of Human Traffic on the Abundance and Activity Periods of Sumatran Rain Forest Wildlife. *Conservation Biology* 7(3): 623–626.

Hayward., M.W. & M.D. Hayward (2012). Waterhole use by African fauna. *South African Journal of Wildlife Research* 42: 117–127.

Hennings, L. (2016). The impacts of dogs on wildlife and water quality: A literature review- Technical Report. Metro Park and Nature-Metro Regional Government. Oregon-Portland, 109 pp.

Hooper, D.U., E.C. Adair, B.J. Cardinale, J.E. Byrnes, B.A. Hungate, K.L. Matulich & M.I. O'Connor (2012). A global synthesis reveals biodiversity loss as a major driver of ecosystem change. *Nature* 486(7401): 105–108.

Hossain, A.N.M., A. Barlow, C.G. Barlow, A.J. Lynam, S. Chakma & T. Savini (2016). Assessing the efficacy of camera trapping as a tool for increasing detection rates of wildlife crime in tropical protected areas. *Biological Conservation* 201: 314–319.

Jenks, K.E. (2012). Distributions of Large Mammal Assemblages in Thailand with a Focus on Dhole (Cuon alpinus) Conservation. Ph.D Dissertation. University of Massachusetts Amherst, United States.

Jhala Y.V., R. Gopal, V.B. Mathur, P. Ghosh, H.S. Negi, S. Narain, S.P. Yadav, M. Amit, R. Garawad & Q. Qureshi (2021). Recovery of tigers in India: Critical introspection and potential lessons. *People and Nature* 3(2): 281–293. https://doi.org/10.1002/pan3.10177

Jhala, Y.V., Q. Qureshi & R. Gopal (2015). The status of Tigers, Co-predators & Prey in India 2014 (eds) 2015. No. TR2015/021pp. 218–220. National Tiger Conservation Authority, New Delhi & Wildlife Institute of India, Dehradun.

Jhala, Y.V., Q. Qureshi, R. Gopal & P.R. Sinha (2011). Status of the Tigers, Co-predators, and Prey in India, 2010. No. TR 2011/003 pp-302. National Tiger Conservation Authority, Govt. of India, New Delhi, and Wildlife Institute of India, Dehradun.

Jhala, Y.V., Q. Qureshi & A.K. Nayak (2020). *Status of Tigers Co-Predators and Prey in India*. National Tiger Conservation Authority Government of India, New Delhi, and Wildlife Institute of India, Dehradun.

Johnsingh, A. & N. Manjrekar (2015). *Mammals of South Asia, 1st edition*. Universities Press (India) Private Limited, Hyderabad, Telangana, 392 pp.

Karamsi, S.R. (2010). "Deconstructing the Caste Hegemony –Lambada Oral Literature" *Journal of Alternative Perspectives in the Social Sciences* 2(1): 455–467.

Kamler, J.F., B. Jędrzejewska & W. Jędrzejewski (2007). Activity patterns of red deer in Białowieża National Park, Poland. *Journal of Mammalogy* 88(2): 508–514.

Karanth, K.U. & J.D. Nichols (1998). Estimation of Tiger densities in India using photographic captures and recaptures. *Ecology* 79(8): 2852-2862. https://doi.org/10.1890/0012-9658(1998)079

Karanth, K.K., J.D. Nichols, J.E. Hines, K.U. Karanth & N.L. Christensen (2009). Patterns and determinants of mammal species occurrence in India. *Journal of Applied Ecology* 46(6): 1189–1200. https://doi.org/10.1111/j.1365-2664.2009.01710

Kasiringua, E., G. Kopij, & S. Proches (2017). Daily activity patterns of ungulates at water holes during the dry season in the Waterberg National Park, Namibia. *Russian Journal of Theriology* 16(2): 129–138. https://doi.org/1015298/rusjtheriol.16.2.02

Kipkeu, M.L. (2014). Understanding community participation in wildlife conservation in Amboseli ecosystem, *IOSR Journal of Environmental Science, Toxicology and Food Technology* 8(4): 68–75.

Kothari, A., P. Pande, S. Singh, & D. Variava (1989). Management of National Parks and Wildlife Sanctuaries in India. A status report. Indian Institutes of Public Administration, New Delhi, 298 pp.

