BRINGING BACK THE CHEETAH TO INDIA

ANNUAL PROGRESS REPORT

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project cheetah

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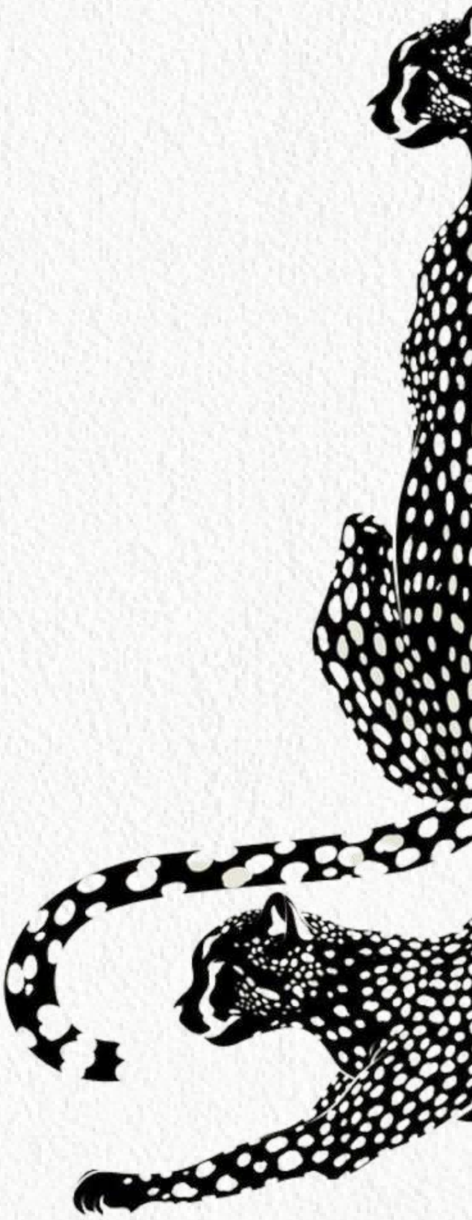

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project cheetah

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Restoring Nation's Natural Heritage
Reviving Open Natural Ecosystems

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Executive Summary
- Prayas Auddy & Bipin C.M.

1. Preamble
- Diksha Prasad & Bipin C.M.

2. Cheetah monitoring and management

Section 2.1. Introduction
- Moulik Sarkar & Gunasekaran Machakkalai

Section 2.2. Predation by cheetahs in Kuno National Park
- Moulik Sarkar, Navneeth M, Ashish Joseph, & Bipin C.M.

Section 2.3. Home range and movement of free-ranging cheetahs in Kuno National Park
- Moulik Sarkar, Abhishek Shukla, Gunasekaran Machakkalai, Manvi & Bipin C.M.

Section 2.4. Habitat selection by free-ranging cheetahs in Kuno Wildlife Division
- Moulik Sarkar, Abhishek Shukla, Manvi, Gunasekaran Machakkalai & Bipin C.M.

Section 2.5. Comparative analysis of dietary preferences of cheetahs and co-predators in and around Kuno National Park using a metabarcoding approach
- Himanshu Matta, Vishnupriya Kolipakam & Bipin C.M.

Section 2.6. Longitudinal monitoring of stress, nutrition and reproductive health and assessment of the physiological impacts on cheetahs in Kuno National Park
- Sourabh Ruhela, Samrat Mondal & Bipin C.M.

Section 2.7. Monitoring of cheetahs in Gandhi Sagar Wildlife Sanctuary
- Moulik Sarkar, Navneeth M, Utkrisht Raj Singh Champawat, Dhammpal Goswami, Surjya Barhoi, Ashish Joseph & Bipin C.M.

Section 2.8. Veterinary monitoring in Gandhi Sagar Wildlife Sanctuary
- Sumit Kumar Patel, Ganga Datt Kandpal, Bommu Meenakshi Reddy, Sanath K. Muliya & Bipin C.M.

Section 2.9. Sourcing of cheetahs from range countries in Southern Africa
- Sanath K. Muliya, Bipin C.M., Vaibhav C. Mathur & Sanjayan Kumar

Section 2.10. Preparations of potential sites for cheetah release as part of metapopulation management
- Bipin C.M., Sanath K. Muliya & Vaibhav C. Mathur

3. Co-predator monitoring

Section 3.1. Status of co-predators in Kuno National Park
- Prayas Auddy, Nibedita Basu, Khushbu Kaushik,, Somya Sindoor, Yashi Gaur, Prateeksha Nath & Bipin C.M.

Section 3.2. Density estimation of small carnivores using camera trap-based distance sampling (CTDS) in Kuno National Park
- Riya Adak, Sagarika das, Moulik Sarkar & Bipin C.M.

Section 3.3. Relative abundance and spatial distribution of co-predators in Kuno National Park
- Khushbu Kaushik, Prayas Auddy, Moulik Sarkar, Manvi & Bipin C.M.

Section 3.4. Space use of striped hyena in Kuno National Park
- Moulik Sarkar, Manvi, Ankita Chandra & Bipin C.M.

Section 3.5. Space use of golden jackal in Kuno National Park
- Parul Sen, Moulik Sarkar, Manvi & Bipin C.M.

Section 3.6. Space use of jungle cat in Kuno National Park
- Kathan Bandopadhyay & Bipin C.M.

Section 3.7. Co-predator monitoring in Gandhi Sagar Wildlife Sanctuary
- Sultan, Moulik Sarkar, Manvi & Bipin C.M.

4. Prey Monitoring

Section 4.1. Prey assessment in Kuno National Park
- Moulik Sarkar, Abhishek Shukla & Bipin C.M.

Section 4.2. Relative Abundance Index and spatial distribution of prey in Kuno National Park
- Khushbu Kaushik, Prateeksha Nath, Manvi, Moulik Sarkar & Bipin C.M.

Section 4.3. Space use of chital in Kuno National Park
- Moulik Sarkar, Abhishek Shukla, Nibedita Basu, Manvi & Bipin C.M.

Section 4.4. Sex-specific seasonal comparison in activity patterns of chital (*Axis axis*) in Kuno National Park
- Shrestha Singh, Prayas Auddy, Moulik Sarkar & Bipin C.M.

Section 4.5. Prey assessment in Gandhi Sagar Wildlife Sanctuary
- Abhishek Shukla, Moulik Sarkar & Bipin C.M.

Section 4.6. Prey assessment using camera trap-based distance sampling in Gandhi Sagar Wildlife Sanctuary
- Parul Sen, Sagarika Das & Bipin C.M.

5. Habitat monitoring

Section 5.1. Vegetation structure and composition in Kuno National Park
- Himanshu Sahu, Akash Rana, Sneha Kumari, Manvi & Bipin C.M.

Section 5.2. Distribution of invasive species in Kuno National Park
- Akash Rana, Himanshu Sahu, Gunasekaran Machakkalai, Manvi & Bipin C.M.

Section 5.3. Vegetation dynamics in incentivized voluntarily relocated villages of Kuno National Park: A pilot survey
- Himanshu Sahu, Akash Rana, Manvi & Bipin C.M.

Section 5.4 Vehicle movement in Gandhi Sagar Wildlife Sanctuary
- Gunasekaran Machakkalai, Akash Rana, Prayas Auddy, Moulik Sarkar & Bipin C.M.

Section 5.5. Seroprevalence studies for understanding major carnivore diseases
- Ritika Sharma, Lallianpuii Kawlni & Sanath K. Muliya

Section 5.6. Management activities undertaken in Kuno and Gandhi Sagar Wildlife Sanctuary
- Uttam Sharma, R. Thirukural, Sanjay Raikhere, Amit Rathore & Bipin C.M.,

6. Human dimensions

Section 6.1. Human dimensions of cheetah introduction in India
- Rishi Raj Singh Jodha, Moulik Sarkar, Manvi & Bipin C.M.

Section 6.2. Community engagement in and around Kuno National Park
- Uttam Sharma & Bipin C.M.

Section 6.3. Outreach and awareness activities in and around Gandhi Sagar Wildlife Sanctuary
- Amit Rathore, Sanjay Raikhere & Bipin C.M.

Section 6.4. Kuno-Gandhi Sagar cheetah metapopulation management landscape
- Manvi, Ashish Joseph & Bipin C.M.

Section 6.5. Preparation of integrated landscape management plan for establishing viable cheetah metapopulation in India
- Prayas Auddy, Ashish Joseph & Bipin C.M.

7. Way ahead
- Bipin C.M., Vishnupriya Kolipakam & Bilal Habib

Proof reading
- Bipin C.M., Prayas Auddy & Moulik Sarkar

EXECUTIVE SUMMARY

The establishment of the cheetah (*Acinonyx jubatus*) population in India represents one of the most ambitious conservation translocation initiatives undertaken globally in recent decades. Conceived as a flagship effort to restore open natural ecosystems, Project Cheetah seeks not only to re-establish a viable cheetah population within its historical range but also to catalyze the ecological revival of India's grassland and savanna landscapes. These ecosystems, historically undervalued and often misclassified as "wastelands," harbour unique biodiversity and provide critical ecosystem services. The present reporting period (2024-2025) marks a significant phase in the transition from acclimatization to adaptive, science-based metapopulation management across Kuno National Park (NP) and Gandhi Sagar Wildlife Sanctuary (WLS), Madhya Pradesh.

India currently has a total of 53 cheetahs, comprising 13 adults, 17 sub-adults and 23 cubs. In February 2026, nine cheetahs were translocated from Botswana. During the reporting period, multiple individuals were sequentially released into free-ranging conditions at Kuno NP, while select animals were translocated to Gandhi Sagar WLS as part of the planned multi-site metapopulation framework for long term viability. This shift reflects a strategic progression from initial stabilization to landscape-scale integration, consistent with IUCN guidelines on conservation translocations and the Action Plan for Cheetah Introduction in India.

In and around Kuno NP, chital (*Axis axis*) deer emerged as the principal prey species, accounting for the majority of detected kills within both soft-release enclosures and free-ranging environments. Adult chitals were more frequently preyed upon than young individuals, and females constituted a slightly higher proportion of kills across most social units. Kill rates varied among individuals and social configurations. Within soft-release enclosures, kill intervals ranged between 3.7 and 18 days per kill, while in free-ranging conditions, intervals ranged from 2.48 to 7.32 days per kill. Free-ranging mothers with cubs, such as Jwala and Gamini, demonstrated higher hunting frequencies, reflecting elevated energetic demands. Notably, certain free-ranging groups exhibited predation on domestic livestock, particularly goats and cattle, though immediately ex-gratia payments were disbursed, underscores the importance of proactive negative interaction mitigation and community engagement measures.

Patterns of prey selection were influenced by social structure. Solitary females tended to target younger chital, whereas coalitions and mothers with cubs predominantly preyed on adult individuals. Male coalition cheetahs such as Agni and Vayu displayed dietary flexibility, preying upon both wild ungulates and domestic livestock. Supplementary feeding protocols were applied judiciously, particularly during early acclimatization phases or prolonged fasting (>5 days), and for pregnant females with elevated nutritional requirements. Such interventions were carefully regulated to avoid behavioural dependency while ensuring animal welfare.

During the reporting period, cheetahs were released into free-ranging conditions. Spatial analyses using Minimum Convex Polygon (MCP) and Kernel Density Estimation (KDE) methods revealed substantial exploratory movements during the initial 30 days post-release, followed by gradual stabilization of home ranges. Total distances covered ranged from approximately 560 km (Asha) to nearly 894 km (Jwala with cubs). Average daily movement varied between 3.2 km and 6.05 km, with male coalitions generally exhibiting greater displacement than solitary females. Early expansive ranging, such as >3000 km^2 in the first month for certain individuals, likely reflects exploratory dispersal prior to the establishment of localized activity centres. One adult female cheetah Asha has been ranging in an area of <50km^2 for an extended period now. These movement patterns demonstrate both high mobility and adaptability within heterogeneous landscapes. Occasional long-distance excursions required veterinary-assisted recapture from the vicinity of human habitations and repositioning, highlighting the necessity of responsive field teams and landscape-level preparedness.

Resource Selection Function (RSF) analyses were conducted to evaluate habitat preferences of free-ranging cheetahs relative to environmental covariates. Preliminary findings indicate positive selection for open grassland and savanna mosaics interspersed with moderate woodland cover, aligning with cheetah hunting ecology as pursuit-adapted predators. Areas with adequate prey densities and lower anthropogenic disturbance were preferentially used.

Longitudinal health assessments constitute a critical component of adaptive management. Hormonal profiling, nutritional monitoring, and disease surveillance, including seroprevalence studies for major carnivore pathogens were conducted to evaluate physiological stress and reproductive status. Veterinary interventions were implemented when necessary, including treatment of injuries sustained during hunting attempts and routine health evaluations during collaring or translocation events.

The introduction of a predator into a multi-carnivore system necessitates comprehensive monitoring of co-predators. Camera trap-based surveys and distance sampling approaches (including Camera Trap Distance Sampling) were deployed to estimate density and spatial distribution of striped hyena, golden jackal, jungle cat, and other small carnivores. Preliminary findings suggest spatial overlap with temporal partitioning, indicative of behavioural adjustments rather than direct displacement.

Prey assessments in Kuno NP and Gandhi Sagar WLS demonstrate relatively robust ungulate populations, with chital exhibiting stable relative abundance and predictable activity patterns. Sex-specific seasonal activity analyses of chital provide critical insights into vulnerability windows and predator–prey synchrony. Continued prey augmentation and habitat enhancement remain central to sustaining reproductive female cheetahs and growing cub cohorts. Vegetation monitoring in Kuno NP revealed ongoing changes in structure and composition, including the presence and spatial distribution of invasive plant species. Restoration measures are being aligned with cheetah habitat requirements while simultaneously benefiting sympatric species dependent on open ecosystems.

As part of the consolidating Kuno-Gandhi Sagar metapopulation landscape, selected individuals were translocated to Gandhi Sagar WLS. Preparatory measures included habitat assessment, prey evaluation, disease risk analysis, staff training, and infrastructure development. Monitoring protocols parallel those implemented in and around Kuno NP, ensuring methodological consistency and comparability. Management interventions in Gandhi Sagar WLS include vehicle movement regulation, habitat improvement, and enhanced surveillance to minimize anthropogenic pressures. The establishment of multiple sites reduces demographic and environmental stochasticity risks, strengthening long-term population viability.

Recognizing that long-term success depends on socio-ecological integration, the project emphasizes community engagement and participatory conservation. Outreach activities, awareness campaigns, and livelihood-linked initiatives are being implemented in both Kuno and Gandhi Sagar landscapes. Pilot surveys of incentivized voluntarily relocated villages provide insights into socio-economic transitions and perceptions of wildlife restoration. Livestock depredation events are addressed through compensation frameworks and rapid response teams, fostering coexistence and reducing retaliatory risks. The cheetah's flagship status continues to enhance ecotourism potential and generate broader support for grassland conservation.

This reporting period reflects a transition from introduction to consolidation. Reproductive success evidenced by multiple litters combined with progressive free-ranging releases and inter-site translocations indicates encouraging demographic momentum. The integration of ecological monitoring, veterinary science, spatial analytics, prey management, and community engagement exemplifies a holistic conservation model. The Kuno-Gandhi Sagar landscape is being operationalized as a dynamic cheetah metapopulation, with future plans to incorporate additional suitable sites. Continued international collaboration with African cheetah range countries such as Namibia, South Africa, Botswana *etc*., reinforcement from source countries for genetic health and fitness, and adaptive management grounded in robust scientific evidence is essential to achieving self-sustaining populations.

Project Cheetah thus represents more than species revival. It is a landscape restoration initiative with cascading ecological, climatic, and socio-economic benefits. By restoring a top predator to India's open natural ecosystems, the programme aspires to re-establish ecological functionality, enhance biodiversity resilience, and demonstrate a globally relevant model for large carnivore recovery in human-dominated landscapes.

1. Preamble

Large carnivores are important indicators of a functioning ecosystem and its health (Marker, 2000). They play crucial roles by potentially limiting ungulate populations through predation, thereby reducing grazing pressure in habitats essential for both terrestrial and avian fauna, as well as controlling meso-carnivore populations through intraguild competition (Marker, 2019). The trophic, or engineering, effects of large carnivores as top predators in an ecosystem are so large that they are considered keystone species, whose impacts are not only functionally irreplaceable but also excessively great in relation to their abundance (Lacher *et al.* 2019).

Felines, especially charismatic big cats, have long held a central place in global conservation strategies as a flagship species, both in terms of attracting the public's attention and serving as a focus for research and large-scale conservation efforts. The cheetah (*Acinonyx jubatus*) is a top predator in many different types of landscapes in its range (Ranjitsinh *et al.* 2010). It is similar to apex predators like the tiger (*Panthera tigris*), lion (*Panthera leo*), leopard (*Panthera pardus*), jaguar (*Panthera onca),* and snow leopard (*Panthera uncia*) in that it can adapt to different habitats and diets.

In the recent past, populations of cheetahs and other large mammalian carnivores have faced numerous challenges around the world owing to detrimental human activities that have fundamentally changed the dynamics of ecosystems (Ripple *et al.* 2014). The loss of habitat, agricultural development, and growing infrastructures have decreased the amount of territory available to these wide-ranging species, confining them to small areas that are unable to support viable populations (Woodroffe & Ginsberg, 1998). Infrastructure development exposes animals to obstacles in their movement, thereby distorting dispersal routes required to maintain genetic diversity (Benítez-López *et al.* 2010). Domestic livestock overgrazing has led to the degradation of grassland ecosystems, decreasing the availability of prey in the ecosystem and changing the vegetation structure (Namgail *et al.* 2007). Diversion of water resources has increased the competition for resources, and pollution has further directly and indirectly depleted large carnivore populations (Inskip and Zimmermann, 2009).

Originally described in the work of J.C.D. von Schreber in 1775, the cheetah is one of the most remarkable models of nature in terms of evolutionary specialization in speed and hunting efficiency (Marker, 2019). Cheetahs have been a part of human society as early as 3000 BCE, with depictions of hooded cheetahs on a leash as a royal symbol during the Sumerian period and in the form of the ancient Egyptian feline-faced female deity Mafdet (Marker *et al.* 2018; IBCA). These animals were kept as pets by historical figures such as Genghis Khan, Charlemagne, and Akbar the Great of India (IBCA). In the 1900s, approximately 100,000 cheetahs were found in at least 44 countries throughout Africa and Asia (Bothma & Walker, 2013). Despite their ecological and economic importance, cheetahs face numerous threats that have led to dramatic population declines worldwide (Marker, 2019). The degradation of their natural habitats through anthropogenic activities, poaching, trafficking, and hunting have placed these magnificent carnivores under unprecedented stress across their distributional range in Africa and Asia (Marker *et al.* 2018).

The cheetah is a lightweight big cat with a slender body built for speed. Its small head features distinctive black "tear marks" running from eyes to mouth, presumably for reducing the glare of the sun during hunting. Large nostrils, lungs, and heart support efficient oxygen intake and circulation during high-speed chases. These spotted cats have tawny fur with solid black spots and measure 112-142 cm in body length, plus a 66-84 cm tail. They weigh 21-72 kg and stand 67-94 cm tall at the shoulder. Cheetahs are the world's fastest land animals, attaining speeds of 90-112 kmph and accelerating from 0 to 72 kmph in under 2.5 seconds (Marker, 2002). Their exceptional bursts of speed come from adaptations including a light frame, long thin legs, and an extended tail for balance during sprints, as it exemplifies the critical connections and uniqueness of evolutionary history and genetic diversity and thus warrants coordinated and impactful global conservation efforts (Schmidt-Küntzel *et al.* 2018).

Translocation and reintroduction programs have become an important mechanism in the toolkit of conservation interventions around the world to recover species and revitalize ecosystems (Seddon *et al.* 2007). Restoration ecology is increasingly prioritized in conservation efforts to mitigate extinction and restore conditions resembling those from one to two centuries ago, prior to significant human-induced environmental degradation (Palmer *et al.* 2016). Reintroduction and conservation translocation are vital strategies for restoring ecosystem services and safeguarding endangered species to reverse population declines (NTCA, 2023). The reintroduction of wolves (*Canis lupus*) into Yellowstone National Park in the United States of America during 1995 proved the ability of apex predators to re-establish ecological functions perturbed due to trophic cascades (Ripple & Beschta, 2012). The introduction of African wild dogs (*Lycaon pictus*) in southern Africa has formed new populations in Botswana and Zimbabwe and is a remarkable success (Gusset *et al.* 2008). Iberian lynx (*Lynx pardinus*) reintroductions in Spain and Portugal have had positive outcomes (IUCN, 2024), whereas Eurasian lynx (*Lynx lynx*) reintroductions in Switzerland, Austria, and France show mixed results (Breitenmoser, 2001). Nonetheless, translocations of large carnivores are characterized by challenges such as the assessment of habitats, mitigation of negative interactions with humans, and conservation of genetic diversity (IUCN, 2013). The high population density of India is a special challenge, but effective tiger translocations to Sariska and Panna Tiger Reserves offer plenty of insights (Jhala *et al.* 2019).

Cheetahs, which once roamed India's open natural ecosystems of grasslands and open dry forests, went extinct in India during the early 1950s. India's grassland and scrub-thorn forest ecosystems have been declining as they are generally considered a wasteland from colonial times, as nearly all the productive grasslands have been converted into croplands. Historically, the principal prey of the cheetah in these habitats, the blackbuck (*Antilope cervicapra*), is also living a very precarious life due to antagonism of the agrarian communities (Vanak *et al.* 2016). Populations of species such as the critically endangered great Indian bustard (GIB) (*Ardeotis nigriceps*), lesser florican (*Sypheotides indicus*), caracal (*Caracal caracal)* and the Indian wolf (*Canis lupus pallipes*) have declined drastically due to the systemic neglect and degradation of these habitats in India. Establishing a population of cheetahs necessitates the revival of their prey, which includes restoration as well as protection of their habitats, and consequently, secure areas for grassland and open forest ecosystem-dwelling threatened species. Successful conservation approaches will require recognizing grasslands and savannas as valuable ecosystems while finding ways and devising policies for wildlife and farming communities to co-occur (Rawat & Adhikari, 2015).

With major and far-reaching conservation implications, the primary objective of bringing the cheetah back to India is to restore its functional role in representative ecosystems within its historical range. The Government of India aims to revive the nation's natural heritage and restore open natural ecosystems by establishing viable breeding populations of cheetahs, while simultaneously restoring grassland and savanna ecosystems to enhance biodiversity values and ecosystem services. This restoration effort will help sequester carbon to mitigate climate change, improve the balance between predators and prey in various areas, encourage community involvement through ecotourism and local participation, enhance livelihoods, strengthen global cheetah conservation, and provide important scientific information for future species relocation programs (Qureshi *et al.* 2024).

As a first step towards establishing cheetah populations in India, 20 cheetahs from Namibia and South Africa were translocated to Kuno National Park (Kuno NP) in Madhya Pradesh by the Government of India during 2022-23, with the first batch released into quarantine by the Hon. Prime Minister of India. Subsequently, nine cheetahs were translocated from Botswana to Kuno NP in Feb 2026 to augment the founder population. The cheetahs in India will be managed as a metapopulation in three to five sites to begin with, as recommended by the action plan for the introduction of cheetahs in India (Jhala *et al.* 2021) based on the IUCN guidelines on reintroductions and conservation translocations 2013. Currently, the total number of cheetahs in India is 53, comprising 13 adults, 17 subadults, and 23 cubs. As part of metapopulation management, three cheetahs have been translocated to Gandhi Sagar Wildlife Sanctuary, Madhya Pradesh, from Kuno, during April-September 2025, and more will be shifted in phases. In both the cheetah release sites, activities such as continuous monitoring and management of cheetahs, research and monitoring of co-predators and prey as well as habitat, management of release sites and the surrounding landscape, capacity building, community outreach, and awareness programs are being carried out. Additionally, discussions for sourcing cheetahs from range countries in Africa to reinforce the population in India and preparation of new release sites as part of metapopulation management are underway.

BRINGING BACK THE CHEETAH TO INDIA

01 Purpose

Restoring Nation's Natural Heritage Reviving Open Natural Ecosystems

02 Goal

Establish viable cheetah metapopulation in India, performing functional role & Expansion in historical species distribution range

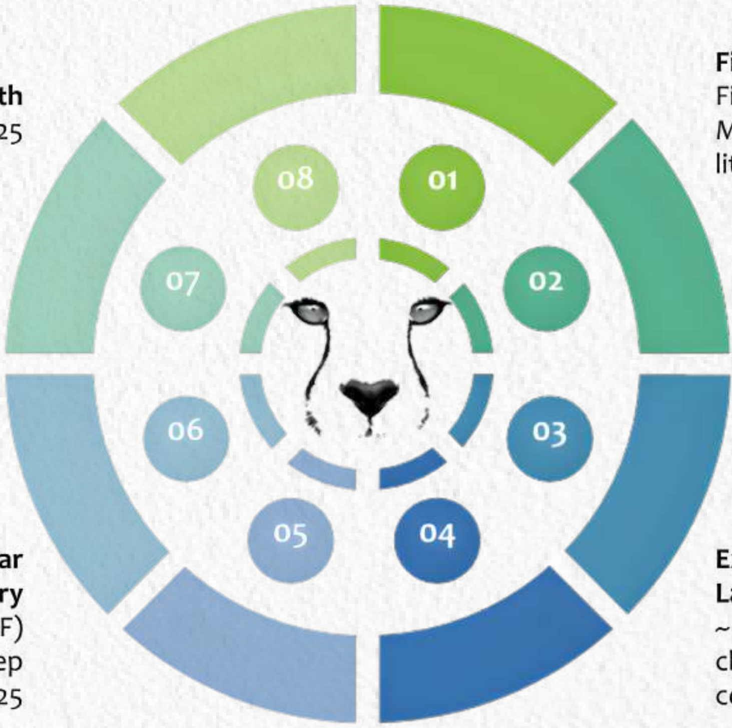
03 Execution

20 cheetahs translocated from Namibia & South Africa during 2022-23

04 Achievements

Kuno National Park & Gandhi Sagar Wildlife Sanctuary cheetah (meta) populations in India

Current Cheetah Population
53 cheetahs -
13 adults (7 Females & 6 Males);
17 subadults (9 F & 8 M)
23 cubs (4 F, 5 M & 14 U)



First Indian Born Cheetah
First Indian born cub (F) Mukhi- 3 years old littered 05 cubs

Delineation of Cheetah Landscape
Kuno-Gandhi Sagar cheetah metapopulation landscape (Rajasthan & Madhya Pradesh)

Extent of Cheetah Landscape
~ 17000 km² Interstate cheetah conservation complex

Recovery of Other Species
First photographic report of caracal from Gandhi Sagar WLS & Dhole from Kuno NP subsequent to habitat consolidation & restoration

Cheetah in Gandhi Sagar Wildlife Sanctuary
3 cheetahs (2 M & 1 F) translocated during Apr-Sep 2025

Cheetah in Kuno National Park
50 Cheetahs-
11 free-ranging cheetahs

2025 Growth
Additional 10 cubs in 2025

ECOSYSTEM MONITORING IN KUNO NATIONAL PARK AND GANDHI SAGAR WILDLIFE SANCTUARY

Cheetah

- Continuous monitoring (Radio-collared)
- Predation
- Well- being (Belly Score)
- Veterinary
- Behaviour
- Space use
- Habitat selection
- Scat and bio sample collection
- Genetics
- Hormones

Prey

- Abundance
- Space use
- Habitat selection
- Behaviour
- Chital & Nilgai (Radio-collared)

Co-predators

- Abundance
- Space use
- Habitat selection
- Scat & bio sample collection
- Carcass utilization
- Leopard capture
- Leopard, Hyena, Jungle cat & Jackal (Radio-collared)

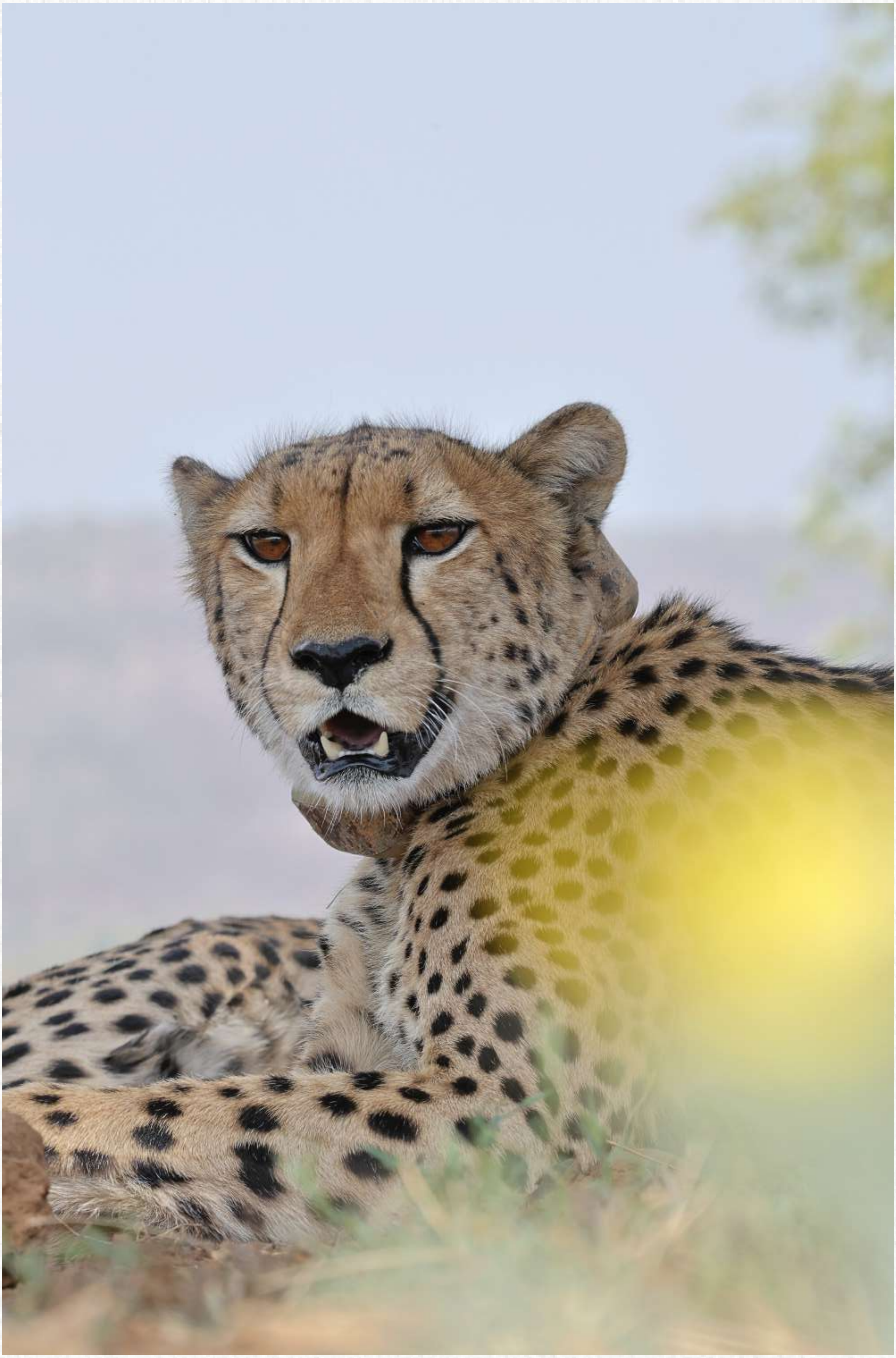
Habitat

- Vegetation
- Soil nutrients
- Anthropogenic activities & vehicular movement
- Disease surveillance
- Tick abundance
- PA LULC classification
- Landscape mapping

Human Dimension

Pilot questionnaire

- Socio-economic, perception & attitudes
- Vehicular traffic
- Oureach, Awareness & Capacity building



2.
Cheetah Monitoring and Management

2.1. Introduction

2.1.1. Cheetah Predatory Adaptations, Hunting Strategy, and Prey Selection

The cheetah (*Acinonyx jubatus*), recognized as the world's fastest terrestrial predator, is an apex carnivore whose survival strategy depends upon a unique set of anatomical, physiological, and behavioral adaptations that collectively optimize hunting efficiency (Caro, 1994; Wilson *et al.* 2013). The species' semi-retractile claw shape, which is uncommon among felids and provides improved grip and traction across a variety of terrains during high-speed chases, lies at the core of these adaptations (Hayward & Slotow, 2009). Located on the first forepaw digit, the robust and sharply curved dewclaw plays a crucial role in capturing prey. During fast chases, it hooks into the prey's flank or hind limb, destabilizing the animal and enabling successful interception (Hudson *et al.* 2012). The cheetah's lightweight and slender skeletal structure reduces overall body mass to enhance acceleration potential, while elongated hind limbs increase stride length, allowing the species to traverse 7 to 8 meters per step and attain accelerations of up to 3 m/s^2 (Wilson *et al.* 2013; Scantlebury *et al.* 2014). The elongated, muscular tail serves as both a counterweight and a rudder, enabling swift directional changes during high-velocity chases (Wilson *et al.* 2013). Larger nasal passages, a bigger heart, and a large pulmonary capacity all contribute to these locomotor adaptations by increasing oxygen intake and circulatory efficiency during strenuous sprints (Caro, 1994; Weibel *et al.* 2004).

The cheetah's ecological niche of sprint-hunting, which has probably placed significant selection pressures on the evolution of cursorial herbivores in African habitats, is defined by its collective morpho-physiological specializations (Hayward & Kerley, 2005). Cheetahs use a two-phase hunting approach. Using vegetation cover and geographical features to stay hidden, individuals approach prey quietly to within 60 to 100 meters during the first stalking phase (Caro, 1994; Mills & Mills, 2014). Since protracted pursuits raise the risk of hyperthermia and abrupt energy depletion, this is followed by a quick, high-speed chase that usually lasts less than 20 seconds and seldom exceeds 300 meters (Wilson *et al.* 2013; Scantlebury *et al.* 2014). Cheetahs use quick, rapid acceleration bursts to overtake prey, ending the hunt with a strangle neck bite, in contrast to ambush predators like tigers (*Panthera tigris*) and leopards (*Panthera pardus*) (Caro, 1994; Hayward *et al.* 2006b). Because carcasses are usually taken by dominant competitors like lions (*Panthera leo*), spotted hyenas (*Crocuta crocuta*), or leopards (*Panthera pardus*) in African environments, cheetahs usually consume prey quickly after successful predation, generally within 30 minutes (Durant, 1998; Marker & Dickman, 2004).

Certain landscapes have kleptoparasitism rates of above 50%, which has a significant impact on cheetah feeding ecology and encourages spatial avoidance of regions with high concentrations of dominant carnivores (Durant, 1998; Broekhuis *et al.* 2018). In order to balance catchability and energetic return, prey selection is typically limited to species weighing 20–80 kg (Hayward *et al.* 2006b; Purchase & du Toit, 2000). Cheetahs primarily hunt springboks (*Antidorcas marsupialis*), young wildebeests (*Connochaetes taurinus*), impalas (*Aepyceros melampus*), and gazelles (*Gazella spp.*) in the savannas of Africa (Hayward *et al.* 2006b). Similar-sized chital (*Axis axis*), sambar (*Rusa unicolor*), chowsingha (*Tetracerus quadricornis*), chinkara (*Gazella bennettii*), blackbuck (*Antilope cervicapra*), juvenile nilgai (*Boselaphus tragocamelus*) and Indian hare (*Lepus nigricollis*) predation by the cheetahs has been reported in India's Kuno National Park (Qureshi *et al.* 2024). Of these, chital seems to be the most prevalent and important prey species in Kuno, whereas chinkara and nilgai calves make up the main prey base in Gandhisagar WLS. For cheetah predation, prey species weighing less than 60 kg are typically

thought to be ideal (Purchase & du Toit, 2000; Hayward *et al.* 2006b). In addition to their hunting ecology, cheetahs face inherent conservation issues brought on by a legacy of historical population bottlenecks and very low genetic diversity (O'Brien *et al.* 1983; Dobrynin *et al.* 2015). This genetic homogeneity increases vulnerability to pathogens, stress-induced illnesses, and male reproductive fitness, which is characterized by low-quality sperm (Menotti-Raymond & O'Brien, 1995; Marker *et al.* 2008). Long-term population viability and veterinary management procedures are made more difficult by these biological limitations, habitat fragmentation, human-wildlife conflict, especially with livestock farmers, and persistent kleptoparasitism (Durant *et al.* 2017; Prost *et al.* 2022).

2.1.2. Kuno National Park:

Kuno National Park (NP), situated in Sheopur district, Madhya Pradesh, encompasses 748.76 km², with the adjoining forest area falling within the Kuno Wildlife Division, which collectively covers 1,235 km² (recently increased to 1,777 km²). The NP forms part of the larger Sheopur-Shivpuri dry deciduous open forests spanning approximately 6,800 km². Kuno River, a major tributary of the Chambal, traverses the entire longitudinal extent and effectively bisecting the NP (Soni *et al.* 2021). The PA supports 33 mammalian species, 206 avian species, 14 fish species, 33 reptilian species, and 10 amphibian species.

The surrounding area under the administration of the forest department encompasses about 11,500 km² (67% of the area is savannah) distributed across Madhya Pradesh (Area~8,833 km²) and Rajasthan (Area~2,733 km²) where contiguous forest area is approximately 6,800 km², of which over 3,200 km² constitutes high-potential cheetah habitat (Qureshi *et al.* 2024). The area is administratively distributed across the districts of Sheopur, Shivpuri, Morena, Gwalior, Guna, and Ashoknagar in Madhya Pradesh, Baran, Sawai Madhopur, and Karauli in Rajasthan. The region is classified within the semi-arid Gujarat Rajputana biogeographic zone (Zone 4B) (Rodgers *et al.* 2002), characterized by a tropical dry deciduous climate. The altitude ranges from 238 to 498 meters above sea level. Temperatures vary from a high of 47 °C in summer to a low of 3°C in winter, and the area receives an average annual rainfall of about 760 mm (Sharma *et al.* 2013).

VEGETATION

Following the revised forest type classification system (Champion & Seth, 1968), the vegetation of Kuno NP and surrounding areas is categorized as Northern Tropical Dry Deciduous Forest. Dominant canopy species include *Anogeissus pendula*, *Boswellia serrata*, *Senegalia catechu*, *Vachellia leucophloea*, *Diospyros melanoxylon*, and *Ziziphus spp*. The shrub layer is characterized by *Grewia flavescens*, *Helicteres isora*, and *Vitex negundo*, while the herbaceous layer is dominated by grasses including *Apluda mutica*, *Aristida hystrix*, *Cenchrus ciliaris*, *Dichanthium annulatum*, *Desmostachya bipinnata*, *Heteropogon contortus*, and *Themeda quadrivalvis* (Champion & Seth, 1968; Rodgers *et al.* 2002).

FAUNA

The region supports considerable faunal diversity. Herbivore assemblages include chital , sambar, nilgai, wild pig (*Sus scrofa*), chinkara, chowsingha, and blackbuck. Smaller mammalian species include the Indian porcupine (*Hystrix indica*) and Indian hare, while the primate community comprises the northern plains gray langur (*Semnopithecus entellus*) and rhesus macaque (*Macaca mulatta*) (Jhala *et al.* 2008).

The carnivore guild consists of leopard, striped hyena (*Hyaena hyaena*), Indian wolf (*Canis lupus pallipes*), sloth bear (*Melursus ursinus*), golden jackal (*Canis aureus*), ratel (*Mellivora capensis*), jungle cat (*Felis chaus*), Asiatic wildcat (*Felis lybica ornata*), rusty-spotted cat (*Prionailurus rubiginosus*), and the Indian fox (*Vulpes bengalensis*). Smaller carnivores include the Asian palm civet (*Paradoxurus hermaphroditus*), small Indian civet (*Viverricula indica*), Indian grey mongoose (*Herpestes edwardsii*), and ruddy mongoose (*Herpestes smithii*). Tigers occasionally disperse into the area, primarily from Ranthambore Tiger Reserve in Rajasthan which is situated at a distance of 20 km from Kuno NP across River Chambal (Kuno Management Plan, 2020).

The landscape supports diverse human communities, including the Sahariya tribe (a Gond sub-caste) and the Gujjar, Yadav, Dhakad, Jatav, Bhil, and Moghiya groups, whose livelihoods are primarily dependent on crop agriculture, pastoralism, casual labour, and non-timber forest product (NTFP) collection. Notably, Kuno NP is free from permanent human habitation following incentivized voluntary village relocations initiated in the late 1990s. By the early 2000s, 24 villages had been resettled outside the park boundaries as part of the Asiatic lion reintroduction, with the most recent relocation completed in 2023.

The Kuno landscape faces a variety of prevailing anthropogenic disturbances. These include activities such as livestock grazing, human presence on forest trails, and the harvesting of resources like bamboo and grass, alongside the felling and lopping of trees. Linear infrastructure, including road and railway networks, constitutes an additional source of habitat fragmentation. Invasive alien plant species documented within the landscape include *Lantana camara*, *Prosopis juliflora*, *Parthenium hysterophorus*, *Senna tora*, *Ageratum conyzoides*, *Mesophaerum suaveolens*, and *Xanthium strumarium* (Qureshi *et al.* 2024).

2.2. Predation by cheetahs in Kuno National Park

Continuous monitoring of the cheetahs, as found during the previous two years, showed that the main prey species hunted by cheetahs in and around Kuno NP was chital. In the free-ranging environment, chital accounted for 42% of detected kills, followed by goat (30%), cattle (20%), Nilgai (2%), hare, sambar, chinkara, sheep, and wild pig contributes (1% each). Inside the Closed Natural Area (CNA), the majority of chital killed were adults. Predation on female chital was more than the proportion of male kills. Most social units (female and male coalitions) predated more on adult and female chital.

The detected kill rate for cheetahs inside the large fenced soft-release area ranged from 3.7 to 18.00 days per kill. The observed kill rate for free-ranging cheetahs ranged from 2.48 to 7.32 days per kill. Detection of kills on many occasions is confounded by various factors such as the size of the prey, rate of consumption by the cheetah social unit as well as scavengers, *etc*., and hence sometimes observed after many days in certain cases and for some animals (*e.g*., male coalitions or mothers and older cubs can deplete a carcass very quickly). Depending on the size of the last meal, cheetahs typically need to feed every three to four days. If a free-ranging cheetah is observed to go without eating for five or more days during the initial six months after release, supplementary feeding may be provided to ensure starvation is not induced by a lack of familiarity with the new locale and prey distribution. This intervention helps ensure nutritional needs are met while they adapt. In Kuno's large closed natural area (0.5-1.5 km^2), adequate natural prey is present, allowing cheetahs to hunt and familiarize themselves with local species like chital. Pregnant females, who have substantially increased nutritional requirements, require maintenance of an adequate prey base or supplementation of dressed meat if they face prolonged fasting bouts (> 5 days), depending on the body condition (belly scores).

Table: 2.2.1.

Monthly detected number of cheetahs kills in Kuno National Park

Sl. No	Animal	Total		Sl. No	Animal	Total
1	AGNI, VAAYU	36		11	ASHA'S CUBS	55
2	ASHA	29		12	MUKHI	5
3	ASHA WITH CUBS	20		13	NABHA	8
4	DHEERA	14		14	NIRVA	17
5	GAMINI WITH CUBS	95		15	NIRVA WITH CUBS	8
6	GAURAV	49		16	PRABHAS, PAVAK	22
7	GAURAV, NIRVA	7		17	VEERA	22
8	JWALA WITH CUBS	111		18	VEERA WITH CUBS	22

** The kills of Agni & Vayu were combined in the above table: Coalition kills- 9, Agni alone- 12 & Vayu- 15. Similarly, Prabhas Pavak Coalition kills- 21, Prabhas alone- 1. Similarly, Jwala, and cubs KJP1 (Female), KJP2 (Female)- 1; Jwala and cubs KJP1, KJP2, KJP3 (Male)- 41; Jwala and cubs KJP1, KJP2, KJP3, KJP4 (Male)- 68; KJP1 and KJP4- 1; Total- 111.*

Table 2.2.2.

Prey species killed by cheetah in Kuno National Park

Ani-mal(s)	**Sex**	**Soft release Enclosure**				**Free-Ranging**									
		Chital	*Sambar*	*Nilgai*	*Hare*	*Chital*	*Sambar*	*Nilgai*	*Chowsingha*	*Chinkara*	*Hare*	*Cattle*	*Goat*	*Sheep*	*Wild pig*
Veera	Female	Yes													
Veera	Female with cubs	Yes													
Asha	Female	Yes			Yes	Yes				Yes					
Asha	Female with cubs	Yes													
Gamini	Female with cubs	Yes				Yes		Yes	Yes		Yes	Yes	Yes	Yes	
Nabha	Female	Yes													
Jwala	Female with cubs	Yes		Yes		Yes	Yes		Yes		Yes	Yes	Yes		
Dheera	Female	Yes						Yes							
Nirva	Female	Yes			Yes										
Nirva	Female with cubs	Yes													
Agni & Vayu	Male	Yes				Yes		Yes				Yes	Yes	Yes	Yes
Prabhas & Pavak	Male	Yes		Yes											
Gaurav	Male	Yes													
Gaurav & Nirva	Mating pair	Yes													
Mukhi	Female	Yes													
Asha's Cubs	Male	Yes				Yes					Yes	Yes	Yes		Yes

Table 2.2.3.

Detected kill rate of cheetahs in Kuno National Park

Animal(s)	Sex/Social Unit	Kill rate (Days per Kills)	
		Inside soft-release enclosure	Free-ranging
Veera	Female	6.40	NA
Veera with Cubs	Female with cubs	6.5	NA
Asha	Female	NA	6.03
Asha with Cubs	Female with cubs	7.3	NA
Gamini with cubs	Female	4.06	2.91
Nabha	Female	NA#	NA
Jwala with cubs	Female with cubs	3.70	2.48
Dheera	Female	**NA**	**NA**
Nirva	Female	12.88	NA
Nirva with cubs	Female with cubs	10.00	NA
Agni & Vayu	Male	18.00	7.32
Prabhas & Pavak	Male	11.5	NA
Gaurav	Male	6.79	NA
Gaurav & Nirva	Mating pair	10.14	NA
Mukhi	Female	NA#	NA
Asha's Cubs	Male	2.5	3.43

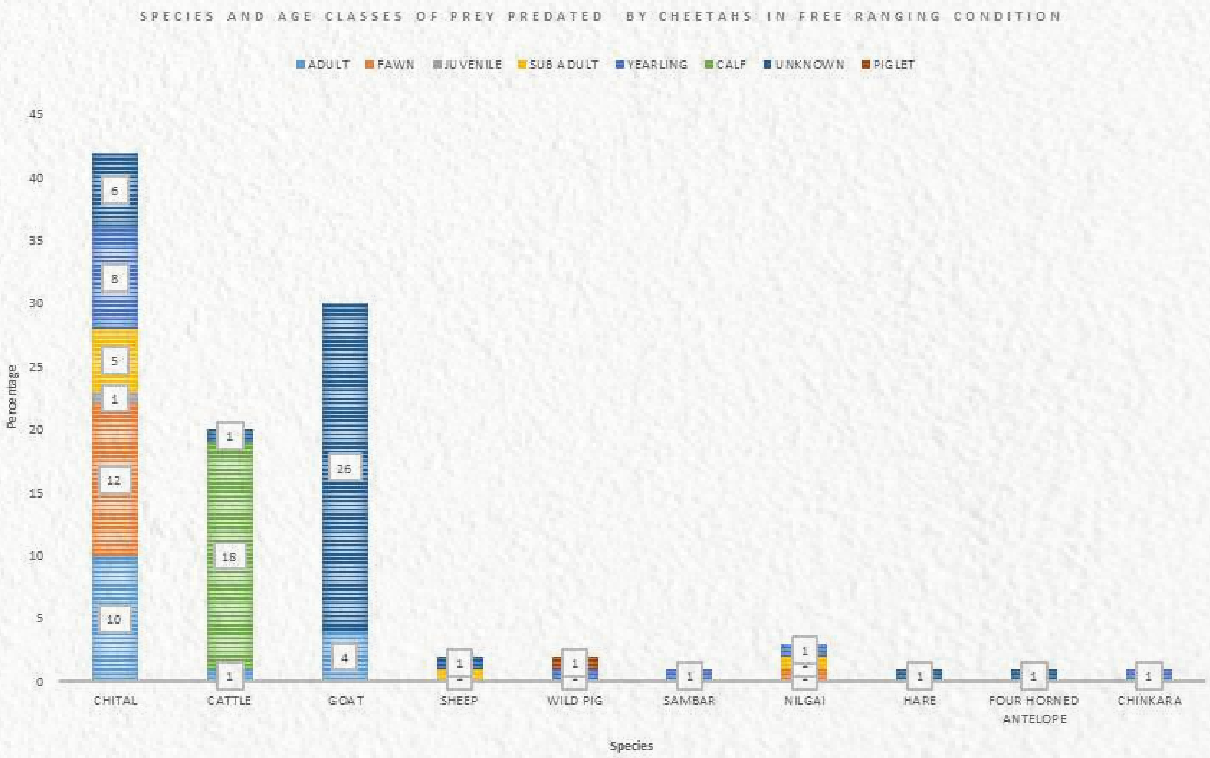


Figure 2.2.1.

Species and age classes of prey predated by the cheetahs in free-ranging condition

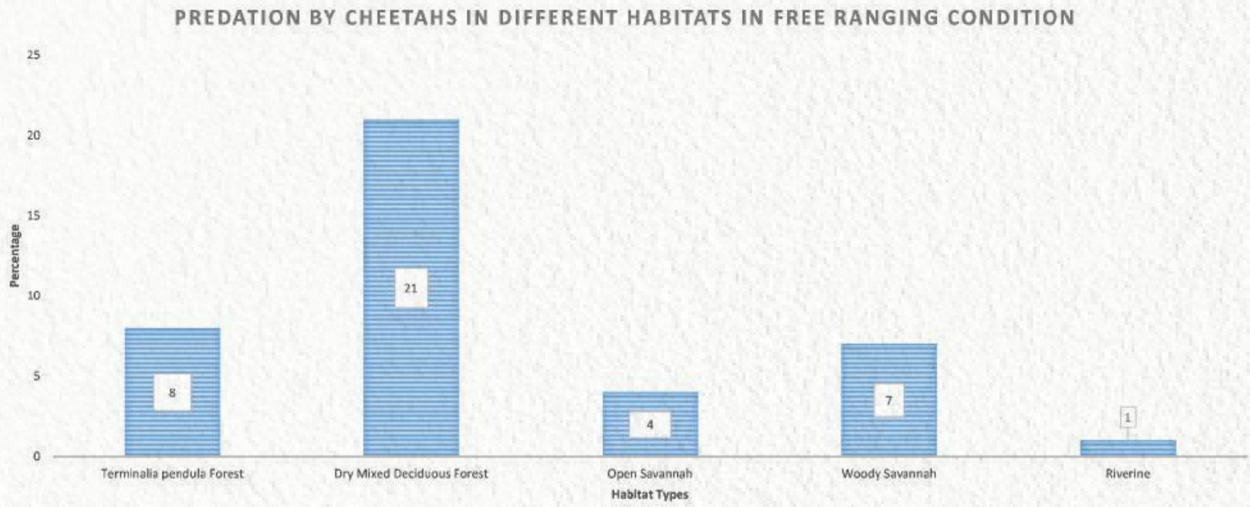


Figure 2.2.2.

Predation by cheetahs in different habitats in free-ranging condition

Figure 2.2.3.