Kothari, A., S. Suri & N. Singh (1995). Conservation in India: A New Direction. *Economic and Political Weekly* 30(43): 2755–2766.

Kronfeld-Schor, N. & T. Dayan (2003). Partitioning of Time as an Ecological Resource. *Annual Review of Ecology, Evolution, and Systematics* 34(6) 153-181. https://doi.org/10.2307/30033773

Lahkar, D., M.F. Ahmed, R.H. Begum, S.K. Das & A. Harihar (2020). Responses of a wild ungulate assemblage to anthropogenic influences in Manas National Park, India. *Biological Conservation* 243: 108425. https://doi.org/10.1016/j.biocon.2020.108425

Madhusudan, M.D. & K.U. Karanth (2002). Local Hunting and the Conservation of Large Mammals in India. *Ambio* 31(1): 49–54. https://doi.org/10.2307/4315210

Madhusudan, M. & C. Mishra (2003). Why big, fierce animals are threatened: conserving large mammals in densely populated landscapes, pp. 31–55. In: Saberwal, V.K. & M. Rangajaran (eds.). *Battles Over Nature: Science and The Politics of Wildlife Conservation*. Permanent Black, 430 pp.

Madhusudan, M. (2004). Recovery of wild large herbivores following livestock decline in a tropical Indian wildlife reserve. *Journal of Applied Ecology* 41(5): 858–869.

Mathur, V.B., A.K. Nayak & N.A. Ansari (2018). Fourth Cycle of

Management Effectiveness Evaluation (MEE) of Tiger reserves in India. National Tiger Conservation Authority and Wildlife Institute of India, Ministry of Environment, Forest and Climate Change, Government of India, 134 pp.

Meyer, S.M.B., S.R.Jnawali, J.B. Karki, P. Khanal, S. Lohani, B. Long, D.I. MacKenzie, B. Pandav, N.M.B. Pradhan, R. Shrestha, N. Subedi, G. Thapa, K. Thapa & E. Wikramanayake (2012). Influence of prey depletion and human disturbance on tiger occupancy in Nepal: Nepal tiger occupancy. *Journal of Zoology* 289(1): 10–18. https://doi.org/10.1111/j.1469-7998.2012.00956.x

Murty, M.K. (1981). Hunter-gatherer ecosystems and archaeological patterns of subsistence behaviour on the south-east coast of India: An ethnographic model. *World Archaeology* 13(1): 47–58. https://doi.org/10.2307/124212

Ministry of Tribal Affairs (2015). Revised Scheme of "Development of Particularly Vulnerable Tribal Groups (PVTGs) http://tribal.gov.in/writereaddata/Schemes/4-5-NGO. Electronic version accessed on 16 January 2023.

National Tiger Conservation Authority (NTCA) (2021). Enhancement of funding assistance for voluntary village relocation.https://ntca.gov.in/assets/uploads/guidelines/Village_Relocation_Order.pdf Electronic version accessed 16 January 2023.

O'Brien, T.G., Kinnaird, M.F., & Wibisono, H.T. (2003). Crouching tigers, hidden prey: Sumatran tiger and prey populations in a tropical forest landscape. *Animal Conservation* 6(2): 131–139. https://doi.org/10.1017/S1367943003003172

Ohashi, H., M. Saito, R. Horie, H. Tsunoda, H. Noba & Y. Hoshino (2013). Differences in the activity pattern of the wild boar Sus scrofa related to human disturbance. *European Journal of Wildlife Research* 59(2): 167–177. https://doi.org/10.1007/s10344-012-0661-z

Oriana Version 4- User's Manual. (2011). Kovach Computing Services, Pentraeth, Wales, U.K., 175 pp. Available online at https://www.kovcomp.co.uk/oriana

Pandey, R., C. Saravanan, D. Mydeen & K. Valli (2013). Tiger Conservation Plan- Nagarjunsagar Srisailam Tiger reserve (for the period 2013-2014 to 2022-2023 Andhra Pradesh Forest Department, 68–79 pp.

Prakash, V., D. Pain, A. Cunningham, P. Donald, N. Prakash & A. Verma (2003). Catastrophic collapse of Indian white-backed Gyps bengalensis and long-billed Gyps indicus vulture populations. *Biological Conservation* (109): 381–390. https://doi.org/ 10.1016/S0006-3207(02)00164-7

Putman, R. (1989). *The Natural History of Deer*, Cornell University Press, 680–681 pp.

R Development Core Team (2018). A language and environment for statistical computing, version 3.5.0. R Foundation for Statistical Computing, Vienna, Austria. Available online at https://www.R-project.org

Rabinowitz, A. (1995). Helping a species go extinct: The Sumatran rhino in Borneo. *Conservation Biology* 9(3): 482–488.

Raju, P.S., C. Sudhakar & C.H. Umamohan (2009). Chenchus and Social Transformation: A Study of a Primitive Tribe in Kurnool District of Andhra Pradesh. *The Anthropologist* 11(3): 167–172. https://doi.org/10.1080/09720073.2009.11891098

Rangarajan, M. & G. Shahabuddin (2006). Displacement and Relocation from protected Areas: Towards a Biological and Historical Synthesis. *Conservation and Society* 4(3): 359–378.

Ridout, M.S. & M. Linkie (2009). Estimating overlap of daily activity patterns from camera trap data. *Journal of Agricultural, Biological, and Environmental Statistics* 14(3): 322–337. https://doi.org/10.1198/jabes.2009.08038

Ritchie, E.G., C.R. Dickman, M. Letnic, & A.T. Vanak (2013). Dogs as predators and trophic regulators pp. 55–68. In: Gompper, M.E. (ed.). *Free-Ranging Dogs and Wildlife Conservation*. Oxford University Press, 336 pp. https://doi.org/10.1093/acprof:oso bl/9780199663217.003.0002

Ross, J., A.J. Hearn, P.J. Johnson, & D.W. Macdonald (2013). Activity patterns and temporal avoidance by prey in response to Sunda clouded leopard predation risk: Activity of Sunda clouded leopards and their prey. *Journal of Zoology* 290(2): 96–106. https://doi.org/10.1111/jzo.12018

Rovero, F., & A.R. Marshall (2009). Camera trapping photographic rate as an index of density in forest ungulates. *Journal of Applied Ecology* 46(5): 1011–1017.

Rowcliffe, J.M. (2022). Animal Activity Statistics. https://Cran.r-Project.Org/Web/Packages/Activity/Activity.Pdf (1.3.2): 24.

Rowcliffe, J.M., & C. Carbone (2008). Surveys using camera traps: are we looking to a brighter future? *Animal Conservation* 11(3): 185–186.

Sankar, K. (1994). The Ecology of three Large Sympatric Herbivores (Chital, Sambar, Nilgai) with Special Reference for Reserve Management in Sariska Tiger Reserve, Rajasthan. PhD Thesis. University of Rajasthan, Rajasthan, 120–128 pp.

Schaller, G.B. (1967). *The deer and the tiger: a study of wildlife in India*. University of Chicago Press, Chicago, 411–413 pp.

Shankar, A. (2016). Socio political pattern of banjaras-a study of Warangal district of Telangana State. *Indian Journal of Society & Politics* 3(3): 10–16.

Shea, S., L. Flynn, R. Marchinton & J. Lewiss (1990). Part II. Social behaviour, movement ecology and food habits. In Ecology of Sambar Deer on St Vincent National Wildlife Refuge, Florida. *Tall Timbers Research Station* 7(25): 13–62.

Srinivasulu, C. (2001). Chital (Axis axis Erxleben, 1777) herd composition and sex ratio on the Nallamala Hills of Eastern Ghats, Andhra Pradesh, India. *Zoos' Print Journal* 16(12): 655–658. https://doi.org/10.11609/JoTT.ZPJ.16.12.655-8

Srivathsa, A., D. Vasudev, T. Nair, S. Chakrabarti, P. Chanchani, R. DeFries, A. Deomurari, S. Dutta, D. Ghose, V.R. Goswami, R. Nayak, A. Neelakantan, P. Thatte, S. Vaidyanathan, M. Verma, J. Krishnaswamy, M. Sankaran & U. Ramakrishnan (2023). Prioritizing India's landscapes for biodiversity, ecosystem services and human well-being. *Nature Sustainability* 6: 568–577. https://doi.org/10.1038/s41893-023-01063-2

Subramanyachary, P. (2013). Status of schedule tribes in Andhra Pradesh. *The Dawn Journal* 2(1): 336–343.