Species and age classes of prey predated by the cheetahs in large Closed Natural Area at Kuno National Park

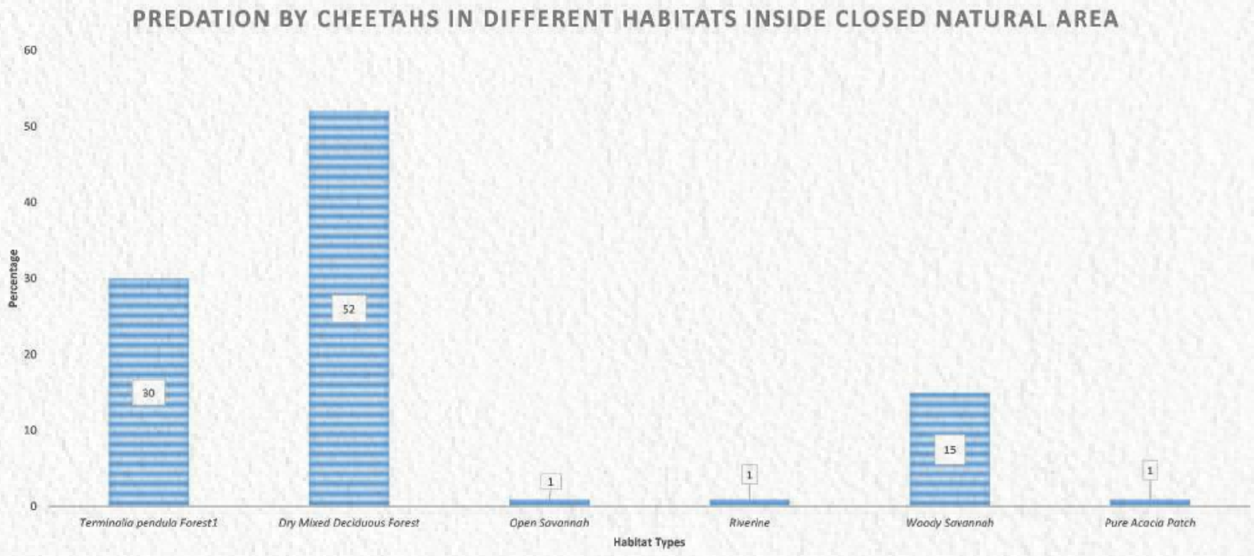


Figure 2.2.4.
Predation by cheetahs in different habitats in large Closed Natural Area at Kuno National Park

2.2.1. Pattern of chital predation by cheetahs

A total of 386 kills of chitals were detected, and 293 of them occurred within the large closed natural area in Kuno NP. Patterns of predation showed nearly half of the chitals that got predated were females, followed by males and individuals of unknown sex. In terms of age category, the majority of chitals predated by the cheetahs were adults. Female chitals were the most targeted species by all social units, including single males, single females, mothers with cubs, coalition males, and mating pairs. All the social groups except solitary female cheetahs predated more on adult chital, while solitary females primarily predated on young chital.

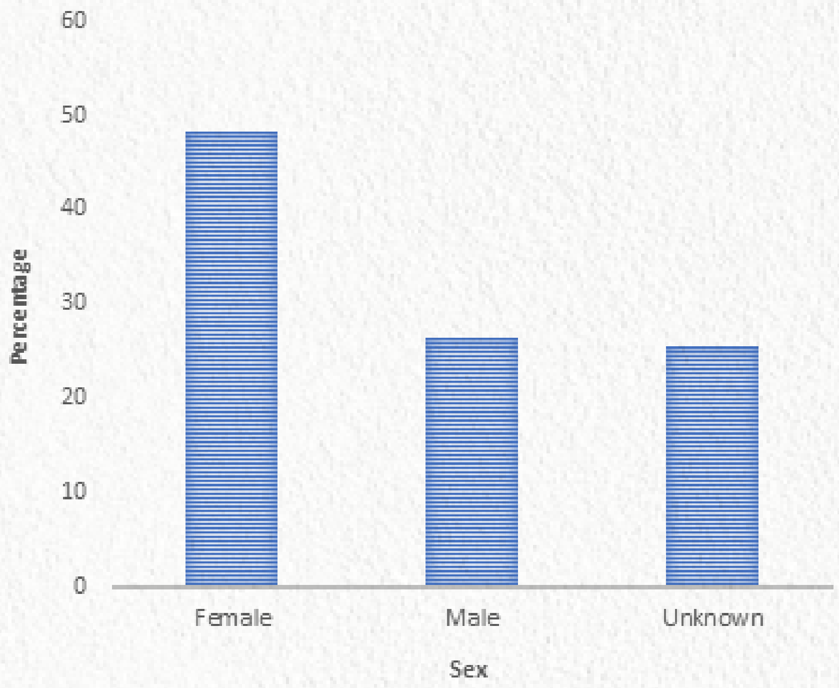


Figure 2.2.5.

Sex of chital predated by free-ranging cheetahs in and around Kuno National Park

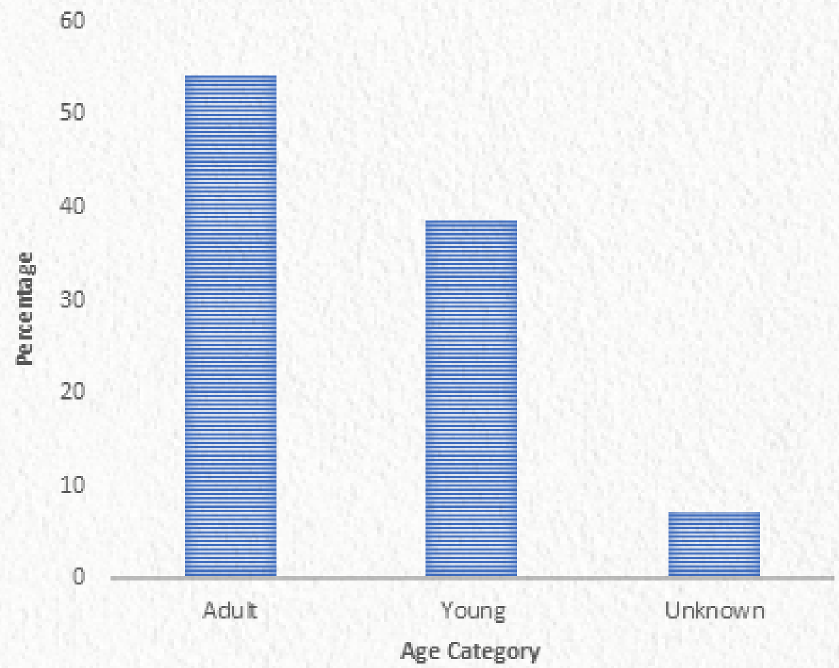


Figure 2.2.6.

Age category of chital predated by free-ranging cheetahs in and around Kuno National Park

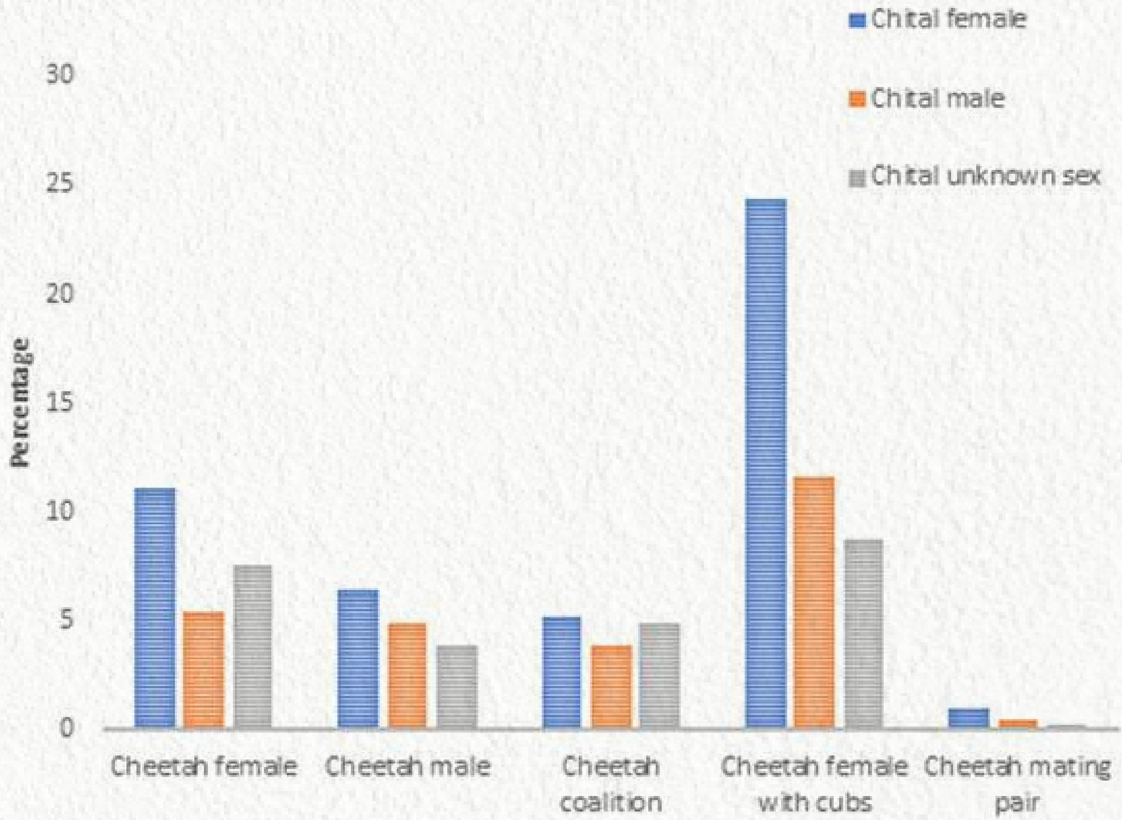


Figure 2.2.7.

Sex of chital predated by free-ranging cheetah social units in and around Kuno National Park

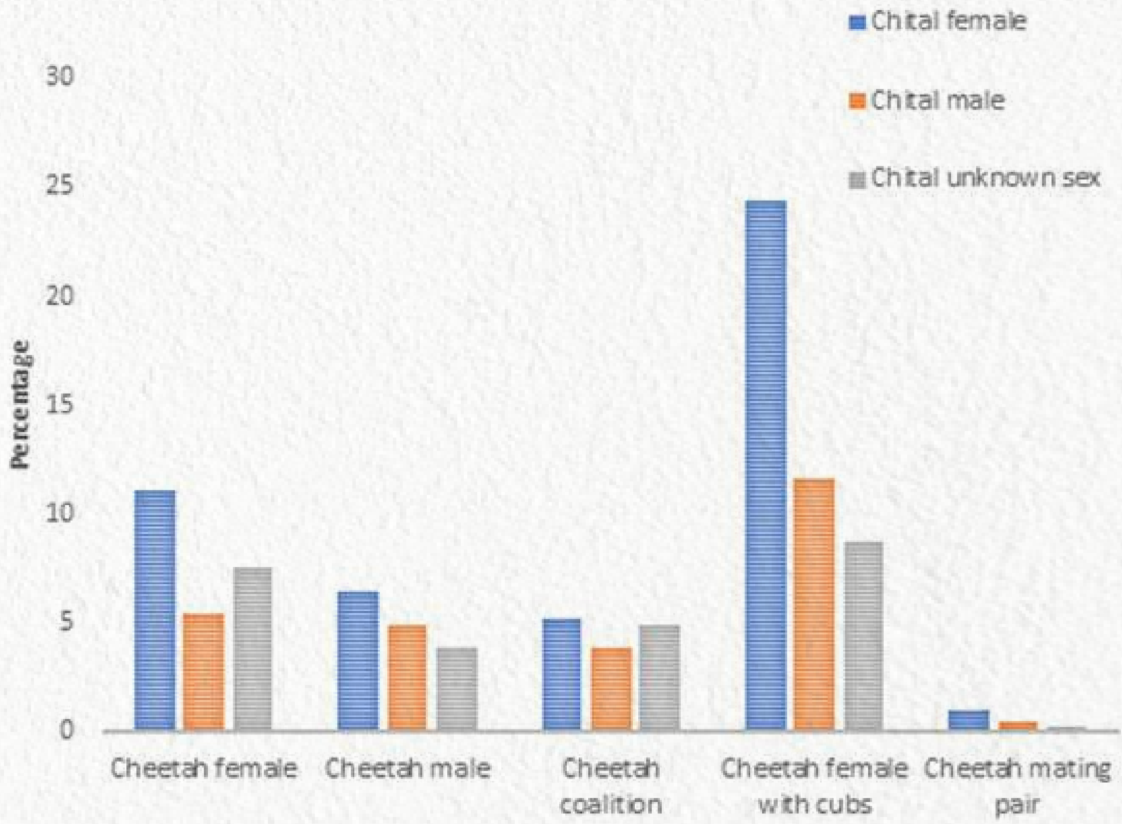


Figure 2.2.8.

Age category of chital predated by free-ranging cheetah social units in and around Kuno National Park

2.2.3. Predation by cheetah social units

The detailed accounts of the prey species killed by different cheetah social units (male, female, male coalition, mother with cubs, and mating pair) are discussed below.

2.2.3.1. Predation by male coalition Prabhas and Pavak

The male coalition partners, Prabhas and Pavak, were in Kuno NP until April 20, 2025, after which they were relocated to Gandhisagar WLS. They shared a large closed natural area in Kuno NP, and the detected kill rate was found to be 11.5 days per kill. They primarily predated on chital, except for two instances of nilgai kills. The majority of kills (n=21) took place as a coalition, except a single kill exclusively by Prabhas. The majority of chital killed by the coalition were adults. In the case of sex class, males accounted for a major percentage of the kills.

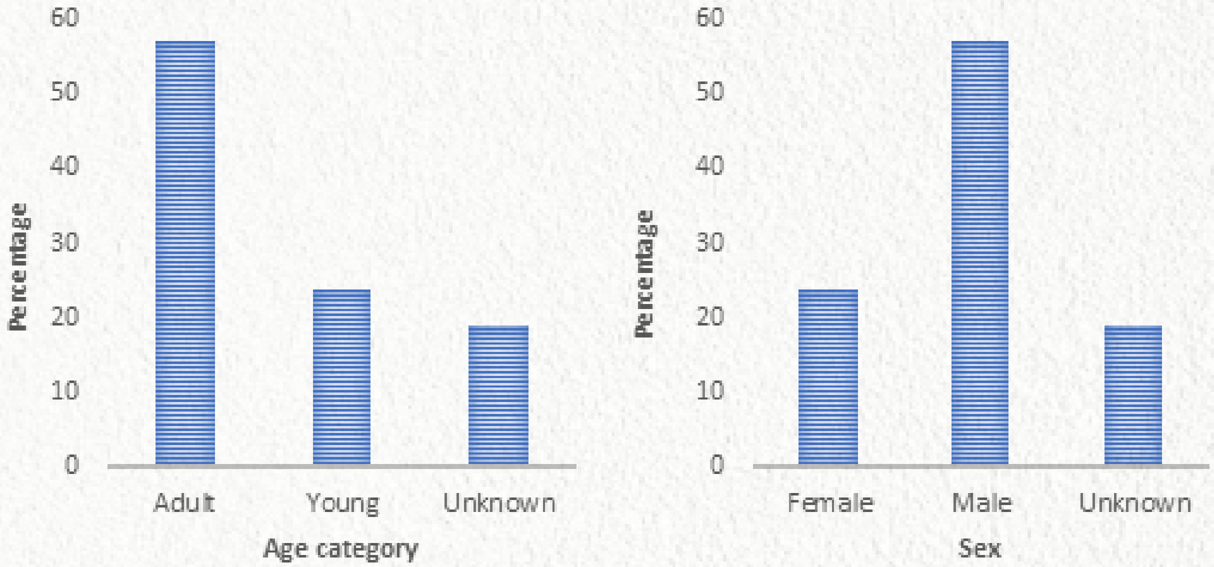


Figure 2.2.9.

Age category (left) and sex (right) of prey species predated by male cheetah coalition Prabhas and Pavak within the large closed natural area in Kuno National Park

2.2.3.2. Predation by female cheetah Nirva

Nirva is an approximately seven-year-old female cheetah of South African origin. She was observed to prey mostly on chital inside the large closed natural area, with one predation event of a hare. The majority of the kills were made independently; however, a few kills were also documented jointly with the male cheetah Gaurav while they were together as a mating pair. In addition, some kills were also recorded with cubs as a social unit. A total of 17 kills were observed entirely by Nirva, with a detected kill rate of 12.88 days per kill. Among the kills attributed solely to Nirva, male and female cheetahs were found to be of equal proportion. The maximum of the predation events involved young chitals.

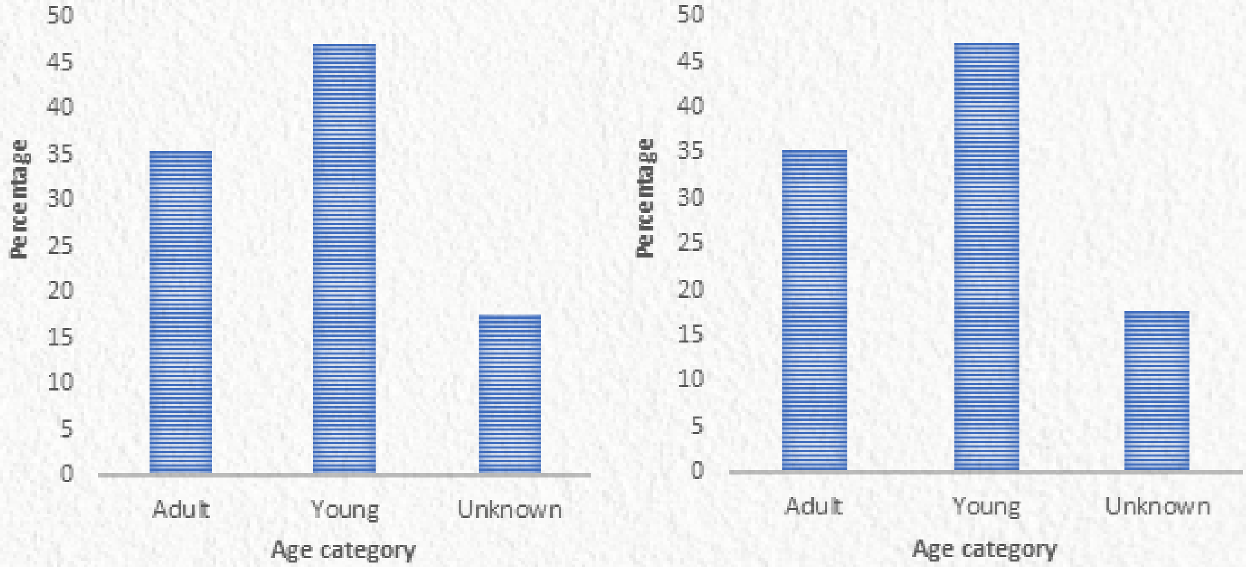


Figure 2.2.10.

Sexwise (left) and age category (right) of prey species predated by female cheetah Nirva within the large closed natural area in Kuno National Park

2.2.3.3. Predation by female cheetah Nirva with cubs

Female cheetah Nirva gave birth to five cubs on 25th April 2025. All detected kills by Nirva and cubs as a social unit were of chitals, and they primarily predated on female individuals in the large closed natural area. Adult chitals were predated more than young ones.

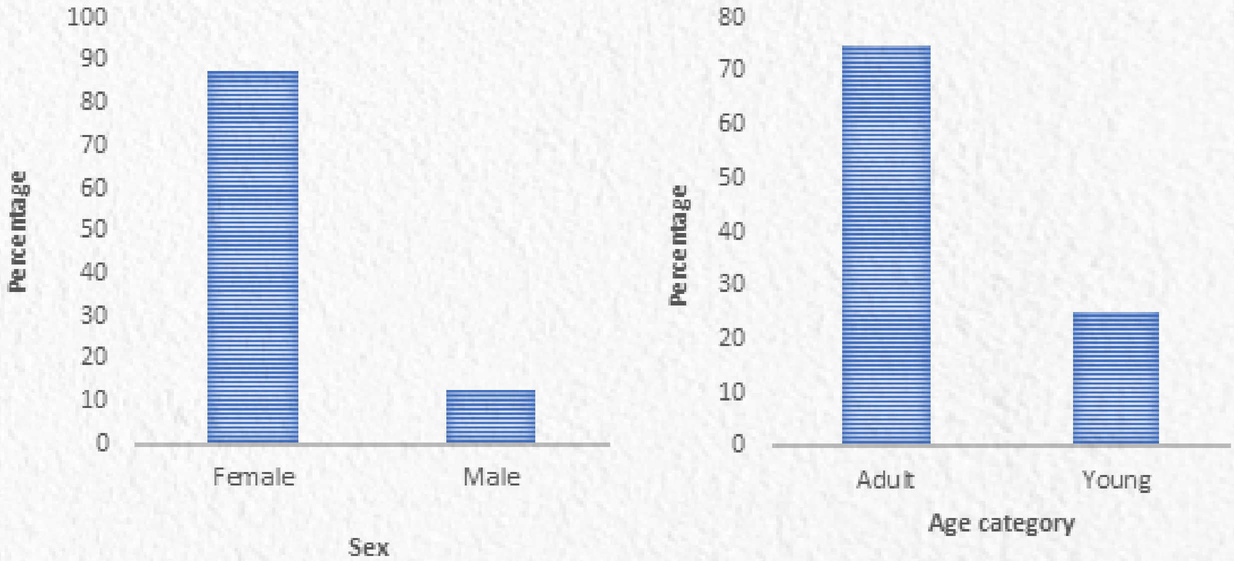


Figure 2.2.11.

Sexwise (left) and age category (right) of prey species predated by female cheetah Nirva with cubs within the large closed natural area in Kuno National Park

2.2.3.4. Predation by female cheetah Nabha

Nabha was a seven-year-old female cheetah housed in the large closed natural area until she died on 11 July 2025 due to the injuries she incurred during a predation attempt. Only a few (n=8) chital kills were recorded. Amongst them, she primarily preyed on young female chitals.

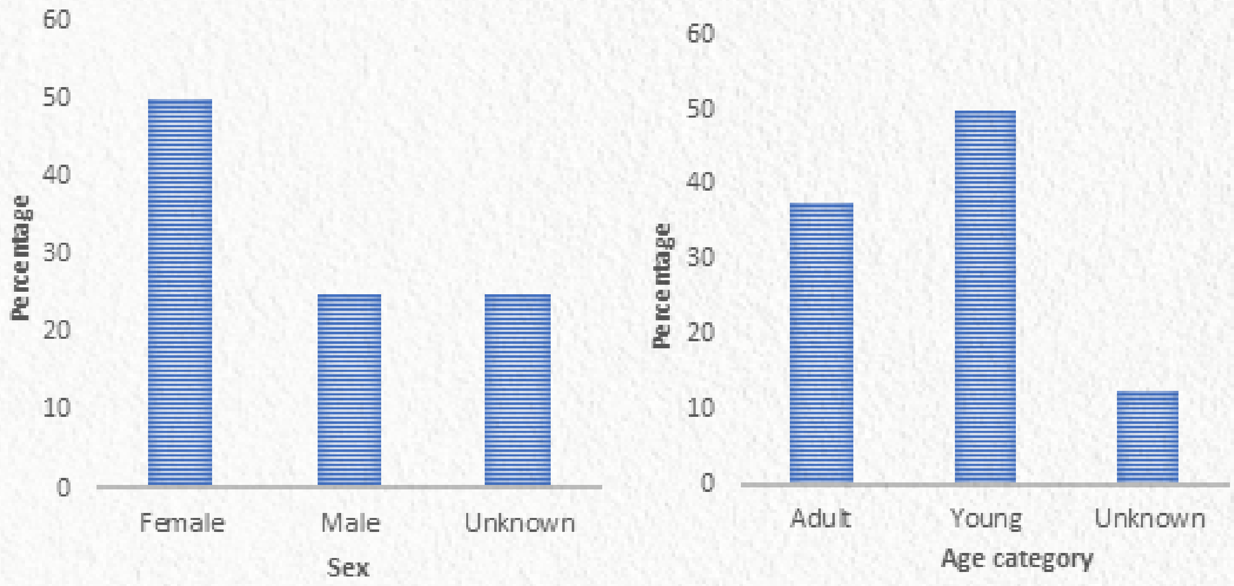


Figure 2.2.12.

Sex (left) and age category (right) of prey species predated by female cheetah Nabha within the large closed natural area in Kuno National Park

2.2.3.5. Predation by male cheetah Gaurav

Gaurav, an adult male cheetah, solely predated chitals in the large closed natural area, with a detected kill rate of 6.79 days per kill. A few predation events were recorded along with the female cheetah Nirva together as a breeding couple. The maximum of the prey species in the kills by Gaurav were female chitals, and a higher proportion were adults.

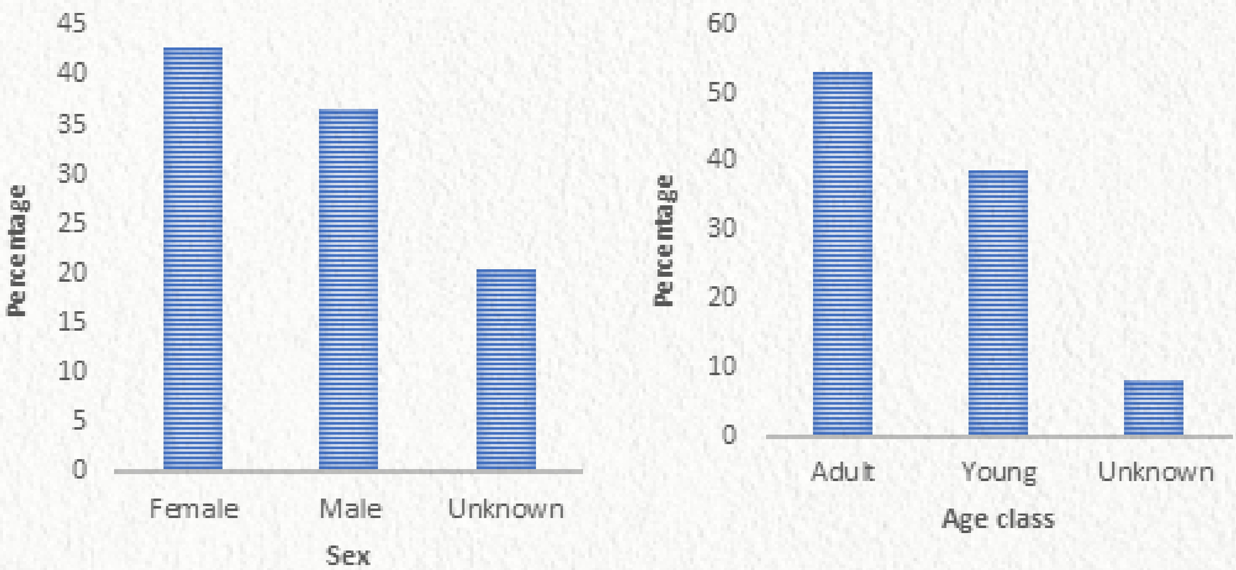
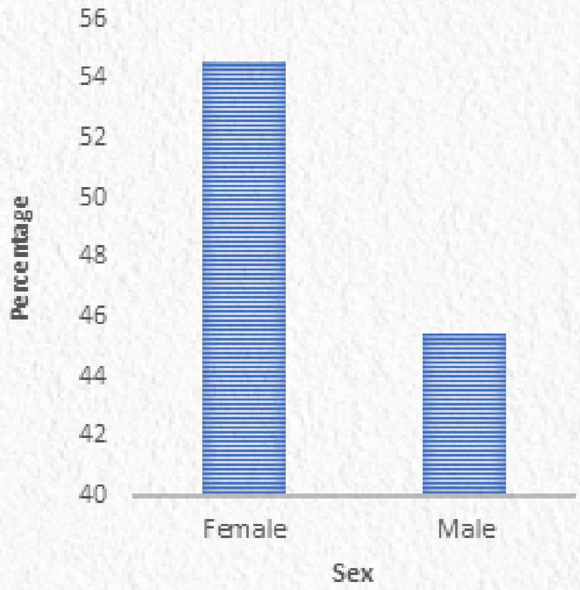


Figure 2.2.13.

Sex (left) and age category (right) of prey species predated by male cheetah coalition Gaurav within the large closed natural area in Kuno National Park

2.2.3.6. Predation by female cheetah Veera

Veera is an approximately seven-year-old female cheetah. Only chital was predated by Veera in the large closed natural area, with a detected kill rate of 6.40 days per kill. A slightly higher proportion of female kills (55%) was observed than male kills (45%). Among these kills, adult chital were predated more than young.



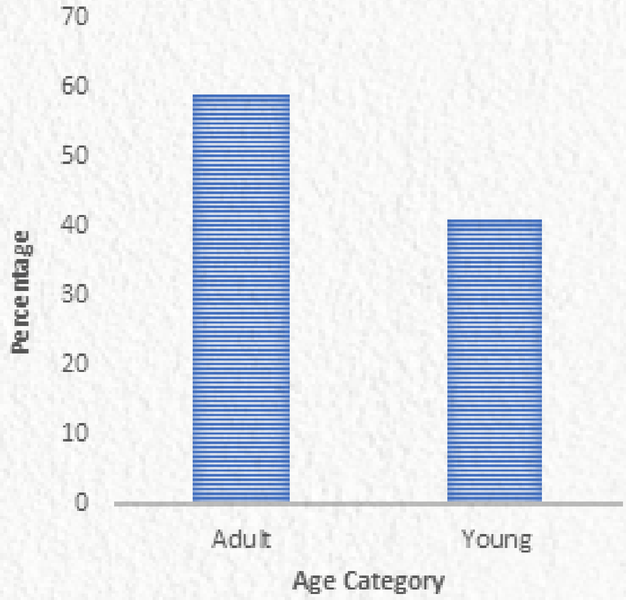
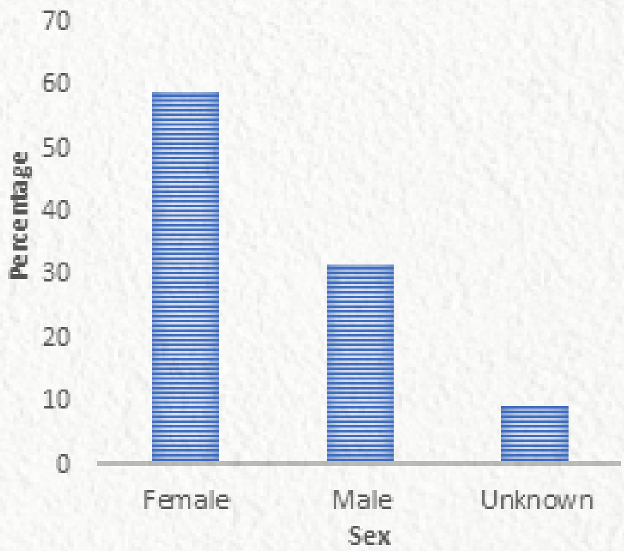


Figure 2.2.14.

Sex (left) and age category (right) of prey species predated by female cheetah Veera within the large closed natural area in Kuno National Park

2.2.3.7. Predation by cheetah Veera and cubs

Female cheetah Veera gave birth to two cubs on 3rd February 2025. A total of 22 kills were detected made by Veera and cubs as a social unit. All of the recorded kills were chital, among which the majority of individuals were females (60%). Adult chitals (80%) were predated more than young ones.



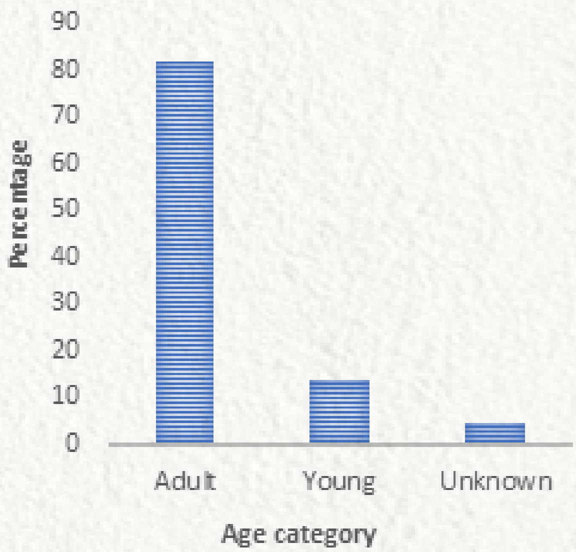


Figure 2.2.15.

Sex (left) and age category (right) of prey species predated by female cheetah Veera with cubs within the closed natural area in Kuno National Park

2.2.3.8. Predation by female cheetah Mukhi

Mukhi, a nearly three-year-old first Indian-born female cheetah, has made a few kills, (n=5), primarily (80%) preying on female chitals. Among the detected kills, 80% were adult chitals.

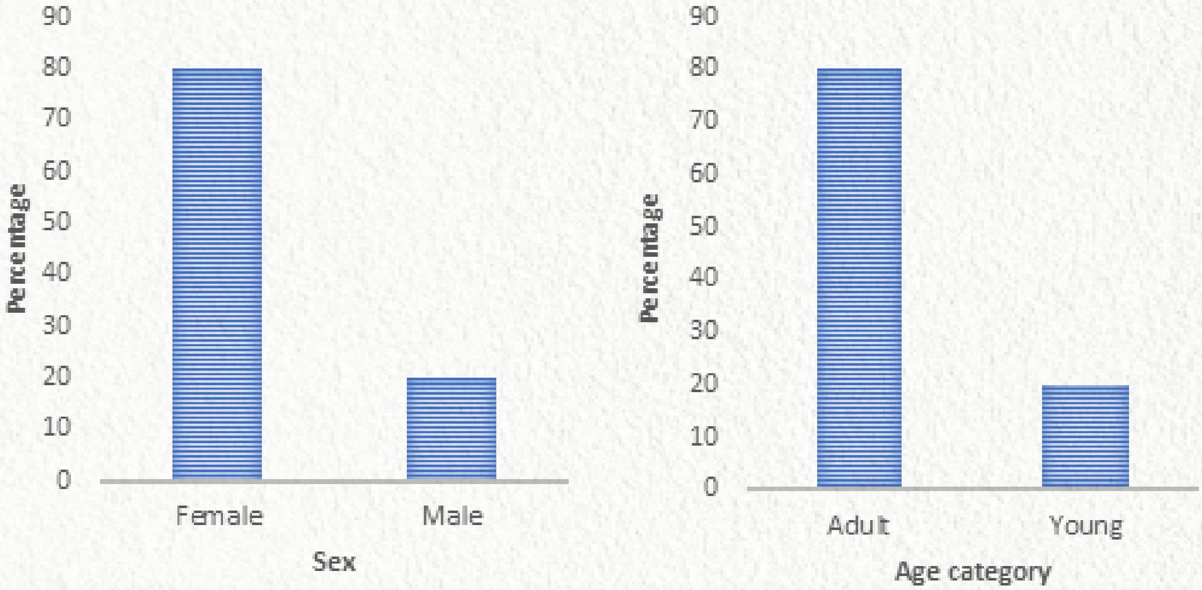


Figure 2.2.16.

Sex-wise (left) and age category (right) of prey species predated by female cheetah Mukhi within the large closed natural area in Kuno National Park

2.2.3.9. Predation by mating pair male cheetah Gaurav and female cheetah Nirva

A few of the kills (n=7) were recorded as joint kills by Gaurav and Nirva while they were briefly together as a mating pair. During this period, individual kills by each animal were also documented. Among the jointly documented kills in the large closed natural area, the majority of prey were female chitals, and with respect to age class, adults were preyed upon more than young.

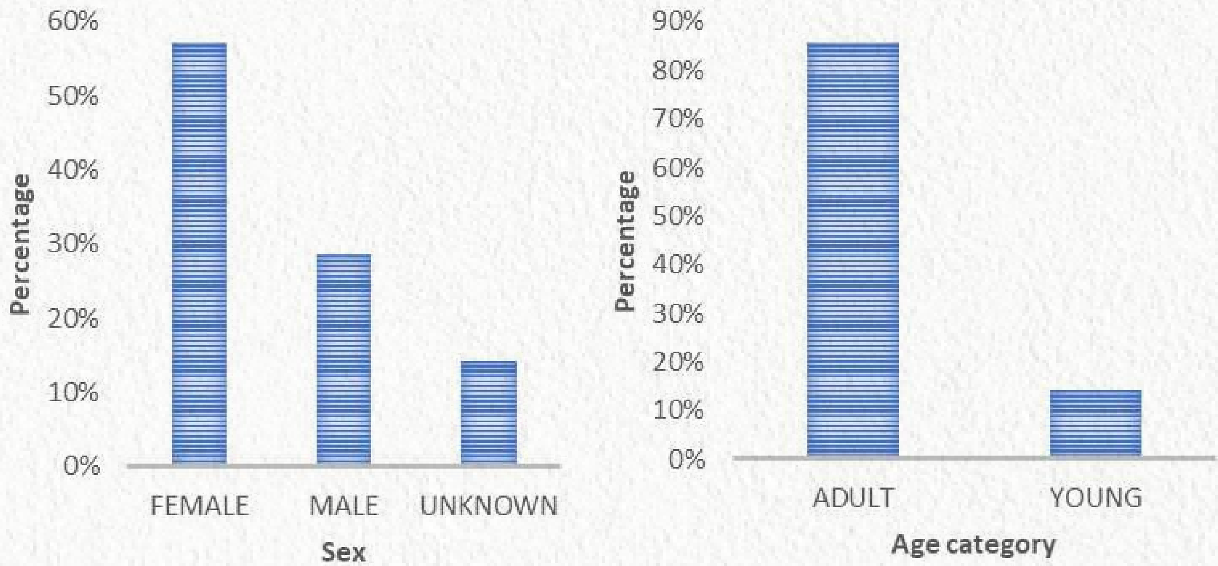


Figure 2.2.17.

Sex (left) and age category (right) of prey species predated by mating pair Gaurav (male) and Nirva (female) within the large closed natural area in Kuno National park

2.2.3.10. Predation by female cheetah Jwala and cubs

Female cheetah Jwala and her four cubs were released into free-ranging conditions on 22nd February 2025. A total of 111 kills were recorded with a kill rate of 2.48 days per kill. The majority of the kills involved the entire group, although a few kills were also recorded by individual animals as well as small subgroups, mainly during the periods when they were temporarily separated. Domestic goat kills (40%) were the maximum, followed by cattle and chital kills. Hare, sambar, and four-horned antelope were documented in equal proportions among the remaining kills.

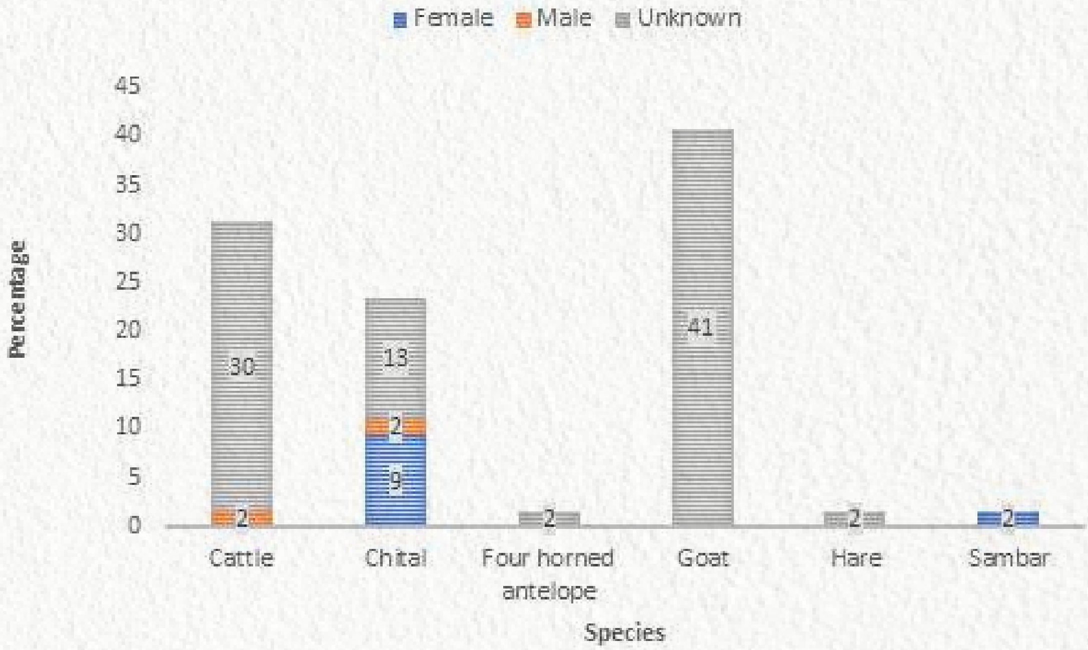


Figure 2.2.18.

Sex of various prey species predated by free-ranging female cheetah Jwala with cubs in and around Kuno National Park

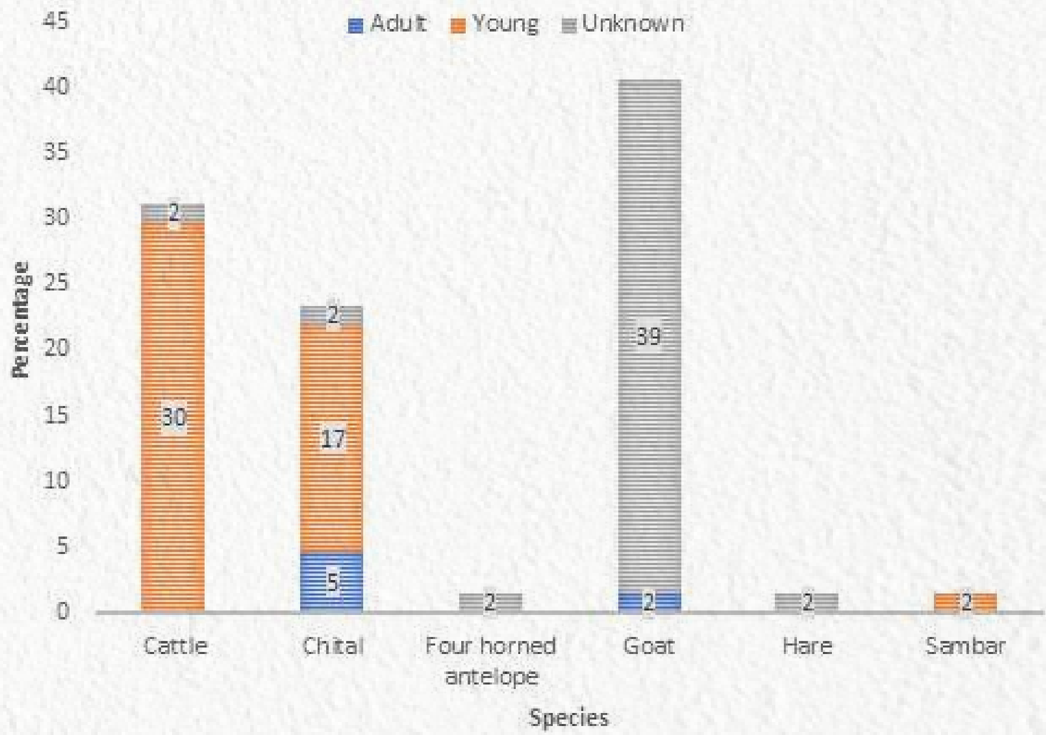


Figure 2.2.19.

Predation on different age classes of prey species by free-ranging female cheetah Jwala with cubs in and around Kuno National Park

Before release into free-ranging conditions, inside the large closed natural area, only chitals were predated, and nearly half of them (49%) were females. Adult chitals were more predated than the young ones. The detected kill rate inside the large closed natural area was 3.7 days per kill.

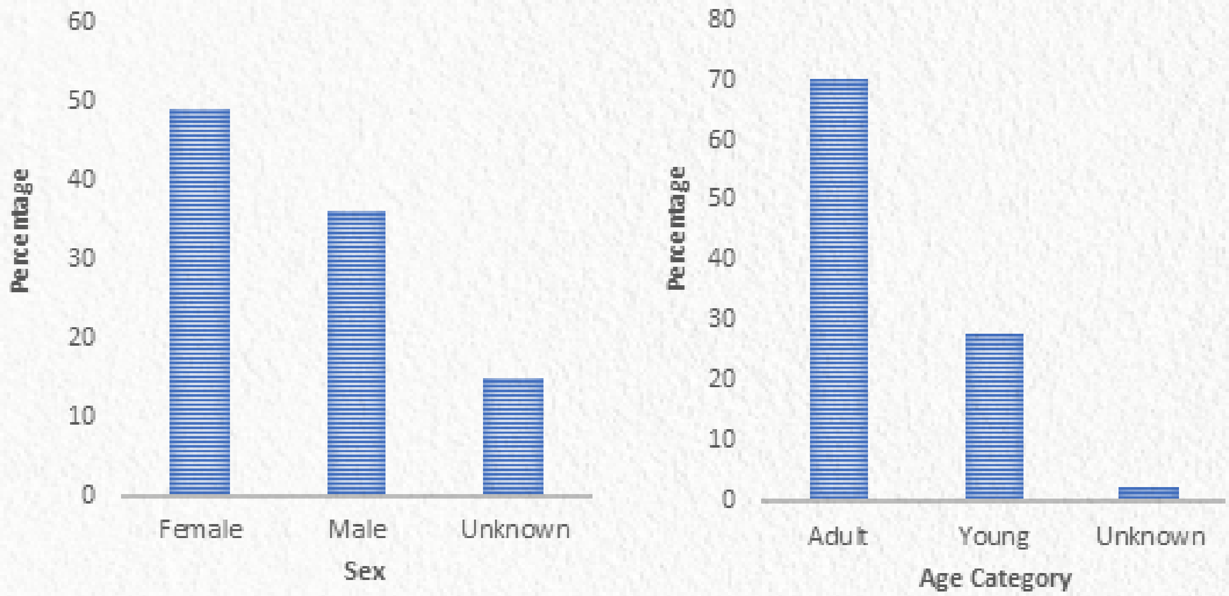


Figure 2.2.20.

Sex (left) and age category (right) of prey species predated by female cheetah Jwala with cubs within the large closed natural area in Kuno National Park

2.2.3.11. Predation by female cheetah Dheera

Dheera is an approximately eight-year-old female. She was released in free-ranging conditions for a short period of time of 26 days, from 4th February to 3rd March 2025. During this period, a single kill of a nilgai was detected. Inside the large closed natural area, only a few (13) kills were detected, all of which were chitals. Adult female chitals made up the majority of these kills.

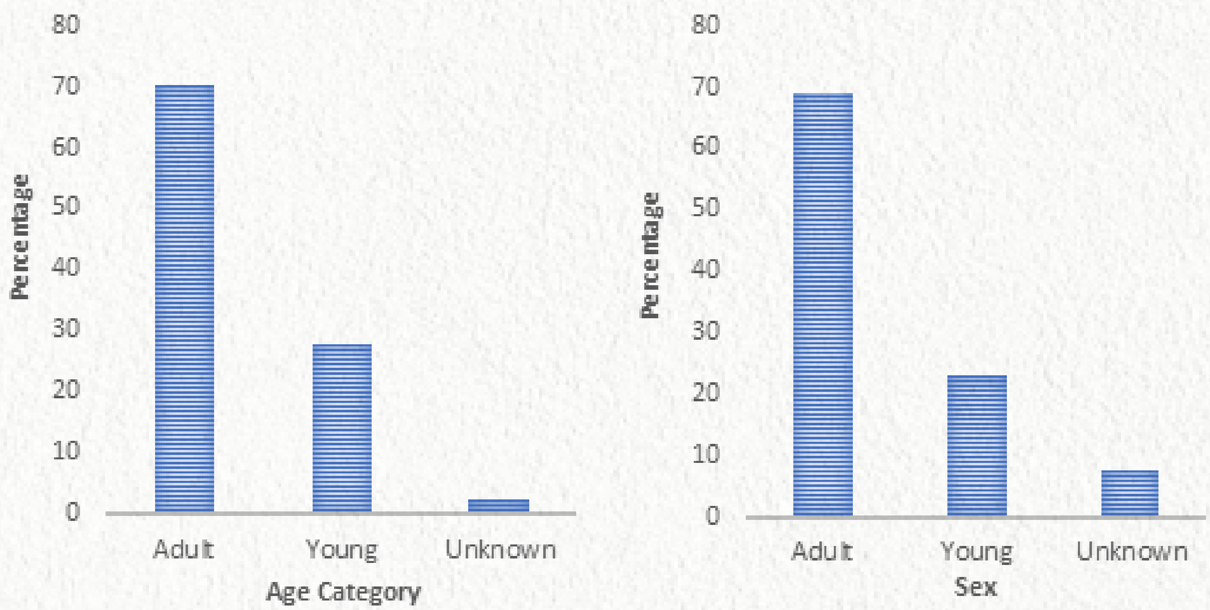


Figure 2.2.21.

Sex (left) and age category (right) of prey species by female cheetah Dheera within the large closed natural area in Kuno National Park

2.2.3.12. Predation by male cheetah coalition Agni and Vayu

The coalition male cheetahs, Agni and Vayu, were released into free-ranging conditions on 4th December 2025. Since then, a total of 31 kills were detected; of these, 4 kills were made jointly as a coalition, while 27 kills were made independently (Agni-12 kills and Vayu-15 kills). They were observed predating on multiple herbivore species found in and around Kuno NP, including both wild and domestic prey. The detected kill rate was observed to be 7.32 days per kill. Agni and Vayu predated mostly on chital (39%), followed by domestic cattle (26%), domestic goats (19%), sheep (10%), and nilgai and wild pigs (3% each). The coalition was observed to predate a similar proportion of adults (19%) and young chital (16%). A comparable trend was also observed in the sex class of predated chitals, with female individuals occurring in 19% and males in 16% of the kills.

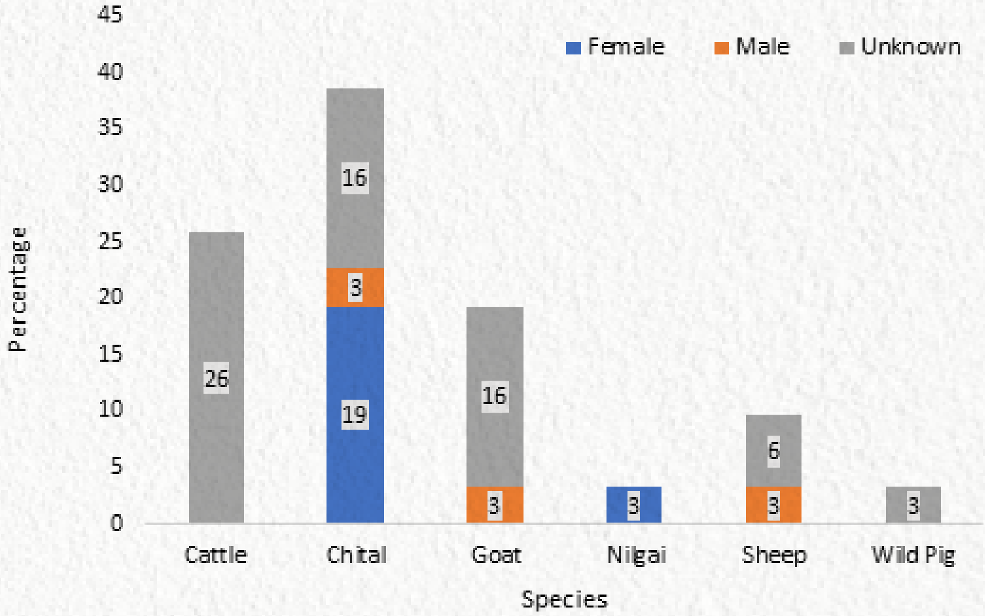


Figure 2.2.22.

Sex of various prey species predated by free-ranging male cheetahs Agni & Vayu in and around Kuno National Park

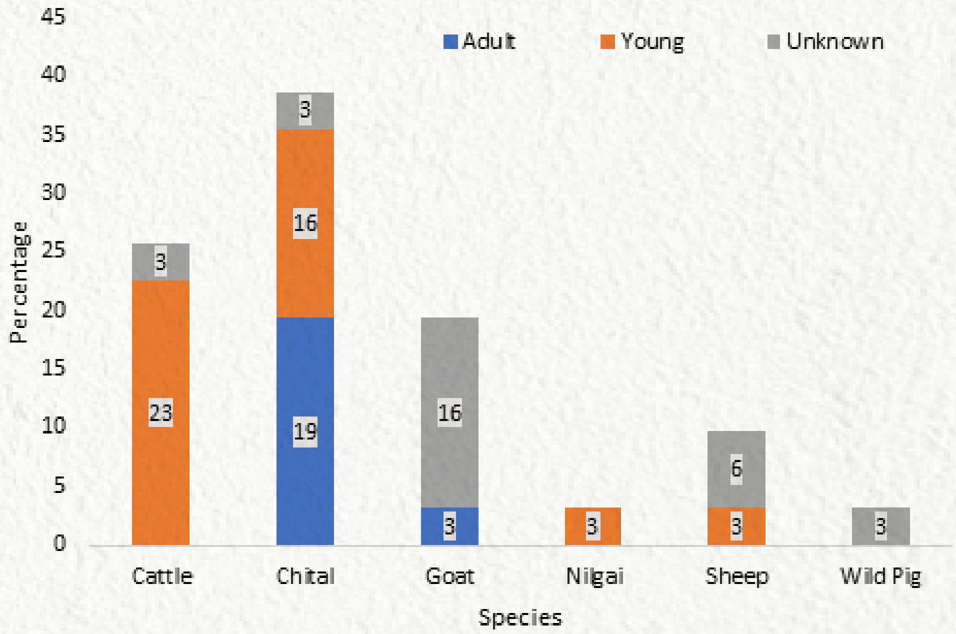


Figure 2.2.23.