Sudeesh, S., & C.R. Sudhakar (2012). Vegetation and Land Cover Mapping of Nagarjunasagar-Srisailam Tiger Reserve, Andhra Pradesh, India using Remote Sensing and GIS. *People International Journal of Geomatics and Geosciences* 2(4): 953–963.

Suryakumari, D., K.B. Rao & C.Vasu (2008). Connecting Lives-Establishing Linkages with Other Players Towards Sustainable Livelihoods in Community Forestry Initiatives. *Centre for People's Forestry*. 7–9 pp.

Ungar, E.D., Z. Henkin, M. Gutman, A. Dolev, A. Genizi & D. Ganskopp (2005). Inference of animal activity from GPS collar data on free-ranging cattle. *Rangeland Ecology & Management* 58(3): 256–266.

Vaditya, V. (2019). Cultural Changes and Marginalisation of Lambada Community in Telangana, India. *Tribal Intellectual Collective India* 31 (2): 13-19

Wegge, P., C.P. Pokheral & S.R. Jnawali (2004). Effects of trapping effort and trap shyness on estimates of tiger abundance from camera trap studies. (7) 251–256. Presented at the Animal Conservation Forum, Cambridge University Press.

Zar, J.H. (2022). *Bio-statistical analysis 5th edition.* Pearson, Norther Illinois University, 255 pp.