Predation on different age classes of prey species by free-ranging male cheetah coalition Agni and Vayu in and around Kuno National Park

Prior to releasing into free-ranging conditions, a few kills by the coalition were recorded within the large closed natural area. All recorded kills involved chital as the prey species. Among these chital kills, the majority of them were females. Adult chitals were predated more than young ones.

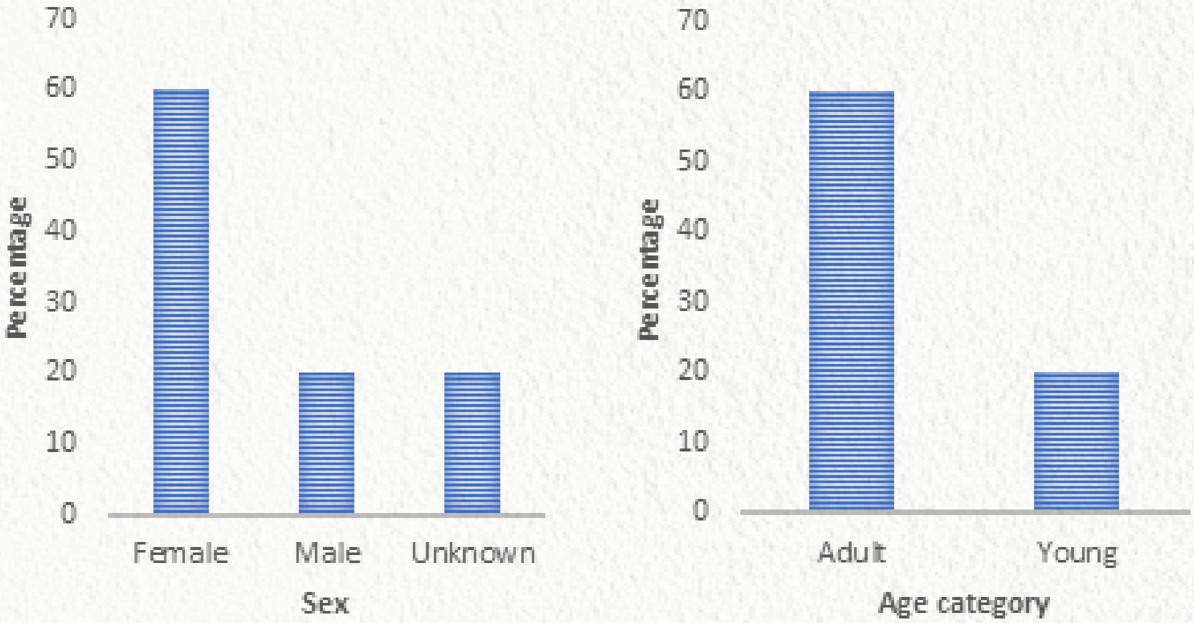


Figure 2.2.24.

Sex (left) and age category (right) of prey species predated by cheetah male coalition Agni and Vayu within the large closed natural area in Kuno National Park

2.2.3.13. Predation by female cheetah Gamini and cubs

Female cheetah Gamini and her four cubs were released to free-ranging conditions on 16th March 2025. Since then, the mother has preyed on a variety of herbivore species in and around Kuno NP, including domestic cattle and goats. The detected kill rate was 2.91 days per kill. They primarily predated goats, chital, and cattle. Among the goat kills, sex and age classes were largely unidentified, whereas in the case of chital, young chitals were majorly predated.

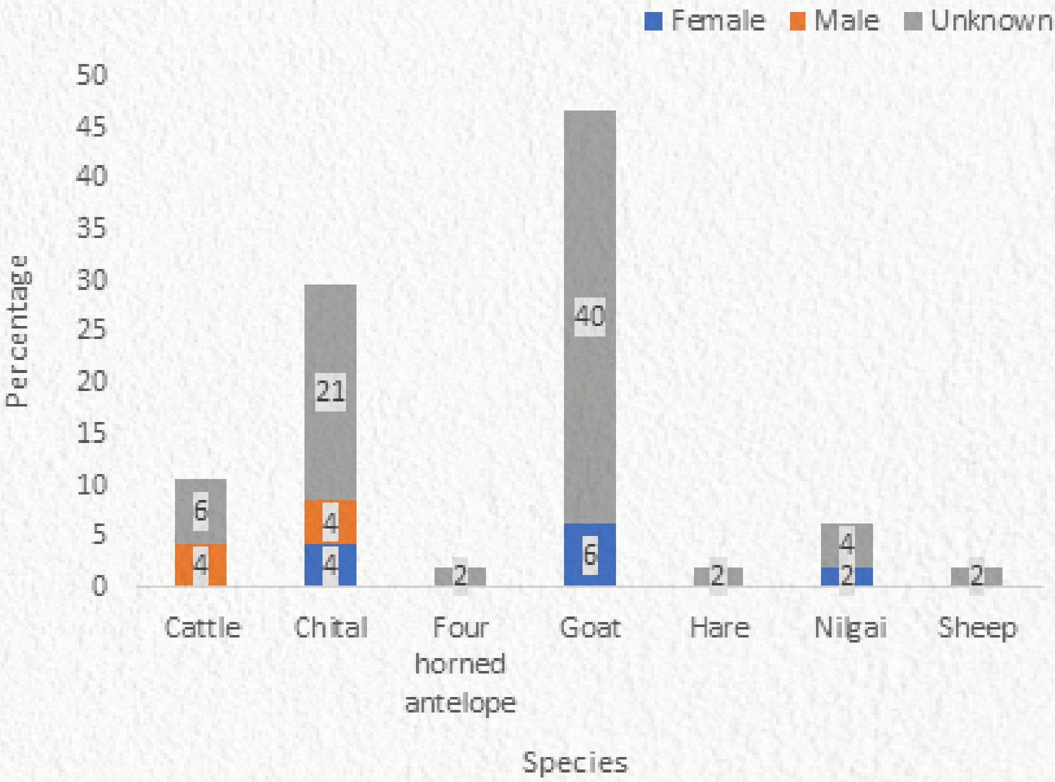


Figure 2.2.25.

Sex of various prey species predated by free-ranging female cheetah Gamini with cubs in and around Kuno National Park

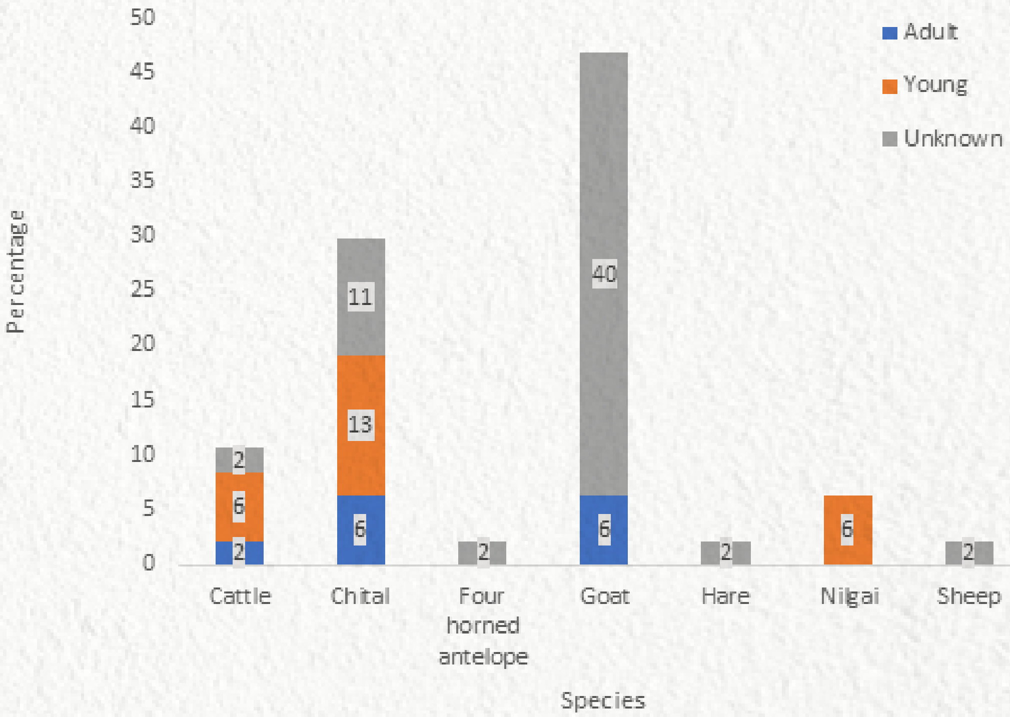


Figure 2.2.26.

Predation on different age classes of prey species by free-ranging female cheetah Gamini with cubs in and around Kuno National Park

Before the release into free-ranging conditions, within the large closed natural area, Gamini and cubs predated only on chital, among which the majority were female chital (58%). A total of 48 kills were recorded with a detected kill rate of 4.06 days per kill. Adult chitals (77%) were predated more than young by Gamini and cubs.

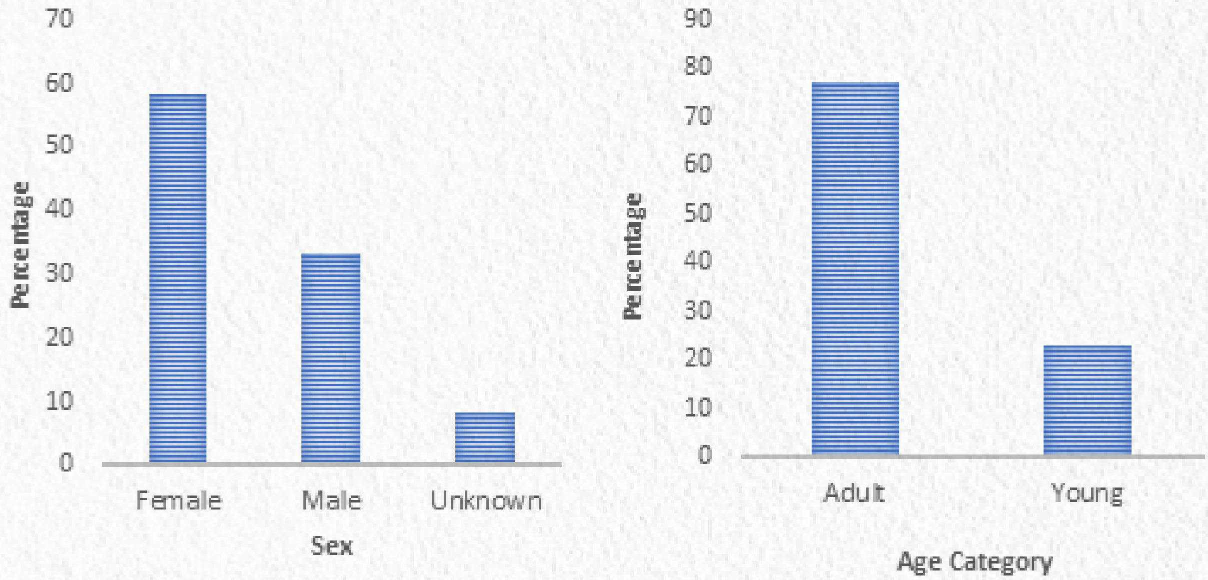
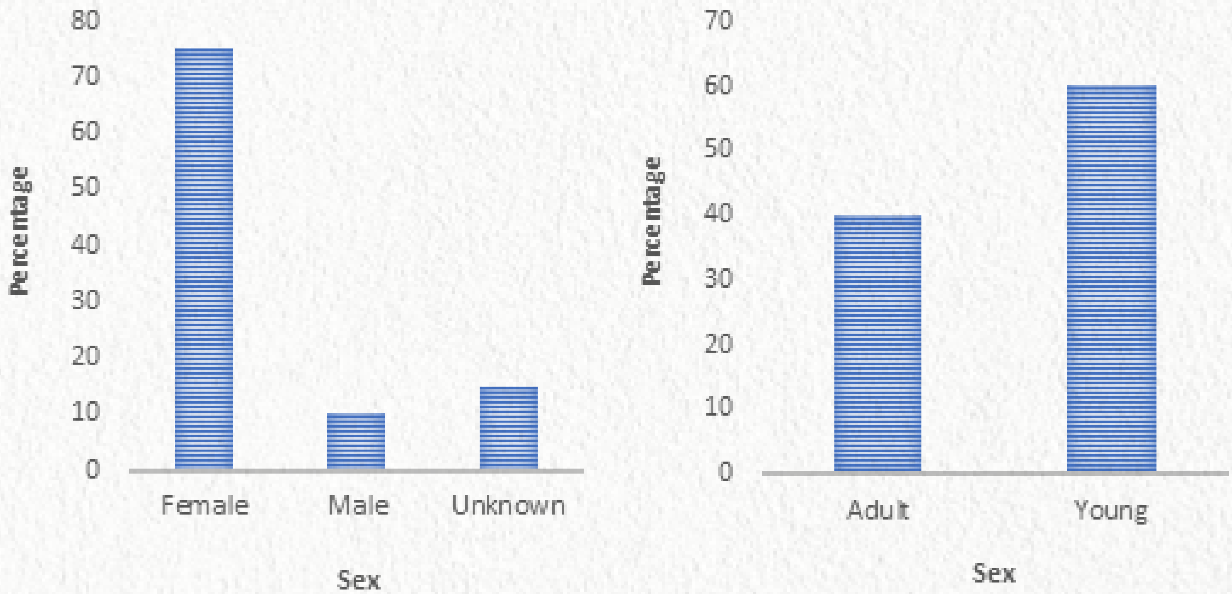


Figure 2.2.27.

Sex (left) and age category (right) of prey species predated by cheetah female Gamini within the large closed natural area in Kuno National Park

2.2.3.14. Predation by female cheetah Asha with cubs

Female cheetah Asha and her three cubs (KAP1, KAP2, and KAP3) were released into free-ranging conditions on 06th February 2025. During the period they remained together in the large closed natural area, 20 kills were detected. All of these involved chital as prey species, and the majority of the kills were females (75%). Young chitals (60%) were predated more than the adults.



4.2.2.28.

Sex (left) and age category (right) of prey species predated by female cheetah Asha and cubs within the large closed natural area in Kuno National Park

2.2.3.15. Predation by female cheetah Asha

After release into free-ranging conditions on 6 February 2025, a total of 29 kills were recorded by female cheetah Asha, with a detected kill rate of 6.03 days per kill. She was observed to prey mostly on chital except for one predation event of chinkara. Among chital kills, young were observed to be predated more, and in males higher than females. However, the sex of the majority of the kills could not be identified.

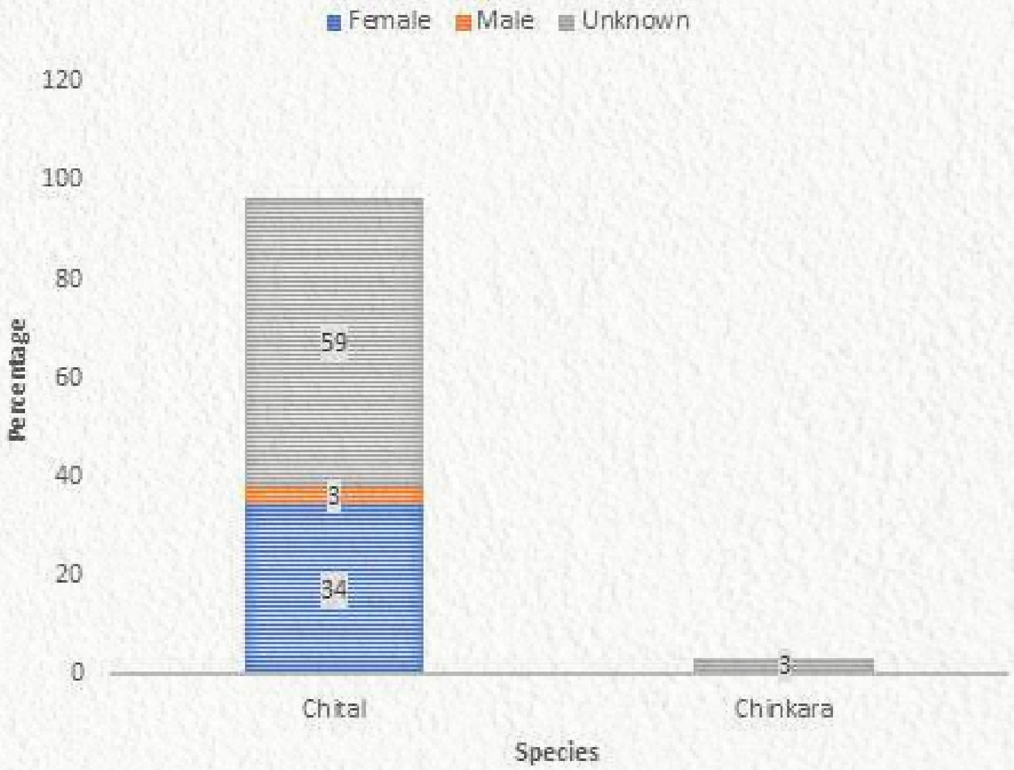


Figure 2.2.29.

Sex of various prey species predated by free-ranging female cheetah Asha in and around Kuno National Park

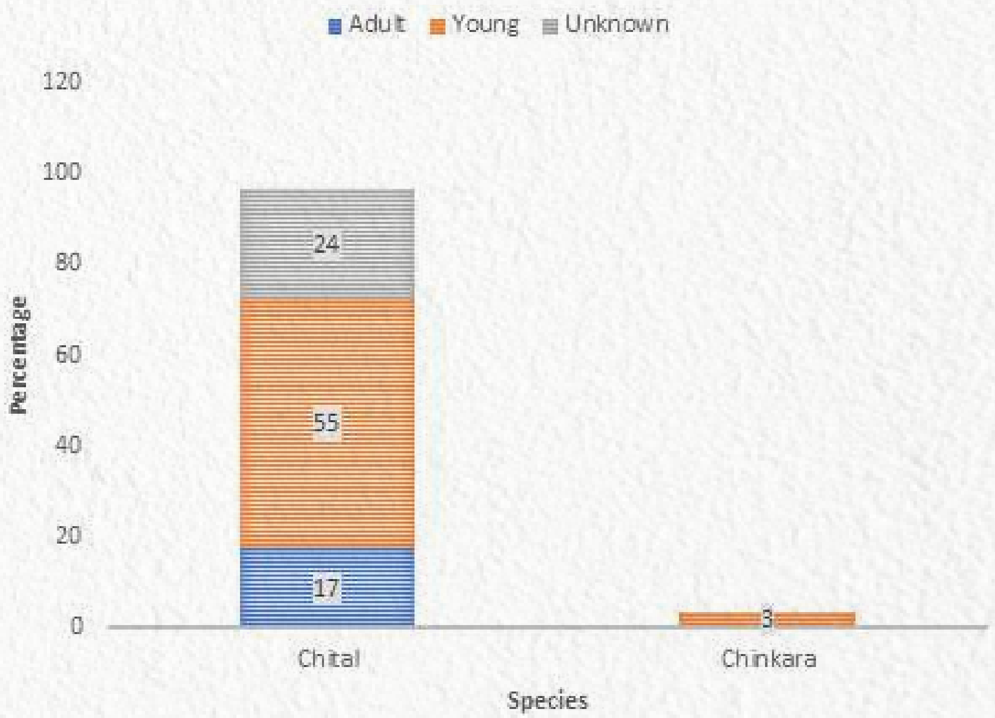
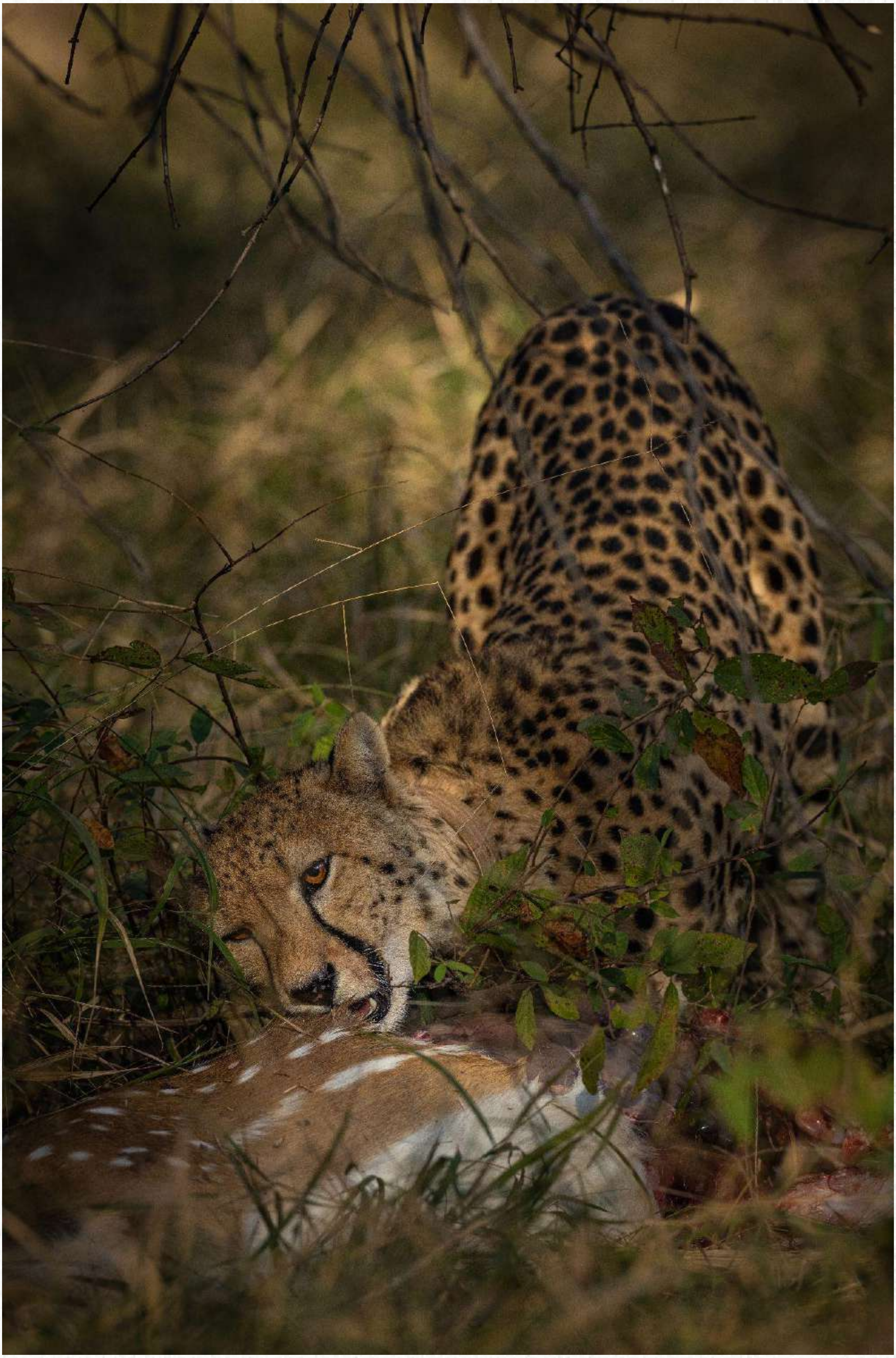


Figure 2.2.30.

Predation on different age classes of prey species by free-ranging female cheetah Asha in and around Kuno National Park



2.2.3.16. Predation by male cheetah coalition-KAP1, KAP2 & KAP3 (Female cheetah Asha's cubs)

The male cheetah coalition- KAP1, KAP2, and KAP3 were released into free-ranging conditions on 06th February 2025. Since then, a total of 51 kills were recorded with a kill rate of 3.43 days per kill. They mainly predated on chital (47%), followed by cattle, goat, hare, and wild pig. Among the chital, males were predated more than females; however, the sex of the majority of the kills could not be identified. Young chitals were predated more than the adults.

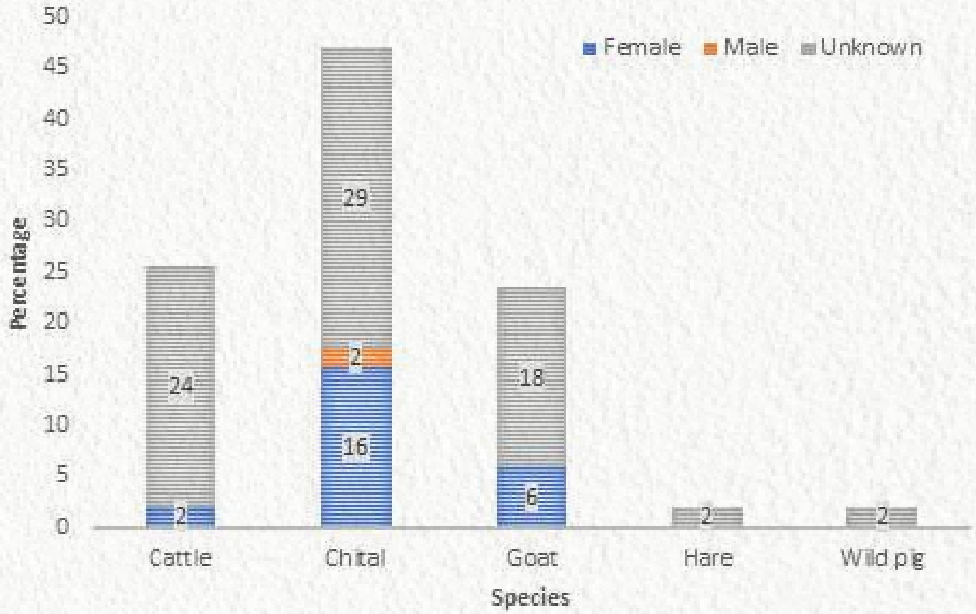


Figure 2.2.31.
Sex of various prey species predated by free-ranging male cheetah coalition- KAP1, KAP2 & KAP3 (female cheetah Asha's cubs) in and around Kuno National Park

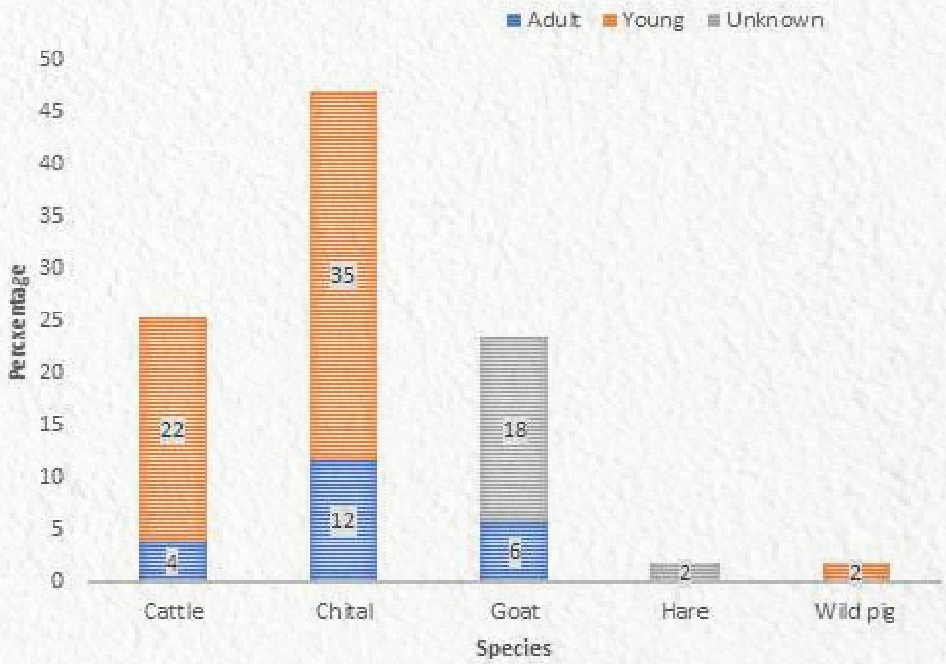


Figure 2.2.32.
Predation on different age classes of prey species by free-ranging male cheetah coalition- KAP1, KAP2 & KAP3 (female cheetah Asha's cubs) in and around Kuno National Park

During the period from 26-01-2025 to 02-02-2025, when the cubs were separated from their mother within the large closed natural area, a few kills were recorded (n = 4). Of these, two kills involved all three individuals together, one kill was made exclusively by KAP1, and one by KAP2 and KAP3 jointly. In these kills, only adult chitals were predated, and the majority of them were females.

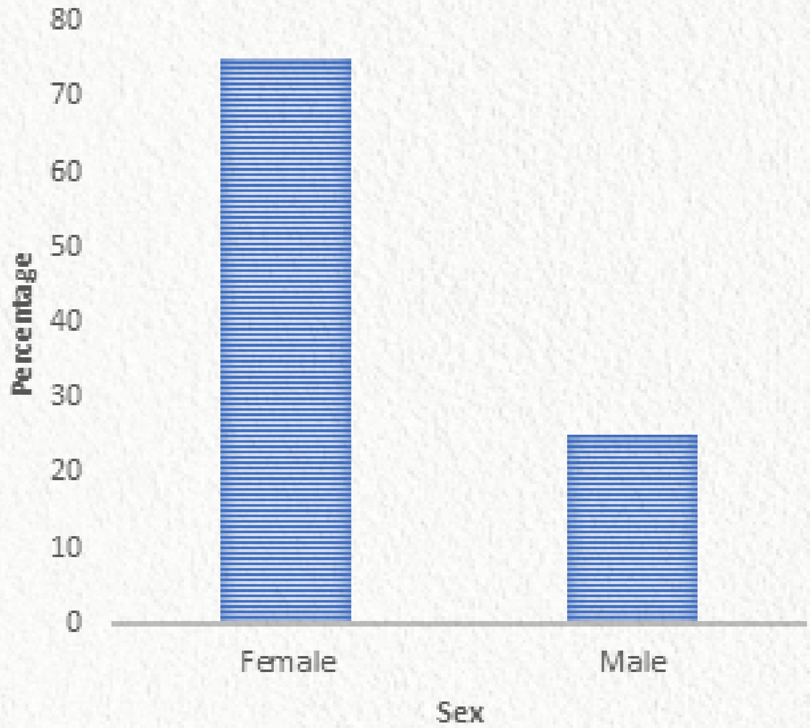


Figure 2.2.33.

Sex (top left) and age category (top right) of prey species predated by male cheetah coalition. Asha's cubs within the large closed natural area of Kuno National Park

2.3. Home range and movement of free-ranging cheetahs in and around Kuno National Park

Between December 2024 and July 2025, eight cheetahs were sequentially released into the free-ranging environment of Kuno NP. The released animals comprised of two male cheetah coalitions- Agni and Vayu, and KAP1, KAP2, and KAP3 (Asha's cubs); one solitary female (Asha); and two mothers with sub-adult cubs (Jwala with four cubs: two males and two females; and Gamini with four cubs: two males and two females). All translocated individuals were equipped with satellite–GPS collars manufactured by African Wildlife Telemetry (AWT), featuring both VHF and UHF transmitters for real-time ground tracking and remote data retrieval through the AWT online interface. The data logging frequency for each individual was customized according to specific monitoring requirements.

Continuous field monitoring was jointly undertaken by trained personnel from the Madhya Pradesh Forest Department and researchers from the Wildlife Institute of India (WII). Observations were conducted from comfortable distances to minimize disturbance and ensure the maintenance of natural behaviors of the animals. During the monitoring period, several cheetahs exhibited extensive movements across the landscape. In a few cases, veterinary intervention was required to humanely as well as safely capture and release some individuals within the NP.

Using the data obtained from the radio collars of individual cheetahs, spatial movement patterns and home ranges were delineated using the Minimum Convex Polygon (MCP) method in ArcMap. Additionally, average daily movement and home ranges were computed with the Kernel Density Estimator (KDE) of home ranges using the R package adehabitatHR (Calenge, 2006), providing critical insights into space-use behavior and adaptation to the free-ranging environment.

The movement data of free-ranging cheetahs in Kuno NP revealed considerable variation among individuals and groups. The male coalition cheetah Agni covered a total distance of 672.7 km, with an average daily movement of 6.05 (0.35SE) km over 214 days, while his coalition partner Vayu travelled 642.5 km, averaging 4.86 (0.34SE) km per day over 101 days. The solitary female cheetah Asha moved 560.6 km during the monitoring period, with a mean daily distance of 3.26 (0.23SE) km over 185 days. Among the female cheetahs with cubs, Gamini and her four cubs covered 767.5 km, averaging 4.62 (0.33 SE) km per day over 166 days, whereas Jwala and her four cubs recorded the highest movement, travelling 893.5 km with an average daily distance of 5.48 (0.28SE) km in 174 days. The three male cheetahs from another coalition, KAP1, KAP2, and KAP3, each exhibited relatively similar movement patterns, covering 675.7 km, 662.5 km, and 685.3 km, respectively, with mean daily movements of 3.29 (0.13SE) km, 3.23 (0.12SE) km, and 3.37 (0.15SE) km respectively in 203-205 days.

Table 2.3.1.

Total distance and average daily distance moved by free-ranging cheetahs in and around Kuno National Park

Individual	Social Unit, Age Category & Sex	Total distance moved (km)	Average daily distance moved (km)	No of days
AGNI	Coalition Adult Male	672.7	6.05 (0.35SE)	214
VAYU	Coalition Adult Male	642.5	4.86 (0.34SE)	101
ASHA	Solitary Female	560.6	3.26 (0.23SE)	185
GAMINI & CUBS	Adult Female with Cubs (2 Males & 2 Females)	767.5	4.62 (0.33SE)	166
JWALA & CUBS	Adult Female with Cubs (2 Males & 2 Females)	893.5	5.48 (0.28SE)	174
KAP1	Coalition Sub-adult Male	675.7	3.29 (0.13SE)	205
KAP2	Coalition Sub-adult Male	662.5	3.23 (0.12SE)	204
KAP3	Coalition Sub-adult Male	685.3	3.37 (0.15SE)	203

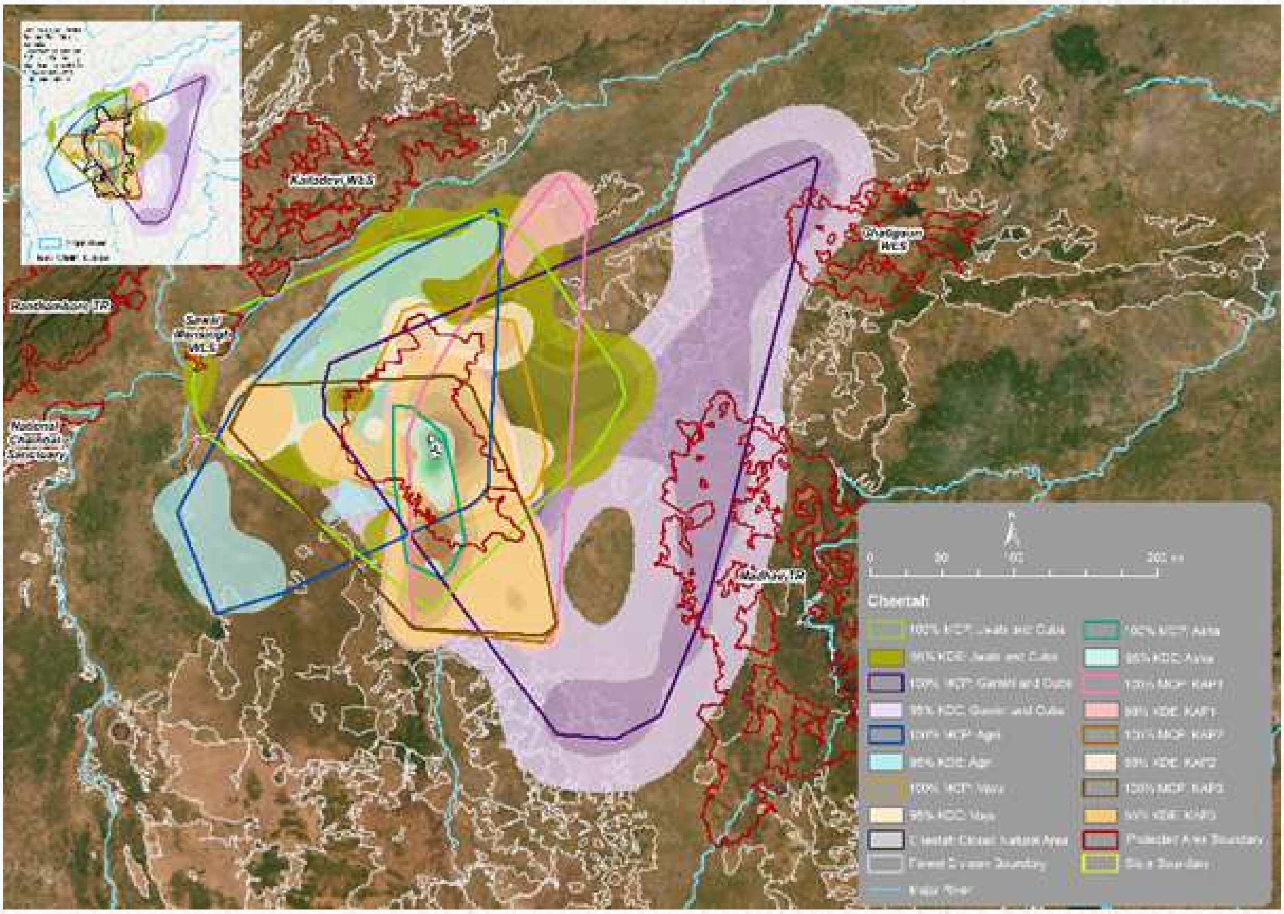


Figure 2.3.1.

Home range (100% MCP and 95% KDE) of free-ranging cheetahs in and around Kuno National Park

The spatial movement analysis of free-ranging cheetahs in and around Kuno NP showed notable differences in the extent of area covered during the initial and subsequent monitoring periods. The adult male cheetah Agni explored a vast area of 3,198 km² within the first 30 days, followed by 1,334 km² over the next 184 days, while his coalition partner Vayu covered 471 km² initially and expanded to 716 km² over the subsequent 71 days. The solitary adult female cheetah Asha utilized 385 km² during the first month, with her space use later restricted to 47 km² over the following 155 days. Among female cheetahs with cubs, Gamini and her cubs exhibited extensive movement, covering 572 km² in the first 30 days and a remarkably larger 6,888 km² in the next 136 days. Similarly, female cheetah Jwala and her cubs ranged across 1,690 km² during the first month, later expanding to 3,204 km² over the next 144 days. In comparison, the male cheetah sub-adult coalition KAP1, KAP2, and KAP3 each initially ranged within 162-164 km², subsequently increasing their area use to 1,399-1,601 km² over 173-175 days, reflecting initial area exploratory behaviour over time for most individuals except the solitary female, who showed reduced space use, likely showing settling down.

Table 2.3.2.

Summary of space use by free-ranging cheetahs in and around Kuno National Park

Individual	Social Unit, Age Category & Sex	Area covered in first 30 days (km^2)	Area covered in subsequent days (km^2)
AGNI	Coalition Adult Male	3198	1334 in 184 days
VAYU	Coalition Adult Male	471	716 in 71 days
ASHA	Solitary Female	385	47 in 155 days
GAMINI & CUBS	Adult Female with Cubs (2 Males & 2 Females)	572	6888 in 136 days
JWALA & CUBS	Adult Female with Cubs (2 Males & 2 Females)	1690	3204 in 144 days
KAP1	Coalition Sub-adult Male	162	1601 in 175 days
KAP2	Coalition Sub-adult Male	164	1399 in 174 days
KAP3	Coalition Sub-adult Male	163	1427 in 173 days

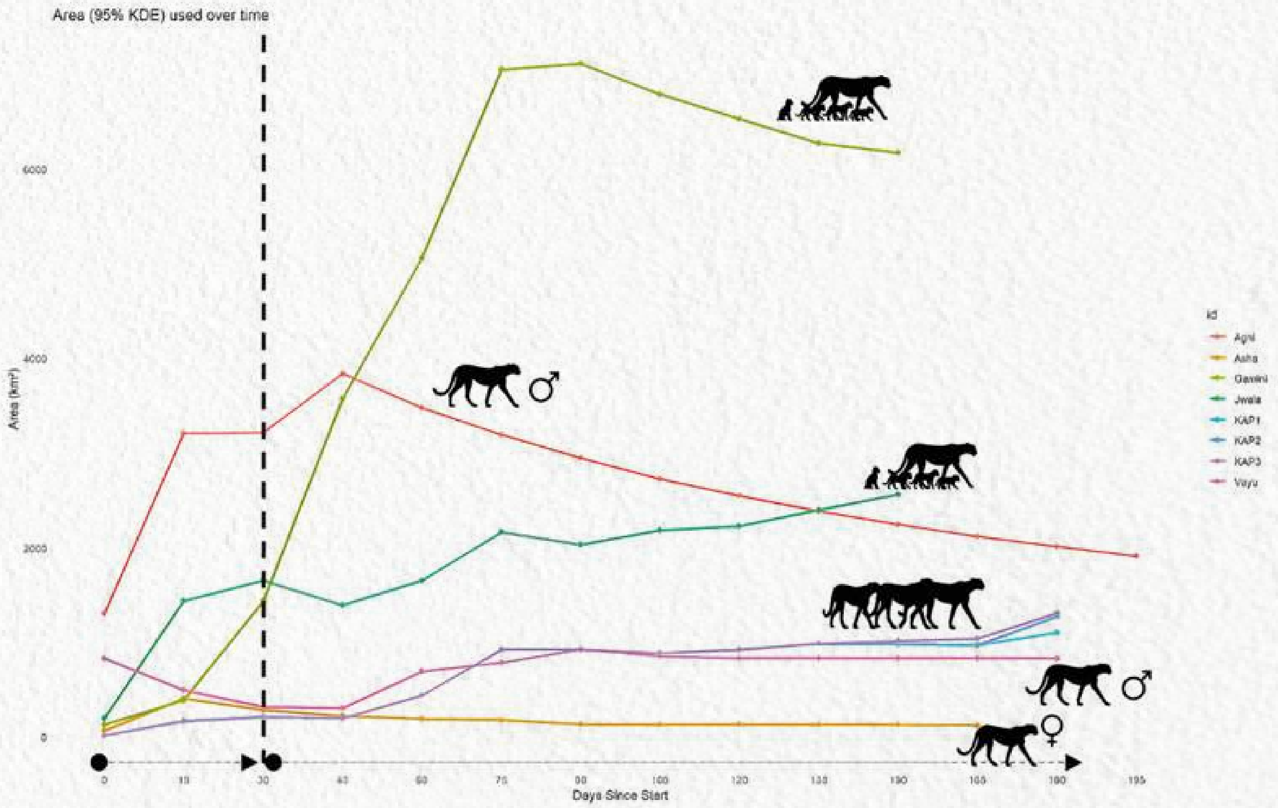


Figure 2.3.2.

Space use of free-ranging cheetahs over time in and around Kuno National Park

2.4. Habitat selection by free-ranging cheetahs in and around Kuno National Park

To understand habitat preferences of free-ranging cheetahs in and around Kuno NP, Resource Selection Function (RSF) analysis was employed based on the utilization of available resources. RSF evaluates the probability of habitat use as a function of specific environmental attributes, comparing used locations with available but unused areas (Johnson *et al.*, 2006; Manly *et al.* 2007). RSF models were developed in R using the amt package (Signer *et al.*, 2019), applying logistic regression to telemetry data from radio-collared individuals. Land Use/ Land Cover (LULC) classes included Open Natural Ecosystem (savannah/grassland), dhonk forest, riverine areas, miscellaneous dry deciduous forest, areas adjacent to water bodies, human habitation, and agricultural land.

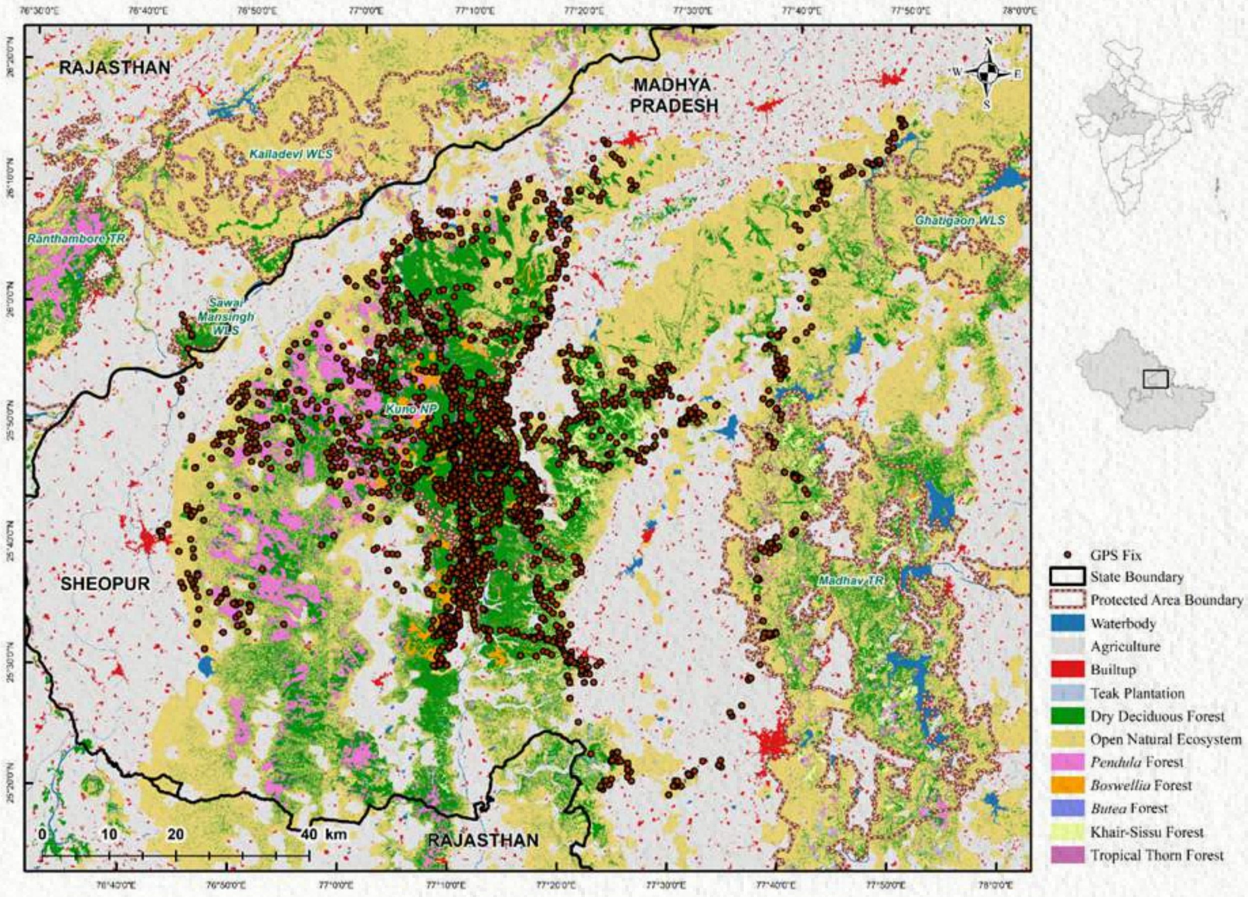


Figure 2.4.1.

Locations of radio-collared free-ranging cheetahs overlaid on the forest type map of the area in and around Kuno National Park

Second-order habitat selection was evaluated seasonally for all active radio-collared individuals. Selection ratios were computed to quantify the relative use of each habitat type at the home-range level. The Ivlev's Electivity Index (Ei) was calculated using the formula Ei = (ui – ai)/(ui + ai), where ui represents the proportion of locations used within a habitat and ai represents its availability. Values range from –1 (strong avoidance) to +1 (strong preference). Computations were conducted using the adehabitatHS package in R Studio (version 4.3.2) (Calenge, 2006).

The analysis was conducted for five adults and three sub-adult cheetahs fitted with satellite collars. The highest proportion of cheetah locations were within open natural ecosystems (savannah/grasslands), reflecting the current habitat distribution within the monitored area. Based on the spatial data from these radio-collared cheetahs using both methods, Khair Forest emerged as the most preferred habitat, followed by Dry Mixed Deciduous Forest and Open and Natural Ecosystem (savannah and grassland). Further, Dhonk (*Terminalia pendula*) forest and Boswellia forest were also selected.

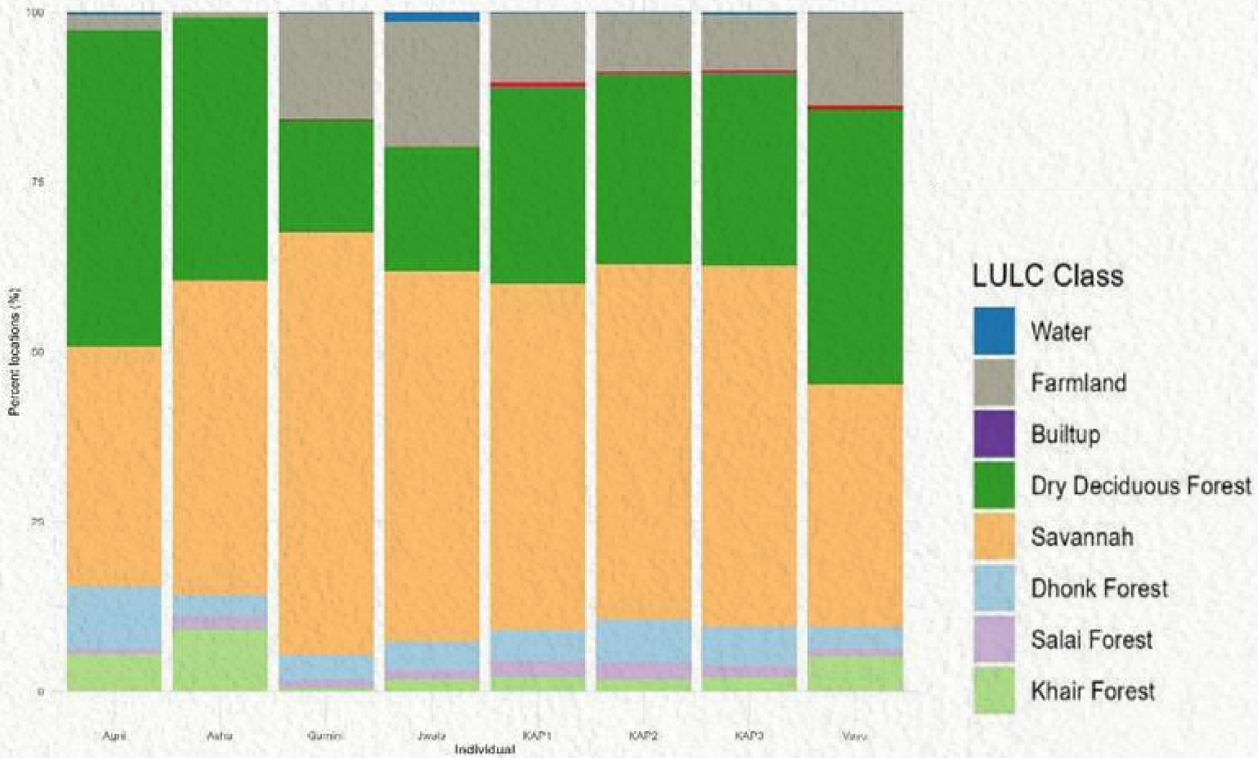


Figure 2.4.2.