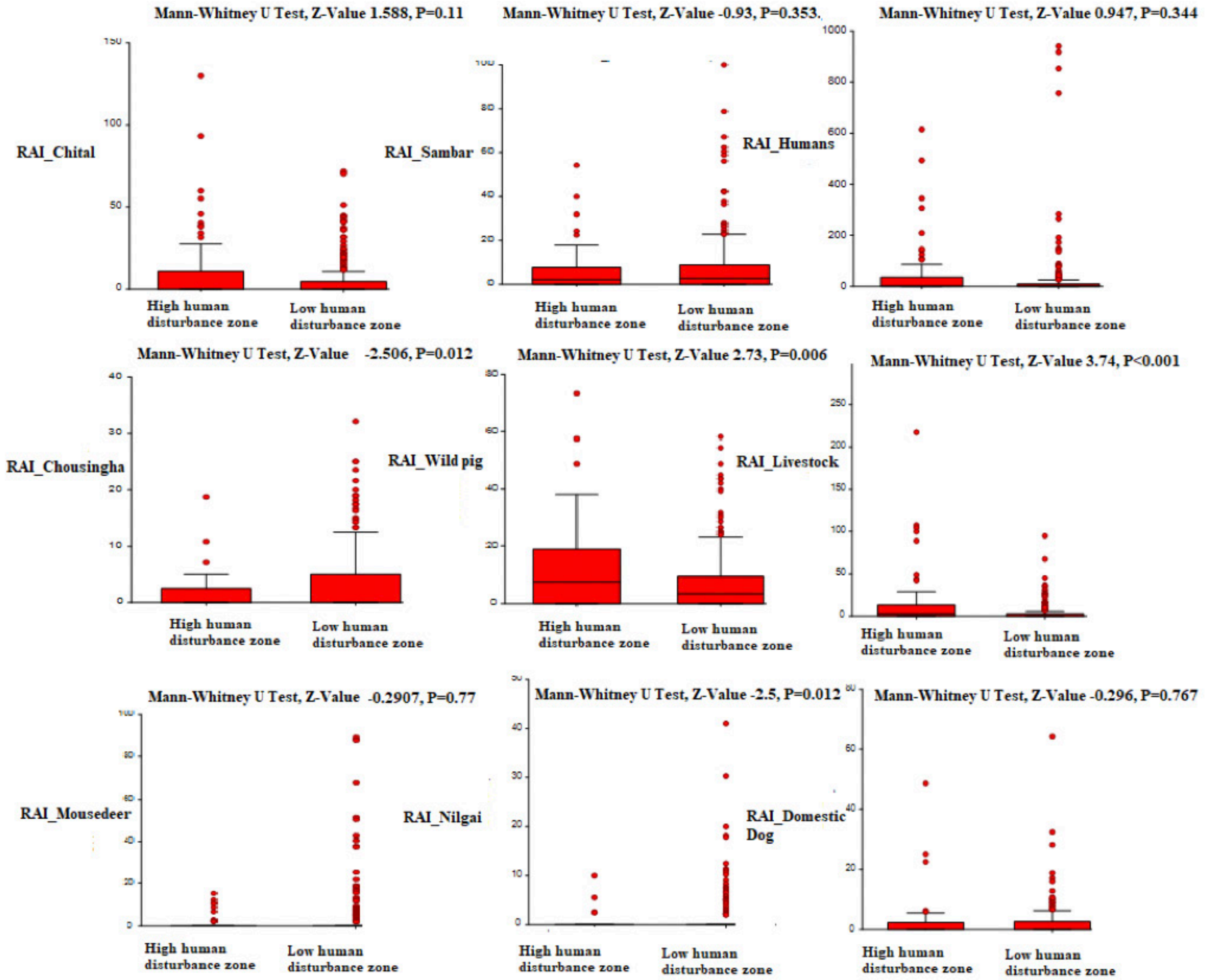


Figure S1. Box plots of relative abundance index (RAI) for wild ungulates as well as humans, domestic dogs, and livestock in proximity to settlements (high human activity zone) and