Habitat use of radio-collared free-ranging cheetahs from percentage of locations in each habitat type in and around Kuno National Park

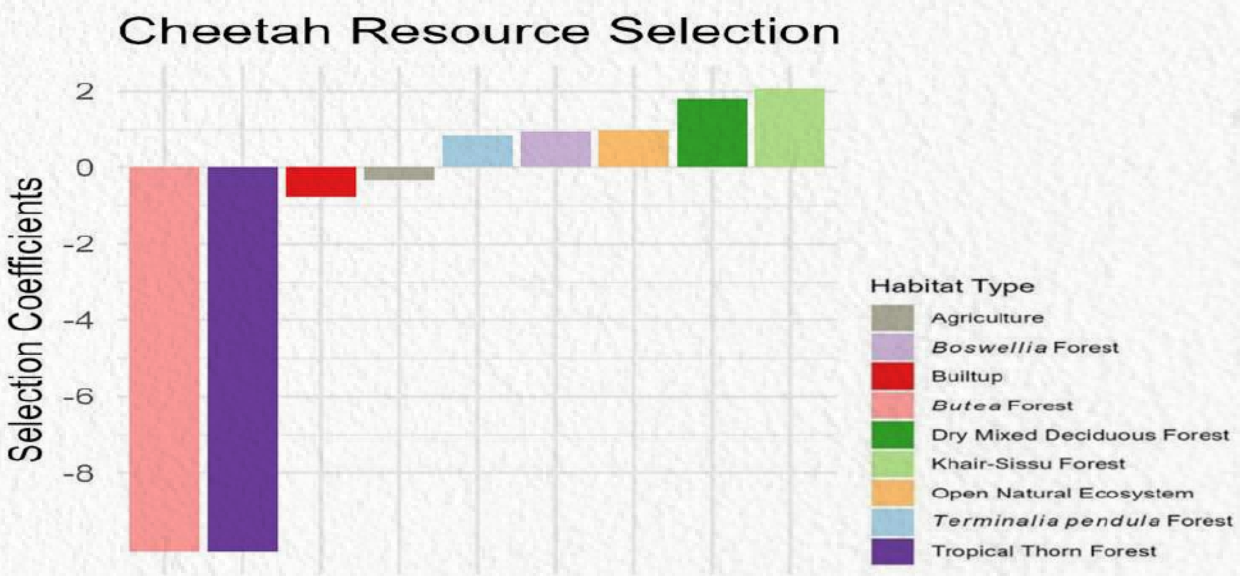


Figure 2.4.3.

Habitat selection of radio-collared free-ranging cheetahs in and around Kuno National Park using Resource Selection Function

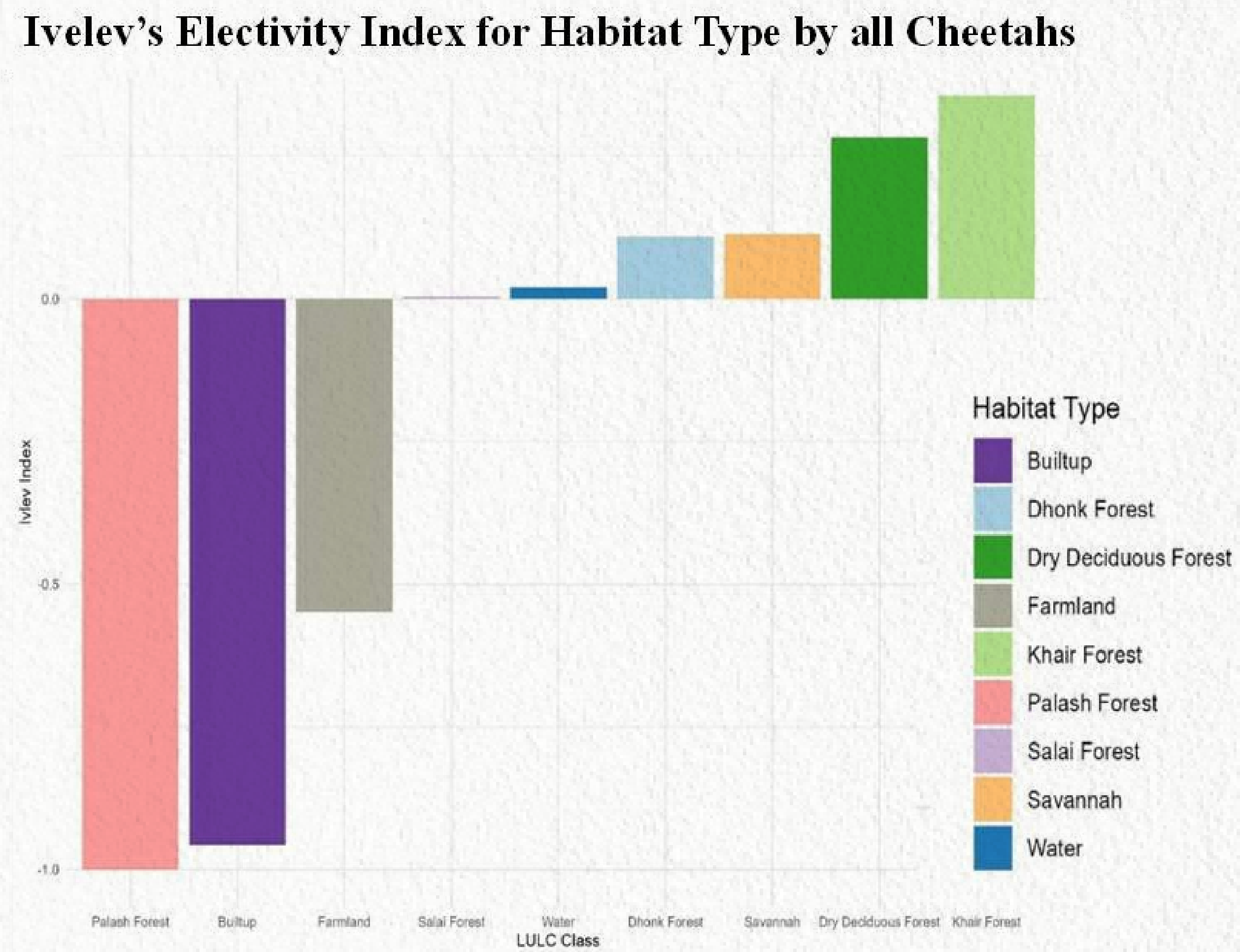


Figure 2.4.4.

Habitat selection of radio-collared free-ranging cheetahs using Ivlev's index in and around Kuno National Park

2.5. Comparative analysis of dietary preferences of cheetahs and co-predators in and around Kuno National Park using a metabarcoding approach

2.5.1. Introduction

Studying the dietary preferences of animals, the specific prey selection and frequency is fundamental to ecology and conservation. This information underpins knowledge about predator-prey dynamics and energy flow and reveals how species interact and coexist. Diet preferences influence survival and maintain ecosystem stability (Abraham *et al.* 2022); particular diet preferences also provide information about needed prey conservation for the long-term viability of the predators. Dietary niche partitioning and coexistence are well-recognized mechanisms that reduce competition among sympatric carnivores (Di Bitetti *et al.* 2009; Carvalho & Gomes, 2004; Shao *et al.* 2021). In rich carnivore communities, coexistence is often maintained through segregation along dietary, spatial, and temporal axes (Linnell & Strand, 2000; Schoener, 1983). Hence, robust knowledge about the diet of trophic relationships supports conservation planning and management of both predators and their prey.

Previous studies relying on morphological scat analysis, direct observation, or stable isotope profiling offered valuable insights into carnivore diets and niche partitioning. Many of these studies have informed various conservation strategies by indicating critical prey species, clarifying seasonal resource use, and also guiding conflict mitigation measures in human-wildlife interfaces. Yet traditional methods often suffer from low taxonomic resolutions, human errors, or detectability bias, particularly compromising the accuracy and missing the identification of small or highly degraded digested prey. Each of these methods has limitations in resolution, throughput, or non-invasive applicability. In particular, widely used morphological scat analysis often misses highly digested prey, while isotopes provide broad dietary categories, lacking fine taxonomic details (Villsen *et al.* 2022; O'Connor *et al.* 2024).

The new and modern metabarcoding approach has recently gained prominence because of its unbiased, highly informative, and non-invasive sample compatibility. It is a high-throughput, DNA-based method that uses broad-range primers and high-resolution next-generation sequencing to target and identify the broad spectrum of prey taxa simultaneously from a mixed environment and highly degraded samples such as fecal matter, gut content, water, air, and soil (Taberlet *et al.* 2012). This approach offers fine taxonomic resolutions, enabling detection of elusive, small, or highly degraded prey, which are usually tough to detect using the naked eye, overcoming a key shortcoming of traditional methods. Moreover, it allows processing of large-scale population samples with low effort and high efficiency (Villsen *et al.* 2022; O'Connor *et al.* 2024).

Multiple past studies have applied metabarcoding to assess dietary preferences and niche partitioning among coexisting species. In a study by Shao *et al.* (2021), a metabarcoding approach was used to reveal complex dietary webs across multiple large carnivore species in southwestern China, demonstrating niche separation along prey-size axes and uncovering keystone prey species that underlie ecosystem functioning. Similarly, a study by Lu *et al.* (2023), which analyzed carnivore communities on the Qinghai-Tibet Plateau, highlighted interspecific differences in prey composition, revealing how dietary partitioning forces coexistence even in highly competitive assemblages. Another study by Harper *et al.* (2020) used metabarcoding to compare diets of European otters (Lutra lutra) and invasive American mink (Neogale vison), demonstrating the clear trophic partitioning between the two semi-aquatic predators.

From a conservation perspective, metabarcoding helps in the identification of key species, quantification of niche overlaps, and understanding of food-web dynamics, which are very critical for ecosystem resilience and predator management (Bolnick *et al.* 2003; Villsen *et al.* 2022). Using this information about how resources are shared, this approach enables targeted conservation of prey resources, reduction of conflict risk (*e.g.*, livestock *vs.* wild prey), and enhanced planning for multispecies management.

Moreover, for species like the cheetah in India, diet monitoring is crucial for tracking the prey selection, habituation to new ecosystems, and signals whether their trophic requirements are met and to understand the pressure of existence with co-predators like the leopard, sloth bear, and striped hyena. The methodological advantages and ecological insights from metabarcoding make it a vital tool to evaluate the success of species restoration programs in such contexts. Hence, with this study, we tried to evaluate the current prey preferences and diet overlaps of cheetahs and co-predators such as leopards, sloth bears, hyenas, and jackals as a first step to understand how cheetahs are settling in the ecosystem.

2.5.2. Methodology

Non-invasive putative carnivore scat samples were collected across Kuno NP by field researchers. Cheetah scat samples were obtained during routine monitoring. All samples were preserved in silica gel and stored at -20°C until genomic DNA extraction. In total, 130 samples were processed for DNA isolation, including 37 from cheetahs and 93 from other putative carnivore scats. DNA extraction was performed following the Qiagen Stool Kit protocol. Successfully extracted DNA from 70 carnivore samples was subjected to species identification using universal Cytochrome b (cytb) primers (Kocher *et al.* 1989), and amplification was verified using gel electrophoresis. 63 samples were passed and further processed for Sanger sequencing. The resulting sequences were compared against the NCBI database using BLAST for taxonomic confirmation of putative carnivore samples.

Following species identification, all samples underwent PCR amplification using vertebrate-targeting 16S primers (Kitano *et al.* 2007) to detect both host and prey DNA. Amplified products from cheetah (37 samples), leopard (8 samples), sloth bear (7 samples), striped hyena (7 samples), and jackal (8 samples) were pooled based on species. DNA concentrations of pooled samples were measured using the Invitrogen Qubit 4 Fluorometer. These pooled samples were then processed for next-generation sequencing (NGS) on the Illumina platform.

The raw high-throughput sequencing data underwent a multi-step bioinformatics pipeline. Low-quality reads and adapter sequences were removed, and reads shorter than 20 bp were discarded using Trimmomatic v0.39 (Bolger *et al.* 2014) in paired-end mode. The remaining reads were merged using PEAR v0.96 (Zhang *et al.* 2014), converted to FASTA format, and only sequences between 200 and 300 bp were filtered and processed for further analysis. Filtered sequences were then clustered using CD-HIT v4.8.1 (Li & Godzik, 2006; Fu *et al.* 2012) at 95% nucleotide identity. Cluster representative sequences were aligned against a curated database using BLAST+ v2.5.0 (Camacho *et al.* 2013) using a query coverage threshold of 30% and a percentage identity threshold of 80%. The genus-level taxonomic assignments with corresponding read counts were derived based on cluster membership. Genus abundance tables were generated for each sample.

These genus-level abundance tables were processed in R (v4.5.0; R Core Team, 2025) for data compilation, cleaning, and visualization of dietary composition and overlap. Genus-level prey composition data were processed and analyzed in R using packages such as tidyverse (Wickham *et al.* 2019), dplyr (Wickham *et al.* 2023), vegan (Oksanen *et al.* 2025), pheatmap (Kolde, 2025), igraph (Csardi & Nepusz, 2006; Csardi et. al. 2024), and forcats (Wickham, 2017). The matrix for the genus-level composition of all the species was compiled, and reads associated with the host species were removed only for the corresponding data before further analysis. The Relative Read Abundance was calculated per sample and visualized through faceted genus-wise panels. Diet similarity between each species was assessed using Bray-Curtis Distances (Bray & Curtis, 1957) and visualized using clustered heatmaps. Diversity metrics, including Shannon diversity (Shannon, 1948), and genus richness were evaluated for each species using vegan to understand the genus richness and evenness.

2.5.3. Results

After processing the data of each sample through the bioinformatics pipeline, the distribution of reads is shown in table no. 2.5.1. In total, 32 prey genera were identified (Figure 2.5.1). Genus richness (Figure 2.5.2, right panel) was highest in leopard (20 genera), closely followed by cheetah and sloth bear (19 each), with jackal (16) and striped hyena (15) showing slightly lower richness. However, when compared with the Shannon diversity index (Figure 2.5.2, left panel), which incorporates both richness and evenness, notable differences were seen, with the jackal showing the highest dietary diversity (1.43), followed by cheetah (1.31), sloth bear (0.53), striped hyena (0.43), and leopard (0.22) with the lowest. These results showed that despite the high richness, the leopard's diet is highly dominated by only a single genus, *i.e.*, Bos, contributing 96% of its diet composition (Figure 2.5.3). Similarly, our results also showed Bos as a major prey for cheetahs (44.9%) and striped hyenas (91%). In contrast to this, the sloth bear diet is dominated by antelope (84.2%), with a significant contribution from Herpestes as well (16.5%). Jackal, however, displayed a balanced dietary profile, lacking a single dominant genus and even contribution across multiple genera.

Table 2.5.1.

Summary of read classification for each sample after pipeline processing.

Parameter	Cheetah	Striped Hyena	Jackal	Leopard	Sloth bear
Reads associated to Host Species	386927	514218	445811	435053	529873
Reads associated to Diet Species	11731	15181	1221	32737	24785
Total reads	398658	529399	447032	467790	554658

Figure 2.5.1.

Genus composition by faceted bar plots showing the relative abundance of various genera across five different samples: Cheetah (CH), Striped Hyena (HY), Jackal (JK), Leopard (LP), and Sloth Bear (SB). Each facet represents a different genus, with bar colours indicating relative abundance in each sample type.

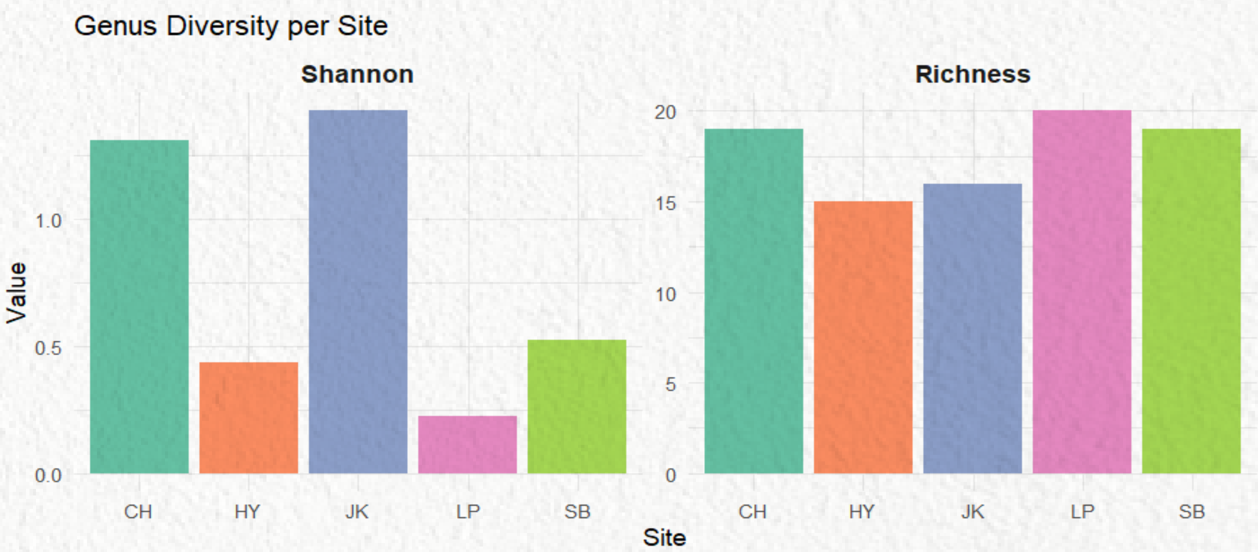


Figure 2.5.2.

Prey Genus Diversity and Richness in Carnivore Diets. Bar plots show (left) Shannon diversity, representing both richness and evenness of prey genera, and (right) prey genus richness for Cheetah (CH), Striped Hyena (HY), Jackal (JK), Leopard (LP), and Sloth Bear (SB).

The dominance of Bos and Antilope in the diet of these carnivores highlights reliance on large herbivore prey (Figure 2.5.3.). However, other genera also contribute, indicating dietary depth. For example, the cheetah's diet also involves Viverricula (36.8%) and Axis (1%), while the sloth bear's includes Herpestes (16.5%). Our data also reveal low-abundance genera in the diet, such as Paradoxurus, Hystrix, Manis, Suncus, Lepus, Mus and Rattus, suggesting opportunistic feeding on small mammals, particularly in jackals and cheetahs (Figure 2.5.4). Furthermore, typically on low frequencies, the presence of bird genera was also detected in the diet, including Bubalcus, Pavo, Corvus, Vanellus and Sterna, indicating broader opportunistic tendencies. The Bray-Curtis similarity matrix (Figure 2.5.5) shows high dietary dissimilarity among these species, with especially low overlap between species-specific dietary profiles.

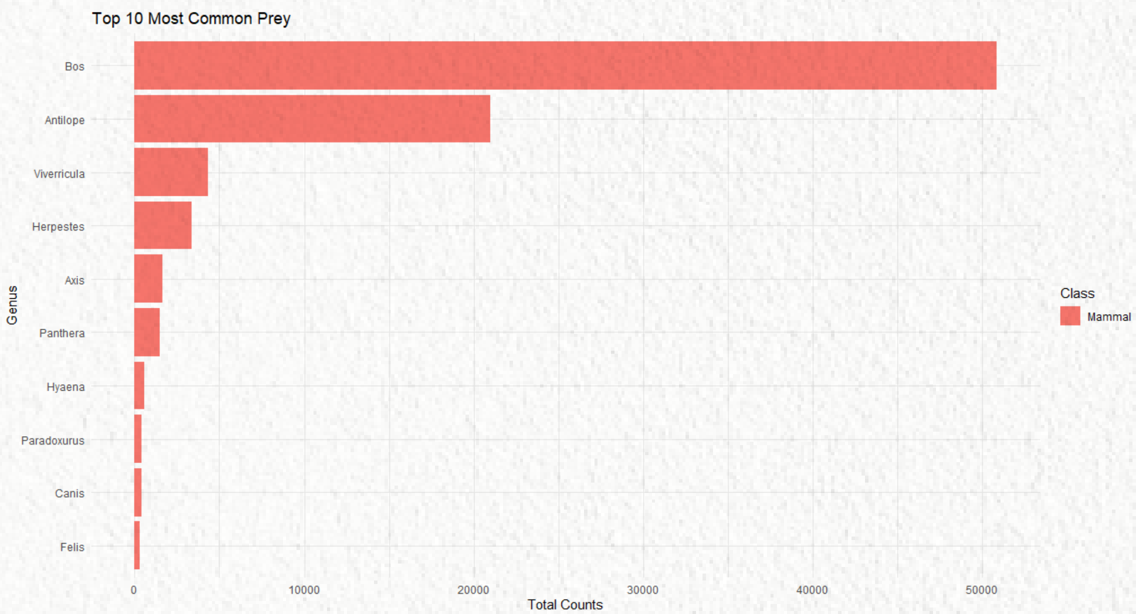


Figure 2.5.3.

Most Common Prey Genus. Bar plot highlighting the ten most frequently consumed prey genera across all carnivores. Bos and Antilope are especially dominant, indicating a heavy reliance on these large ungulates.

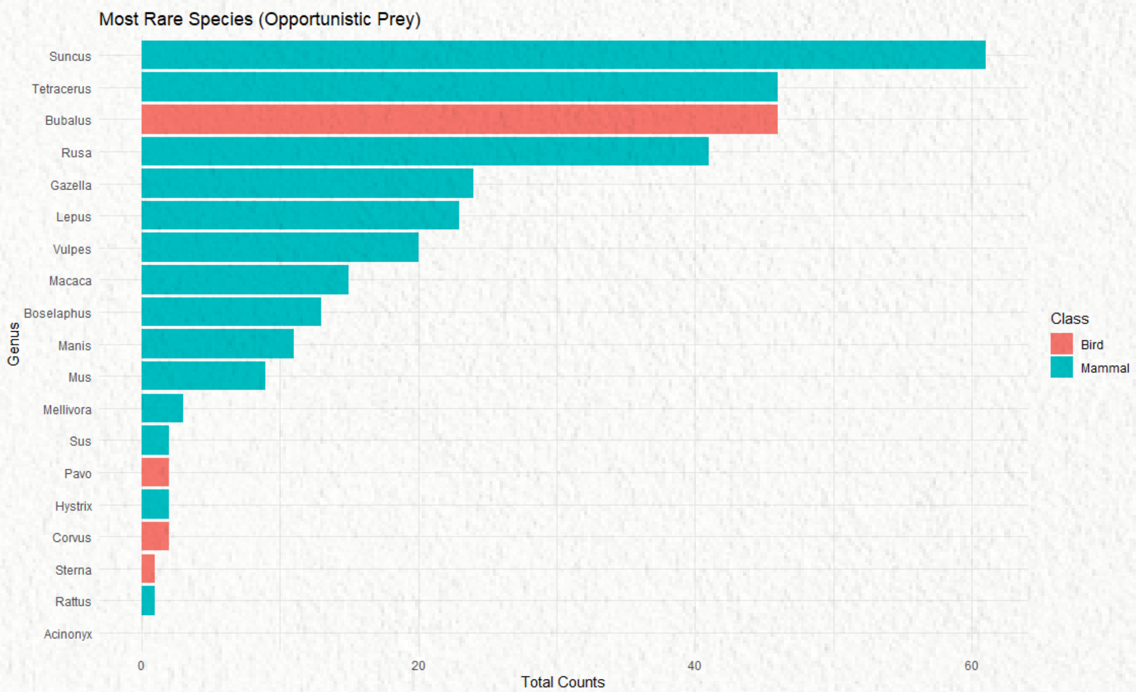


Figure 2.5.4.

Rare and Opportunistic Prey. Horizontal bar plot of infrequently detected genera in carnivore diets, coloured by class (mammals in blue, birds in red). The presence of small mammals and birds illustrates opportunistic feeding tendencies across species.

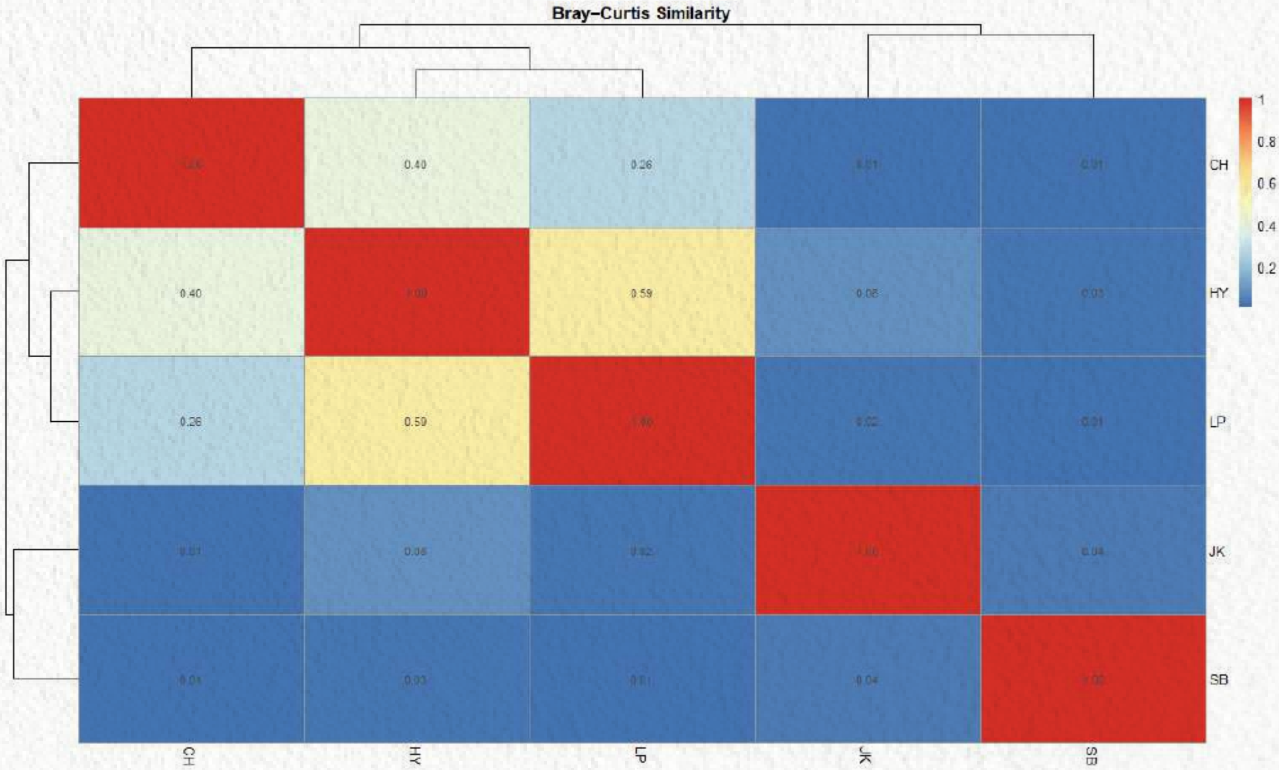


Figure 2.5.5.

Bray–Curtis similarity of carnivore diets. Heatmap of dietary similarity among the five carnivores, based on Bray–Curtis indices. Lower similarity values demonstrate distinct dietary preferences and limited overlap between species.

2.5.4. Discussion

Overall, our results have provided an overview of carnivore dietary ecology in the region, which can be important for the conservation implications, especially with the growing cheetah population. Leopards illustrated a case of dietary specialization, overwhelmingly focused on Bos, which could be majorly because of the high abundance of free-ranging cattle in Kuno NP, making them the easy prey. However, the heavy reliance of multiple species on Bos suggests potential for competitive interactions, especially if prey populations decline or habitat changes reduce abundances. While the striped hyena, jackal, and sloth bear, being scavenger species, have shown a high diversity of prey base ranging from large to smaller mammals. The dominance of Antilope in the sloth bear diet is possibly due to the sampling, as its distribution is concentrated outside the park, where most of the sloth bear samples were collected. We can further evaluate this using a more detailed study by understanding the full spectrum of the sloth bear diet by including plants and insects; this might provide us with a more detailed understanding of the species› diet. Our findings also highlight the importance of conducting thorough landscape-wide sampling for a more detailed study of dietary preference and niche partitioning among these carnivore species.

The cheetahs appear to be adapting with its diet, with significant utilization of Bos, possibly because of the easier prey, while Viverricula possibly reflects local prey availability. Its relatively high dietary diversity suggests it is exploring a wide prey base, possibly reflecting a period of ecological adjustments. The presence of opportunistic prey, particularly small mammals and birds, in the diet of cheetahs reflects both dietary plasticity and the capacity to exploit alternative or secondary food resources, which may buffer against prey shortages or seasonal fluctuations. Some of these patterns may also be influenced by mixed sampling and the shifting of cheetahs between compartments of the large closed natural area during sample collection. It is clearly seen that expanding cheetah populations while exploring Kuno NP has high potential for diet expansion to other major herbivore species in the region, such as chital, chousinga, nilgai, blackbuck, and chinkara.

No clear evidence of strong dietary overlap or direct competition was detected. However, limitations such as low sequencing depth and small sample sizes may have restricted the detection of rarer prey DNA, potentially underestimating diversity. These results should therefore be viewed as a preliminary ecological assessment, forming a foundation for more detailed dietary studies to evaluate prey preferences, niche overlap, and adaptive strategies, particularly in the cheetah population. Targeted sampling of currently free-ranging cheetahs is crucial to better understand their diet and integration into the local ecosystem.

2.6. Longitudinal monitoring of stress, nutrition and reproductive health and assessment of the physiological impacts on cheetahs in Kuno National Park

2.6.1. Introduction

In the animal kingdom, carnivores from the Felidae, Canidae, and Ursidae families are among the most at risk, facing a significant threat of extinction worldwide (Cardillo *et al.* 2006; Schipper *et al.* 2008; Ceballos *et al.* 2005). These remarkable predators endure substantial pressures, primarily from hunting, habitat destruction, and escalating negative interactions with humans (Morrison, 2007). Additionally, physiological stressors, including psychological strain and nutritional deficiencies, are known to severely impact the reproductive capabilities of these wild populations and heighten their vulnerability to parasites and disease outbreaks (Romero, 2004; Wikelski & Cooke, 2006; Charmandari *et al.* 2005; Busch & Hayward, 2009). Therefore, monitoring variations in psychological and nutritional stress across different populations is crucial for understanding how these external pressures affect the health and reproductive success of large carnivores. The data obtained from measuring these stress indicators are also essential tools for developing effective strategies to mitigate these pressures and for evaluating the success of conservation and management initiatives aimed at protecting these species (Millspaugh *et al.* 2004; Keay *et al.* 2006).

Natural and human-related disruptions significantly affect wildlife, leading to population declines due to poaching (Schipper *et al.* 2008), habitat loss, food shortages, and negative interactions. An animal's susceptibility is linked to its life stage and exacerbated by psychological and nutritional stress, which diminishes reproductive success (Millspaugh *et al.* 2004; Keay *et al.* 2006; Wingfield *et al.* 1997). For survival, animals engage in physiological or behavioural responses to environmental signals (Friend, 1980). To cope and restore balance, the body releases stress hormones, specifically glucocorticoids (Möstl & Palme, 2002). Although short-term stress can have beneficial effects (Moberg, 2000), chronic stress and elevated glucocorticoid levels negatively impact fitness (Munck *et al.* 1984) and reproductive health (Liptrap, 1993) and can lead to serious behavioural problems, ultimately reducing survival rates. Stress hormones work towards achieving homeostasis by releasing energy (glucose) and inhibiting functions such as reproduction and immune response. While this mechanism is beneficial in the short term, extended periods of stress can deplete energy reserves (Asterita, 1985; Broom *et al.* 1993), lowering reproductive potential and overall health while increasing disease vulnerability. Chronic habitat disruption leads to behavioural changes, suppressed reproduction, stunted growth, and weight loss, often evident later. Early identification of stress causes is vital for mitigating threats to animals, requiring focus on their behaviour, reproduction, and diet. Environmental disturbances greatly affect resource use, making access to necessary resources stressful or impossible. Monitoring nutritional and physiological stress, alongside reduced reproduction, effectively connects these impacts (Monfort *et al.* 1998; von der Ohe *et al.* 2004; Van Meter *et al.* 2009; Wasser & Waterhouse, 1983). Studies indicate that physiological stress (psychological and nutritional) weakens immunity, lowers disease resistance, and impairs reproduction (Keay *et al.* 2006; Monfort *et al.* 1998; Van Meter *et al.* 2009; Wasser & Waterhouse, 1983). Non-invasive measures of stress and nutrition, combined with resource selection data, effectively link environmental pressures to animal well-being. These accessible measures provide immediate physiological indices that reflect disturbances impacting population growth over time (Millspaugh *et al.* 2004; Keay *et al.* 2006; Wingfield *et al.* 1997). Monitoring animal physiology as part of conservation translocations helps understand their experience and adaptation to new environments (Tarszisz *et al.* 2014). This information is useful in understanding responses of translocated animals and developing management decisions regarding their health. Standard observations and long-term demographic changes are logistically challenging in the wild, and live-capture methods are intrusive and infrequent. Faecal sample collection offers extraordinary access, avoiding stress measures confounded by wildlife capture for blood withdrawal. Faecal hormone (Velloso *et al.* 1998; Wasser *et al.* 2000) measures integrate better over time, with each sample reflecting cumulative stress and parasites from prior exposures.

The flagship cheetah translocation program undertaken by the Government of India offered an excellent chance to observe the individual physiological patterns of the animals after translocation. It also created a unique opportunity to evaluate the physiology of these cheetahs from the outset, enhancing our understanding of various physiological factors (such as stress, nutrition, and reproductive cycles) that influence their survival and reproduction. Alongside regular ecological data (like prey density, habitat conditions, and disturbance parameters), the physiological and dietary insights are intended to provide vital management recommendations for these newly translocated animals. The main objectives are to (1) assess population-level physiological health of translocated cheetahs in Kuno National Park, Madhya Pradesh, focusing on the interplay between stress, nutrition, and reproductive health and (2) comparative assessment across temporal scales to elucidate physiological adaptations of cheetahs introduced to Kuno National Park, Madhya Pradesh. This section provides updates on the work conducted regarding the cheetah physiology component.

2.6.2. Methodology

2.6.2.1. Sample Collection

From August 2024 to February 2025, 176 scat samples were collected by the cheetah monitoring team/field staff from all cheetah individuals. The majority of these samples were collected from Closed Natural Area, a.k.a. Hunting bomas, a.k.a. Larger bomas (LB, n=150), followed by the Quarantine bomas (QB, n=17) and Free-ranging (FR, n=9) cheetahs in Kuno National Park, Madhya Pradesh. Of the 176 samples, 70 are from males, 92 from females, and the remaining 14 samples were unidentified. The samples were collected in a sterile manner to reduce any cross-contamination and stored in butter paper inside airtight zip-lock bags. After field collection, the samples were kept at -20°C at the field station in Kuno National Park. They were later transferred to the Wildlife Endocrinology Facility at WII, Dehradun, for further processing and analysis.

2.6.2.2. Sample Processing

2.6.2.2.1. DRYING & SIEVING

Frozen fecal samples (n=176) were thawed overnight, pulverized, and dried in disposable aluminum trays inside an oven (Promax Heating Oven, Techno Engineer, Dehradun) at 50°C for 72 hours. The dried samples were sieved through a fine 1 mm mesh to separate the fecal powder from any remaining coarse materials (such as bones and hair). The resulting well-homogenized fecal powder was used for hormone extractions.

2.6.2.2.2. HORMONE METABOLITE EXTRACTION

Each dried fecal powder sample (n=176) was thoroughly mixed, and 0.1 grams were weighed for hormone extraction. The extraction procedure involved suspending the weighed powder in 10 ml of 70% ethanol solution and vortexing it for 30 minutes. This was followed by centrifugation at 2200 rpm for 20 minutes (Wasser *et al.* 2010; Mondol *et al.* 2020). The hormone extracts were collected in 2 ml cryochill vials (1:10 dilution) and stored at -20°C in the freezer until assays.

Further, 0.1 grams of faecal powder from each sample were weighed and ashed individually in a muffle furnace (Model NSW-101, NSW, New Delhi, India) at 450°C for 1.5 hours. The weight of the ashed sample was measured again to determine the amount of inorganic matter (IOM). As suggested in Patel *et al.* (2021), samples with < 80% IOM were used for hormone assays (n=174).

2.6.2.2.3. ENZYME IMMUNOASSAY (EIA)

Based on the earlier standardized protocols (Ruhela *et al.* 2024), hormone metabolite measurements were conducted using the commercially available EIA kits for corticosterone (#ISWE007), triiodothyronine (#K056-H5), progesterone (#ISWE003), 17β-estradiol (#ISWE008), and testosterone (#ISWE001). During the assays, sample extracts were air-dried inside an incubator (Promax Bacteriological Incubator, Techno Engineer, Dehradun) and re-suspended in assay buffer (AB) according to the required dilutions (Table 2.6.1). Each sample (n=174) was assayed in duplicate following the respective kit protocols, and the optical density was measured at 450 nm using an ELISA plate reader (#EPOCH2, Agilent Technologies, California, USA).

Hormone metabolite concentration was interpolated using four parametric logistic curve (4PLC) regression functions from GraphPad Prism version 8 (GraphPad Software, California, USA). Cross-reactivities of the respective antibodies are listed in Table 2.6.1. The inter- and intra-assay coefficients of variation for the assays were calculated (Table 2.6.1).

Table 2.6.1.

Details for fecal hormone assay of cheetah

Hormone	Dilution	Inter-Assay CV	Intra-Assay CV	Cross-reactivities
Corticosterone	1:1280	4.21	4.34	100% with corticosterone, 12.30% with Desoxycor-ti-costerone, 2.30% with Tetrahydrocorticosterone and <1% with Aldosterone, Cortisol, Progesterone, Dexamethasone, Corticosterone-21-Hemisuccinate, Cortisone and Estradiol
Triiodothyronine	1:40	3.13	2.18	100% with T3, 0.88% with thyroxine, and less than 0.1% with reverse T3 (3,3',5'-Triiodo-L-thyronine)
Progesterone	1:200	4.13	4.15	100% with Progesterone, 172% with 3β-hydroxy-progesterone, 188% with 3α-hydroxy progesterone, 147% with 11α-hydroxy progesterone, 2.7% with 11β-hydroxy-progesterone, 7% with 5- α-hydroprogesterone, 5.9% with Pregnenolone, & less than 1% with Corticosterone & Androstenedione
17β-estradiol	1:80	4.7	5.36	100% with 17β-Estradiol, & less than 1% with Estrone, 17α-Estradiol, 17α-Ethynylestradiol, Estrone sulfate, Progesterone, Testosterone, 5α-dihydroprogesterone, cortisol, corticosterone
Testosterone	1:160	4.13	4.8	100% with Testosterone, 56.8% with 5a-Dihydrotestosterone, 2.34% with 11-Ketotestosterone, & less than 1% with Androstendione, Androsterone, DHEA, Cholesterol, 17β-Estradiol, Progesterone, Pregnenolone, Hydrocortisone, Cholic Acid, Cholic Derivatives, Aldosterone, Cortisol, Corticosterone, Cortisone

2.6.3. Data Analysis

Before conducting any data analyses, hormone concentration values were log-transformed, and their distributions were assessed using the Shapiro–Wilk test. Because the data exhibited a non-normal distribution, non-parametric statistical tests were utilized. All analyses were performed using PAST 4.03 Software (Hammer *et al.* 2001) and GraphPad Prism Version 8 (GraphPad Software, California, USA).

Following biochemical validation, which established the reliability of hormone data, we conducted biological validation to assess the physiological relevance of targeted hormone (P4, E2, T & GC) measurements in relation to different reproductive stages (pregnant (n=27) & non-pregnant (n=64)) in females) using Mann-Whitney U tests. We also investigate the relationship between age and testosterone levels in males: fTM levels in older male individuals (Agni & Vayu, (n=17), close to 10 years old) were compared with the younger males (Prabhas & Pawak (n=34) & Gaurav,(n=14), aged between 6 to 8 years), using the Kruskal-Wallis and Mann-Whitney U tests. Furthermore, continuous sample collection from two female individuals (Veera & Nabha) over a period of 4 to 5 consecutive months enabled the generation of individual hormonal profiles to examine variations across different reproductive stages.

We compared faecal stress (fGCM) and nutritional (fT3M) hormone measures among three major groups of translocated cheetahs (based on their locations) in Kuno National Park: Quarantine bomas (QB; n=15), Closed Natural Area a.k.a Hunting bomas a.k.a. Larger bomas (LB; n=150), and Free-ranging (FR; n=9). The Kruskal-Wallis and Mann-Whitney U tests were used to determine any statistically significant differences among the hormone levels. Additionally, hormone level differences were compared between sexes (males (n=70) and females (n=92)) and within male Coalition (Agni & Vayu, n = 7; Prabhas & Pawak, n = 34) and Solitary (Gaurav, n = 9; Vayu, n = 14) groups using the Mann-Whitney U test.

For reproductive hormones (progesterone (fP4M), estradiol (fE2M), and testosterone (fTM) metabolites), differences were examined using the Mann-Whitney U test between different sex groups (male (n=70) and female (n=92)).

Finally, to ascertain the temporal physiological adaptations of the released cheetah individuals, we conducted pairwise comparisons between the current year's samples (August 2024 to February 2025) (n=174; ♂=70, ♀=92) and previous year's samples (September 2022 to February 2024) (n=160; ♂=64, ♀=96), stratified by group and sex.

2.6.4. Results & Discussion

2.6.4.1. Biological validation of targeted hormones and hormonal profiling of selected individuals

2.6.4.1.1. PREGNANT *VS.* NON-PREGNANT FEMALE CHEETAHS

Comparative analysis between pregnant and non-pregnant females revealed significantly higher fecal metabolite concentrations of fP4M ($p<0.0001$) (Figure 2.6.1a), fE2M ($p=0.002$) (Figure 2.6.1b), fTM ($p<0.0001$) (Figure 2.6.1c), and fGCM ($p=0.001$) (Figure 2.6.1d) during the pregnant state (Table 2.6.2).

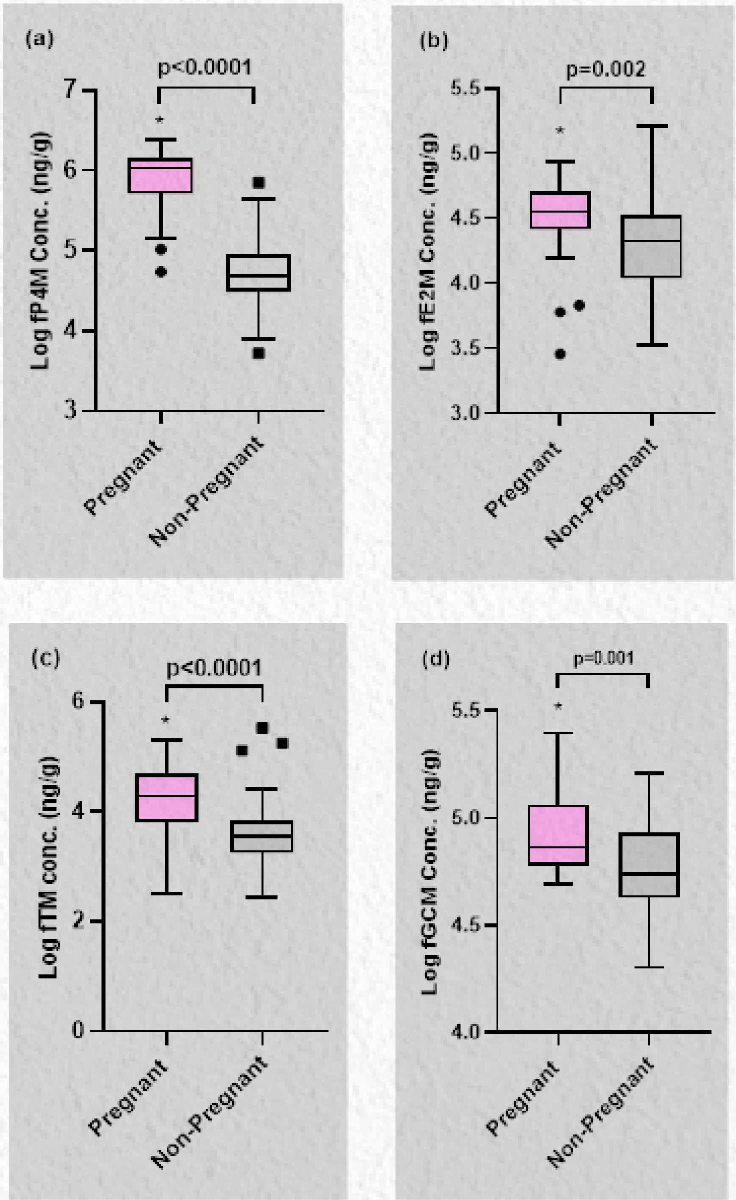


Figure 2.6.1.
Pairwise comparison of (a) fP4M (b) fE2M (c) fTM (d) fGCM levels of pregnant (n=27) and non-pregnant female cheetah samples (n=64), * Indicates significant differences

Table 2.6.2.

Details of hormone metabolite concentration ranges in different female cheetah reproductive states

Reproductive state	fP4M (ug/g)	fE2M (ug/g)	fTM (ug/g)	fGCM (ug/g)
Pregnant	54.6 – 2437.7	2.8 – 86.3	0.3 – 205.7	48.8-248.1
Non-pregnant	5.2 – 708.3	3.3 – 162.3	0.2 – 337.4	19.9- 160.5

2.6.4.1.2. AGE-BASED ANALYSIS OF TESTOSTERONE IN MALE CHEETAHS

An age-based analysis of fTM levels in male cheetahs detected a significant difference in testosterone across age groups (p=0.006). Comparative analysis showed expectedly higher fTM levels in Prabhas & Pawak (p=0.001) and Gaurav (p=0.03) compared to older male cheetahs Agni & Vayu (Figure 2.6.2.), indicating a decline in testosterone levels at higher age groups (Zirkin *et al.* 2012). However, no significant difference in overall fTM levels was found between Prabhas & Pawak and Gaurav (p=0.64) (Figure 2.6.2).

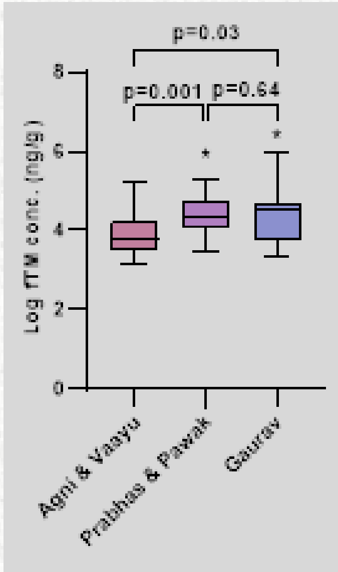


Figure 2.6.2.
Comparative analysis of fTM levels in male cheetahs across different age classes/individual groups,
* Indicates significant differences

2.6.4.1.3. HORMONAL PROFILING OF SELECT CHEETAH INDIVIDUALS

We created an illustrative hormone profile for a female cheetah named Veera using samples (n=27) collected between October 2024 and January 2025, during which this individual experienced both pregnant and non-pregnant phases (Figure 2.6.3). The profile indicates fluctuations in all five target hormones (GC, T3, P4, E2, and T) between these phases. Previous studies also reported similar findings (Brown *et al.* 1996; Koester *et al.* 2022).

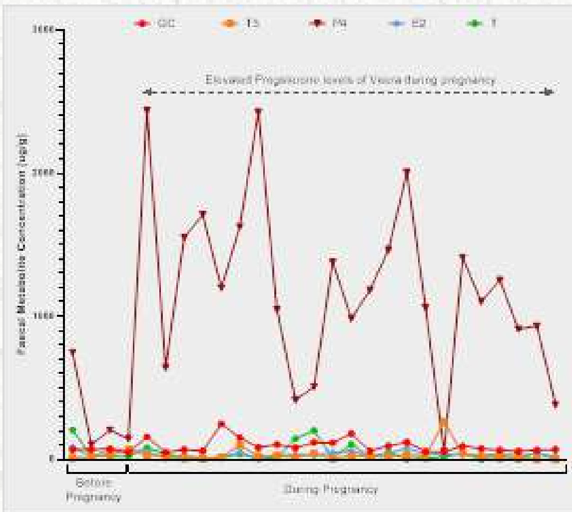


Figure 2.6.3.
Illustration of hormonal profile of female cheetah Veera

Similarly, multiple hormone profiles for another female cheetah, Nabha, were created using samples (n=35) collected between October 2024 and February 2025. This profile showed the hormone variations associated with potential non-pregnant luteal and estrous phases (Figure 2.6.4), as reported by Brown *et al.* (1996) and Koester *et al.* (2022).

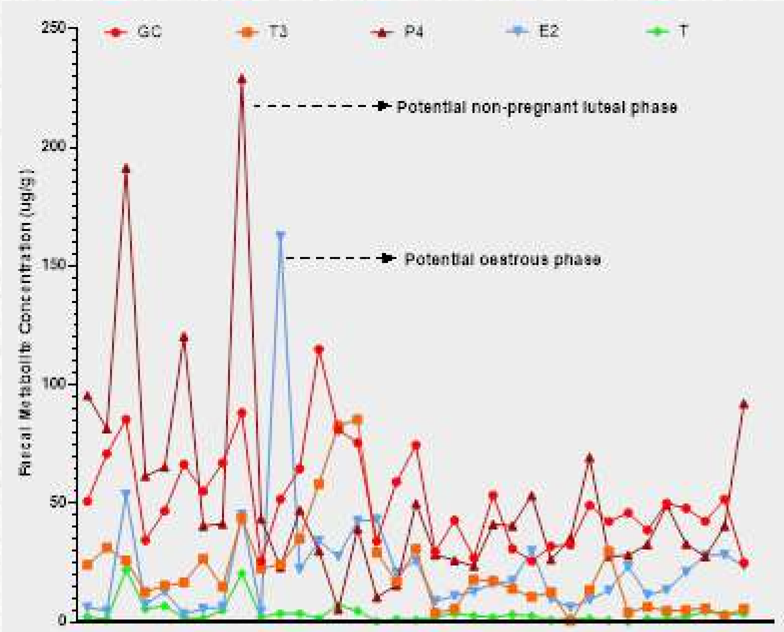


Figure 2.6.4.
Illustration of hormonal profile of female cheetah Nabha

2.6.4.2. Comparative analysis for stress hormone (fGCM) in cheetahs

Analysis of fGCM showed no significant differences between the groups (QB, LB, FR) in either pooled (p = 0.13) or pairwise comparisons (p > 0.05, Figure 2.6.5).

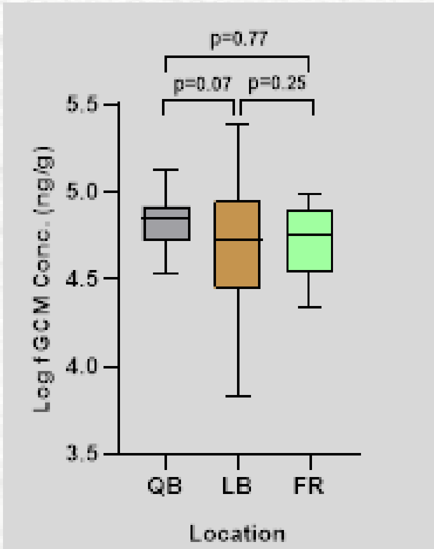


Figure 2.6.5.
Comparison of fGCM in cheetahs among all three categories (QB=17, LB=150, FR=9)

The pairwise analysis by sex revealed a statistically significant difference in fGCM levels between males and females (p = 0.0002) (Figure 2.6.6). The higher fGCM levels in females may result from fluctuations linked to different reproductive stages.

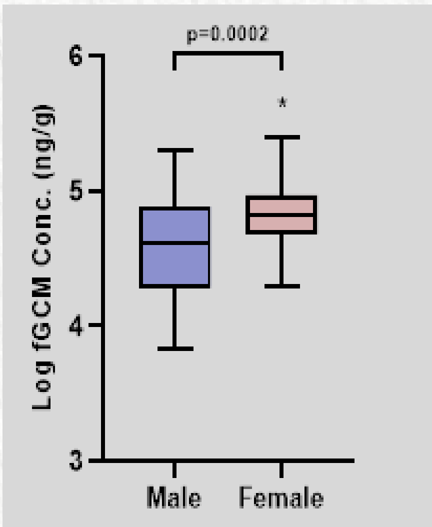


Figure 2.6.6.
Pairwise comparison of fGCM levels in male (n=70) and female cheetah samples (n=92), * Indicates significant differences

Pairwise comparisons of fGCM concentrations revealed a significant elevation in solitary males compared to coalition males (p<0.0001), indicating heightened physiological stress during social isolation versus coalition phases. No significant differences in fGCM levels were found among distinct coalition groups (p=0.52). However, comparisons showed higher fGCM concentrations in male cheetah Gaurav, who experienced prolonged solitude after his coalition partner Shaurya's death, compared to Vayu, recently separated from his coalition partner Agni for a short time (p=0.017) (Figure 2.6.7).

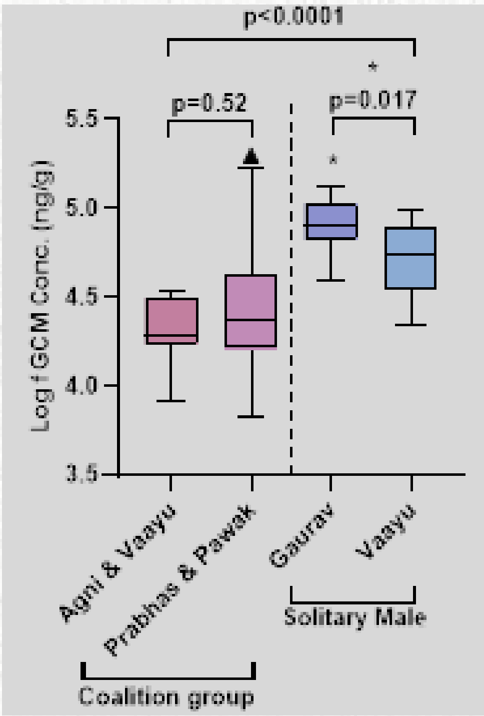


Figure 2.6.7.
Inter and intra group pairwise comparison of fGCM levels in cheetahs between solitary male (Gaurav, n = 9; Vayu, n = 14) and coalition males (Agni & Vayu, n = 7; Prabhas & Pawak, n = 34), * Indicates significant differences

2.6.4.3. Comparative analysis for nutritional hormone (fT3M) in cheetahs

Analysis of fT3M revealed significant variation across the three groups (p=0.0002). Pairwise analysis indicated that the QB group presented significantly elevated fT3M concentrations compared to both the LB (p<0.0001) and FR (p=0.006) groups. However, fT3M levels between the LB and FR groups did not differ significantly (p=0.6, Figure 2.6.8), potentially due to similar conditions regarding resource/food availability.

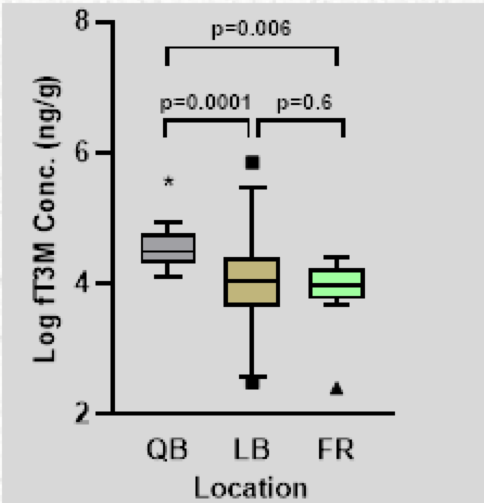


Figure 2.6.8.
Comparison of fT3M in cheetahs among all three categories (QB=17, LB=150, FR=9), * Indicates significant differences

In the pairwise sex-based analysis, the fT3M levels of females were significantly higher than those of males (p < 0.0001), as depicted in Figure 2.6.9.

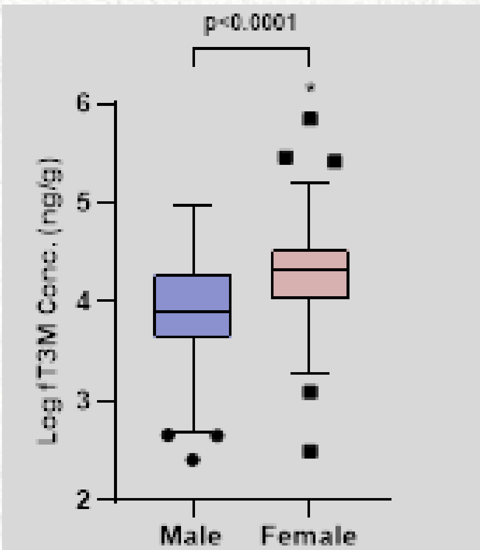


Figure 2.6.9.
Pairwise comparison of fT3M levels of male (n=70) and female cheetah samples (n=92), *Indicates significant differences

For fT3M analysis, solitary males exhibited significantly elevated levels compared to male coalitions (p=0.016). In contrast, no statistically significant differences in fT3M levels were observed between the two coalition groups (p=0.29) or between the two individual males (p=0.06) (Figure 2.6.10).

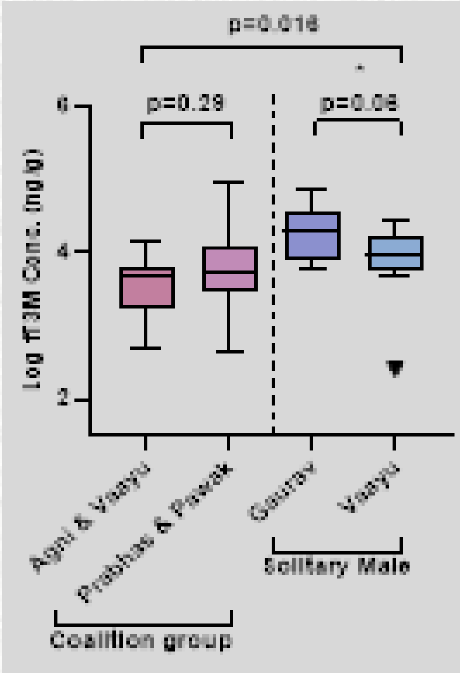
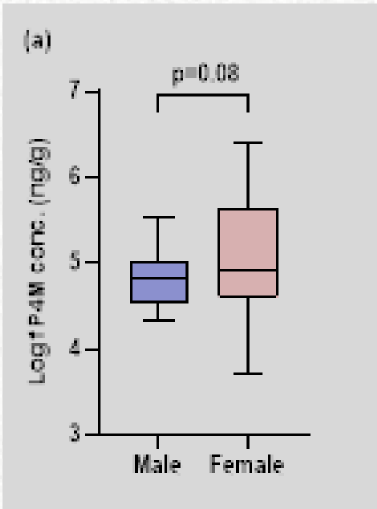
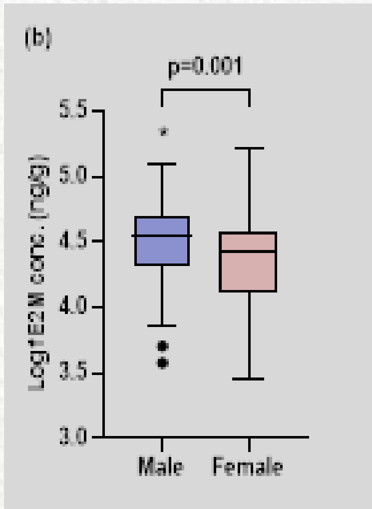


Figure 2.6.10.
Inter and intra group pairwise comparison of fT3M levels in cheetahs between solitary males (Gaurav, n = 9; Vayu, n = 14) and coalition males (Agni & Vayu, n = 7; Prabhas & Pawak, n = 34), * Indicates significant differences

2.6.4.4. Comparative analysis for reproductive hormones (fP4M, fE2M & fTM) in cheetahs

In a gender-based analysis, no significant difference was observed in fP4M levels between males and females (p=0.08, Figure 2.6.11a). In contrast, and unexpectedly, males exhibited significantly higher levels of fE2M compared to females (p=0.001, Figure 2.6.11b). As expected, males showed significantly higher fTM levels than females (p<0.0001, Figure 2.6.11c).





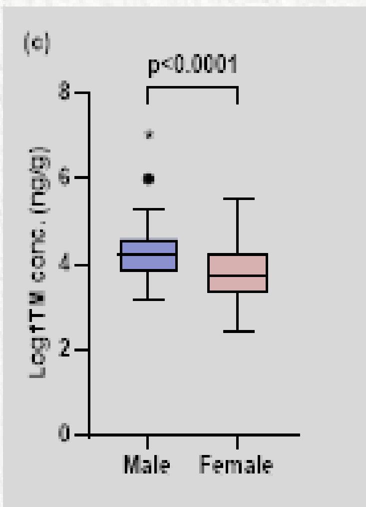


Figure 2.6.11.
Pairwise comparison of (a) fP4M, (b) fE2M & (c) fTM levels of male cheetah samples (n=70) and female cheetah samples (n=92),
* Indicates significant differences

2.6.4.5. Temporal scale analysis of stress (fGCM) and nutritional (fT3M) hormone levels in cheetahs

A statistically significant reduction ($p<0.0001$) in faecal glucocorticoid metabolite (fGCM) levels was observed in the translocated cheetahs when samples from last year's cohort were compared with those of the current year (see Figure 2.6.12a; Table 2.6.3). fGCM levels in the older sample set were significantly higher than in the recent samples. Additionally, temporal analysis within the same sex group showed a significant decrease ($p<0.0001$) in fGCM levels over time for both male and female individuals (refer to 2.6.12a; Table 2.6.3), suggesting possible physiological adaptation to the new environment following translocation.

Further, fT3M levels showed a comparable trend, as samples from the previous year revealed significantly higher concentrations ($p<0.0001$) than those collected this year, regardless of population level or gender stratification (Figure 2.6.12b; Table 2.6.3). The results may be attributed to the differing contexts in which the samples were collected. The earlier samples were largely from the quarantine phase, having access to provisioned food. Conversely, most samples from the current year were gathered from larger enclosures in a natural wild setting, requiring active foraging for food.

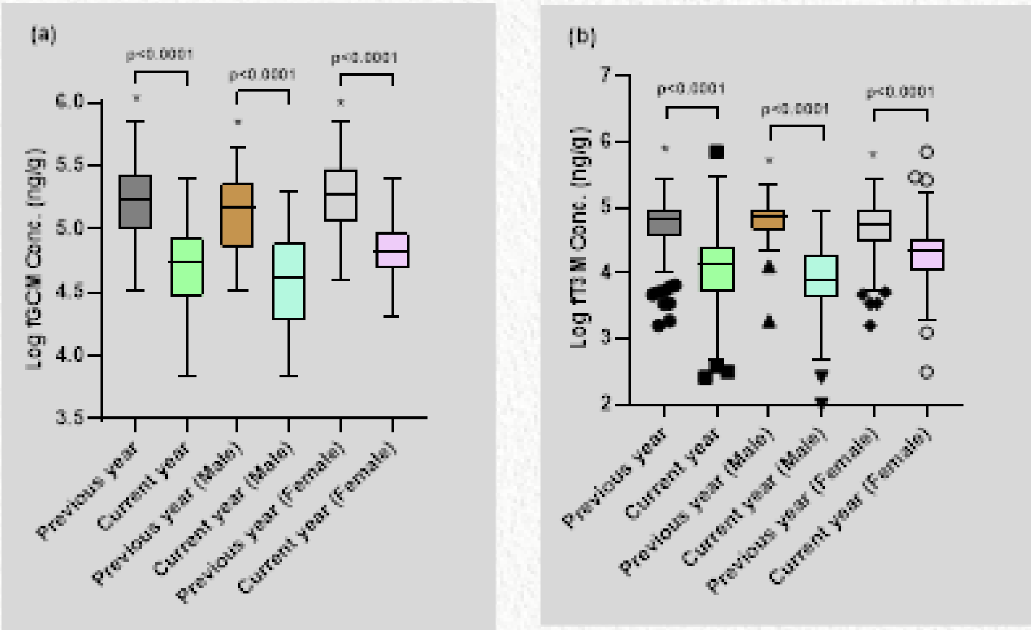
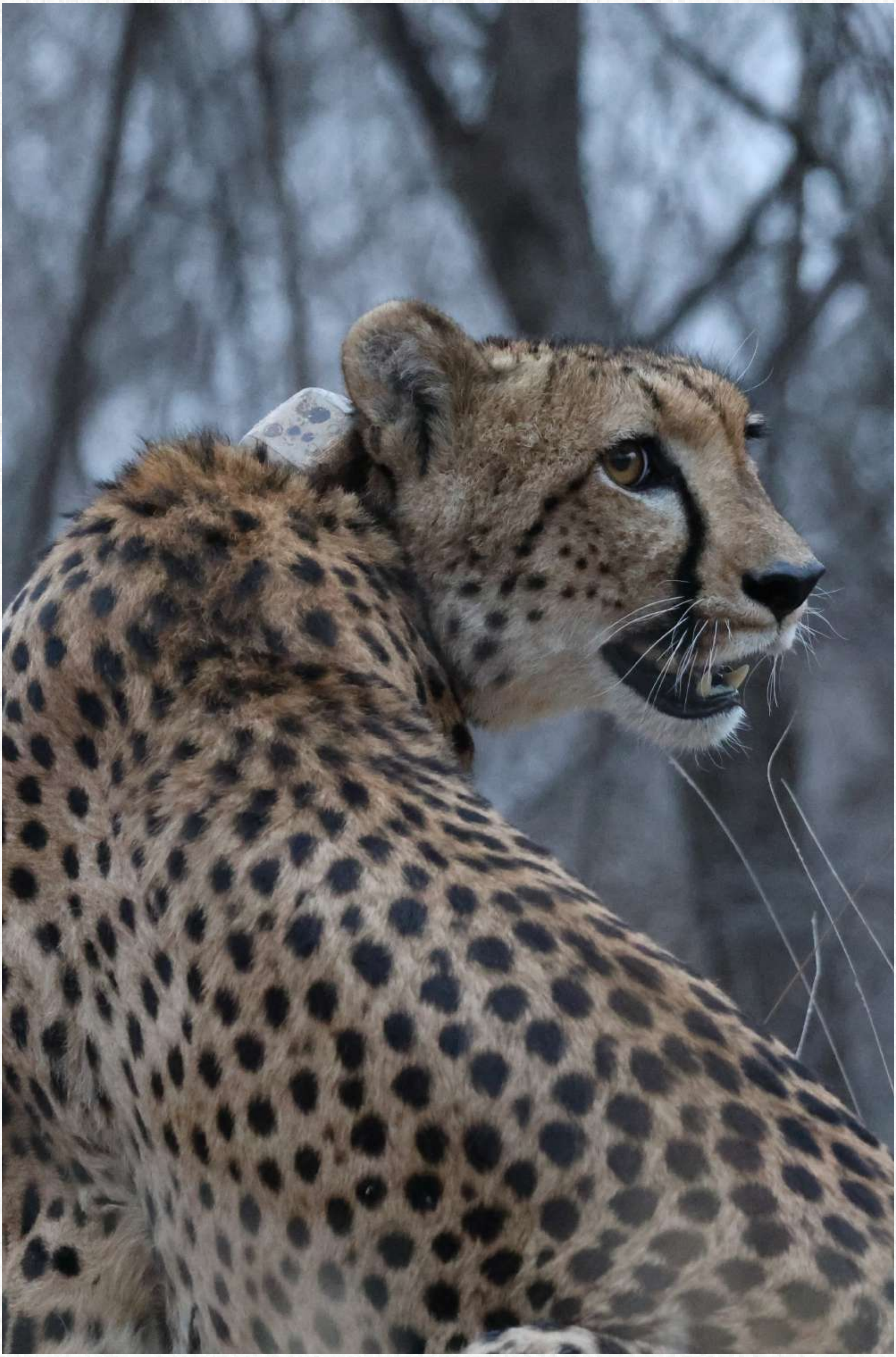


Figure 2.6.12.
Pairwise comparison of (a) fGCM and (b) fT3M levels of cheetah samples from previous year (n=160; ♂=64, ♀=96) & current year (n=174; ♂=70, ♀=92), * Indicates significant differences

Table 2.6.3.
Details of hormone metabolite concentrations in various sample groups of cheetahs

Sample Batch/Gender	fGCM (ug/g)	fT3M (ug/g)
Previous year (September 2022 to February 2024)	32.82 – 703.4	1.5 – 280.8
Current year (August 2024 to February 2025)	6.78 – 248.1	0.2 – 707.3
Previous year (Male)	32.82 – 449.8	1.8 – 226.3
Previous year (Female)	39.37- 703.4	1.5 – 280.8
Current year (Male)	6.78- 198.1	0.2 – 92.2
Current year (Female)	19.59 – 248.1	0.3 – 707.3



2.6.5. Conclusion

In the first year of cheetah physiology monitoring, we standardized analytical protocols for five hormone measurements: faecal glucocorticoid (fGCM), triiodothyronine (fT3M), progesterone (fP4M), testosterone (fTM), and estradiol (fE2M) metabolites. This enabled reliable generation of endocrine data (see Ruhela *et al.* 2024 for detailed methodology). We also established baseline information regarding stress, nutrition, and reproductive measures from the translocated cheetah individuals. During the second year, we successfully conducted biological validations for these hormones using strategically collected faecal samples from the same populations. The final standardizations for non-invasive cheetah physiological monitoring have been completed after combining the data from both years (biochemical and biological validations). The physiological data generated from both years revealed important insights.

Overall, fGCM levels showed no significant variation across locations, but females consistently showed higher fGCM levels than males, a trend noted in the previous year. This heightened stress endocrine activity in females seems related to their reproductive status, with pregnant females exhibiting higher fGCM levels compared to their non-pregnant counterparts. Interestingly, solitary males had elevated stress hormone levels compared to those in coalitions, highlighting the possible protective effect of social grouping. Importantly, a temporal analysis indicated a notable decrease in fGCM levels over time across both populations and genders, suggesting a physiological adaptation to this new environment.

Evaluations of nutritional status through fT3M levels indicated that QB had a relatively superior nutritional condition compared to LB and FR. This disparity is likely due to the transition from a controlled, provisioned diet to the need for hunting in the wild. Generally, females showed higher fT3M levels than males. No notable differences in fT3M were found between male social units (coalition *vs.* solitary). Over time, fT3M levels significantly decreased, which may be linked to their shifting to larger enclosures in wild environments.

Pregnant females showed elevated levels of all three reproductive hormones, particularly fP4M, which increased significantly during gestation.

As expected, males exhibited higher fTM levels than females. Furthermore, among the male population, young adult males showed greater fTM concentrations compared to older individuals.

Finally, systematic and longitudinal sampling of two female individuals (Veera & Nabha) across 4-5 months enabled the creation of distinct hormonal profiles, yielding significant insights into their reproductive cycles and estrous stages.

In summary, the faecal hormone analysis provides crucial baseline data on the translocated cheetahs' health, revealing insights into their stress responses (affected by sex, reproductive status, and social dynamics), nutritional condition (influenced by diet and environment), and reproductive patterns. Decreases in stress markers indicate some amount of physiological adaptation to the new environment. These findings are essential for ongoing monitoring and effective management strategies aimed at ensuring the long-term success of the cheetah translocation program.

Successfully implementing non-invasive physiological monitoring via faecal hormone analysis has established a strong basis for evaluating the overall health and reproductive status of the translocated cheetah population. Ongoing longitudinal sampling of males and females from various age groups and social structures is essential for creating comprehensive, individualized hormonal profiles. Future monitoring should involve a larger sample size to validate the trends observed and ensure the data accurately reflects the full range of physiological and reproductive conditions within the population. Building on the insights from this initial phase, subsequent efforts should concentrate on expanding and refining the methodology to improve the understanding of the cheetahs' adaptation processes and their long-term sustainability in a new environment. By continually enhancing this foundational data, the cheetah translocation project can adapt and refine its strategies to better support the translocated cheetahs, facilitating their successful reintegration into the wild and aiding their long-term survival.

2.7. Gandhi Sagar: India's Second Home for Cheetahs

As part of India's plan to bring cheetahs back to the wild, three cheetahs were moved to Gandhi Sagar Wildlife Sanctuary (WLS) in Madhya Pradesh, the country's second chosen site for cheetah release. Before translocating them, a team including scientists and managers carefully studied the area and prepared a detailed action plan. Between April and September 2025, two male and one female cheetah were released into a large fenced close natural area of ~64 km² in the Sanctuary's West Range as part of metapopulation management.

Gandhi Sagar WLS covers an area~368 km², whereas the potential cheetah habitat around is much larger. Including the nearby forests in Neemuch, Mandsaur in Madhya Pradesh and parts of Rajasthan, the connected habitat stretches to nearly 2,500 km², and the broader forested region across both states covers about 6,500 km². Managing this landscape will need long-term cooperation between Madhya Pradesh and Rajasthan (Quereshi *et al.* 2024). The Sanctuary is located on the Malwa Plateau, with the Chambal River running through its middle, dividing it roughly in half. To the south of the Sanctuary, the Gandhi Sagar Dam reservoir acts as a natural boundary. Elevation in the Sanctuary ranges from 346 m - 518 m above mean sea level. The area was officially declared a PA in 1974 and situated in the semi-arid zone that receives around 880-1,000 mm of rain each year. Summers can be scorching, reaching up to 42°C, while winters cool down to about 10°C.

The landscape is quite varied with rocky plateaus, river valleys, steep cliffs, and open grasslands. This mix of terrain is actually ideal for cheetahs, which prefer open, grassy areas where they can spot and chase prey. According to Champion & Seth (1968), Gandhi Sagar WLS supports three forest types: Northern Tropical Dry Deciduous Forest, Northern Tropical Dry Mixed Deciduous Forest, and Dry Deciduous Scrub Forest. Dominant tree species include *Butea monosperma*, *Lannea coromandelica*, *Senegalia chundra*, *Ziziphus mauritiana*, *Terminalia elliptica*, *Stereospermum colais*, *Terminalia pendula*, *Flacourtia indica*, *Boswellia serrata*, *Sterculia urens*, *Diospyros melanoxylon*, and *Mitragayna parvifolia*. Grass cover is abundant and diverse, with species such as *Cynodon dactylon*, *Aristida adscensionis*, *Bothriochloa bladhii*, *Eragrostis sp.*, *Chloris virgata*, *Digitaria ciliaris*, *Heteropogon contortus* , *Themeda quadrivalvis*, *Apluda mutica*, *Setaria viridis*, *Dactyloctenium aegyptium*, *Chrysopogon fulvus*, *Digitaria decumbens*, *Urochloa ramosa*.

Wildlife here is rich and diverse with carnivores such as leopard, sloth bear, striped hyena, caracal (*Caracal caracal*), Indian wolf, golden jackal, Indian fox, ratels/honey badgers, jungle cat, rusty-spotted cat, Asiatic wildcat, common palm civet, small Indian civet, and Indian grey mongoose. Common herbivores and omnivores include nilgai, chinkara, wild pig, grey langur, Indian porcupine, black-naped hare , and Indian pangolin (*Manis crassicaudata*). Aquatic fauna includes the smooth-coated otter (*Lutrogale perspicillata*) and the marsh crocodile (*Crocodylus palustris*). The area is also significant for avifauna, particularly critically endangered vultures such as the red-headed vulture (*Sarcogyps calvus*), Indian vulture (*Gyps indicus*), and white-rumped vulture (*Gyps bengalensis*). This landscape also shelters the critically endangered lesser florican (*Sypheotides indicus*).

However, the Sanctuary is subjected to various pressures from anthropogenic activity. Thousands of people live nearby, with an average population density of around 237 people per km² in surrounding districts. Livestock grazing is high, with about 88 cattle or buffalo and 45 goats or sheep per square kilometre. A road (state highway) cuts through the Sanctuary, fishing communities have settled along the reservoir, and the Gandhi Sagar township, built during dam construction, continues to grow right in the heart of the area. Farming is the main livelihood for local communities, with crops ranging from wheat and maize to coriander, fennel, orange and even regulated opium cultivation, which is a legal and economically important crop in the region. Communities like the Bhil, Gurjar, Banjara, and Thakur call this landscape their home, and continuous cooperation from these communities will be essential for the cheetah programme to succeed in this landscape.

Despite these challenges, Gandhi Sagar remains one of the most promising places in India to build a cheetah population for the long-term. The habitat is large, the ecosystem is diverse, and steps like predator-proof fencing are already in place. With continued work on restoring grasslands, boosting prey numbers, and building trust with local communities by the forest department and scientific inputs from authorizing agencies, this landscape could genuinely become a safe and thriving home for cheetahs in the years ahead.

Table 2.7.1.
Key Features of the Gandhi Sagar Landscape.

Attribute	Details
Location	Western Madhya Pradesh (Mandsaur & Neemuch) and adjoining Rajasthan (Chittorgarh, Baran, Jhalawar, Kota, Bundi)
Protected Areas	Gandhi Sagar WLS (368.62 km²), Bhainsrodgarh WLS (~208 km²), adjoining territorial forests of Neemuch (~1,000 km²), Mandsaur (~500 km²), and Chittorgarh (~1,000 km²)
Total Potential Cheetah Habitat	~2,500 km² (within a larger ~6,500 km² forested transboundary landscape)
Biogeographic Zone	Semi-arid Gujarat–Rajputana zone (4b)
Altitude	300–500 m above mean sea level
Climate	Annual rainfall 880–1000 mm; summer max 42°C; winter min ~10°C
Habitat Types	Northern Tropical Dry Deciduous Forest, Northern Tropical Dry Mixed Deciduous Forest, and Dry Deciduous Scrub Forest
Major Habitat Types	Open savannah, Woody savannah, Mixed Forest, Riverine Forest
Dominant Flora	*Butea monosperma, Boswellia serrata, Terminalia pendula, Diospyros melanoxylon, Terminalia arjuna, Ziziphus jujuba.*
Key Grasses	*Apluda mutica, Cynodon dactylon, Dichanthium annulatum, Heteropogon contortus, Vetiveria zizanioides, Themeda quadrivalvis.*
Major Fauna	Cheetah, leopard, sloth bear, striped hyena, Indian wolf, caracal, golden jackal, Indian fox, jungle cat, rusty-spotted cat, nilgai, chinkara, wild pig, grey langur, Indian pangolin, smooth-coated otter, marsh crocodile, red-headed vulture, Indian vulture, white-rumped vulture
Human Population Density	~237 persons per km² (range: 193 per km² in Neemuch to 374 per km² in Kota)
Livestock Density	~88 cattle/buffalo and ~45 goats/sheep per km²
Communities	Bhil, Banjara, Gurjar, Chamar, Thakur
Major Crops	Wheat, gram, jowar, bajra, maize, coriander, fennel, vegetables, oranges, and regulated opium cultivation
Key Pressures	Livestock grazing, agriculture, fisheries in the reservoir, roads (State Highway 31A, Rawatbhata–Gandhi Sagar interstate), and township expansion
Cheetah introduction Area	~64 km² predator-proof fenced zone in West Range (cheetahs released April-September 2025)

2.7.1. Predation by cheetah in Gandhisagar Wildlife Sanctuary

To better understand how the newly translocated cheetahs hunt and what they eat, researchers from WII and the staff of the forest department are continuously monitoring the cheetahs in Gandhi Sagar WLS. Two male cheetahs - Prabhas and Pavak, are currently based in the Khemla compartment in the West Range of the Sanctuary. Both were originally relocated from Kuno NP in Madhya Pradesh. Another female cheetah Dheera was shifted to Gandhi Sagar WLS in September 2025 to boost up the population.

Every confirmed kill made by these three cheetahs is carefully recorded. For each predation event, field teams document details such as the type of habitat where the kill occurred, the date and time, and any relevant field observations. Kill rates were then calculated based on the total number of confirmed carcasses found during the monitoring period. However, it is important to note that some kills may have remained undetected. Smaller prey like hares, for instance, are easy to miss; also, some carcasses are quickly consumed by scavengers or simply hard to spot in dense vegetation. Despite these limitations, the monitoring team made every effort to record all observable kills as accurately and completely as possible.

Beyond just tracking and predation, researchers also noted the broader ecological role these carcasses play. Leftover kills regularly attract scavengers, and whenever such activity was observed, it was documented as part of the overall ecological record. One particularly encouraging finding during this period was the complete absence of livestock predation. This suggests that the predator-proof fencing system currently in place is working well, effectively keeping cheetahs and livestock separate, a critical factor in reducing negative interactions with local people.

Table 2.7.2.
Detected number of cheetah kills in Gandhi Sagar Wildlife Sanctuary

Sl. No.	Cheetah	Sex	Number of detected kills
1.	**Prabhas**	M	72
2.	**Pavak**	M	72
3.	**Dheera**	F	15

Table 2.7.3.
Prey species killed by cheetah in Gandhisagar Wildlife Sanctuary

SL. No.	Cheetah	Sex	Number of detected kills						
			Chital	Nilgai	Chinkara	Wild pig	Hare	Cattle	Blackbuck
1.	**Prabhas**	M	Yes	Yes	Yes	No	Yes	No	No
2.	**Pavak**	M	Yes	Yes	Yes	No	Yes	No	No
3.	**Dheera**	F	No	Yes	Yes	No	No	No	Yes

Table 2.7.4.
Detected kill rate of cheetahs in Gandhisagar Wildlife Sanctuary

Sl No	Animals	Sex	Kill rate (days per kill)
1.	Prabhas & Pavak	M	3.54
2.	Dheera	F	7

2.8. Predation by cheetah social units

2.8.1 Predation by male coalition Prabhas and Pavak

The male cheetah coalition Prabhas and Pavak was shifted from Kuno NP on 20th April, 2025. In Gandhi Sagar WLS, the coalition primarily preyed on nilgai, followed by chinkara, chital, and hare. A total of 72 kills were detected, resulting in a detected kill rate of 3.54 days per kill. Half of the predated species were nilgaii, with the majority of the individuals being females. They preyed more on adult individuals than young.

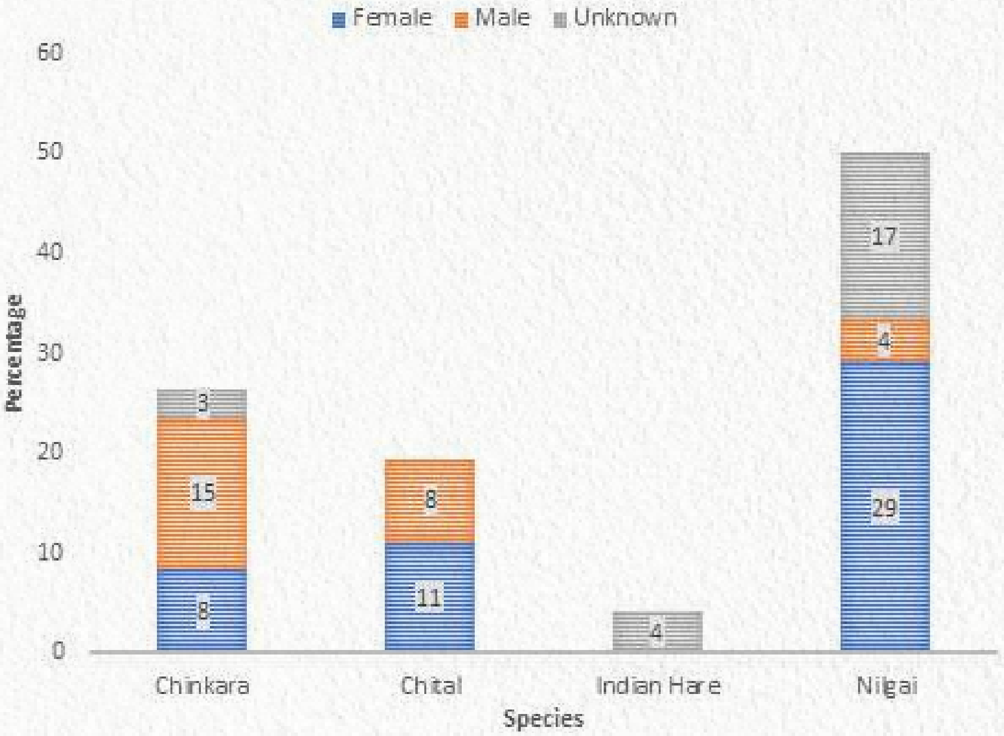


Figure 2.8.1.1
Sex of various prey species predated by cheetah male coalition Prabhas and Pavak in Gandhi Sagar Wildlife Sanctuary

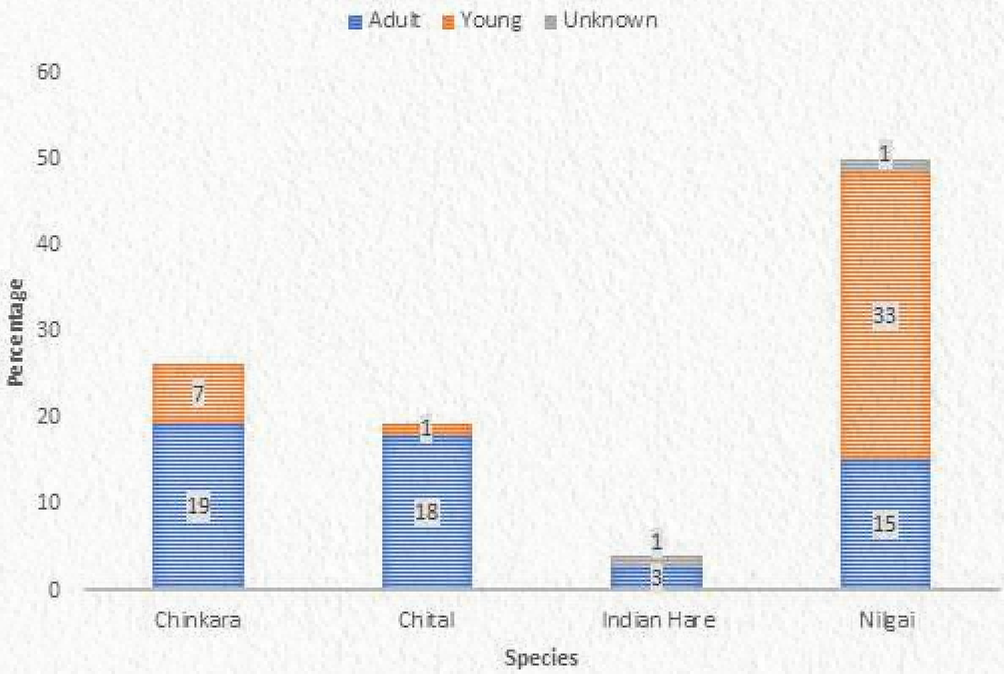


Figure 2.8.1.2
Predation on different age classes of prey species by cheetah male coalition Prabhas & Pavak in Gandhi Sagar Wildlife Sanctuary

2.8.2 Predation by female cheetah Dheera

Dheera, an adult female cheetah, was translocated from Kuno National Park on 17th September 2025. During the period of September to December 2025, 15 kills were documented with a detected kill rate of 7 days per kill. Dheera mainly predated on nilgai (53%), followed by blackbuck (40%) and bhinkara (7%). Among the prey species, young individuals were preyed upon more than adults. In terms of sex class of the kills, predation on females was higher.

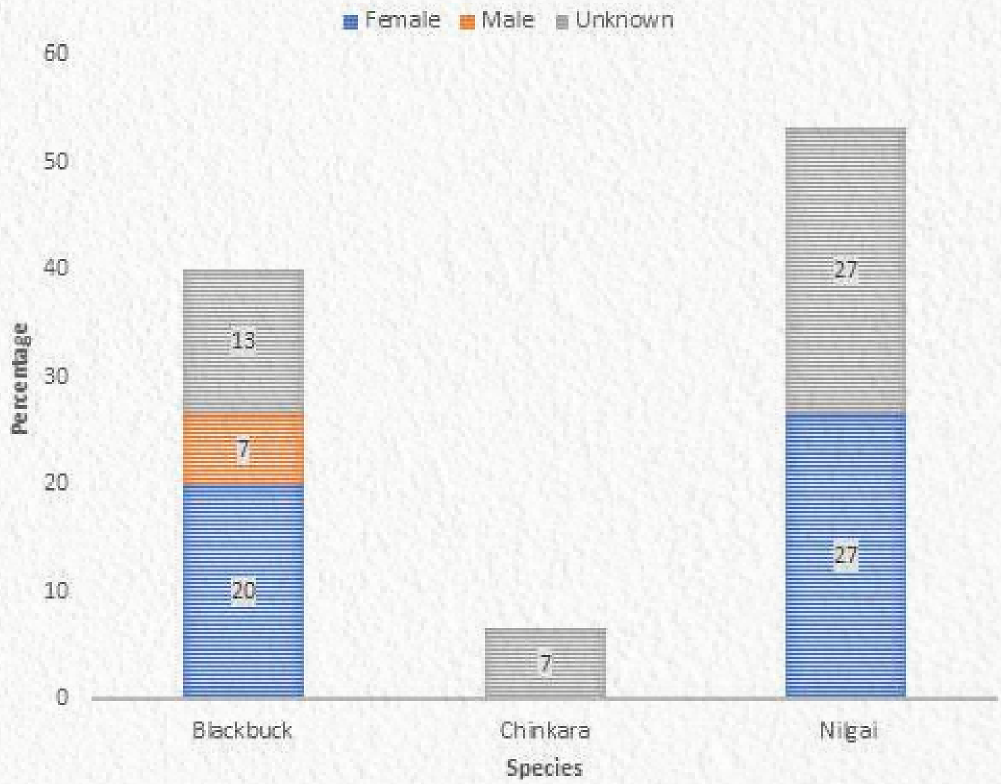


Figure 2.8.1.1
Sex of various prey species predated by female cheetah Dheera in Gandhi Sagar Wildlife Sanctuary

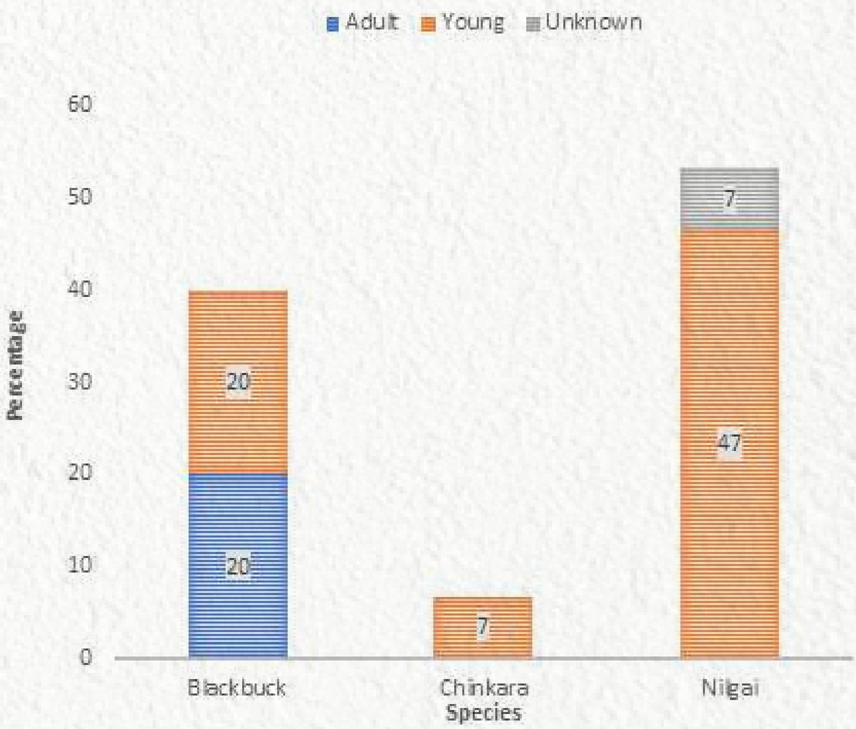


Figure 2.8.1.2
Predation on different age classes of prey species by female cheetah Dheera in Gandhi Sagar Wildlife Sanctuary

2.9. Veterinary monitoring in Gandhi Sagar Wildlife Sanctuary

A dedicated team comprising veterinarians from the NTCA, Madhya Pradesh Forest Department, and the WII is stationed to address the health and welfare requirements of the cheetahs and other wildlife in Gandhi Sagar WLS. This team is responsible for managing all health intervention procedures, including humane and safe capture, immobilization, treatment, and prophylactic care, thereby ensuring the highest standards of wildlife health management. In addition, provisions have been made to ensure capacity building for new veterinarians.

Parallel to veterinary readiness, comprehensive capacity-building programs have been conducted for Sanctuary frontline staff, covering cheetah biology, behaviour monitoring, radio telemetry, and handling protocols. Personnel have also been trained in immobilization assistance, post-release monitoring, and animal rescue and crowd management techniques. These skill development efforts are designed to ensure that both the immediate immobilization process and the long-term management of the cheetah population are conducted with the appropriate professional and welfare standards.

Image 2.9.1. Male cheetah coalition in Gandhi Sagar Wildlife Sanctuary

2.9.1. Relocation of cheetahs from Kuno National Park to Gandhi Sagar Wildlife Sanctuary

The relocation of cheetahs from Kuno NP to Gandhi Sagar WLS was undertaken as part of the establishment of multiple populations of cheetah for long-term viability. A central objective of this program is the establishment of a managed meta-population across multiple sites in India, thereby reducing the risks associated with single-site dependence, promoting genetic exchange, and enhancing long-term population viability (Jhala *et al.* 2021)

To minimize the risks associated with wildlife capture and translocation, veterinary interventions play a central role in ensuring the safe and successful movement of animals. Veterinarians from NTCA, the Madhya Pradesh Forest Department, and the WII undertook extensive pre-relocation planning. This included reviewing the health status and previous medical history of two male cheetahs, Prabhas and Pavak, assembling chemical immobilization kits, preparing transport crates, and establishing contingency protocols for emergencies.

Cheetahs selected for relocation were safely and humanely chemically immobilized under field conditions using predefined drug protocols tailored to the species' physiology. Continuous monitoring of vital parameters (respiration, heart rate, SpO_2, and body temperature) was maintained throughout the procedure to mitigate risks of hyperthermia, hypoxemia, and capture myopathy. Following immobilization, a detailed physical examination was conducted to confirm health status and fitness for translocation. During handling, biological samples (blood, serum, and faecal samples) were collected for haematology, serum biochemistry, and disease surveillance. Point-of-care diagnostics (including EPOC® blood gas analysis) were performed to assess real-time metabolic parameters. Prophylactic interventions included administration of booster vaccinations (TruFel™ HC2PCh and PUREVAX® Rabies).

Cheetahs were transferred to specially designed transport crates, ensuring adequate ventilation and padding to minimize stress and injury during transit. Subsequently, they were shifted from Kuno NP to Gandhi Sagar WLS in two separate air-conditioned vehicles, each ensuring optimal ventilation, temperature control, and reduced stress during the journey. Veterinarians accompanied the relocation team to provide supportive care if required in the transit. At Gandhi Sagar WLS, cheetahs were released into the Khemla compartment for acclimatization under close veterinary supervision. Initial post-release monitoring included visual health checks, behavioural observations, and review of radio-collar fit and function.

Image 2.9.2. Male cheetah coalition during release at Gandhi Sagar Wildlife Sanctuary

2.9.2. Post-release monitoring, veterinary healthcare and management of cheetahs in Gandhi Sagar Wildlife Sanctuary

The acclimatization of relocated cheetahs is dependent on sustained post-release veterinary monitoring and healthcare, particularly during the initial phase. To achieve this, the veterinary team, WII researchers, and the forest department monitoring team have been engaged in continuous health surveillance. Monitoring is conducted twice daily, in the morning and evening, through direct sightings with close attention given to gait, coat condition, feeding patterns, and social interactions. During each observation, the cheetahs are systematically assessed for physical fitness, activity levels, health status, behavioural patterns, predation success, habitat preferences, visible injuries, belly scores, and any abnormal signs or symptoms. Detailed records are maintained for each sighting, including the cheetah's health condition, belly score, and behavioural states such as lying, sleeping, sitting, standing, walking, running, pacing, vigilance, allo- or auto-grooming, scent marking, chasing, and feeding, along with the GPS location of the animal at the time of observation.

To complement veterinary and research-based monitoring, a cheetah tracking team is deployed round the clock (24×7) in Gandhi Sagar WLS. This team, comprising a tracker, a driver, and a staff member from the Forest Department, plays a pivotal role in continuous field-based surveillance of the cheetahs. Their duties include closely following the movements of the animals, observing their behaviour, and reporting any significant developments such as kills, injuries, or abnormal behavioural patterns directly to veterinarians and relevant authorities for timely intervention. The team also corroborates GPS radio-collar data with ground observations, thereby validating collar signals and helping to detect anomalies such as prolonged inactivity, restricted movement, or visible signs of debilitation. In addition, they contribute to accurate documentation of predation events and behavioural states, providing essential field-level information that supports veterinary assessments and management decisions.

Predation monitoring forms an equally critical component of post-release assessment. Each kill made by the cheetahs is systematically documented, and detailed records are maintained on prey species, age and sex class, and carcass utilization patterns. Consumption rates are carefully correlated with belly scores and overall physical condition to assess nutritional fulfilment and dietary adequacy. These data provide valuable insights into predation success, prey preferences, and the ability of cheetahs to sustain themselves in the wild, thereby linking foraging ecology directly with health and survival outcomes. In cases where a cheetah fails to make a kill for an extended period, supplementary feeding is carried out by the veterinary team to ensure that nutritional needs are met and to prevent health deterioration. These adaptive interventions are essential for bridging gaps in predation success during the early acclimatization phase and safeguarding the welfare of the animals.

In addition, non-invasive sample collection, particularly faecal samples, is being undertaken for stress hormone analysis, facilitating the early detection of subclinical conditions. Complementing these efforts, GPS radio-collar tracking generates critical data on activity cycles, movement ecology, and potential health-related anomalies, such as prolonged resting bouts or reduced mobility, thereby strengthening the overall veterinary monitoring framework.

Image 2.9.3. Cheetah scent-marking near an artificial waterhole in Gandhi Sagar Wildlife Sanctuary.

2.9.3. Prophylactic immobilization of cheetahs in Gandhi Sagar Wildlife Sanctuary

Chemical immobilization of free-ranging wildlife carries inherent risks, with potential complications such as hyperthermia, hypoxemia, capture myopathy, and mortality. Cheetahs are particularly vulnerable to these risks owing to their unique physiological characteristics, which require careful management during field immobilization. Nevertheless, capture and chemical restraint are often unavoidable in conservation programs, serving essential purposes such as translocation, collar deployment, health monitoring, vaccination, and treatment (Muliya *et al.* 2016).

On 29th June 2025, cheetahs at Gandhi Sagar WLS were chemically immobilized to facilitate vaccination as part of their routine health management. Established best practices were followed, including careful drug selection, continuous physiological monitoring, and minimizing handling duration, all aimed at reducing stress and risk (Semjonov *et al.* 2019).

A comprehensive physical examination confirmed both the cheetahs to be in optimal health, with no evidence of external injuries or abnormalities. The radio-collars were inspected and found to be properly fitted relative to neck circumference. The following booster immunizations were administered subcutaneously: Inj. TruFel™ HC2PCh (Feline Herpesvirus, Calicivirus, Panleukopenia, and Chlamydia psittaci vaccine) and Inj. PUREVAX® 3 (Rabies vaccine, inactivated). Prior to anaesthetic reversal, biological samples were collected for subsequent haemato-biochemical analysis and disease diagnosis. Point-of-care testing was also conducted using an EPOC® Blood Gas Analyzer to assess real-time metabolic parameters (*e.g.*, pH, pO_2, lactate). Additionally, in-field disease screening was performed to assess exposure to eight epidemiologically significant pathogens in carnivores, using rapid field assay kits, and the results are tabulated below.

Table 2.9.1.
Results of rapid field assay kits for disease screening in cheetahs at Gandhi Sagar Wildlife Sanctuary

S. No.	Test Kits	Disease antigen/ antibody	Sample	Male cheetah-Prabhas	Male cheetah-Pavak
1.	Feli-Check-3	Feline Leukaemia Antigen	Blood	Negative	Negative
2.		Feline Immunodeficiency Disease Antibody	Blood	Negative	Negative
3.		Feline Heartworm Antibody	Blood	Negative	Negative
4.	CPV/CCV/Giardia Ag	Canine Parvovirus Antigen	Faecal Swab	Negative	Negative
5.		Canine Corona Virus Antigen	Faecal Swab	Negative	Negative
6.		Giardia Antigen	Faecal Swab	Negative	Negative
7.	FeliD-3	Feline Parvovirus Antigen	Faecal Swab	Negative	Negative
8.		Feline Corona Virus Antigen	Faecal Swab	Negative	Negative
9.		Giardia Antigen	Faecal Swab	Negative	Negative

Ectoparasites, particularly ticks, are significant health concerns in wild carnivores, causing direct effects such as blood loss, irritation, and hypersensitivity, while also acting as vectors for infectious pathogens (Munson *et al.* 2008). In cheetahs, heavy infestations can lead to persistent scratching and skin trauma, predisposing animals to secondary bacterial infections and septicaemia. Such risks were exemplified in Kuno NPearlier, where cheetah mortality was attributed to septicaemia originating from tick-induced scratch wounds.

To mitigate these risks, a pre-monsoon prophylactic ectoparasite management program was undertaken on the same date. As part of this intervention, Bravecto® (fluralaner), a long-acting systemic ectoparasiticide, was applied topically to anaesthetized cheetahs under veterinary supervision. Bravecto® is a systemic isoxazoline-class ectoparasiticide with proven efficacy against ticks and fleas in felids, thereby reducing the likelihood of infestations and associated health complications (Kilp *et al.* 2014).

Image 2.8.4. Male cheetah coalition during the initial days of release in Gandhi Sagar Wildlife Sanctuary

Image 2.9.5. Immobilization of male cheetah coalition for vaccination and anti-ectoparasitic drug application

The intervention was completed without adverse outcomes, demonstrating the effectiveness of proactive prophylactic measures in maintaining cheetah health. Importantly, no capture-related morbidity or mortality was observed during and after the immobilization, highlighting the effectiveness of rigorous adherence to established best practices.This successful intervention underscores the role of careful immobilization protocols in supporting the long-term health management and conservation of cheetahs (Braud *et al.* 2019).

2.10. Sourcing of cheetahs from range countries in Southern Africa

India's Project Cheetah, initiated in 2022, represents a holistic wildlife conservation initiative aimed at restoring cheetah populations, reviving grassland ecosystems & their biodiversity values, and fostering socio-economic benefits for local communities through eco-development and eco-tourism in the cheetah landscapes in India thereby contributing to country's commitment to achieve global sustainable development goals. In furtherance of these targets, the Governments of the Republic of India with the assistance of the Republics of Namibia, South Africa and Botswana translocated 08 (September 2022), 12 (February 2023) and 20 cheetahs (February 2026) respectively to Kuno NP.

Image 2.10.1. Indian delegation headed by Director General & Special Secretary, Ministry of Environment Forest & Climate Change accompanied by H.E. High Commissioner of India to Botswana presenting project document to Hon. Minister of Environment, Wildlife and Tourism, Botswana

High level delegations from the Government of India comprised of officials and scientists from the MoEFCC, NTCA, Madhya Pradesh Forest Department and the WII visited South Africa, Namibia and Botswana in June 2025, July 2025, September 2025 respectively for sharing, exchange of expertise and capacity building on cheetah and biodiversity conservation and management as well as procuring the cheetahs for Project Cheetah in India, to ensure the project's long-term viability. Furthermore, delegations from South Africa and Botswana comprised of officials and scientists visited India during November 2025 and December 2025 as part of the bilateral collaborations between the countries under Project Cheetah. Meetings were held with the Indian High Commissions of South Africa, Namibia and Botswana, Department of Forestry, Fisheries, and the Environment, South Africa, Ministry of Environment, Wildlife and Tourism of the Republic of Botswana, Ministry of Environment and Tourism (MEFT), Namibia; the Ministry of International Relations and Cooperation, Namibia; former speaker of the National Assembly, Namibia, the Department of Forestry, Fisheries, and the Environment (DFFE); the Department of International Relations and Cooperation (DIRCO), South Africa; Ministry of Environment, Wildlife and Tourism (MEWT), Botswana; Ministry of International Affairs and Cooperation (MIAC), Botswana; Department of Wildlife and National Parks (DWNP), Botswana; the South African National Biodiversity Institute (SANBI); the South African National Parks (SANParks), Cheetah Conservation Fund, Namibia; The (Cheetah) Metapopulation Initiative, South Africa; Rooiberg Veterinary Services, South Africa; Vet and Agric Consultants, Botswana.

Image 2.10.2. H.E High Commissioner of India to South Africa along with the Indian delegation headed by Inspector General of Forest, National Tiger Conservation Authority presenting project document to Department of Forest, Fisheries and Environment, South Africa

The visits and subsequent deliberations served as a critical platform to discuss progress, strengthen bilateral collaboration, and finalize arrangements for the next phase of cheetah translocations. The deliberations reaffirmed the nations' steadfast commitment to ecological diplomacy, scientific cooperation, and their shared vision of establishing a sustainable cheetah population in India. The collaborative discussions and field assessments have laid a strong foundation for the next phase of Project Cheetah, ensuring Government of India's continued cooperation with the Governments of South Africa, Namibia and Botswana in this landmark conservation initiative.