further from settlements (low human activity zone). Mann-Whitney U-Test were done to compare the two RAI's as data were not normally distributed.

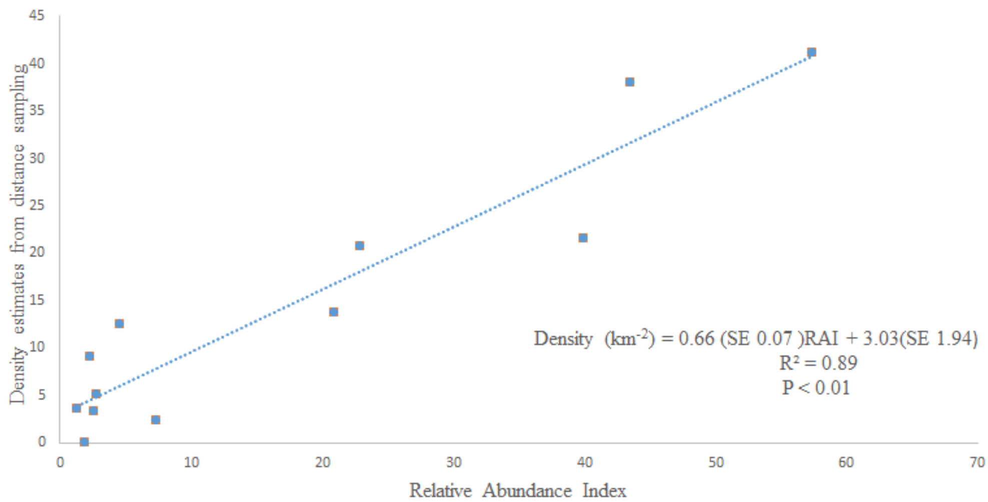
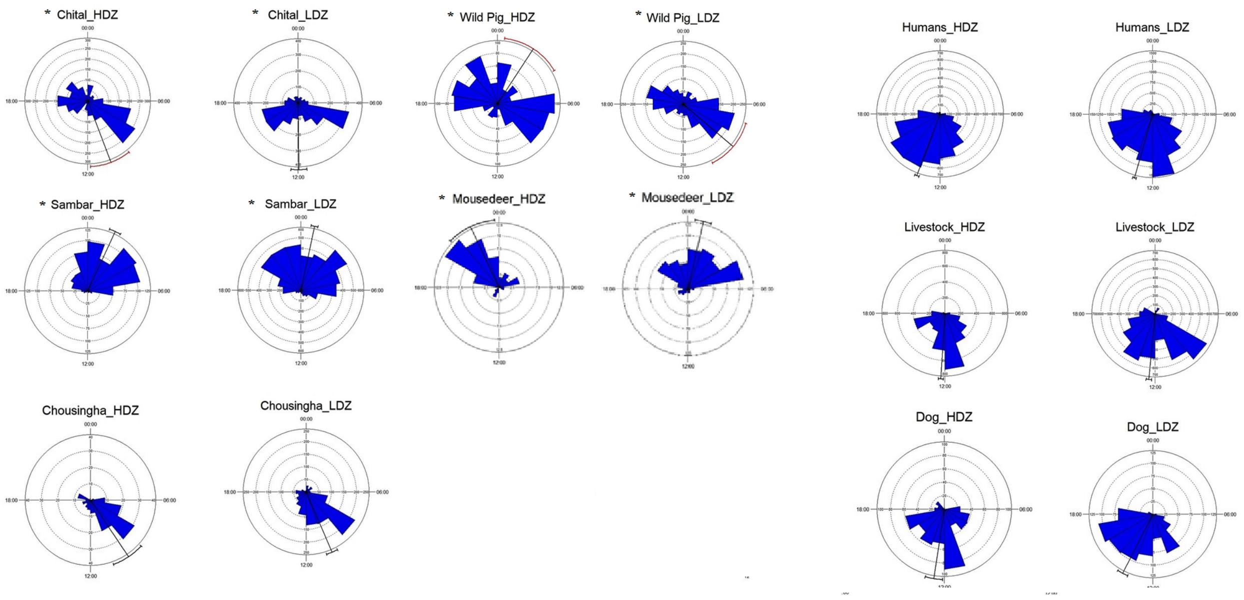