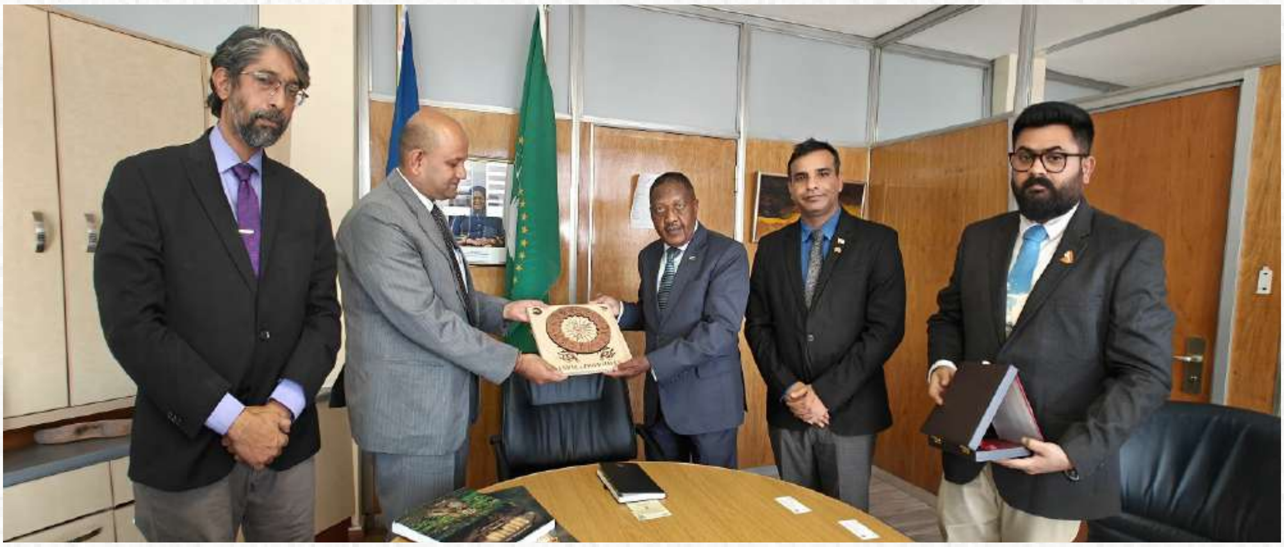


Image 2.10.3. Indian delegation headed by Deputy Inspector General, National Tiger Conservation Authority presenting project document to H.E. Executive Director, Ministry of International Relations and Cooperation, Namibia

Image 2.10.4. South African delegation at Kuno National Park

2.11. Preparations of potential sites for cheetah release as part of metapopulation management

To enable long term viability of cheetah populations in India under the metapopulation management framework, two potential sites are being prepared for release of cheetah as mandated by the MoEF&CC. These two sites-Banni Grasslands in Gujarat and Nauradehi Wildlife Sanctuary in Madhya Pradesh were visited during March 2025 and May 2025 respectively by teams from NTCA and WII to review the progress of the preparations for cheetah release. The teams were accompanied by the CCF of Kutch in Banni and DFO of Nauradehi along with the field officers and staff. Nauradedehi WLS is now part of Veerangana Durgavati Tiger Reserve notified in 2024.

Image 2.11.1. Grasslands of Banni region in Kutch District of Gujarat

During the visits, various site-specific aspects of readiness such as quarantine and veterinary facilities, monitoring/control infrastructure, soft release facility, prey & habitat assessment and management, invasive plant species management, water management, habitat consolidation and restoration, improvement of protection and management infrastructure, Ungulate prey augmentation, road mitigation, disease risk analysis and vaccination of livestock in nearby human habitations, outreach & awareness.

Figure 2.11.1.
Map of Banni grasslands (green line) and Chari Dhand Conservation Reserve (yellow line) showing the location of the soft release enclosures (red boundary on the left) for cheetah introduction

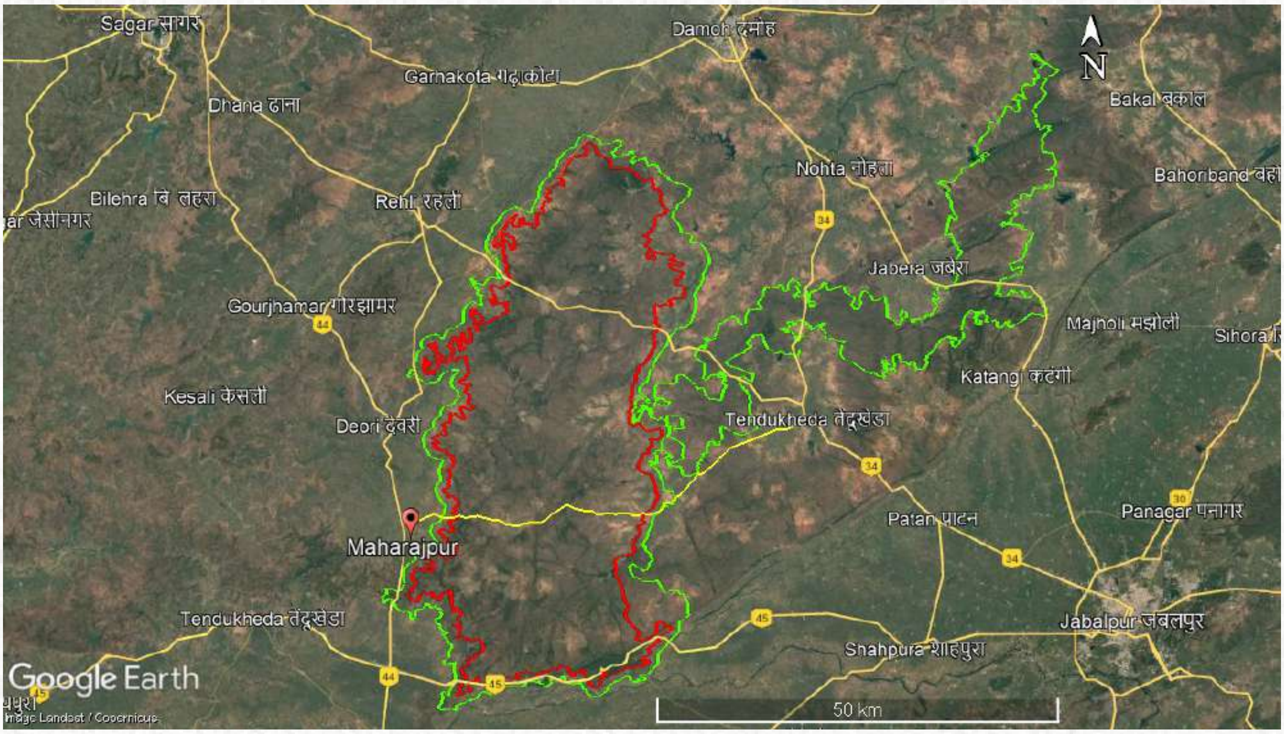


Figure 2.11.2.
Map depicting major roads (yellow line) passing through Veerangana Durgavati Tiger Reserve (green line) including Nauradehi Wildlife Sanctuary (red line)

The deliberations were carried out based on requirements to ensure the successful initiation of the project. As the development process commences, periodic visits will be conducted by the various teams involved in the project to provide ongoing technical guidance, monitor progress, and address any emerging challenges. These efforts will help ensure that the project remains on track and aligns with the overarching goals of habitat restoration, prey augmentation, and long-term cheetah conservation under Project Cheetah.

Image 2.11.2. Open woodland in Nauradehi Wildlife Sanctuary

3. Co-predator Monitoring

3.1 Introduction

Assessing the ecological implications of cheetah introduction on the mammalian carnivore guild in Kuno NP requires systematic monitoring of co-predators. Camera trap sampling, radio-telemetry, and advanced spatial capture-recapture (SECR) models have been employed to estimate densities, movements, and ecological interactions (Jhala *et al.* 2021). These approaches provide insights into how sympatric carnivores, particularly large carnivores like leopards (*Panthera pardus*) and striped hyenas (*Hyaena hyaena*) coexist in semi-arid systems. Large carnivores occupy a pivotal position within tropical ecosystems, functioning as apex regulators that use substantial top-down effects on species dynamics across lower trophic levels. Beyond their trophic roles, large predators reinforce ecological processes, including herbivore population regulation, meso-predator suppression, and the maintenance of overall ecosystem integrity (Mondal *et al.* 2013; Tshabalala *et al.* 2021). In spite of their large-scale ecological importance, large carnivores face rising anthropogenic threats globally, including persecution, habitat loss, degradation, and fragmentation, all of which critically undermine their long-term viability (Ripple *et al.* 2014). Standardized camera trap protocols, adapted from the All-India Tiger Estimation framework, were applied in Kuno NP, ensuring robust sampling for assessing relative abundance, activity patterns, and interspecific interactions (Qureshi *et al.* 2023).

3.1.1. Population Assessment of Co-predators in the Erstwhile Wildlife Sanctuary Area of Kuno National Park

Between December 2024 and January 2025, extensive camera-trap sampling was conducted to assess the status of mammalian co-predators across an area of 344 km^2 encompassing the erstwhile WLS area of Kuno NP. A total of 131 locations were deployed with two cameras each on either side of a motorable track/trail almost facing each other (Figure 3.1.1). Cameras were deployed in a systematic grid-based (size 2 km^2) manner to ensure no sampling gaps are present in the study area. The cameras were positioned in areas where the probability of carnivore capture would be high and at an adequate height (Tanwar *et al.* 2021). This effort was carried out for 5453 trap-nights and produced a substantial dataset of large and meso-carnivore detections. The survey yielded significant information on leopard and hyena densities, relative abundance indices, and spatial distribution patterns, providing a critical baseline for monitoring population trends over time and assessing ecological nuances of co-predator interactions.

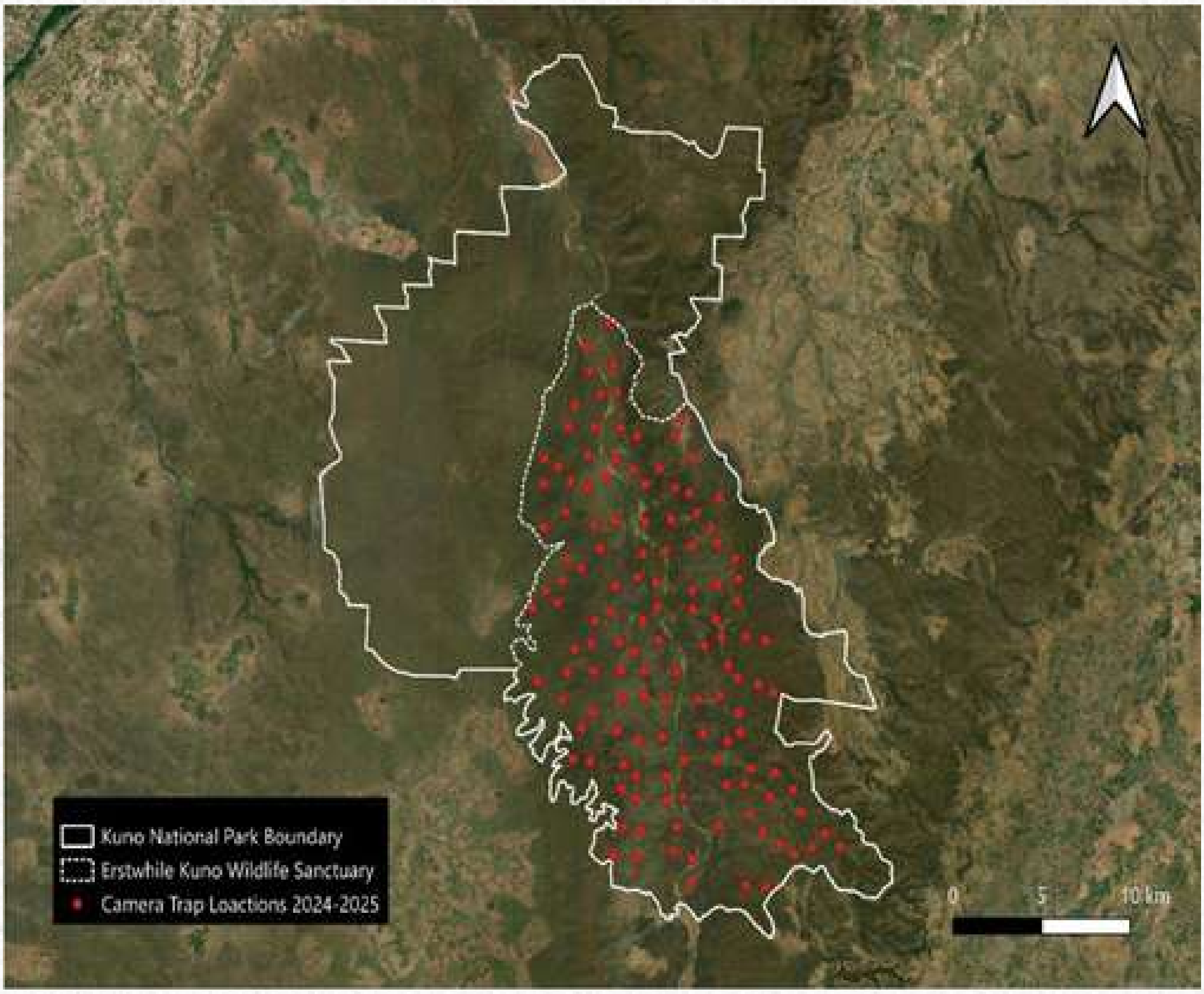


Figure 3.1.1.
Location of camera traps deployed in the erstwhile Wildlife Sanctuary area of Kuno National Park to assess the status of large mammalian predators

3.1.2. Leopard population estimation

The data obtained from camera trap sampling was geo-tagged, and images were segregated species-wise. Leopard images obtained from the survey were processed using the software programs Hotspotter (Crall *et al.* 2013) and Extract-Compare (Hiby *et al.* 2009) and further manually checked for individual identification. First, the individuals were segregated into right and left flanks (based on the direction of the animal), as the rosette patterns vary between the flanks for the same individual. After that, the individuals are carefully checked and matched with their respective flanks through the various pelage markings. Finally, left and right flank comparisons were made based on the date and time to find complementary images between the right and left flanks, and unique identification numbers were assigned to each individual.

A total of 4,984 leopard images were photo-captured in Kuno NP during the sampling period. From these photographs, 4616 images were used for identifying 136 individual adult leopards (50 males, 71 females, and 15 undetermined), and further analysis was conducted using spatially explicit capture-recapture (SECR) models (Efford *et al.* 2009). Sex-specific heterogeneity models including various detection parameters using the package 'secr' (Efford, 2025) in the R platform (R Core Team, 2023) resulted in an estimated density of 40.82 (3.52 SE) per 100 km^2 for leopards in the sampled area (Table 3.1.1.). This relatively high density underscores the ecological significance of Kuno NP as a stronghold for leopards in central India.

Table 3.1.1.
Summary of Spatially Explicit Capture Recapture (SECR) analysis results for density estimation of leopards in the erst while Wildlife Sanctuary area of Kuno National Park

Parameters	**Results**
Number of camera trap locations	131
Sampled Area	344 km^2
Effort	5453 trap nights
No. of Individuals (M(t+1))	136
Density	40.82 (3.52 SE) individuals per 100 km^2
95 % Confidence Interval	34.49 – 48.32
g0 (Male & Female)	0.05 & 0.10
Sigma (Male & Female)	1725.32 (24.85 SE) & 937.92 (19.56 SE)
Pmix (Male & Female)	38 & 62

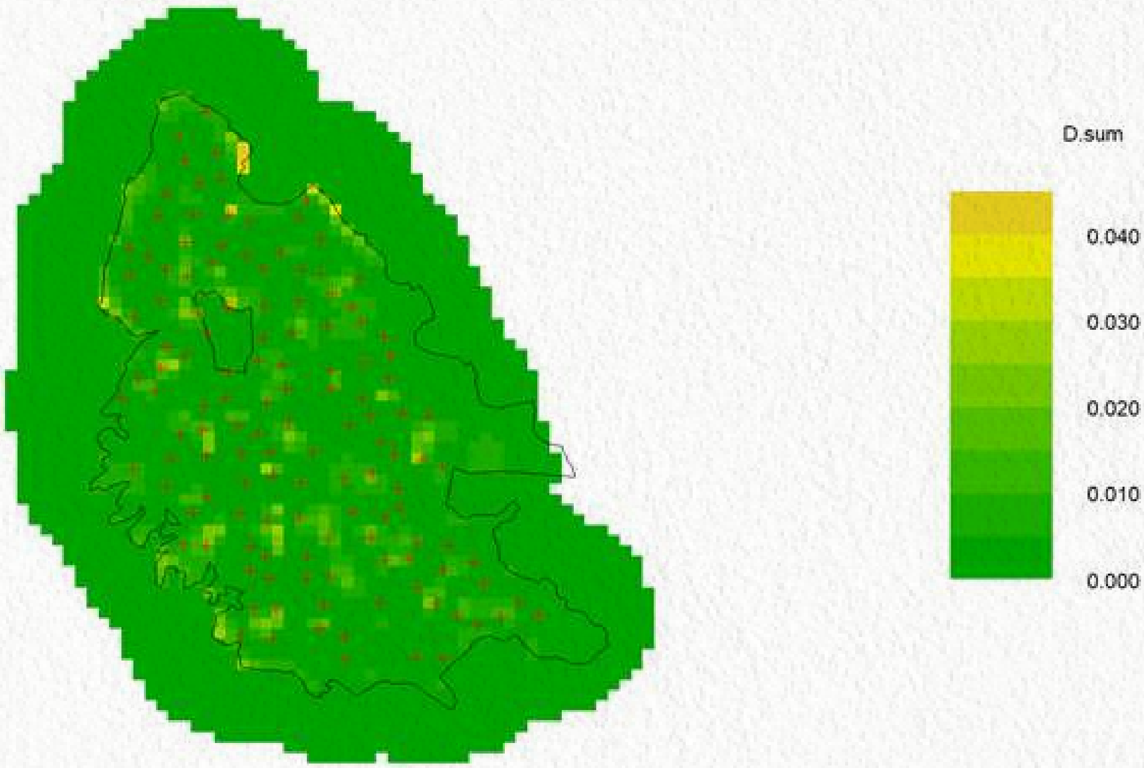


Figure 3.1.2.
Distribution of leopards in the erstwhile Wildlife Sanctuary area of Kuno National Park in 2024-2025 obtained from spatially explicit capture-recapture using camera trap (denoted as +) sampling

3.1.3. Striped hyena population estimation

To assess the population status of striped hyenas from the photo-captures obtained during the camera trap survey in Kuno NP during 2024-2025, a manual identification approach was used to identify unique striped hyena individuals. The markings on the pelage of the hind limbs, forelimbs, and forequarters were visually examined in order to identify the individual striped hyenas from images taken during the camera trap survey in

Kuno NP (Schaller, 1967; Karanth, 1995; Singh, 2008). Rigorous cross-validation was done by multiple trained researchers to minimize the risks of misidentification and double counting. A total of 2280 images were taken of striped hyenas during the survey, out of which 1884 independent photo captures were used to identify 70 unique adult striped hyenas. These included 21 females, 21 males, and 28 individuals whose sex could not be determined. Sex-specific heterogeneity models in SECR were analysed using the package 'secr' (Efford, 2025) in R platform (R core team, 2023) and resulted in an estimated density of 20.44 (2.45 SE) per 100 km^2 for striped hyenas in the surveyed area (Table 3.1.2.).

Table 3.1.2.
Summary of SECR analysis results for striped hyena density in the erstwhile Wildlife Sanctuary area of Kuno National Park

Parameters	Results
Number of camera trap locations	131
Sampled Area	344 km^2
Effort	5453 trap nights
No. of Individuals (M(t+1))	70
Density	20.44 (2.45 SE) individuals per 100 km^2
95 % Confidence Interval	16.18 – 25.83
g0 (Male & Female)	0.12 & 0.04
Sigma (Male & Female)	1712.79 (40.70 SE) & 1940.66 (68.31 SE)
Pmix (Male & Female)	34 & 66

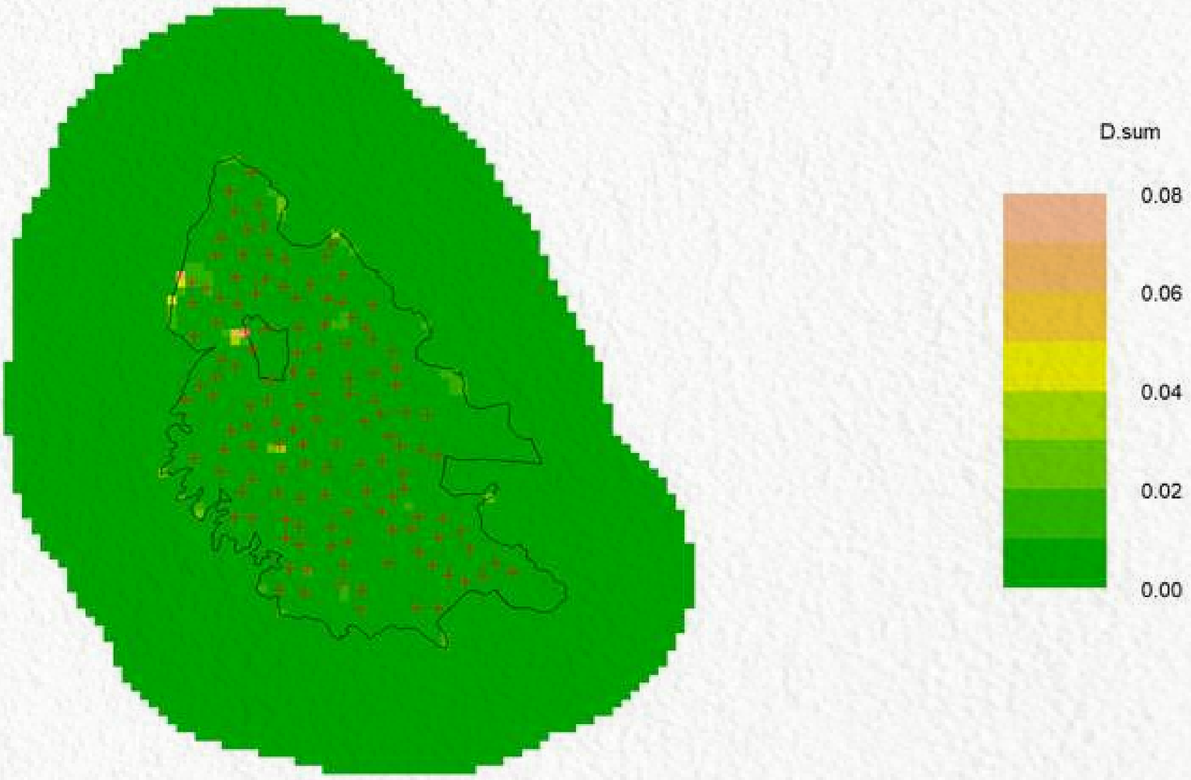


Figure 3.1.3.
Distribution of striped hyenas in the erstwhile Wildlife Sanctuary area of Kuno National Park during 2024-2025 obtained from spatially explicit capture-recapture using camera trap (denoted as +) sampling

3.2. Density estimation of small carnivores using camera trap-based distance sampling (CTDS) in Kuno National Park

3.2.1. Introduction

Small carnivores play an integral role in maintaining ecological balance within terrestrial ecosystems, yet their contributions are often overlooked (Roemer *et al.* 2009, Marneweck *et al.* 2021). They provide vital ecosystem services, including pest control, seed dispersal, and scavenging, and contribute significantly to ecosystem functionality (Polis *et al.* 2000, Do Linh San *et al.* 2022). While large carnivores receive significant conservation focus, small carnivores, *i.e.*, mammals under 15 kg such as civets, mongooses, foxes, and jackals, though equally important, remain underrepresented in research and policy (Prugh *et al.* 2009). Despite their adaptability across diverse habitats, small carnivores face multiple threats such as habitat loss, poaching, negative interactions with humans, and roadkill, with insufficient population data further complicating conservation strategies (Jennings & Veron, 2011). India harbours rich carnivore diversity across varied biogeographic regions. Small carnivores like the jungle cat (*Felis chaus*), small Indian civet (*Viverricula indica*), Asian palm civet (*Paradoxurus hermaphroditus*), Bengal fox (*Vulpes bengalensis*), and golden jackal (*Canis aureus*) are common but poorly studied compared to large carnivores. Despite their ecological importance, these species are frequently marginalized in conservation strategies, especially in India, where efforts tend to focus on large, charismatic fauna (Bandyopadhyay *et al.* 2024). Recognizing this gap, the present study aimed to generate quantitative baseline data on small carnivore populations within the semi-arid, dry deciduous forests of Kuno National Park in northern Madhya Pradesh. In the context of cheetah introduction, it becomes imperative to monitor and understand trophic level interactions, particularly the carnivore guild.

Monitoring small carnivores presents methodological challenges. Their nocturnal and secretive behaviour, low population densities, and lack of individually recognizable markings complicate efforts to apply traditional techniques like capture–recapture or direct observation (Rowcliffe *et al.* 2008). Technological advancements, particularly camera traps, have revolutionized wildlife monitoring by offering a non-invasive, cost-effective, and continuous means of detection (Kays *et al.* 2009). However, using camera trap data to estimate absolute abundance rather than mere presence or relative activity remains a challenge. To address this, Camera Trap Distance Sampling (CTDS), an adaptation of conventional distance sampling that incorporates spatial detection information into population estimates, is being employed (Howe *et al.* 2017).

CTDS is a promising method for estimating the density and abundance of unmarked animals by using camera traps as point detectors and modeling the probability of detection as a function of distance. It has been successfully applied to primates, ungulates, and small carnivores in varied ecosystems, particularly where visual identification of individuals is not feasible (Rowcliffe *et al.* 2011; Howe *et al.* 2017). Unlike index-based methods such as the Relative Abundance Index (RAI), which assumes a linear relationship between detections and abundance, CTDS uses detection functions (e.g., half-normal or hazard rate) to correct for distance-related biases and variability in detection zones. When combined with proper estimation of Effective Detection Radius (EDR), CTDS allows for robust, statistically grounded population estimates, even in logistically difficult terrains. Despite its advantages, CTDS remains underutilized in India, especially for small carnivores. There exists a critical gap in applying such robust analytical tools in Indian Protected Areas, limiting our ability to monitor cryptic species and inform management interventions.

CTDS extends traditional point-transect distance sampling (DS) methods to accommodate data collected from camera traps (Corlatti *et al.* 2020). This allows for leverage of a well-established theoretical framework, complete with existing software and guidelines for study design and data analysis (Buckland *et al.* 2001, 2015; Thomas *et al.* 2010). While traditional camera trapping methods often rely on capture-recapture models that require individually identifiable animals (e.g., by unique coat patterns) (Foster & Humphrey, 1995; Karanth & Nichols, 1998). Many species, including most small carnivores, lack such distinct markings (Kalle *et al.* 2014). CTDS offers a solution for these "unmarked" populations, for density estimation without needing individual recognition. The method works by deploying stationary camera traps and recording photographic detections of moving animals (Howe *et al.* 2017). Key data collected include the horizontal radial distance between the detected animal and the camera at predefined "snapshot moments" (Becker *et al.* 2022; Howe *et al.* 2017; Nakashima *et al.* 2018; Rowcliffe *et al.* 2008). The probability of detection typically declines as an animal moves further from the camera, and CTDS models this detection function to estimate the number of animals that were present but undetected (Howe *et al.* 2017; Rowcliffe *et al.* 2008).

3.2.2. Methodology

The survey used the CTDS approach to estimate small carnivore densities in a 15 km² area. A systematic grid (area: 0.5 km² each) was created, with one camera trap placed at each centroid in 63 cells to ensure even coverage and minimize spatial bias. Cameras were motion-triggered, infrared-enabled, and operated continuously at 30–45 cm above ground without baiting (Tanwar *et al.* 2021), resulting in 984 trap-days between February and April 2025. Captured images were geotagged using the CaTRAT software program (Cheema *et al.* 2018), recording camera ID, GPS, species, date, and observer details. Data was processed in FastStone Image Viewer, with detections filtered to exclude false triggers, ambiguous images, and non-independent events (less than 30 minutes apart). Species-level identification was conducted wherever possible.

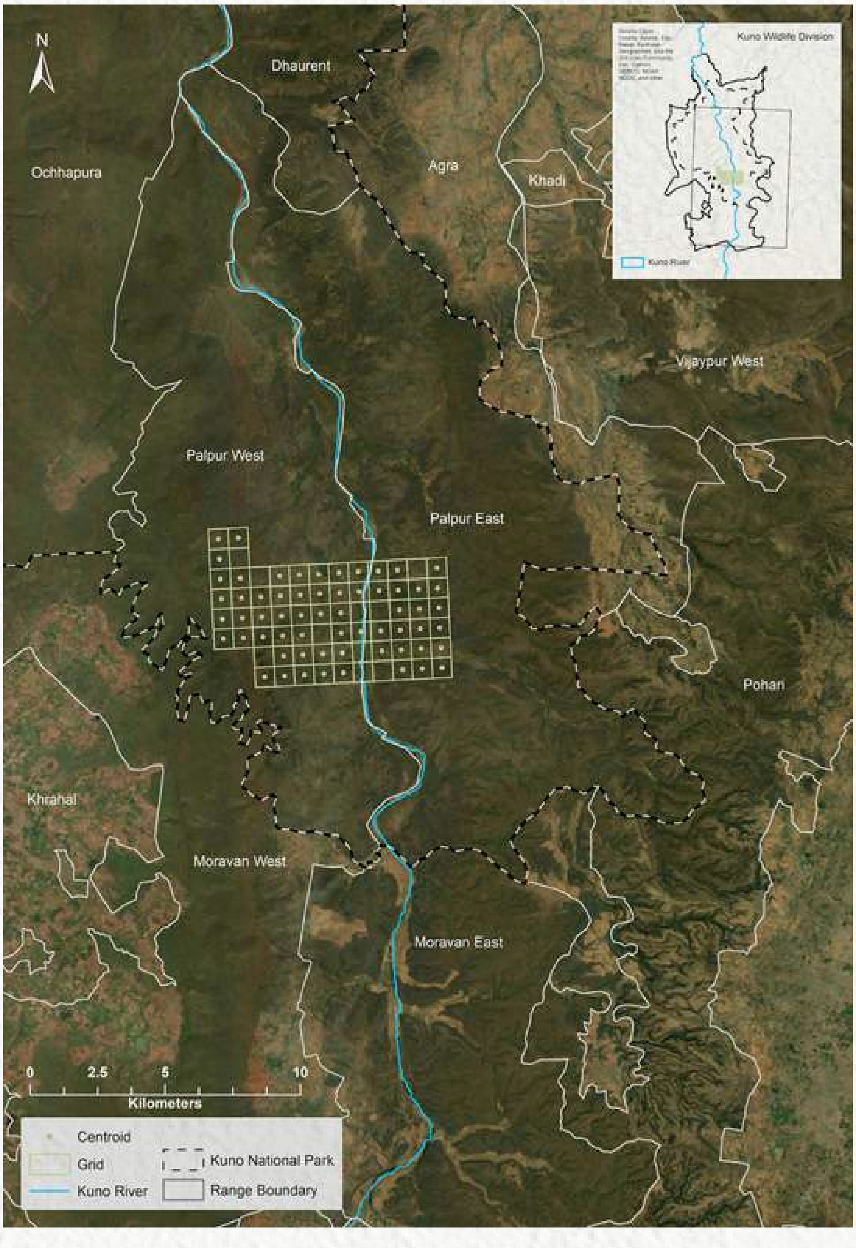


Figure 3.2.1.
Location of camera traps deployed in the erstwhile Wildlife Sanctuary area of Kuno National Park to assess the status of small mammalian carnivores

For distance estimation, the calibration method and tool developed by Haucke *et al.* (2022) were employed. Calibration images with reference boards at known distances were masked and compared with animal detections to generate accurate radial distance estimates. Outputs included species ID, detection distance, geolocation, and effort in CSV format. The processed data were analyzed in Distance software (v7.5) using a half-normal key function with cosine adjustment (Buckland *et al.* 2001, 2015; Thomas *et al.* 2010). The software estimated detection probability, Effective Detection Radius (EDR), and density values. Final density estimates were generated for the pooled group of small carnivores, with species-wise values reported when sample sizes permitted, along with 95% confidence intervals. From the best-fitting model, Effective Detection Radius (EDR) was estimated, which reflects the average distance within which the camera can reliably detect an animal. EDR was used to compute animal density using the formula:

Density = (n /T)/(2πr^2 *(θ/360)*1000000)

Where:

n = number of independent detections,

θ = camera detection angle

T = duration of survey (in seconds),

r = effective detection radius (in meters).

Density estimates were reported along with 95% confidence intervals. Species-wise estimates were calculated where sample sizes allowed, while pooled estimates were generated for the small carnivore group as a whole.

3.2.3. Results

Seven small carnivore species were recorded, with the small Indian civet showing the highest density, and the Asian palm civet and jungle cat occurring at low densities. Other species such as the golden jackal, Bengal fox, and honey badger (*Mellivora capensis*) were detected but at frequencies too low for CTDS analysis.

Asian palm civet (*Paradoxurus hermaphroditus*): Density of 0.28 per km² (95% CI: 0.19–0.40). Despite being elusive, it was consistently detected, highlighting its adaptability to diverse habitats.

Small Indian civet (*Viverricula indica*): Highest density among civets at 0.73 per km² (95% CI: 0.50–1.05), reflecting its ecological plasticity.

Gray mongoose (*Urva edwardsii*): Density of 0.59 per km² (95% CI: 0.50–1.05), showing stable occurrence across heterogeneous habitats.

Ruddy mongoose (*Urva smithii*): Density of 0.68 per km² (95% CI: 0.28–1.64), indicating moderate but variable presence.

Jungle cat (*Felis chaus*): Density of 0.4 per km² (95% CI: 0.22–0.72), showing moderate occurrence.

Rusty-Spotted Cat (*Prionailurus rubiginosus*): Lowest recorded density at 0.04/km² (95% CI: 0.02–0.08), reflecting its rarity and Near Threatened status.

Feral cat (*Felis catus*): Density of 0.22 per km² (95% CI: 0.12–0.4), indicating non-native presence with potential conservation concerns.

Low-detection species such as the golden jackal (17 detections), Bengal fox (4 detections), and honey badger (1 detection) were observed but excluded from CTDS density estimates due to insufficient data (<25 encounters).

Overall, the results highlight a diverse guild of small carnivores with varying densities, from common generalists like the small Indian civet to rare species like the rusty-spotted cat. This underlines the ecological significance of Kuno National Park and the need for continued monitoring.

Table 3.2.1.

Population density of selected small carnivores in Kuno National Park obtained from camera trap distance sampling

Species	Independent Encounters	Mean Effective Detection Distance (m)	Effective Detection Angle (2θ °)	Encounter Rate (detections per sec)	Estimated Density (individuals per km^2)	95% Confidence Interval (individuals per km^2)
Asian Palm Civet	18	3.81	43°	2.12×10^{-7}	0.28	0.19 – 0.40
Small Indian Civet	47	4.03	43°	5.53×10^{-7}	0.73	0.50 – 1.05
Gray Mongoose	18	2.78	43°	2.12×10^{-7}	0.59	0.50 – 1.05
Ruddy Mongoose	21	4.03	43°	2.47×10^{-7}	0.68	0.28 – 1.64
Jungle Cat	18	3.37	43°	2.12×10^{-7}	0.40	0.22 – 0.72
Rusty-spotted Cat	2	3.37	43°	2.35×10^{-8}	0.04	0.02 – 0.08
Feral Cat	10	3.37	43°	2.35×10^{-8}	0.22	0.12 – 0.40

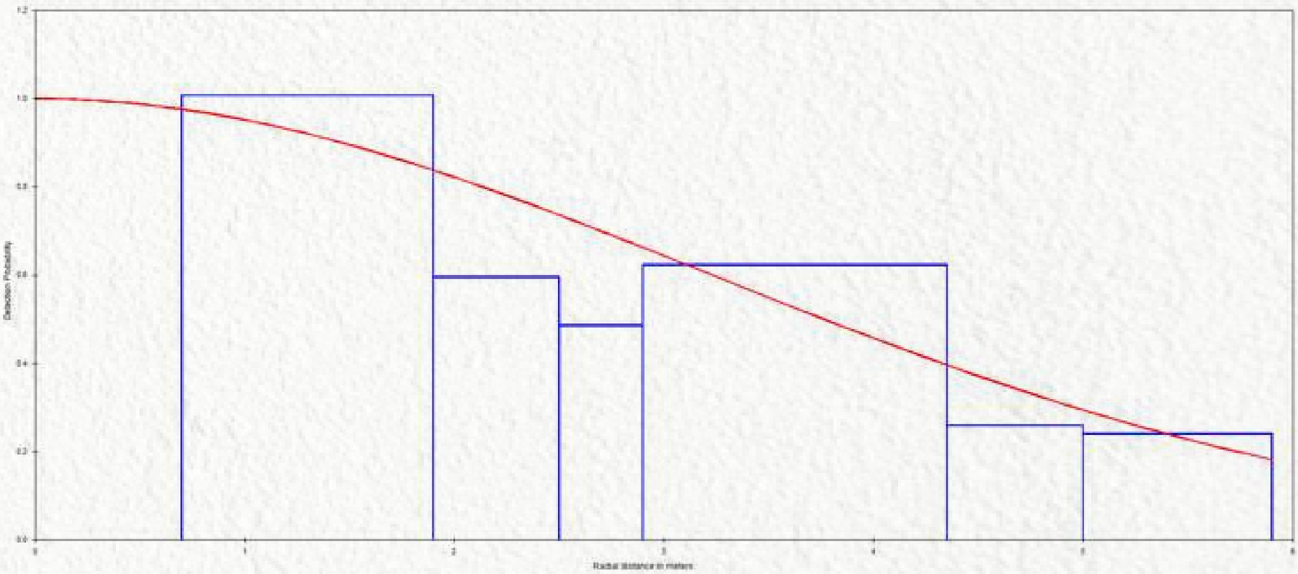


Figure 3.2.2.

Detection function plot of Asian palm civet and small Indian civet using camera trap distance sampling

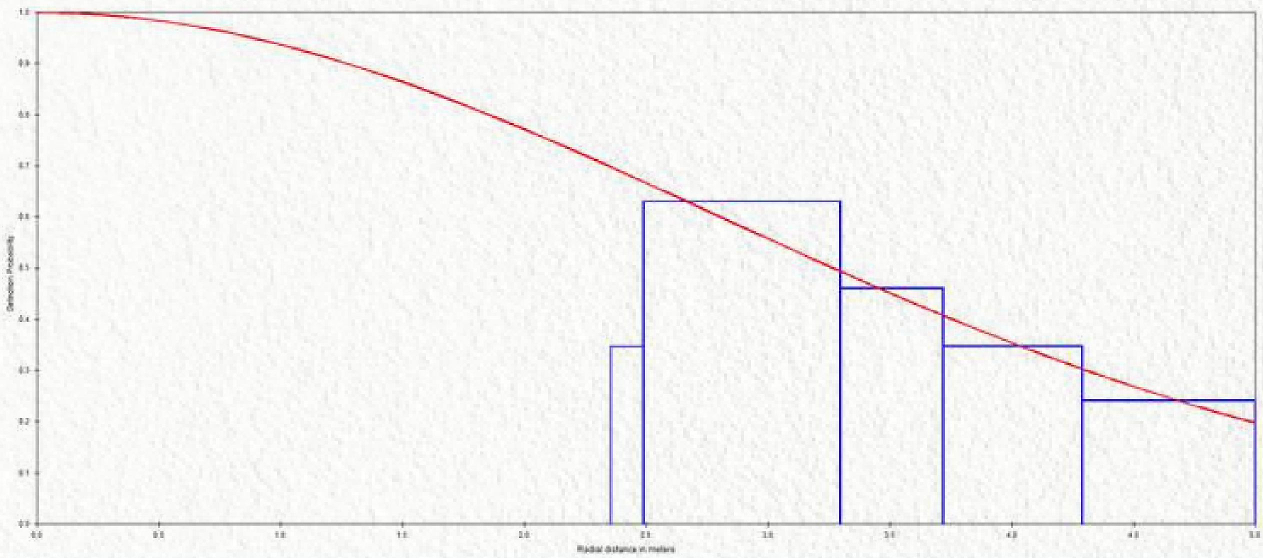


Figure 3.2.3.

Detection function plot of gray mongoose and ruddy mongoose using camera trap distance sampling

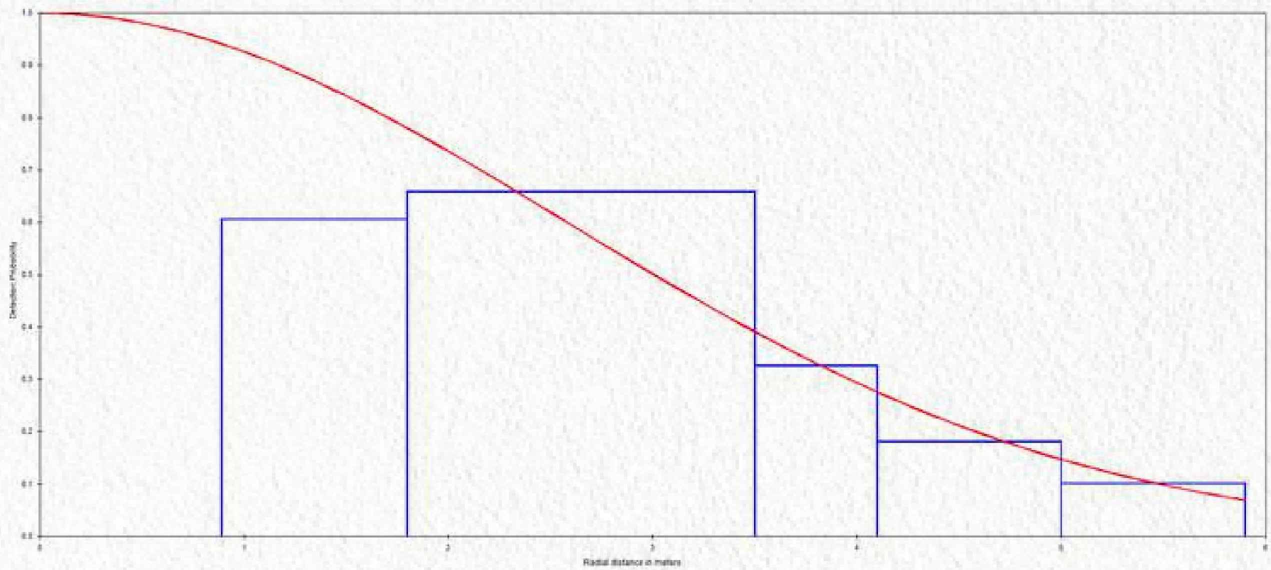


Figure 3.2.4.
Detection function plot of jungle cat, rusty-spotted cat and feral cat using camera trap distance sampling

3.2.4. Discussion

The study provides one of the few quantitative assessments of small carnivores in central India using Camera Trap Distance Sampling (CTDS) in Kuno National Park. Species such as the small Indian civet, jungle cat, and mongoose were successfully modelled, while other species like the golden jackal, Bengal fox, and honey badger were not considered for the density estimation process due to low detections. Results showed small Indian civets had the highest density, followed by ruddy and grey mongooses, whereas jungle cat densities were lower, reflecting species-specific behavior and detectability. Sparse detections of other species highlight the limitations of CTDS for rare, cryptic, or wide-ranging animals. These sparse detections can result from a variety of ecological and methodological constraints. For instance, the Bengal fox, typically associated with open, arid habitats (Vanak & Gompper, 2009), may be underrepresented in forested portions of Kuno. Likewise, the honey badger, known for its wide-ranging behaviour and low population density, is inherently difficult to survey without extensive effort (Begg *et al.* 2016).

While CTDS is highly efficient for estimating densities of medium-sized terrestrial species, its efficacy diminishes for species that are rare, arboreal, avoid trails, or exhibit behaviours that reduce camera detection (Buckland *et al.* 2015). This limitation necessitates a complementary use of alternative approaches such as time-to-event models, sign surveys, or telemetry for a more complete assessment of such species. The detection of a diverse small carnivore assemblage within a relatively small area demonstrates the ecological richness of Kuno National Park. The relatively low densities recorded across most species may reflect natural patterns but could also indicate limitations of the habitat, interspecific competition with larger carnivores, or human pressures from bordering settlements. The presence of low-detection species further suggests that existing conservation and monitoring frameworks should be broadened to include targeted strategies for elusive and data-deficient species. Enhancing sampling duration, using finer-scale trap spacing, and integrating genetic or telemetry data could provide better resolution of species distribution and abundance.

The study is a step forward in understanding the ecological role of small carnivores and their interactions with large predators, particularly in light of cheetah introduction. It also highlights the limitations for rare or elusive species, advocating for integrated multi-method survey designs. Overall, CTDS proved useful for estimating densities of certain species, but integrated methods such as telemetry and sign surveys are recommended for elusive species. Continued monitoring is essential to assess their population trends, habitat use, and potential threats, taking into consideration impending landscape changes due to increasing anthropogenic activities. Long-term monitoring, refined sampling, and inclusive conservation strategies are essential to safeguard the ecological integrity and biodiversity of Kuno National Park and the surrounding landscape. A holistic conservation framework that recognizes the ecological roles and vulnerability of small carnivores is imperative for sustaining the biodiversity and functional integrity of this protected area.

3.3. Relative abundance and spatial distribution of co-predators in Kuno National Park

Based on photo captures obtained from 131 trap locations surveyed in 2024-2025 within the erstwhile Wildlife Sanctuary area of Kuno National Park, the Relative Abundance Index (RAI) of the mammalian carnivores was calculated using the formula mentioned below.

Relative abundance index (RAI) = (No. of independent detections ÷ Total trap effort) × 100.

RAI is used as a proxy for abundance in cases for species that lack distinct individual markings (Carbone *et al.* 2001; O'Brien *et al.* 2003). These RAI values are mapped to depict the spatial distribution and abundance of species, assuming a linear relationship with actual abundance (Güthlin *et al.* 2014). The obtained RAI values are presented in Table 3.2.1. Using these RAI values by plotting kernel density in ArcGIS Map, species-specific maps were generated to depict the spatial distribution of photo-captures across all camera trap locations (Figure 3.2.1)

Table 3.3.
Relative Abundance Index (RAI) of mammalian carnivores obtained during the camera trap survey conducted in Kuno National Park between December 2024 and January 2025.

Species	**Total no. of photocaptures**	**Total no. of independent events**	**RAI**
Leopard	4976	1498	27.81
Striped Hyena	2237	1146	20.83
Jungle Cat	2243	1067	19.51
Golden Jackal	2060	987	18.23
Small Indian Civet	1186	640	11.81
Sloth Bear	791	223	4.25
Ratel	274	174	3.33
Indian Fox	123	94	1.96
Grey Mongoose	240	75	1.38
Common Palm Civet	90	72	1.33
Ruddy Mongoose	241	67	1.24
Rusty Spotted Cat	21	17	0.32

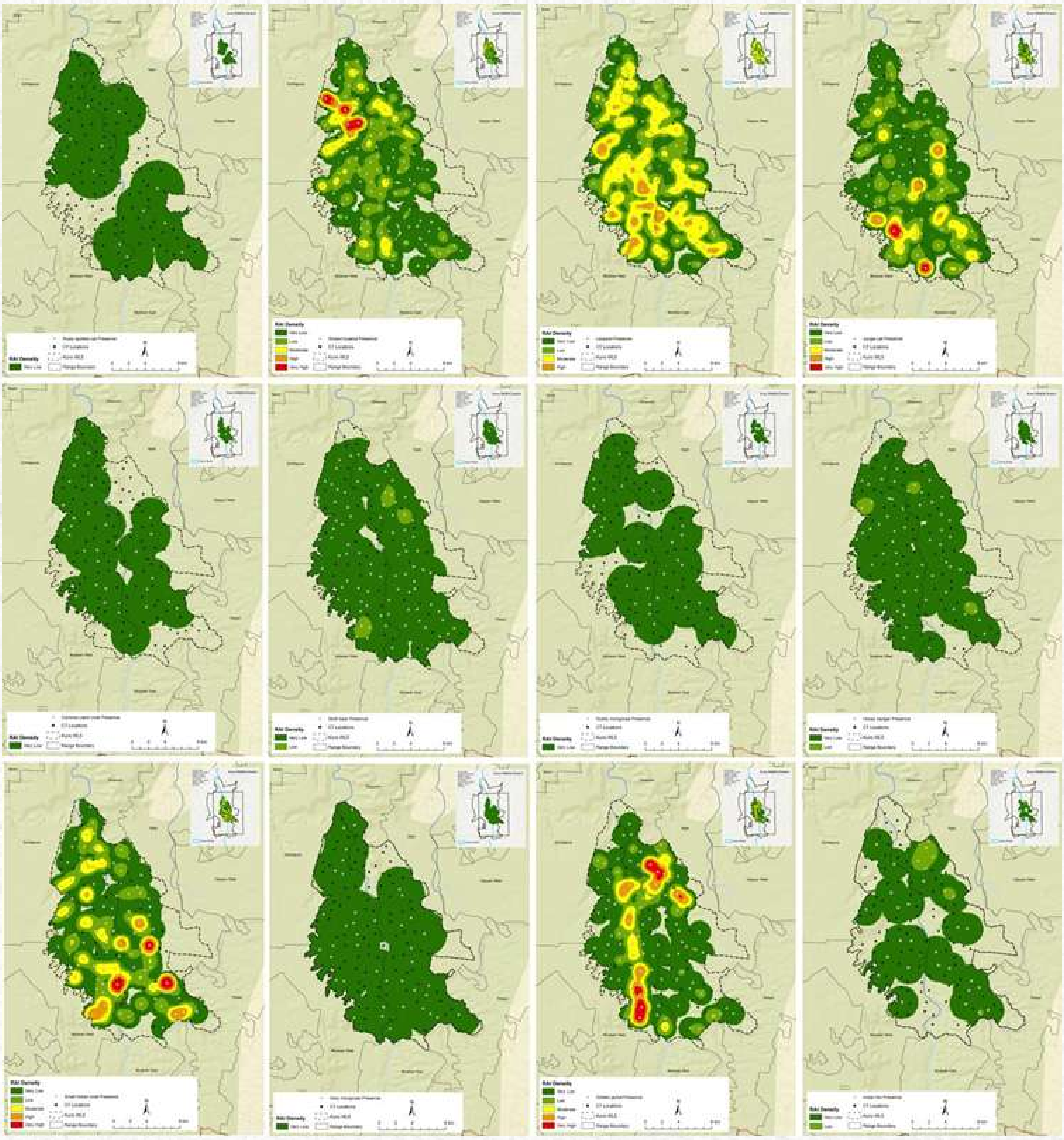


Figure 3.3.

Spatial distribution of mammalian carnivores using the Relative Abundance Index (RAI) of photo captures obtained from camera trap sampling conducted in the erstwhile Wildlife Sanctuary area of Kuno National Park. Rusty spotted cat, striped hyena, leopard and jungle cat (top row L-R); Common palm civet, sloth bear, ruddy mongoose, and Honey badger (middle row L-R); and Small Indian civet, grey mongoose, golden jackal and Indian fox (bottom row L-R)

3.3.1. Activity pattern of mammalian carnivores in Kuno National Park

The activity pattern graphs for carnivore species in Kuno National Park display a rich diversity of temporal behaviours that likely reflect ecological adaptations and interspecific interactions. These graphs were obtained using the package "activity" on R Studio using timestamps of photocaptures of different species, as represented below (Rowcliffe *et al.* 2014).

As shown in Figure 3.3.2., striped hyena, common palm civet, small Indian civet, honey badger, rusty spotted cat, Indian fox, and sloth bear demonstrate nocturnal activity. Gray mongooses and ruddy mongooses exhibit strict diurnal behaviour. Leopards and jungle cats exhibit crepuscular and nocturnal behaviour with peaks of independent photo captures during dusk and dawn. Jackal's activity suggests a cathemeral pattern (Figure 3.2.2).

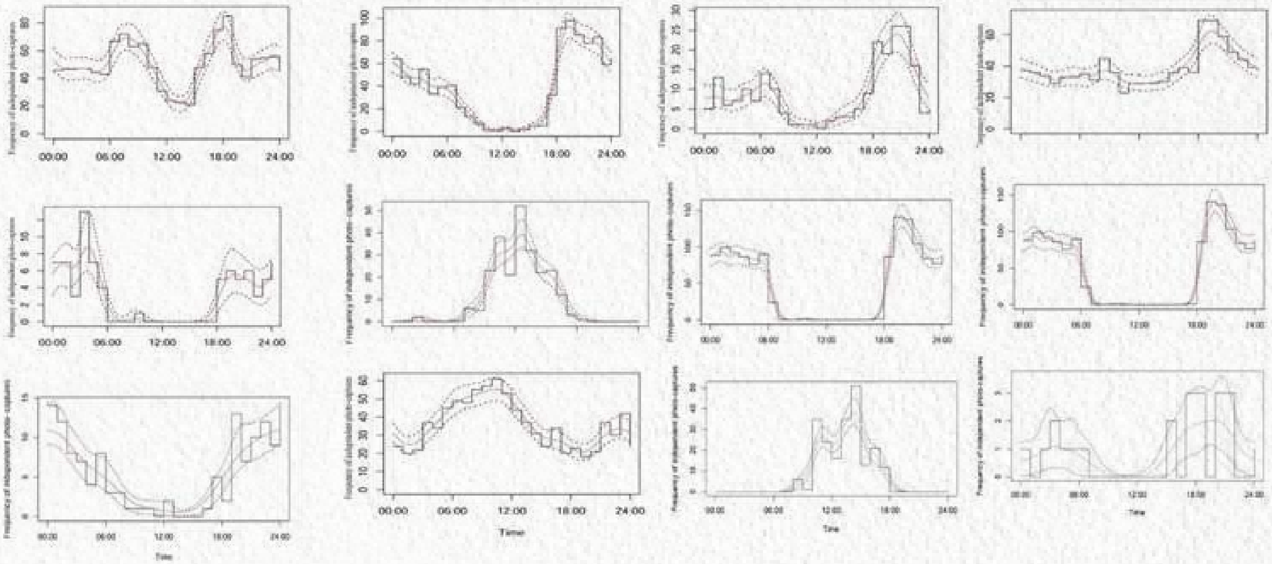
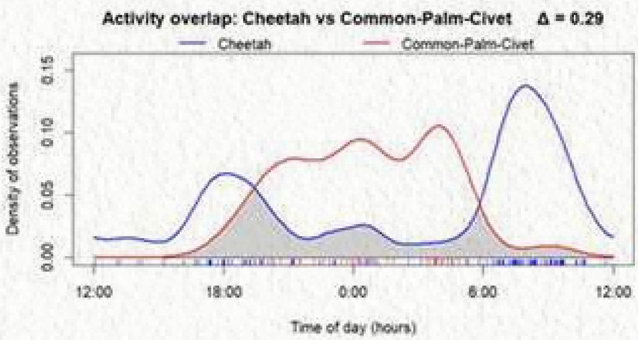
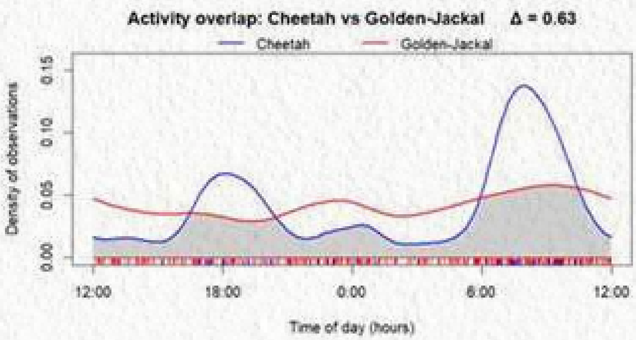


Figure 3.3.1.
Activity patterns of leopard, striped hyena, sloth bear, and jungle cat (top row L-R); common palm civet, grey mongoose, small Indian civet, and Indian fox (middle row L-R); and honey badger, golden jackal, ruddy mongoose, and rusty-spotted cat (bottom row L-R) in the erstwhile Wildlife Sanctuary area of Kuno National Park.

3.3.1.1. Temporal overlap of mammalian carnivores in Kuno National Park

Temporal overlap describes the degree to which two or more species share a similar period of activity within the daily cycle, quantifying how much their activity patterns coincide over time. This metric is estimated using a coefficient (Dhat). Camera trap images were used to develop a record table, and R package activity overlap is used to create activity overlap among mammalian predators. The resulting graphs are presented in the following figures (Figures 3.3.1.1-2).





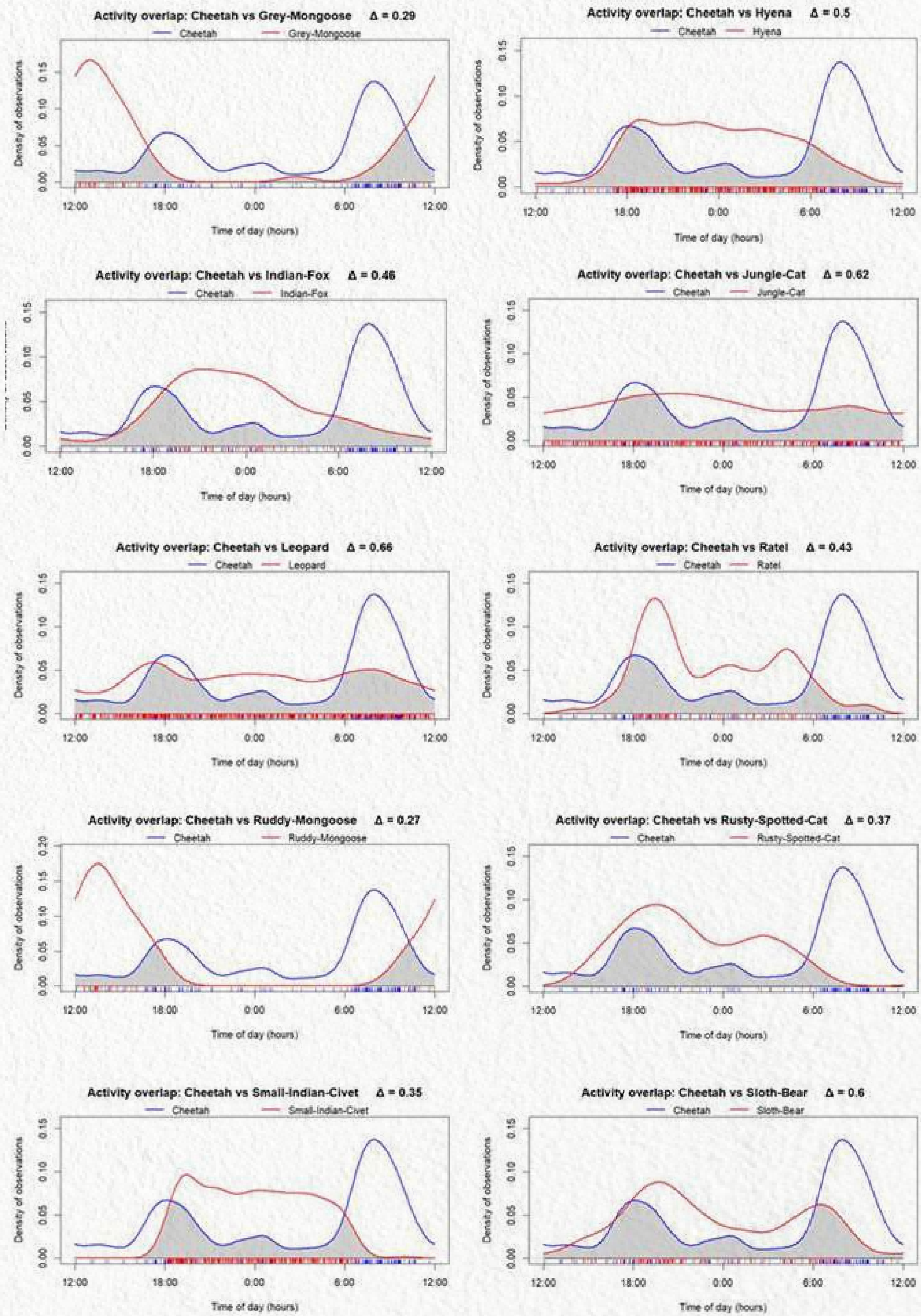
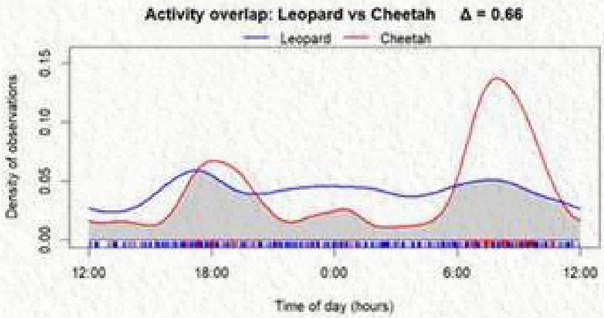
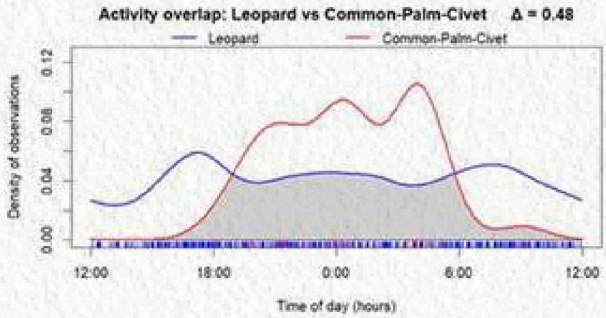
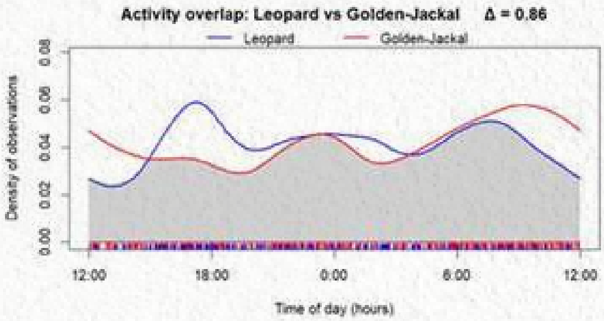


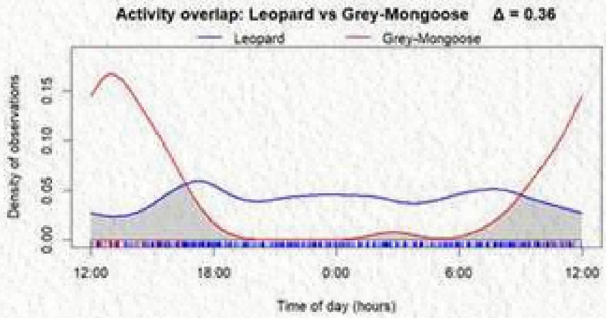
Figure 3.3.1.1.
Activity overlap of cheetah with other mammalian carnivores

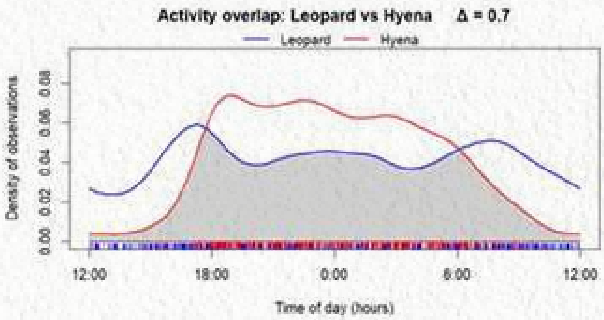
These graphs plot 24-hour density of activity estimates for cheetahs and other mammalian carnivores, revealing temporal overlap and separation among carnivore species of the study area. Cheetahs exhibit moderate overlap with major competitors like hyenas and leopards, especially during dawn and dusk (crepuscular periods), consistent with the premise that apex predators partition core activity windows but retain some shared time to exploit similar resources (Havmøller *et al.* 2020). In contrast, several mammalian carnivores, including civets, mongooses, jungle cats, and Indian foxes, show pronounced temporal separation from cheetahs, likely adopting avoidance strategies to minimize interference competition or predation (Havmøller *et al.* 2020).

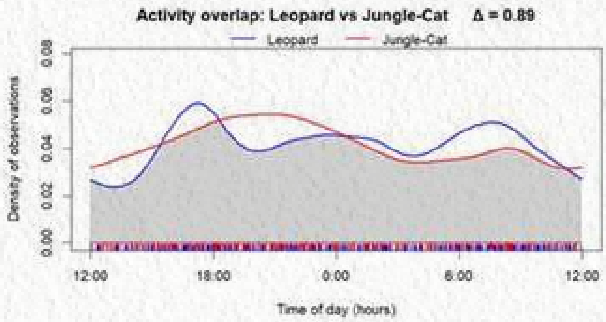


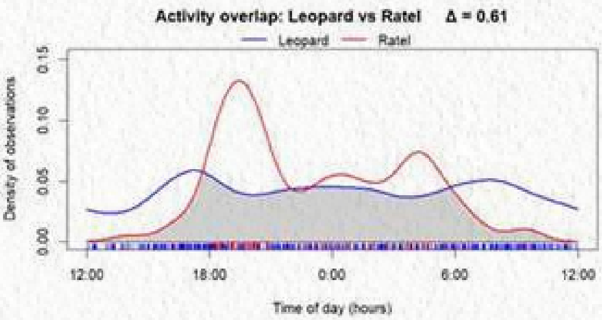


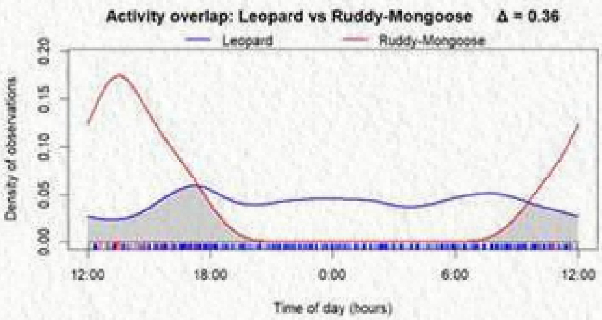












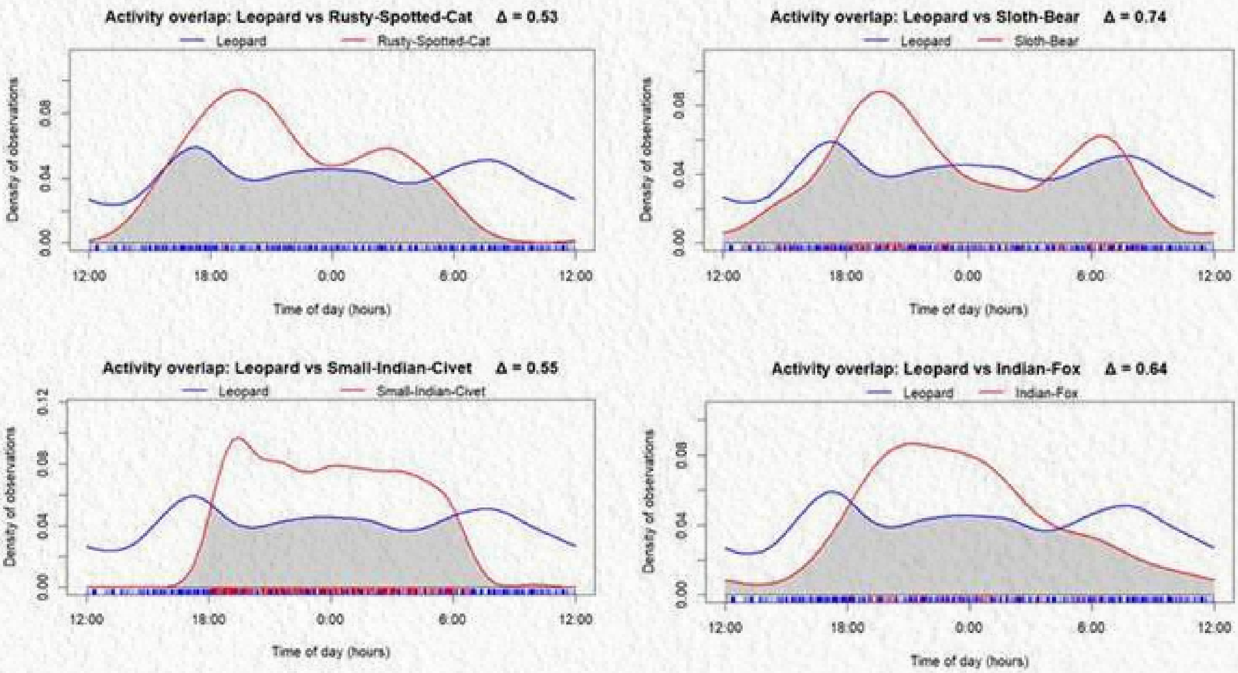


Figure 3.3.1.2.
Activity overlap of the leopard with other mammalian carnivores

When the temporal overlap pattern was generated among leopards and other mammalian carnivores, a notable overlap was observed with some nocturnal and crepuscular carnivores such as the jungle cat and hyena, suggesting potential periods of increased interspecific encounters or resource competition. Contrarily, some species, including civets and mongoose, display clear separation in the activity peaks, indicating temporal partitioning and a strategy to avoid any confrontations.

3.4. Space use of striped hyena in Kuno National Park

3.4.1. Introduction

Energy transfer across trophic levels, conventionally attributed to predation, is also substantially mediated through scavenging. Many predatory species engage in facultative scavenging, opportunistically exploiting carrion without exclusive dependence upon it, a strategy that is taxonomically widespread and demonstrably more energetically efficient than active predation under certain ecological conditions (Foltan *et al.* 2005). By occupying this functionally distinct niche, scavengers contribute disproportionately to ecosystem functioning through three principal services: augmenting food web stability via increased inter-trophic connectivity (Rooney *et al.* 2006; Wilson & Wolkovich, 2011), facilitating nutrient cycling within and across the ecosystem (Helfield & Naiman, 2001), and conferring sanitary benefits through carcass removal, which suppresses bacterial proliferation and mitigates disease transmission risks to wildlife, human populations, and associated economies (Kaden *et al.* 2003; Beasley *et al.* 2015).

Among the four extant species within the family Hyaenidae, only the striped hyena (*Hyaena hyaena*) occurs in India. The species exhibits a broad but increasingly fragmented distribution spanning northern Africa, the Middle East, the Arabian Peninsula, and parts of Asia (Derouiche *et al.* 2020; Kolowski & Holekamp, 2006), with populations predominantly occupying arid and semi-arid landscapes (Akash *et al.* 2021). As a facultative scavenger and opportunistic predator, the striped hyena co-occurs with a sympatric carnivore guild comprising tigers (*Panthera tigris*), leopards (*Panthera pardus*), and golden jackals (*Canis aureus*), while delivering critical ecosystem services through organic waste recycling and disease risk reduction (Panda *et al.* 2023). Despite their ecological and evolutionary significance, the spatial ecology and activity patterns of striped hyenas remain comparatively understudied (Wagner, 2006). As a predominantly solitary and nocturnal species, their movement ecology and home range dynamics reflect adaptive responses to resource-limited and human-dominated landscapes (Mandal, 2019). The species additionally exhibits considerable behavioral plasticity, with documented instances of social behavior and cooperative offspring care under specific ecological conditions (Tichon *et al.* 2020). Investigating interspecific interactions between striped hyenas and sympatric carnivores, including reintroduced cheetahs (*Acinonyx jubatus*) and leopards within Kuno National Park, is essential for elucidating mechanisms of resource partitioning, habitat utilization, and coexistence (Allen *et al.* 2015; Moleón *et al.* 2014; Hayward *et al.* 2006a). Such knowledge will further enable more robust predictions of population responses to habitat fragmentation, anthropogenic disturbance, and climate change (Singh, 2008).

3.4.2. Capture, immobilisation, and post-release monitoring of striped hyenas

Trapping sites were selected based on camera trap detection frequencies, field observations, and species-specific signs, including tracks, scat, and butter (secretion from anal glands for territory marking). Humane leghold traps with integrated rubber padding were deployed and baited under veterinary and Forest Department supervision, with trap floors lined with black adhesive tape and dry leaf litter to minimize visual and tactile aversion. Scent trails were established by dragging bait around capture sites, exploiting the species' olfactory foraging behaviour (Woodmansee *et al.* 1991).

Captured individuals were immobilised using a combination of Zoletil 100, butorphanol, and medetomidine hydrochloride by a licensed veterinary team. Blood and ectoparasite samples were collected for disease screening and genetic analyses, while morphometric measurements, tooth dimensions, reproductive status, and photographic records of stripe patterns, dentition, and genitalia were documented for individual identification and demographic profiling. Age estimation was based on body size, mass, and tooth wear. All individuals were fitted with IR-SAT Iridium satellite GPS collars, followed by reversal with Atipamezole, and released following confirmed physiological recovery.

During the study period, the mortality of one radio-collared female, ID-6784, was recorded, whose carcass was recovered after two consecutive days of no transmission. Field examination revealed consumption patterns and injury characteristics most likely predated by a leopard (*Panthera pardus*).

Table 3.4.1.
The details of radio-collared striped hyenas in Kuno National Park

Hyena ID	Collar Type	Date of Collaring	Collar Status
ID: 6309	IR-SAT	03rd May, 2023	Not Active
ID: 6307	IR-SAT	21st Nov, 2023	Not Active
ID: 6784	IR-SAT	13th Dec, 2023	Not Active
ID: 6225	IR-SAT	09th Apr, 2024	Not Active
ID: 8028	IR-SAT	31st Jan, 2025	Active

3.4.3. Home range and movement of striped hyenas in Kuno National Park

Home ranges (100% MCP) of the radio-collared hyenas varied from 30.38 km^2 for a young animal to 94.75 km^2 for a subadult male. The home range sizes using 95% KDE and 100% MCP methods are listed in Table 3.4.2. The average daily distance moved by the animals ranged from 5.37 (0.15 SE) to 7.90 (0.21 SE) km.

Table 3.4.2.
Home range sizes and average daily movement of radio-collared striped hyenas in and around Kuno National Park

Tag ID/Type	Age Category & Sex	100% MCP Area (km²)	95% KDE Area (km²)	50% KDE Area (km²)	Average Daily Distance Moved (km)	Days
IR-SAT 6309	Adult Male	84.09	26.38	3.18	5.37 (0.15 SE)	424
IR-SAT 6307	Sub-adult Male	94.75	76.65	14.30	7.90 (0.21 SE)	372
IR-SAT 6225	Young	30.38	19.75	4.15	5.39 (0.18 SE)	293
(6-7 months)	30.38	19.75	4.15	5.39 (0.18 SE)	293	27
IR-SAT 6784	Young female (6-7 months)	10.09	5.49	0.51	2.04 (0.66 SE)	27
IR-SAT 8028	Adult Male	51.78	22.63	4.29	6.17 (0.26 SE)	199

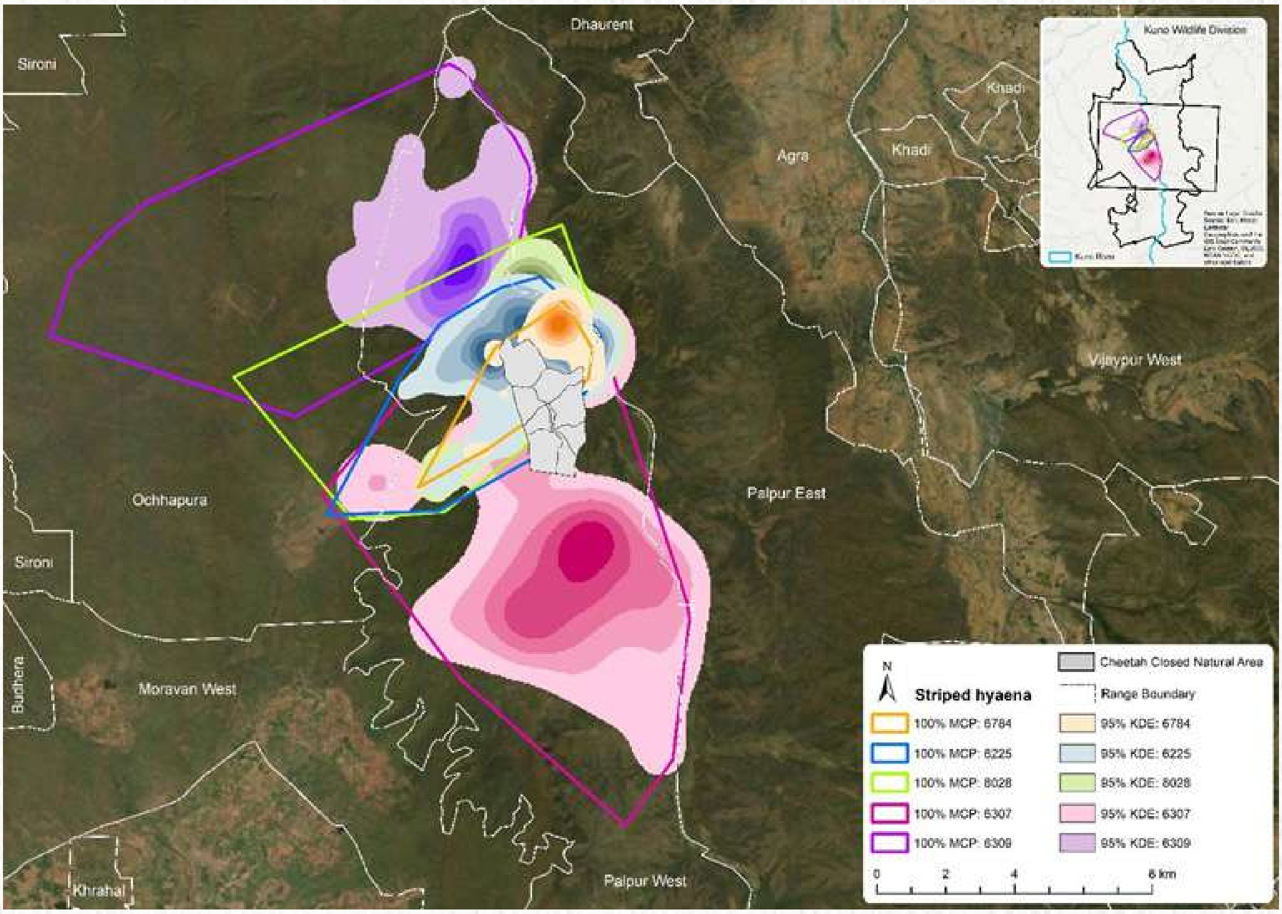


Figure 3.4.1.
Home ranges (100% MCP & 95% KDE) of radio-collared striped hyenas in and around Kuno National Park

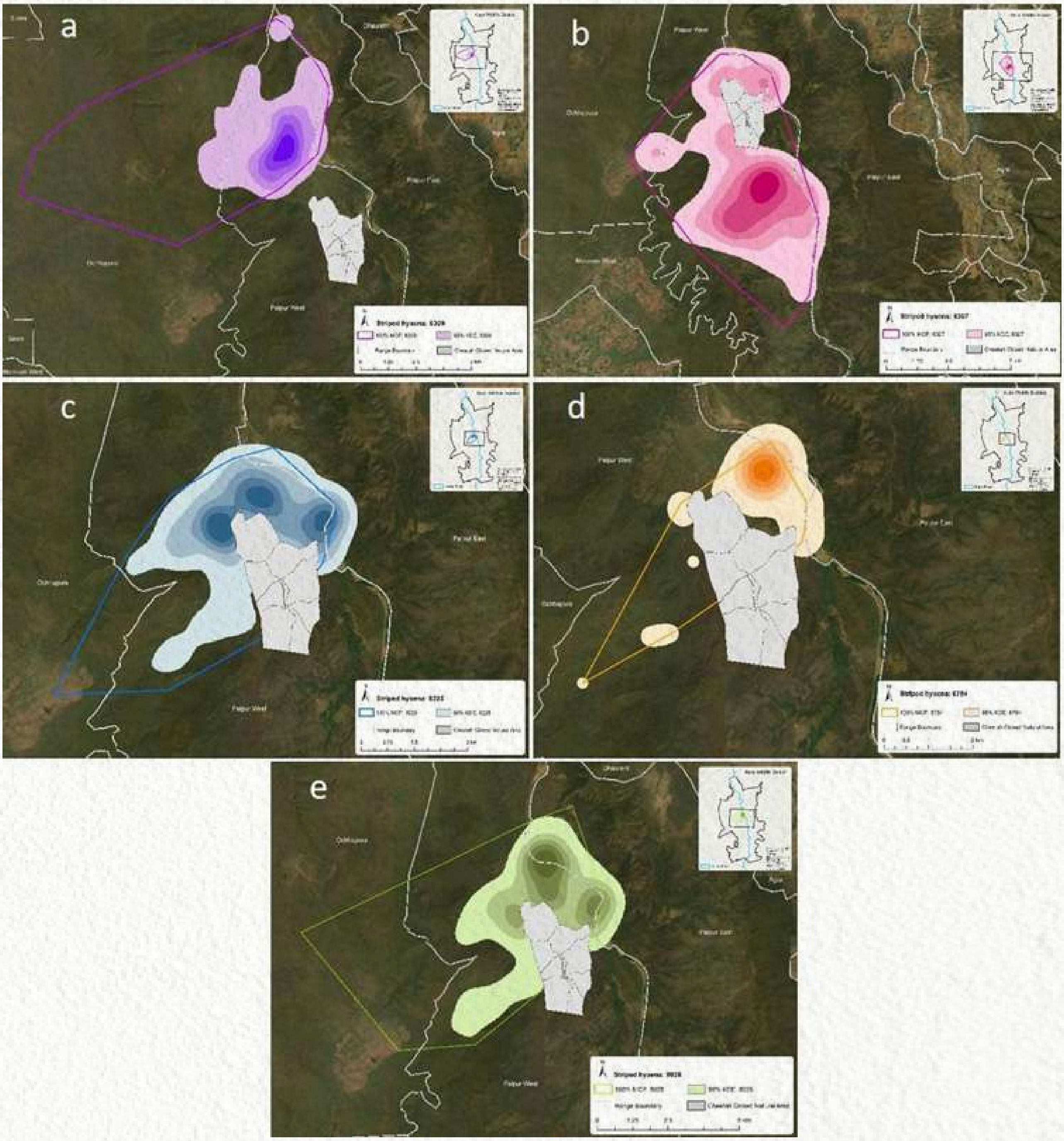


Figure 3.4.2.
Home ranges using 100% Minimum Convex Polygon (MCP) and 95% Kernel Density Estimator (KDE) of radio-collared striped hyenas. (a). TagID: 6309, (b). TagID: 6307, (c). TagID: 6225, (d). TagID: 6784, & (e). TagID:8028 in and around Kuno National Park

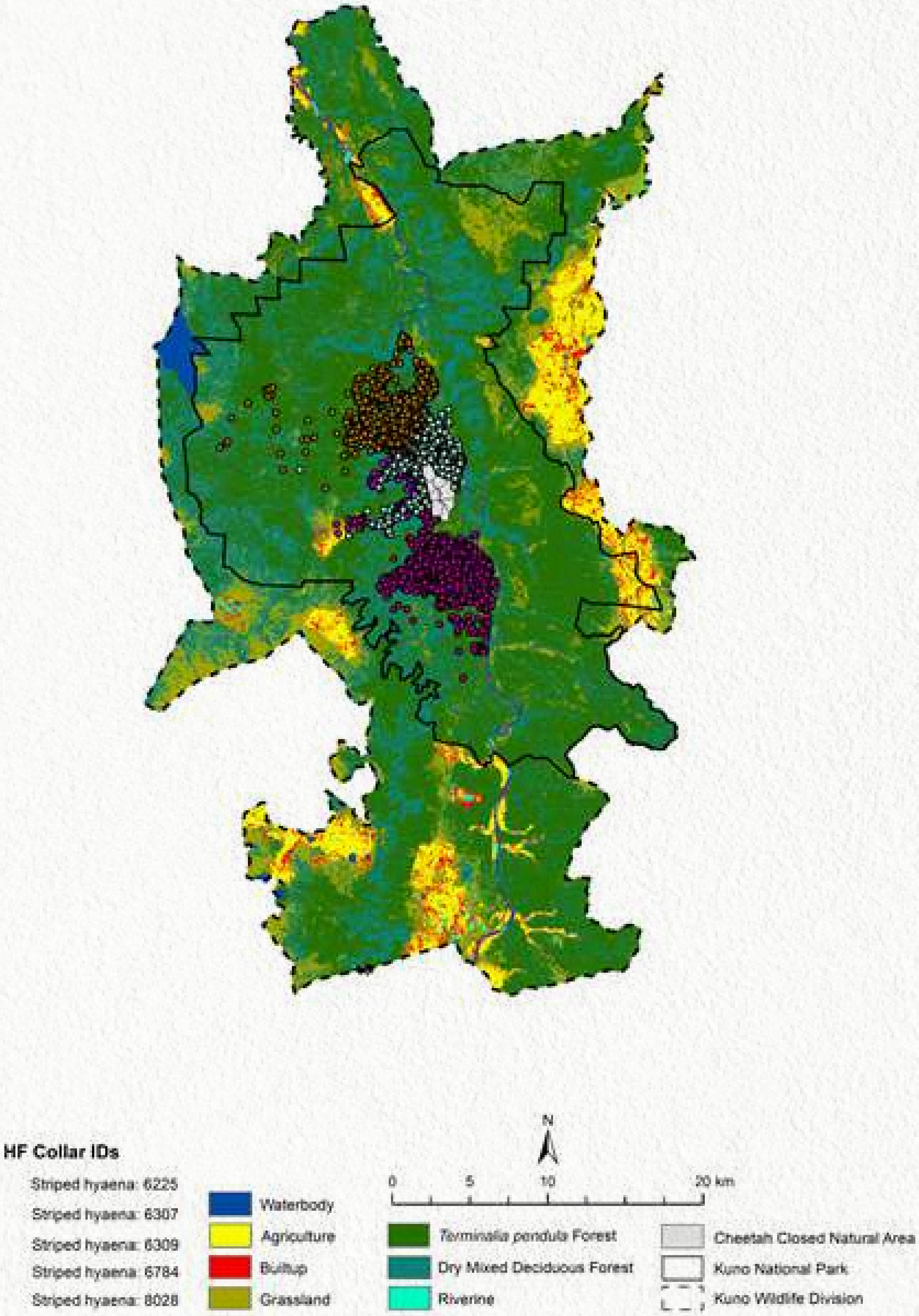


Figure 3.4.3.
Locations of radio-collared striped hyenas overlaid on the forest type map of Kuno Wildlife Division

3.4.4. Habitat selection of striped hyenas in and around Kuno National Park

Habitat preferences of radio-collared striped hyenas in and around Kuno National Park were quantified using the Resource Selection Function (RSF), which evaluated observed habitat use relative to available habitat within each individual's range. Second-order habitat selection was further assessed using Ivlev's Electivity Index, calculated independently for each Land Use and Land Cover (LULC) class, comprising grassland, dhonk forest, riverine habitat, miscellaneous dry deciduous forest, water bodies, built-up areas and human habitation, and agricultural land.

RSF analysis indicated that striped hyenas exhibited a strong and consistent preference for riverine habitat patches relative to all other available habitat types. This pattern was corroborated at the individual level by Ivlev's Electivity Index, which demonstrated positive selection for riverine patches across the majority of home ranges assessed. Notwithstanding this overarching trend, inter-individual variation in habitat selection was evident. Two individuals exhibited disproportionately higher utilisation of savannah grassland relative to its availability, while the adult male demonstrated a comparatively greater degree of selection for dhonk forest. These findings collectively suggest that while riverine habitat constitutes the primary selected habitat type for striped hyenas in Kuno, individual-level variation in land cover preferences may reflect differences in age, sex, territory configuration, or localized resource distribution.

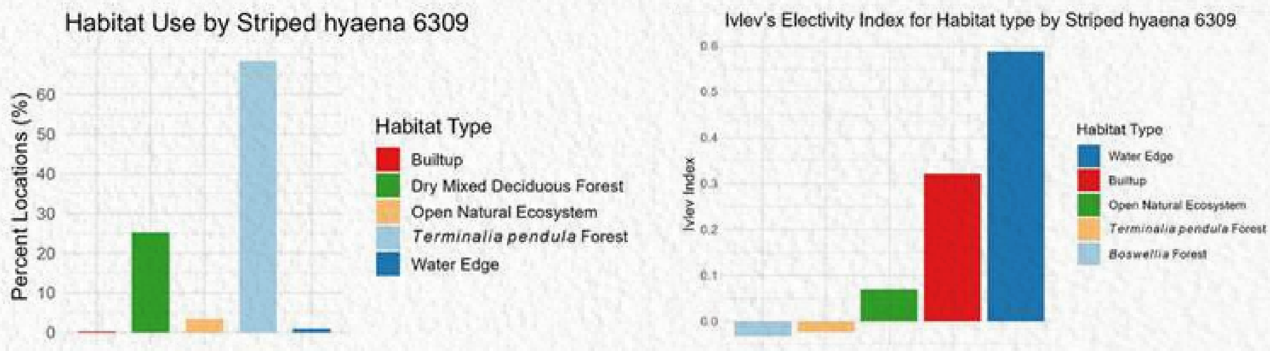


Figure 3.4.3.
Habitat selection of radio-collared striped hyena (6309) adult male using Ivlev's index (right) and percentage of locations in each habitat type (left)

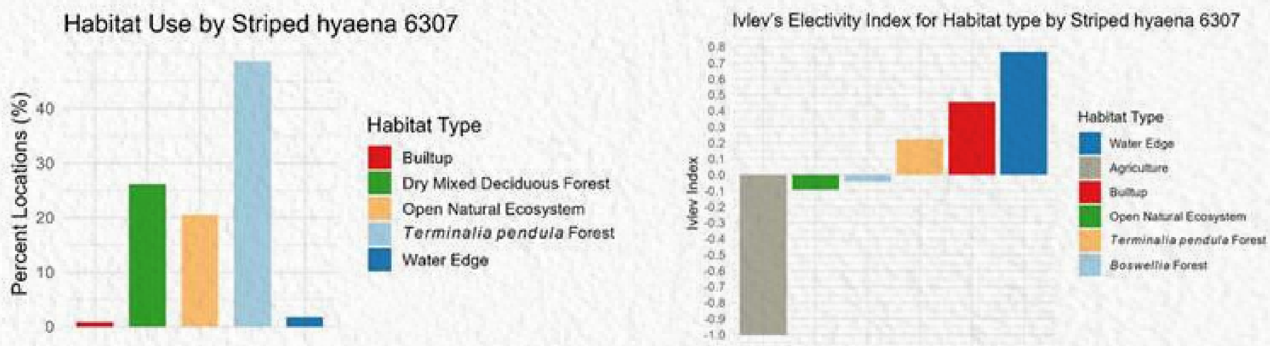


Figure 3.4.4.
Habitat selection of radio-collared striped hyena (6307) adult male using Ivlev's index (right) and percentage of locations in each habitat type (left)

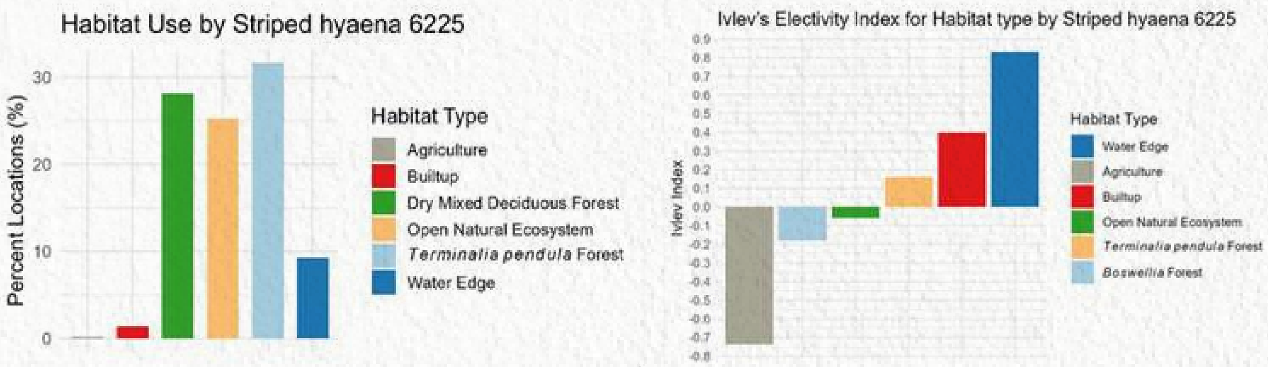


Figure 3.4.5.
Habitat selection of radio-collared striped hyena (6225) adult male using Ivlev's index (right) and percentage of locations in each habitat type (left)

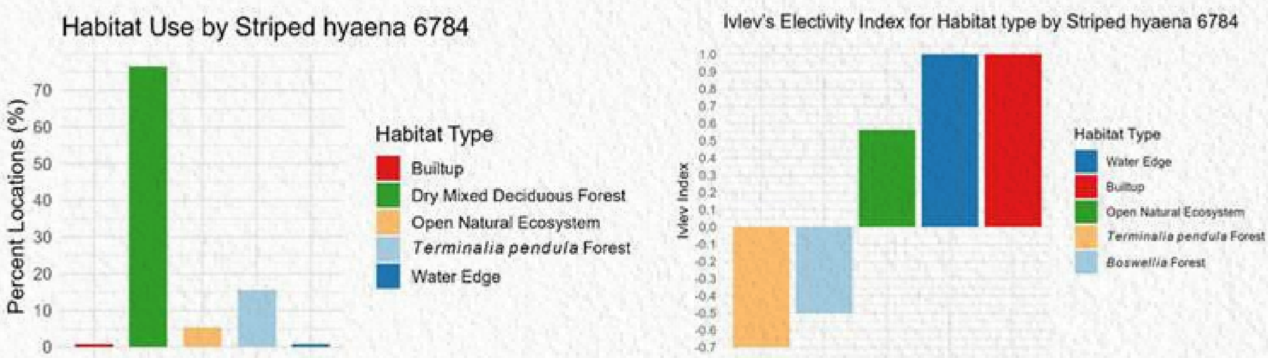


Figure 3.4.6.
Habitat selection of radio-collared striped hyena (6784) adult male using Ivlev's index (right) and percentage of locations in each habitat type (left)

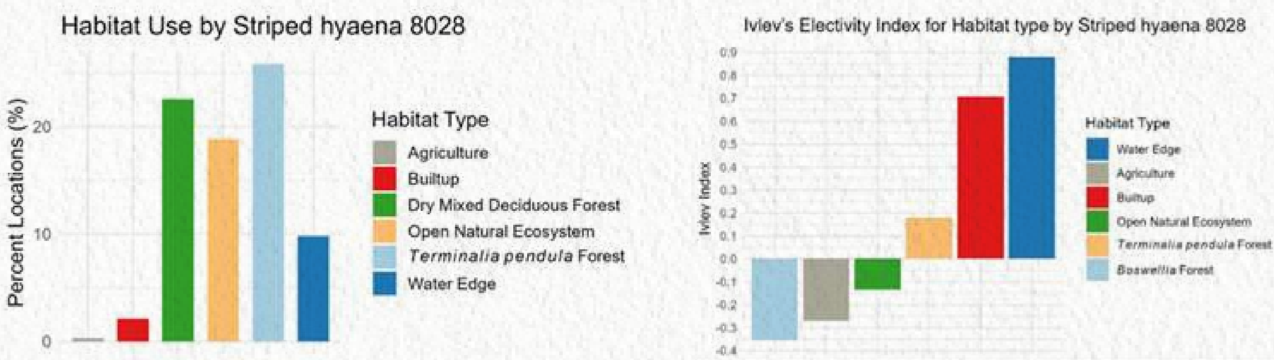


Figure 3.4.7.
Habitat selection of radio-collared striped hyena (8028) adult male using Ivlev's index (right) and percentage of locations in each habitat type (left)

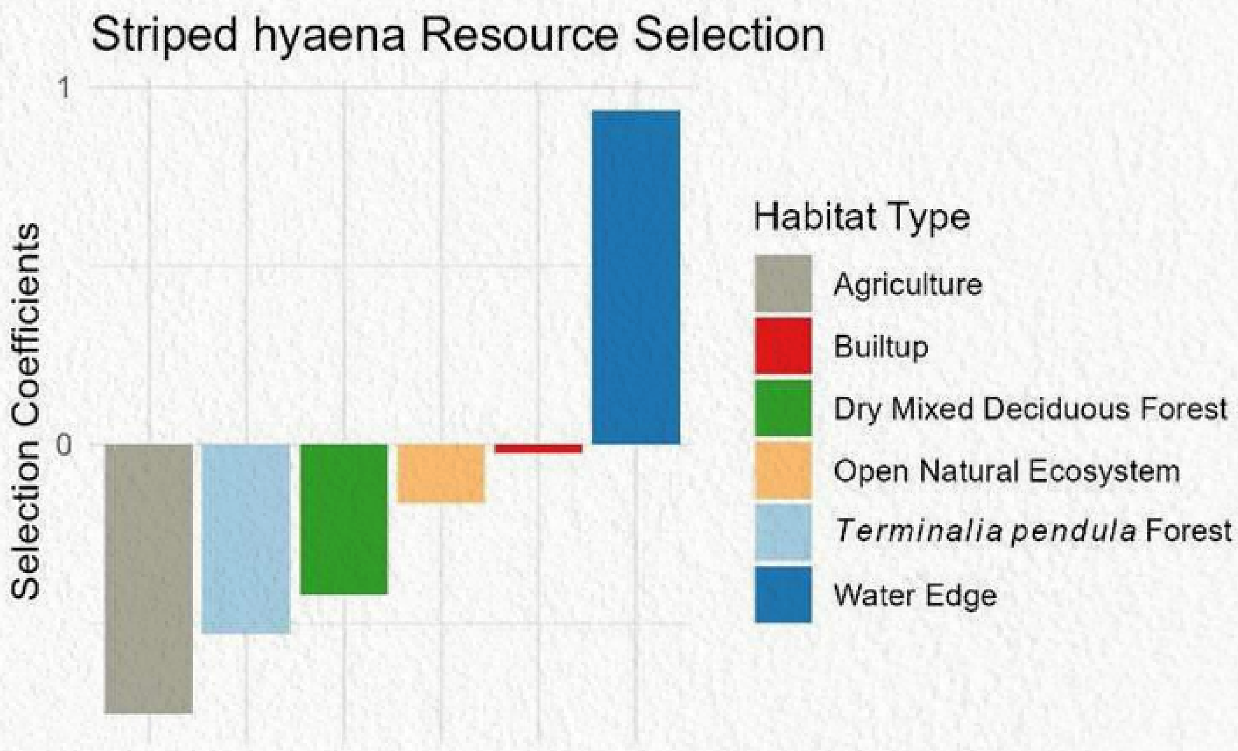


Figure 3.4.8.
Habitat selection of radio-collared striped hyenas in Kuno Wildlife Division using the Resource Selection Function

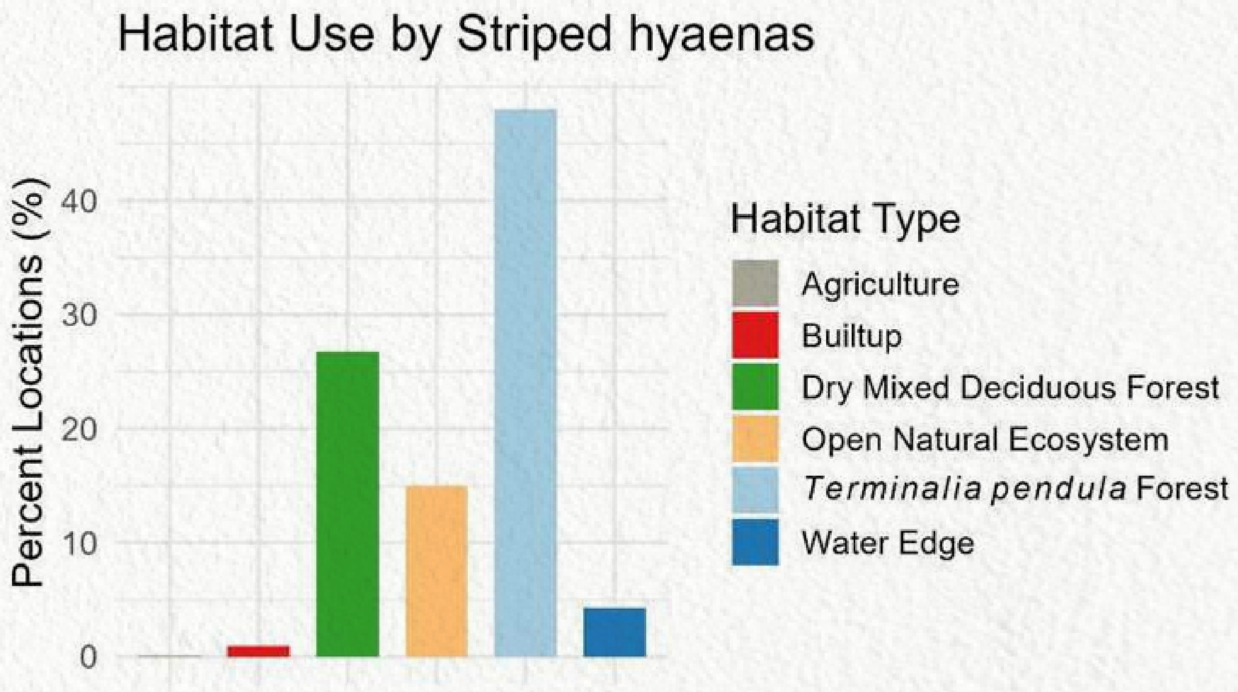


Figure 3.4.9.
Habitat use of radio-collared striped hyenas in Kuno Wildlife Division using the percentage of locations in each habitat type

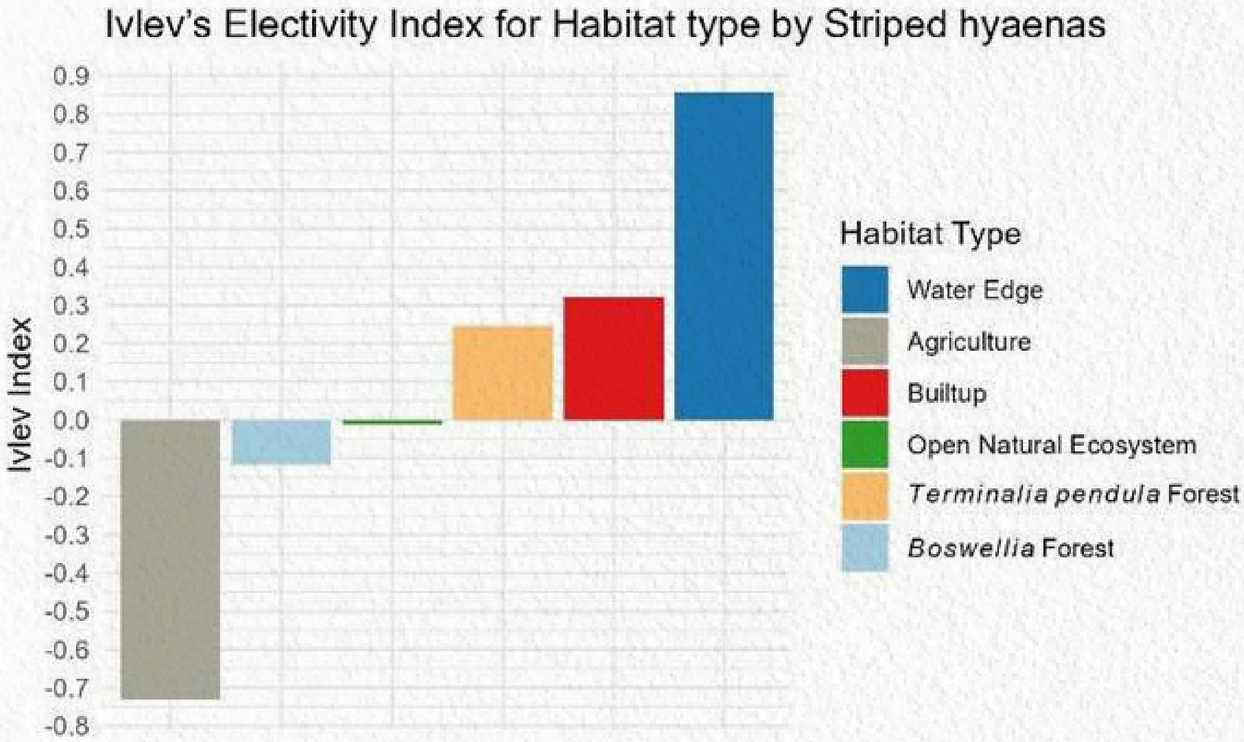


Figure 3.4.10.
Habitat use of radio-collared striped hyenas in Kuno Wildlife Division using the Ivlev's index

3.5. Space use of golden jackals in Kuno National Park

3.5.1. Introduction

The golden jackal is a medium-sized canid widely distributed across South Asia, the Middle East, and parts of Europe and Africa. Highly adaptable and opportunistic, the species often attains medium to high densities in areas with plenty of food and cover (Jhala & Moehlman, 2013). Although it's capable of hunting, it often subsists by scavenging (Sheldon, 1992). As an omnivorous species, its diet primarily consists of rodents, birds, and fruits (Mukherjee *et al.* 2004). In India, they often wander into human habitations at night to feed on anthropogenic food resources (Aiyadurai & Jhala 2006). It plays a significant role in the removal of considerable amounts of discarded animal waste and potential crop pests in urban ecosystems (Ćirović *et al.* 2016). As a facultative scavenger, it contributes to nutrient cycling and maintenance of ecosystem health (Vanak & Gompper, 2009). It has a flexible social system (Macdonald, 1979), and it varies according to availability of food (Chourasia *et al.* 2012). It is not strictly territorial (Aiyadurai & Jhala, 2001), and their home range size varies between 3 and 30 km^2 (Aiyadurai & Jhala, 2006).