Figure S2. Scatter plot and correlation between distance sampling based density estimates for Chital with relative abundance index (RAI) from camera trap data.



*95% CI not overlapping between high and low human impact zones for peak activities are significantly different.

Figure S3. Temporal activity pattern of wild ungulates, in Nagarjunasagar Srisailam Tiger Reserve. Circular rose plot for 24 hours. Activity relative frequency of records of each hour. Red-line running from the center to the outer edge represents the mean angle of the data. The arc extending to either side represents the 95% confidence limit of the mean showing a more significant clustering of data around that hour.

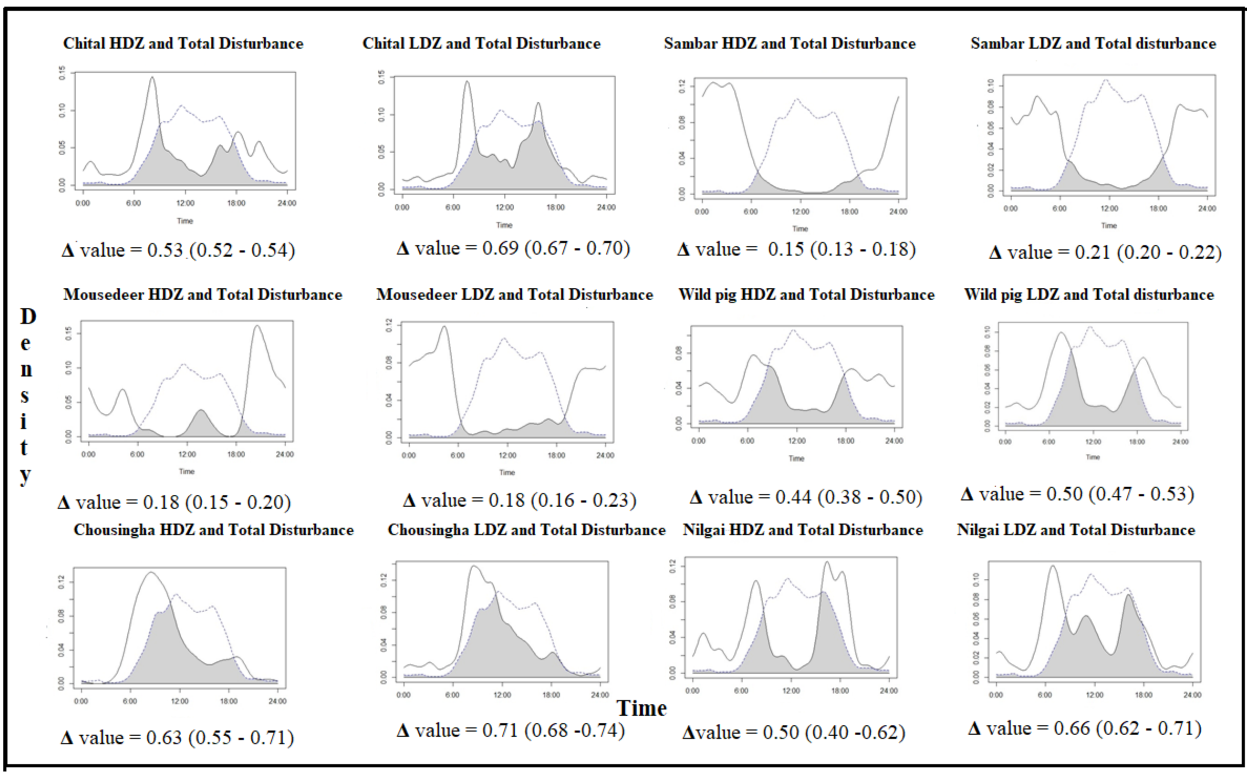


Figure S4. Temporal overlap depicted as kernel density functions of wild ungulate (bold line) activity with combined anthropogenic disturbances (photo-captures of humans, livestock and dogs as dotted line) in areas of high human impacts (HDZ, in proximity to settlements) and low human impacts (LDZ, away from settlements). Overlap was defined as the area under the curve formed by taking the minimum of the two activity patterns at each point in time (denoted in grey) (Δ – Coefficient of overlap, confidence interval in brackets) in Nagarjunsagar Srisailam Tiger Reserve.

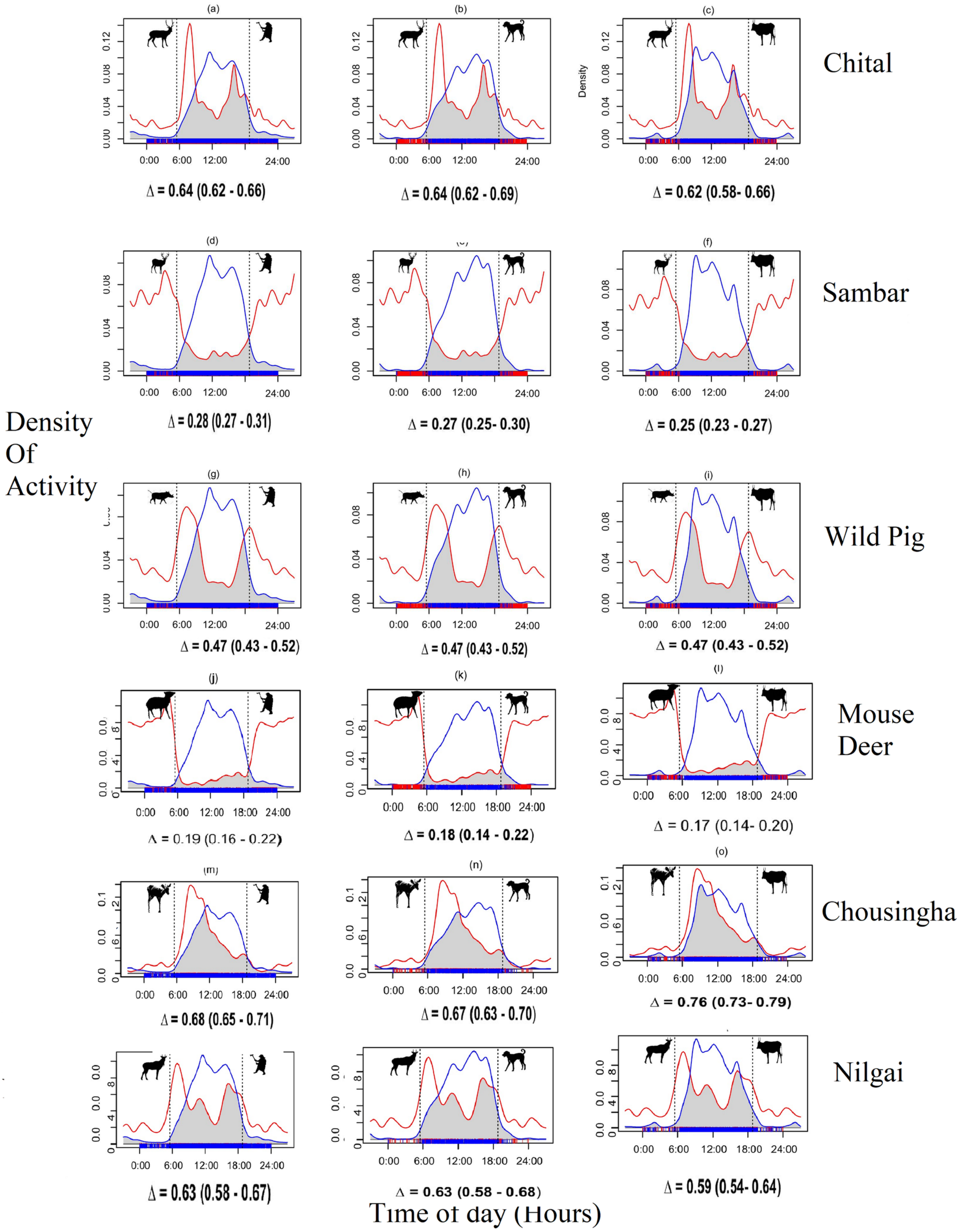


Figure S5. Overall temporal overlap of wild ungulate activity with different anthropogenic disturbance factors. Activity patterns of various anthropogenic disturbances shown as blue lines and of wild ungulates (red lines) depicted as kernel density functions. Overlap was defined as the area under the curve formed by taking the minimum of the two activity patterns at each point in time (denoted in grey) (Δ – Coefficient of overlap; confidence interval in brackets).

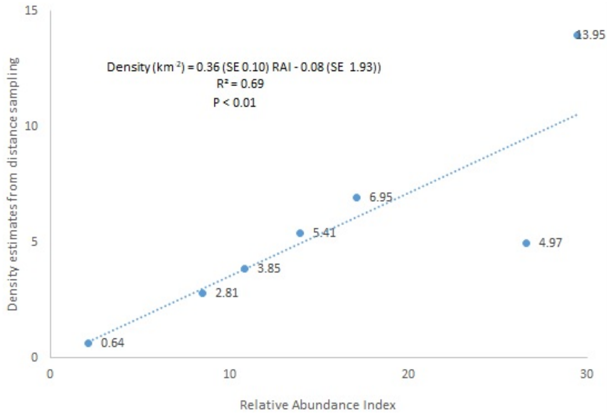


Figure S6. Scatter plot and correlation between distance sampling based density estimates for Sambar with relative abundance index (RAI) from camera trap data.

Image S1. Camera trap image of hunting by local communities in this landscape.

Table S1. Distance sampling based density estimates for Chital and relative abundance index (RAI) Jhala et al. (2020) obtained from camera trap data for habitats similar to Nagarjunasagar Srisailam Tiger Reserve.

Site	Density #/ km² (SE)	RAI
Nagarjunsagar Srisailam Tiger Reserve		8.0
Panna Tiger Reserve	13.78 (2.77)	20.89
Achanakmar Tiger Reserve	12.62 (1.78)	4.54
Nawegaon Nagzira Tiger Reserve	5.16 (1.16)	2.74
Pench Tiger Reserve (Maharashtra)	20.87 (4.36)	22.84
Ranthambore Tiger Reserve	21.66 (3.34)	39.90
Bandhavgarh Tiger Reserve	41.36 (4.09)	57.30
Kanha Tiger Reserve	38.14 (5.04)	43.46

Table S2. Distance sampling based density estimates for Sambar and relative abundance index (RAI) (Jhala et al. 2020) obtained from camera trap data for habitats similar to Nagarjunasagar Srisailam Tiger Reserve.

Site	Density #/ km² (SE)	RAI
Nagarjunsagar Srisailam Tiger Reserve		8.6
Panna Tiger Rserve	4.97	26.58
Achanakmar Tiger Reserve	0.64	2.15
Nawegaon Nagzira Tiger Reserve	2.81	8.51
Pench Tiger Reserve (Maharashtra)	5.41	13.98
Ranthambore Tiger Reserve	13.95	29.43
Bandhavgarh Tiger Reserve	3.85	10.89
Kanha Tiger Reserve	6.95	17.14

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