Despite being locally abundant, the population is declining almost across its entire range, except in protected areas, primarily due to human modifications of traditional land-use patterns (Jhala & Moehlman, 2013). The diseases and competition from feral dogs pose serious threats to golden jackal populations (Jhala *et al.* 2021).

Studying the abundance, home range, movement patterns, and habitat use of golden jackals will give a better understanding of their ecology and help in understanding interactions among the mammalian carnivore community and introduced cheetahs in Kuno National Park.

India's open-natural ecosystems have been undervalued and misclassified to the point where they are officially categorized as 'degraded lands' or 'wastelands' (Vanak, 2019; Vanak *et al.* 2017). Hence, prioritizing the conservation of these open-natural ecosystems is essential, and initiatives such as Project Cheetah (Jhala *et al.* 2021) are vital steps towards securing the long-term preservation of these ecosystems and associated wild species.

3.5.2.1. Trap deployment and capture protocol

Two types of traps were used for capturing golden jackals: padded foothold traps and double-door walk-through cages. These traps were strategically placed based on locations with frequent direct sightings and high photo-capture rates from the camera trap survey dataset. Baits were used to lure target species, and these traps were monitored every 2-3 hours to ensure animal safety.

3.5.2.2. Immobilization and collaring procedure

Immobilization of three individuals (n=3) was conducted by an experienced veterinary team using a combination of medetomidine and zolazepam-tiletamine (Zolatil). Each animal was fitted with a GPS (UHF) collar from African Wildlife Tracking, weighing 2-4% of body weight. The age of each jackal was assessed through tooth wear and their sexes. A detailed health examination was conducted, and morphometric measurements were recorded. A reversal agent was administered after the procedure to ensure complete recovery from anesthesia and release.

3.5.2.3. Telemetry and monitoring protocol

The GPS collars were programmed to record locations at three-hour intervals throughout the telemetry period. These GPS locations were downloaded using an AWT transceiver in the field while tracking radio-collared individuals by researchers. During visual monitoring, researchers also record environmental parameters such as habitat type, microhabitat characteristics, weather condition, terrain type, and proximity to the nearest water source.

At present, two out of the three deployed collars are active: one fitted on an adult male and the other on an adult female. Data from these individuals are being used to estimate home range size, quantify average daily distance travelled, and assess habitat selection patterns.

Table 3.5.1.
Active collar details of golden jackal in and around Kuno National Park

Jackal ID	Collar Type	Date of Collaring	Period of Data Available	Collar Status
ID: 6792	IR-SAT (Iridium satellite)	23 November, 2023	476 days	Active
ID: 6796	IR-SAT (Iridium satellite)	29 January, 2025	109 days	Active

3.5.3. Home range and average daily movement of golden jackals in and around Kuno National Park

The home-range sizes of the golden jackals using kernel density estimates (95% and 50% KDE) and the 100% and 95% Minimum Convex Polygon (MCP) method and the average daily distance are listed in Table 3.4.2.

Table 3.5.2.
Home range sizes and average daily movement of radio-collared golden jackals in and around Kuno National Park.

Tag ID/Type	Age/Sex	100% MCP Area (km^2)	95% MCP Area (km^2)	95% KDE Area (km^2)	50% KDE Area (km^2)	Average Daily Distance Moved (km)
UHF 6792 (GPS)	Adult/ Male	65.7	19.98	12.75	1.4	4.56
UHF 6796 (GPS)	Adult/ Male	101.67	87.45	55.7	5.34	3.13

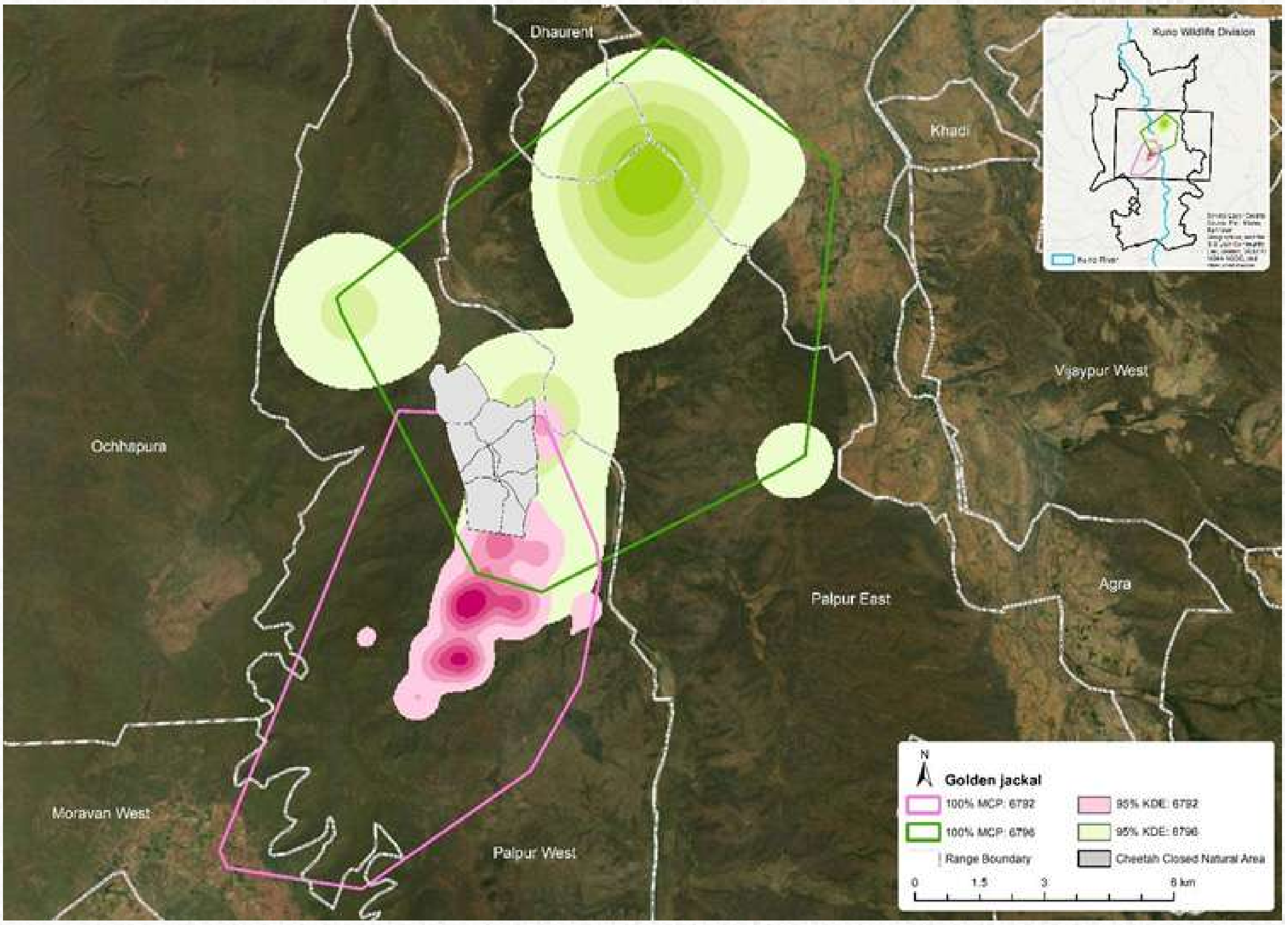


Figure 3.5.1.

Home ranges using 100% Minimum Convex Polygon (MCP) and 95% Kernel Density Estimator (KDE) of radio-collared golden jackals (TagID:6792 & TagID:6796) in and around Kuno National Park.

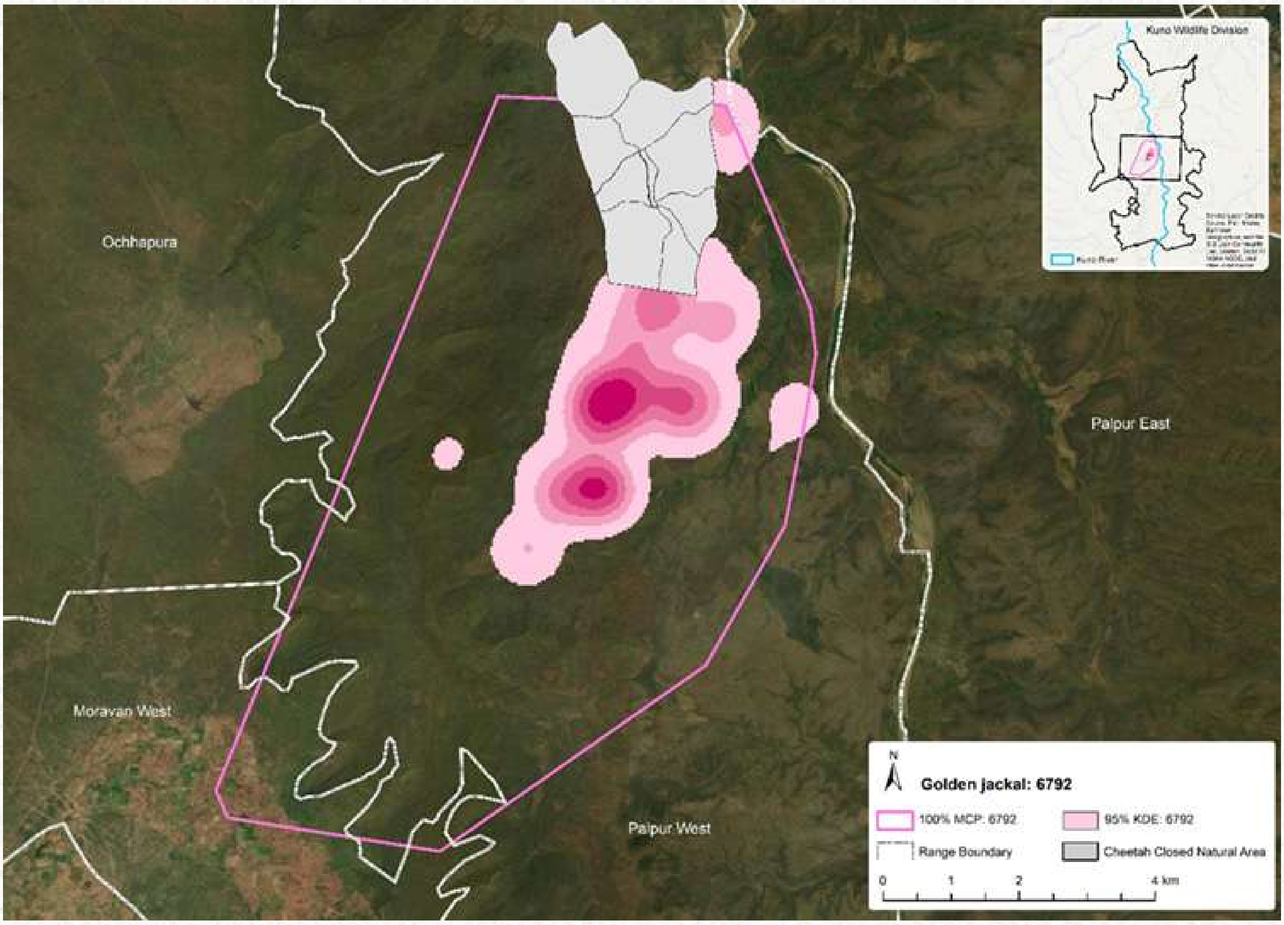


Figure 3.5.2.
Home ranges using 100% Minimum Convex Polygon (MCP) and 95% Kernel Density Estimator (KDE) of radio-collared golden jackal (TagID:6792) in Kuno National Park.

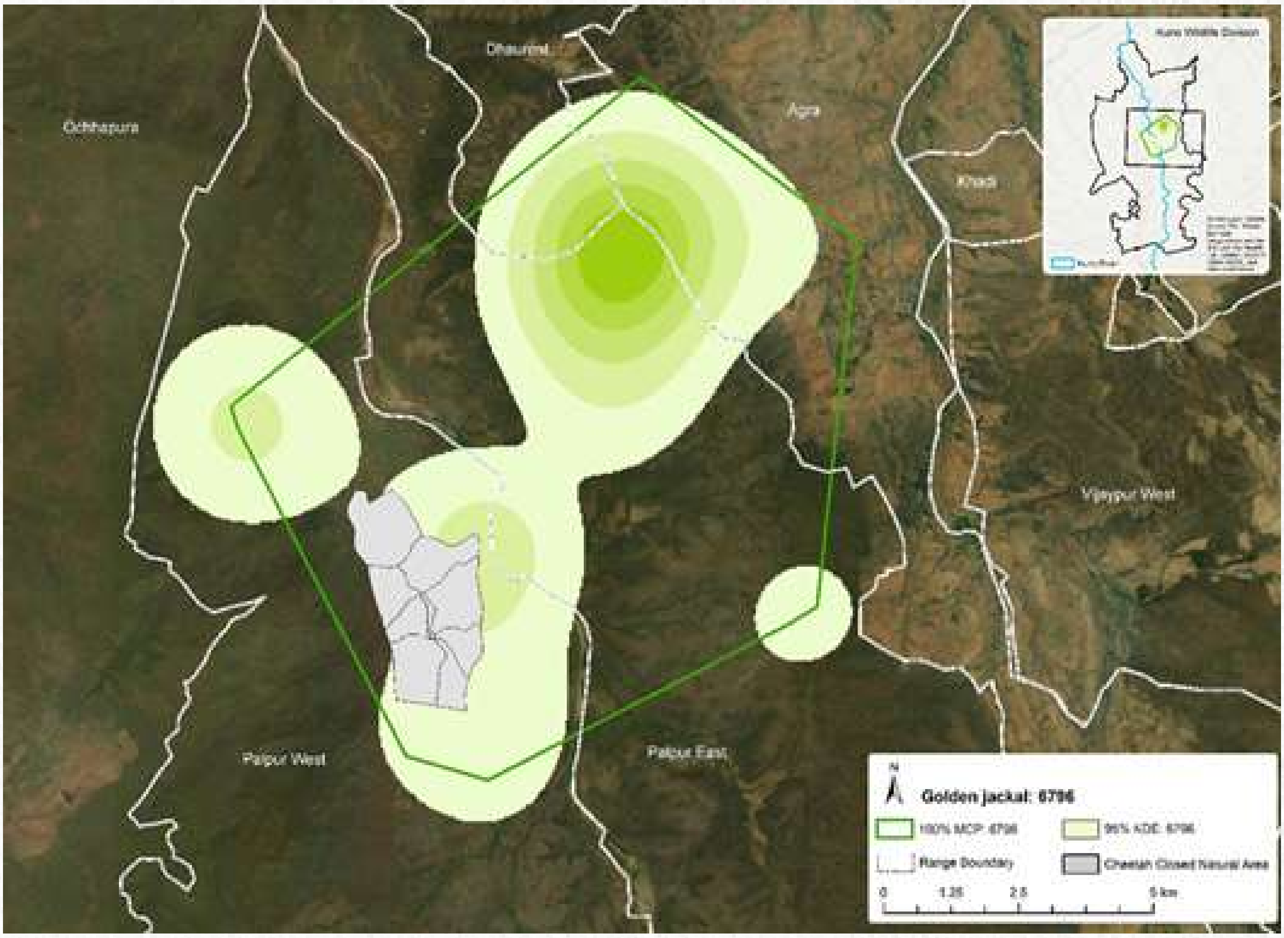


Figure 3.5.3.
Home ranges using 100% Minimum Convex Polygon (MCP) and 95% Kernel Density Estimator (KDE) of radio-collared golden jackal (TagID: 6796) in and around Kuno National Park.

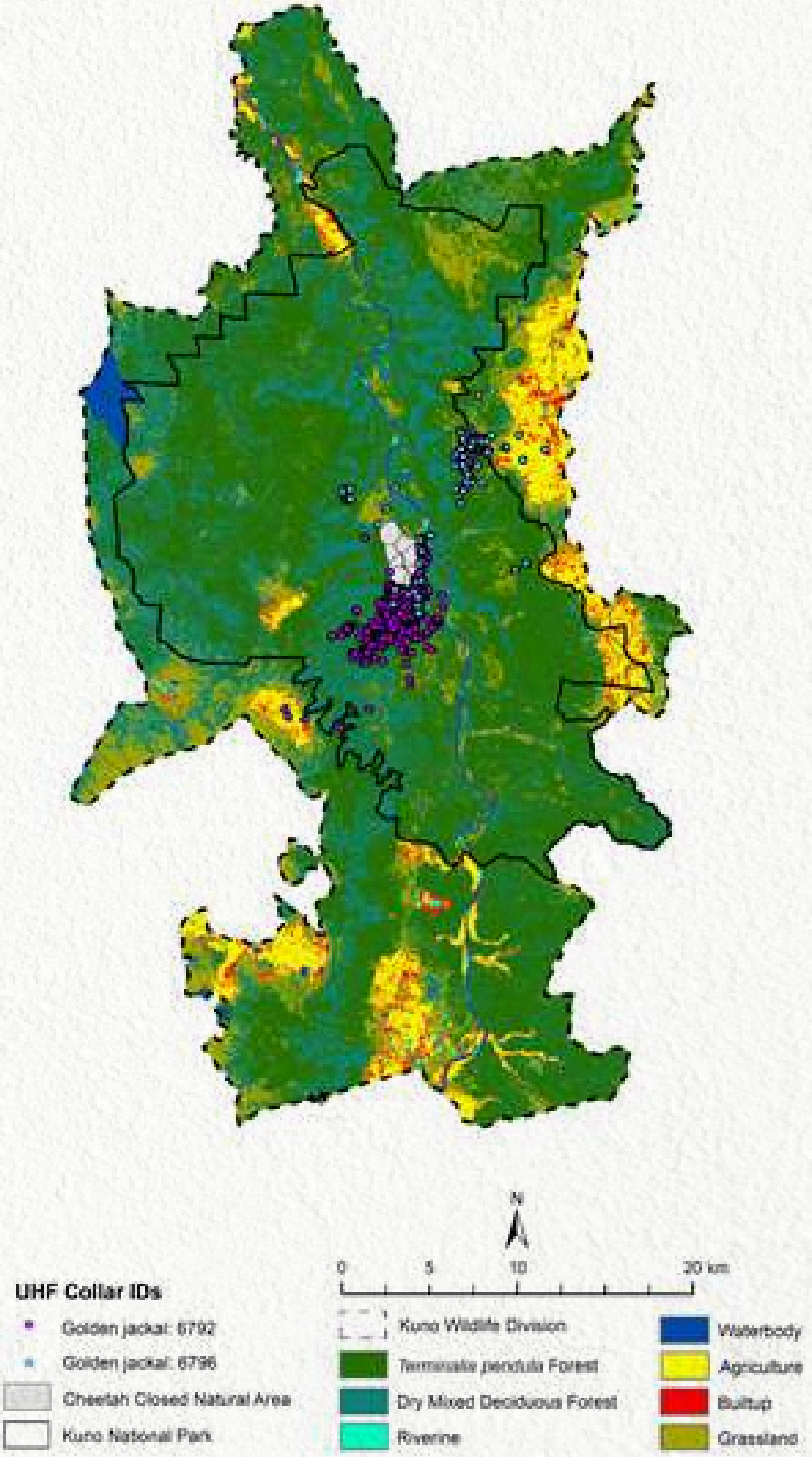


Figure 3.5.4.
Locations of radio-collared golden jackals overlaid on the forest type map of Kuno Wildlife Division

3.5.4. Habitat selection of golden jackal in and around Kuno National Park

Using the Resource Selection Function, it was found that golden jackals selected riverine areas, followed by open natural ecosystems, and also human habitations, which are mostly next to patrolling camps of the forest department as well as *T. pendula* forest. Proportionality of locations shows high use of *T. pendula* forest.

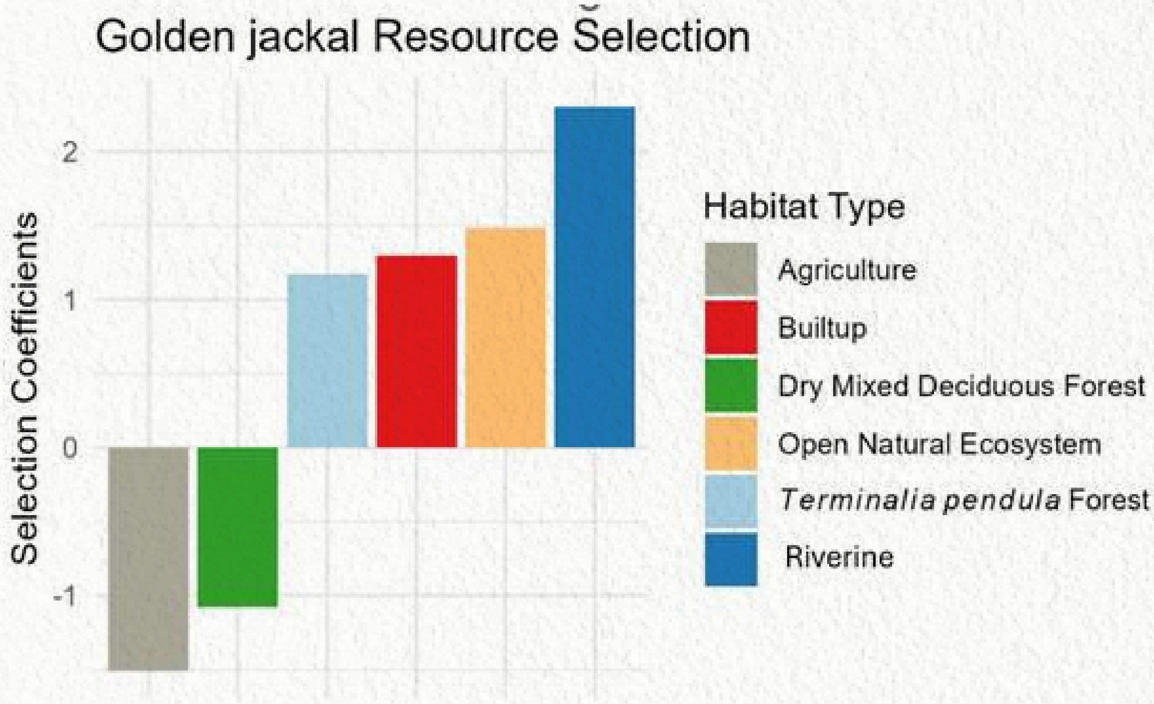


Figure 3.5.4.
Habitat selection of radio-collared golden jackals in Kuno National Park using Resource Selection Function (RSF).

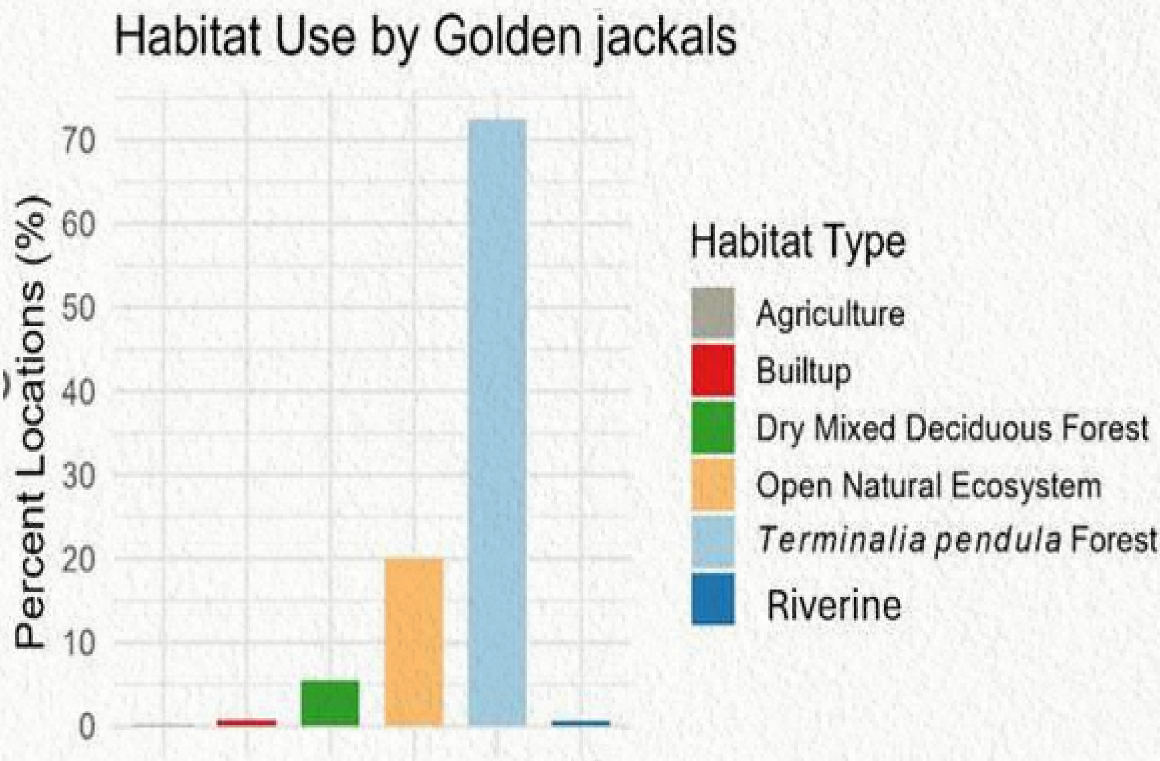


Figure 3.5.5.
Habitat use by radio-collared golden jackals in Kuno National Park.

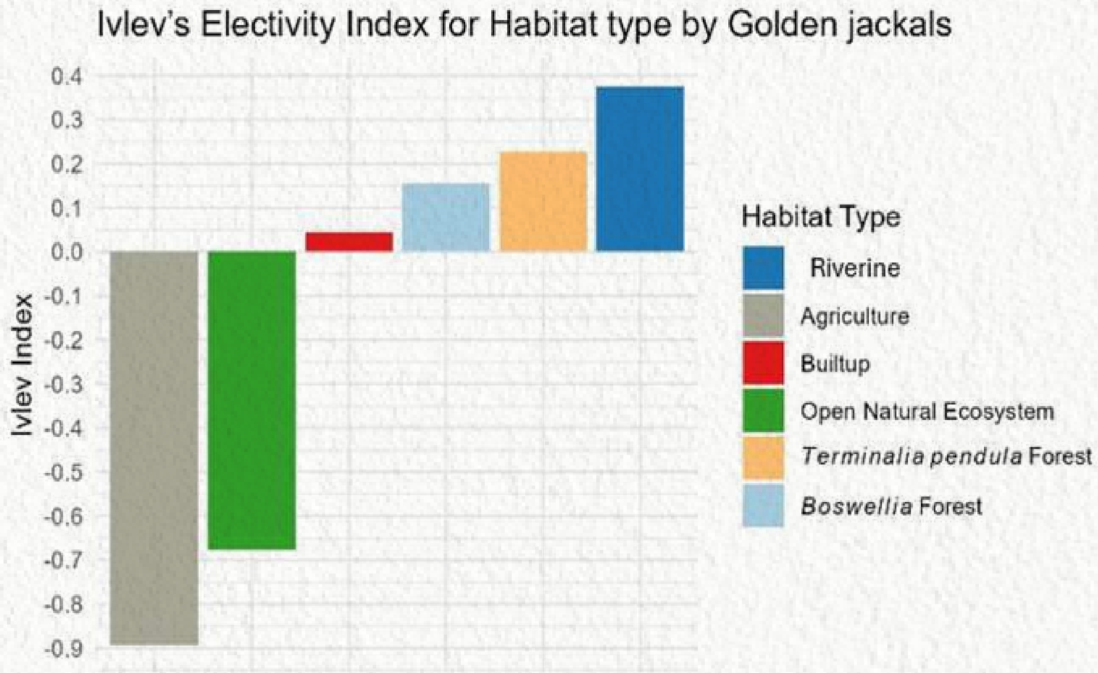


Figure 3.5.6.
Habitat selection by radio-collared golden jackals using Ivlev's index in Kuno National Park.

3.6. Space use of jungle cat in Kuno National Park

3.6.1. Introduction

Although often overshadowed by apex predators, small carnivores play indispensable roles in ecosystem regulation through "middle-out" processes, exerting top-down control on prey populations and indirectly influencing vegetation dynamics, trophic cascades, and ecosystem stability (Bandyopadhyay *et al.* 2024; Marneweck *et al.* 2022; Nagy-Reis *et al.* 2017). Their ecological functions extend beyond natural habitats: by suppressing rodent populations and reducing vector-borne disease risks, they contribute significantly to agro-pastoral resilience and human well-being (Mukherjee *et al.* 2004; Hofmeester *et al.* 2017). Acting as ecological sentinels, small carnivores influence connectivity, seed dispersal, bioaccumulation, and disease ecology, linking biodiversity conservation to broader sustainability and One Health agendas (Pérez, 2019; Peterson *et al.* 2021). In India, where open natural ecosystems such as grasslands and scrublands face severe degradation (Ranjitsinh & Jhala, 2010), initiatives like Project Cheetah (Jhala *et al.* 2021) offer a unique opportunity to integrate small carnivore research into ecosystem restoration and management frameworks. Reliable data on mesocarnivore distribution, density, and space use made possible by advances in camera trapping, telemetry, and species distribution modeling are essential for understanding their ecological roles and safeguarding these landscapes (Karanth & Nichols, 1998; Jhala *et al.* 2019; Tanwar *et al.* 2021). Incorporating small carnivores into Project Cheetah's monitoring framework will ensure a multi-trophic approach to conservation, bridging biodiversity protection with climate resilience, agro-ecological stability, and human health, thereby positioning India as a leader in integrated, evidence-based ecosystem management under the Post-2020 Global Biodiversity Framework (CBD, 2022; IPBES, 2019; Destoumieux-Garzón *et al.* 2018; WHO, 2021).

3.6.2. Animal capture & telemetry

Study animals (jungle cats) were captured using a combination of cage traps and padded foothold traps, with traps being monitored visually every 2-3 hours. Visual and olfactory lures enhanced capture efficiency. Immobilization of individuals (n=4, adult males) was performed by experienced veterinarians using a combination of ketamine, medetomidine, and butorphanol or alternative formulations as available. Animals were fitted with GPS (UHF) collars (Africa Wildlife Tracking), weighing between 2% and 4% of their body weight. Age and body mass index were estimated by examining teeth wear and collecting morphometric data from all captured animals. Following full recovery from anesthesia, all animals were released into the wild. GPS (UHF) collars were programmed to record location data every 3 hours during the telemetry period.

3.6.3. Home range and average daily movement

Home range size (100% MCP) of male jungle cats ranged from 9.87 to 11.52 km^2, wherein the average daily distances moved ranged from a minimum of 1.87 (0.3 SE) km to a maximum of 2.62 (0.6 SE) km.

Table 3.6.1.
Home range sizes and average daily movement of radio-collared jungle cats in Kuno National Park.

Animal & Tag ID / Type	Age Category & Sex	100% MCP Area (km²)	95% KDE Area (km²)	50% KDE Area (km²)	Average Daily Distance Moved (km)
Jungle Cat UHF 6795 (GPS)	Adult male	9.87	7.89	0.64	1.87 (0.3 SE)
Jungle Cat UHF 6794 (GPS)	Adult male	11.52	9.17	0.43	1.85 (0.4 SE)

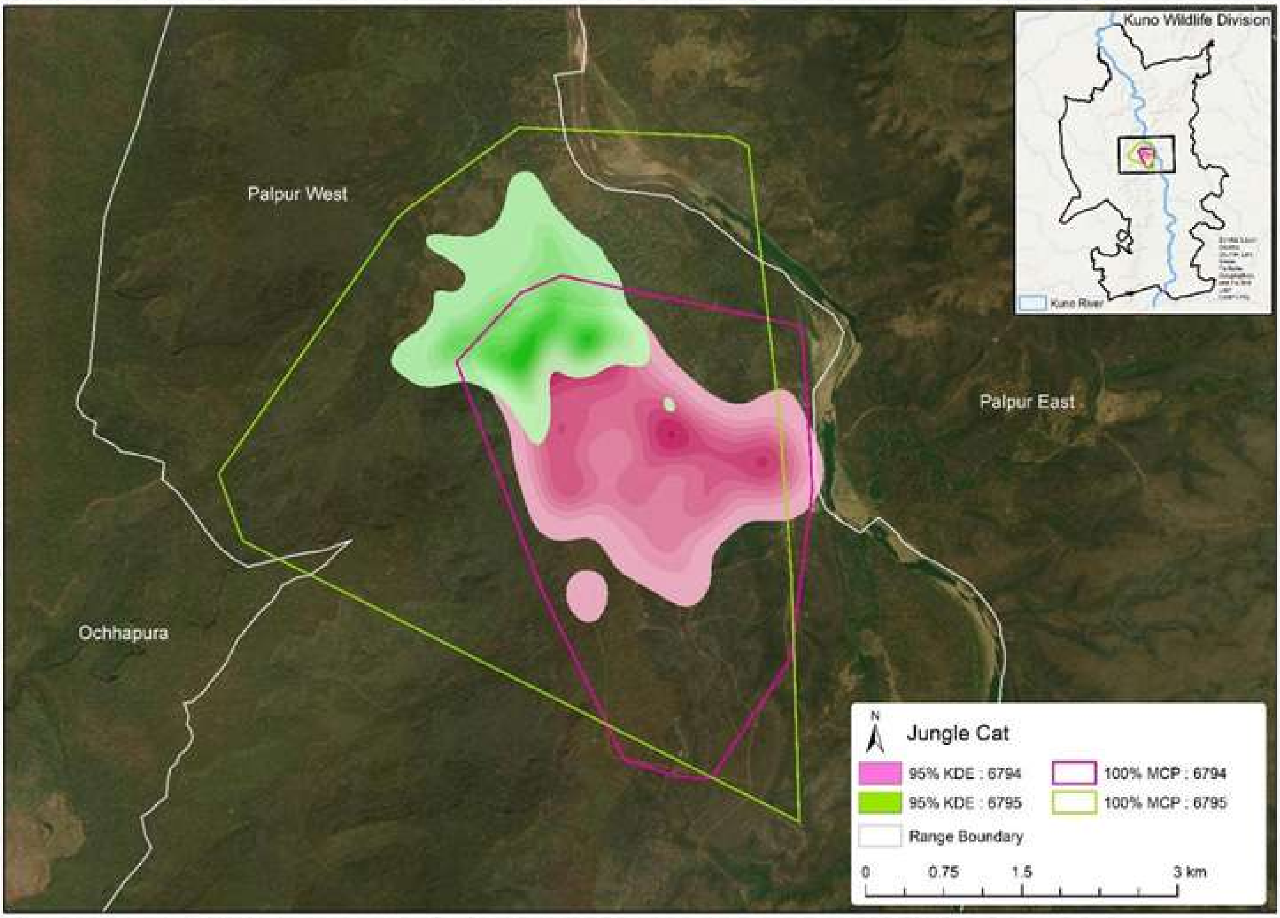


Figure 3.6.1.
Home ranges using 100% Minimum convex polygon (MCP) and 95% Kernel Density estimator (KDE), of collared jungle cats (TagID: 6794 & TagID: 6795) in Kuno National Park

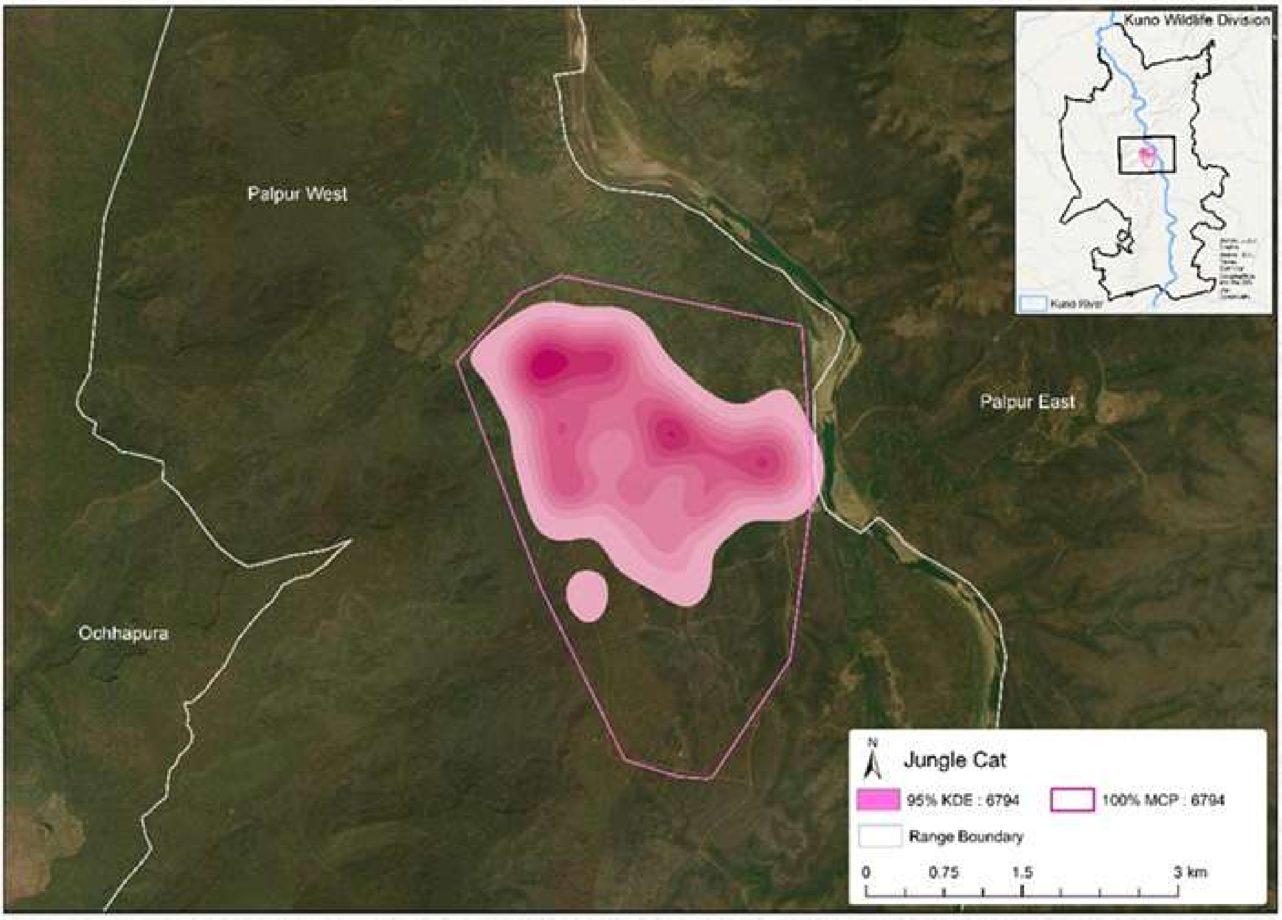


Figure 3.6.2.
Home ranges using 100% Minimum Convex polygon (MCP) and 95% Kernel Density Estimator (KDE), of collared jungle cat (TagID: 6794) in Kuno National Park

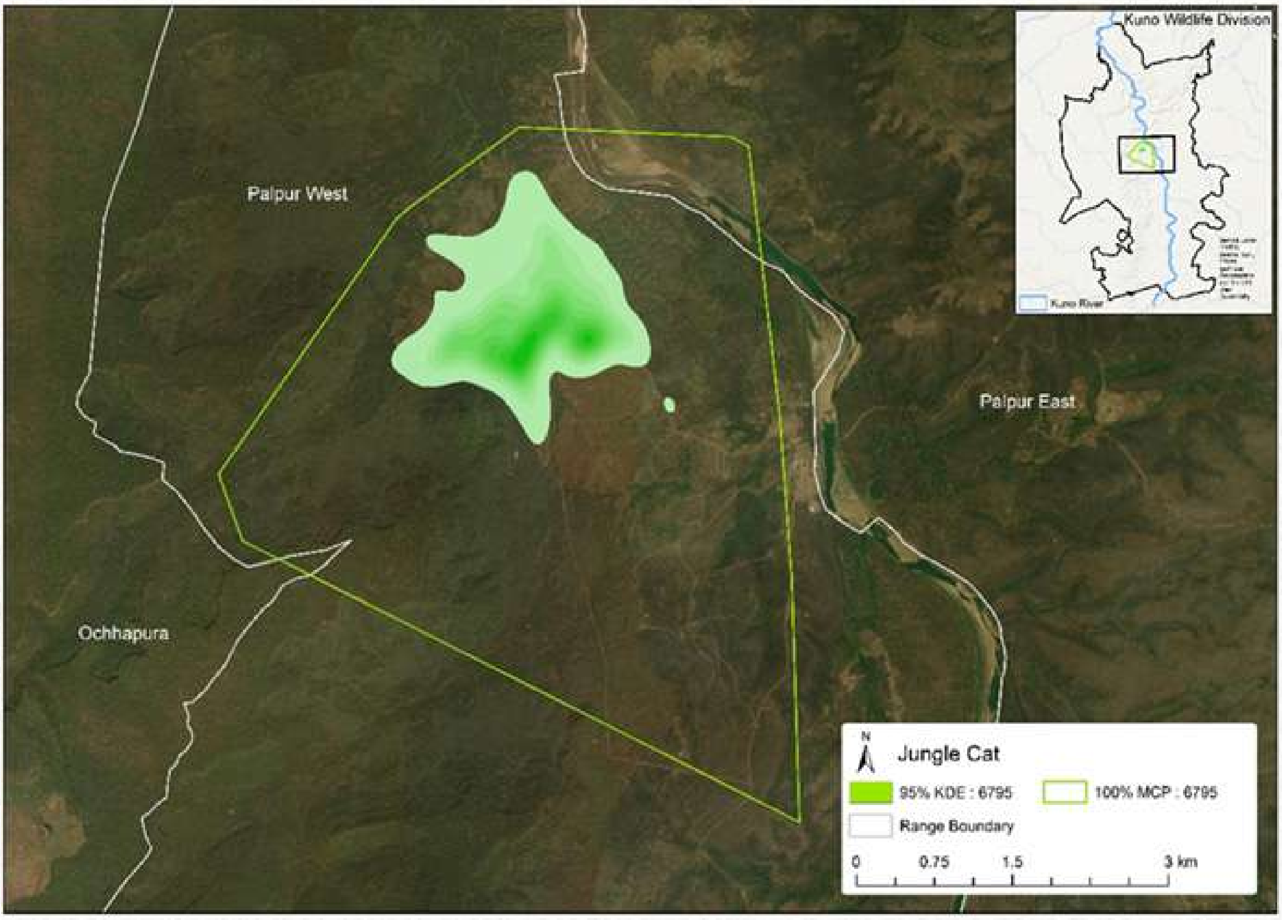


Figure 3.6.3.
Home ranges using 100% Minimum convex polygon (MCP) and 95% Kernel Density estimator (KDE) of collared jungle cat (TagID: 6795) in Kuno National Park

3.6.4. Habitat selection of jungle cats in Kuno National Park

We assessed second-order habitat selection across seasons for radio-collared jungle cats. We used selection ratios to determine habitat selection at home-range levels, as these illustrate the probability of a resource being utilized with respect to the availability of the resource. For the second-order habitat selection, we compared the proportion of each LULC type available at the 100% MCP scale with the proportion of used locations selected within individual home ranges. We calculated species-specific selection ratios through Ivlev's index for each LULC class (grassland, dhonk forest, riverine, miscellaneous dry deciduous, water bodies, built-up, and agriculture) across seasons, using the R package adehabitatHS. For habitat selection, ratios range from -1 to +1 scale; -1 denotes strong avoidance for that habitat class, and +1 denotes strong preference for that habitat class. All analyses were done in R Studio Version 4.3.2.

Within the home range of two active collared jungle cats (UHF ID: 6794 and 6795), they highly selected grasslands (Ivlev's index = 0.68) and strongly avoided buildup and waterbodies (Ivlev's index = -1). They moderately dis-selected miscellaneous dry-deciduous, riverine, and *T. pendula* dhonk forests (Ivlev's index = -0.1, -0.45, and -0.1, respectively).

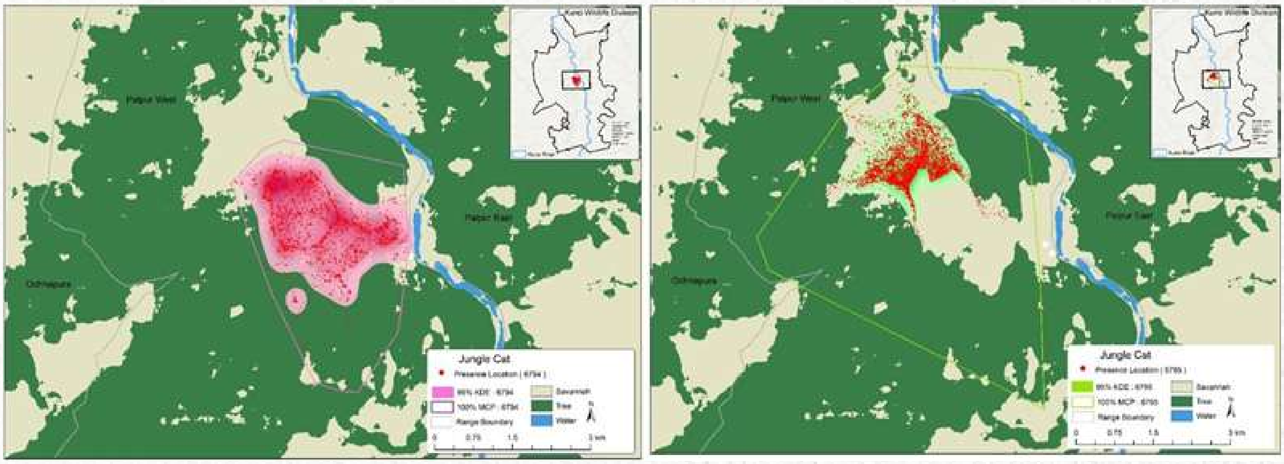


Figure 3.6.4.

Resource Selection Function (RSF) of radio-collared jungle cat UHF 6794 (left) & UHF 6795 (right) in Kuno National Park.

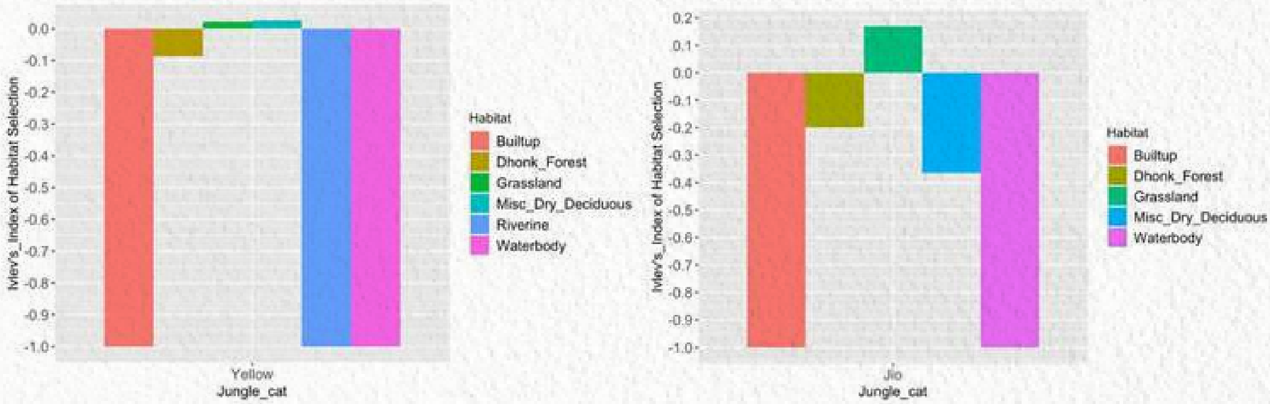


Figure 3.6.5.
Habitat selection of radio-collared jungle cat UHF 6794 (left) & UHF 6795 (right) in Kuno National Park

3.7. Co-predator Monitoring in Gandhi Sagar Wildlife Sanctuary

3.7.1. Space use of leopard in Gandhi Sagar Wildlife Sanctuary

3.7.1.1. Introduction

The movement patterns of large carnivores are shaped by a complex relationship of ecological and anthropogenic factors (Rodríguez-Recio *et al.* 2022). A comprehensive understanding of the factors governing foraging range and dispersal behaviour is therefore essential for anticipating conservation risks and formulating effective long-term management strategies (Mondal *et al.* 2011). Leopards (*Panthera pardus*) function as apex predators, exerting top-down regulation on herbivore populations and moderating the behaviour and spatial distribution of meso-predators, thereby serving as a key regulatory mechanism in maintaining the ecosystem dynamics. Consequently, leopards are widely regarded as reliable indicators of ecosystem health and structural integrity (Mondal *et al.* 2013; Tshabalala *et al.* 2021; Chamaillé-Jammes *et al.* 2019). Movement patterns and home range are essentially interconnected, with home range boundaries emerging as a direct consequence of individual movement decisions accumulated over time (Powell, 2012). The movement and home range ecology of leopards reflect both the species' remarkable adaptability and its capacity to optimise resource acquisition across heterogeneous landscapes (Mondal *et al.* 2011). Through flexible movement and foraging strategies, leopards have successfully inhabited across a wide spectrum of habitat types and ecological conditions (Basak *et al.* 2020; Mondal *et al.* 2013). Explaining these spatial patterns carries critical implications for conservation planning, particularly with respect to maintaining habitat connectivity and mitigating human-leopard conflict (Mondal *et al.* 2011).

As anthropogenic pressures continue to increase, securing adequate spatial resources for leopard populations is imperative for ensuring the species' long-term survival and the broader integrity of the ecosystems they inhabit.

3.7.1.2. Capturing and radio-collaring of leopards

Walk-through cage traps measuring 2.9 m × 0.8 m × 1 m were deployed for humane capture of leopards. Unlike conventional single-mesh cage designs, these double-door traps incorporated a double-layer wire mesh, providing the elasticity necessary to minimize injury to captured individuals without compromising structural integrity. Traps were baited, deployed under veterinary and Forest Department supervision, and monitored at regular intervals following a strict response protocol to minimize post-capture stress.

Upon successful capture, the individual was cautiously approached by vehicle and chemically immobilized remotely using Dan-Inject or Pneu-Dart projectors. A combination of ketamine, xylazine, and medetomidine was administered, with dosages calibrated according to estimated body mass, age, and sex. Following immobilization, veterinary procedures, including continuous monitoring of physiological parameters, morphometric measurements, and biological sample collection, were conducted in the presence of Forest Department staff. Each individual was fitted with an African Wildlife Telemetry (AWT) satellite GPS collar, programmed to record positional fixes at three-hour intervals. Anaesthesia was subsequently reversed, and the animal was monitored for a minimum six-hour post-recovery period at an adequate distance using ground-based tracking equipment. Collared leopards were thereafter remotely tracked and monitored via the AWT online telemetry interface.

3.7.1.3. Home range and average daily movement of leopards in Gandhi Sagar Wildlife Sanctuary

The telemetry data from five radio-collared leopards in Gandhi Sagar Wildlife Sanctuary during 2024-2025 revealed substantial variation in home range sizes and movement patterns. The 100% Minimum Convex Polygon (MCP) estimates ranged from as small as 159 km² (Leopard 8032) to as large as 1853 km² (Leopard 8029), while 95% Kernel Density Estimates (KDE) varied between 125 km² and 2433 km². These differences reflect contrasting life-history stages and ranging strategies, with some individuals exhibiting localized, intensive space use, while others ranged widely across the landscape. Average daily movement distances also varied, from 3.4 km to 6.77 km per day, with total distances covered ranging from 309 km to 1731 km over the monitoring period. Collectively, the results highlight the plasticity of leopard space-use strategies in Gandhi Sagar Wildlife Sanctuary.

Table 3.7.1.
Home range sizes of radio-collared leopards in Gandhi Sagar Wildlife Sanctuary

Animal ID (Collar ID) Age & Sex	Monitoring Period	No. of Days	100% MCP (km²)	95% KDE (km²)	Avg. Daily Distance Moved (km)	Total Distance Moved (km)
8029 Adult Male	Aug 2024 – Jun 2025	277	1853	2433	3.40	963
8032 Adult Male	Sep 2024 – Sep 2025	329	159	125	4.42	1455
8038 Adult Female	Nov 2024 – Jan 2025	53	1303	1946	6.77	359
8039 Adult Male	Jul 2024 – Sep 2024	63	435	743	4.91	309
8040 Adult Female	May 2024 – Aug 2025	462	1611	857	3.75	1731

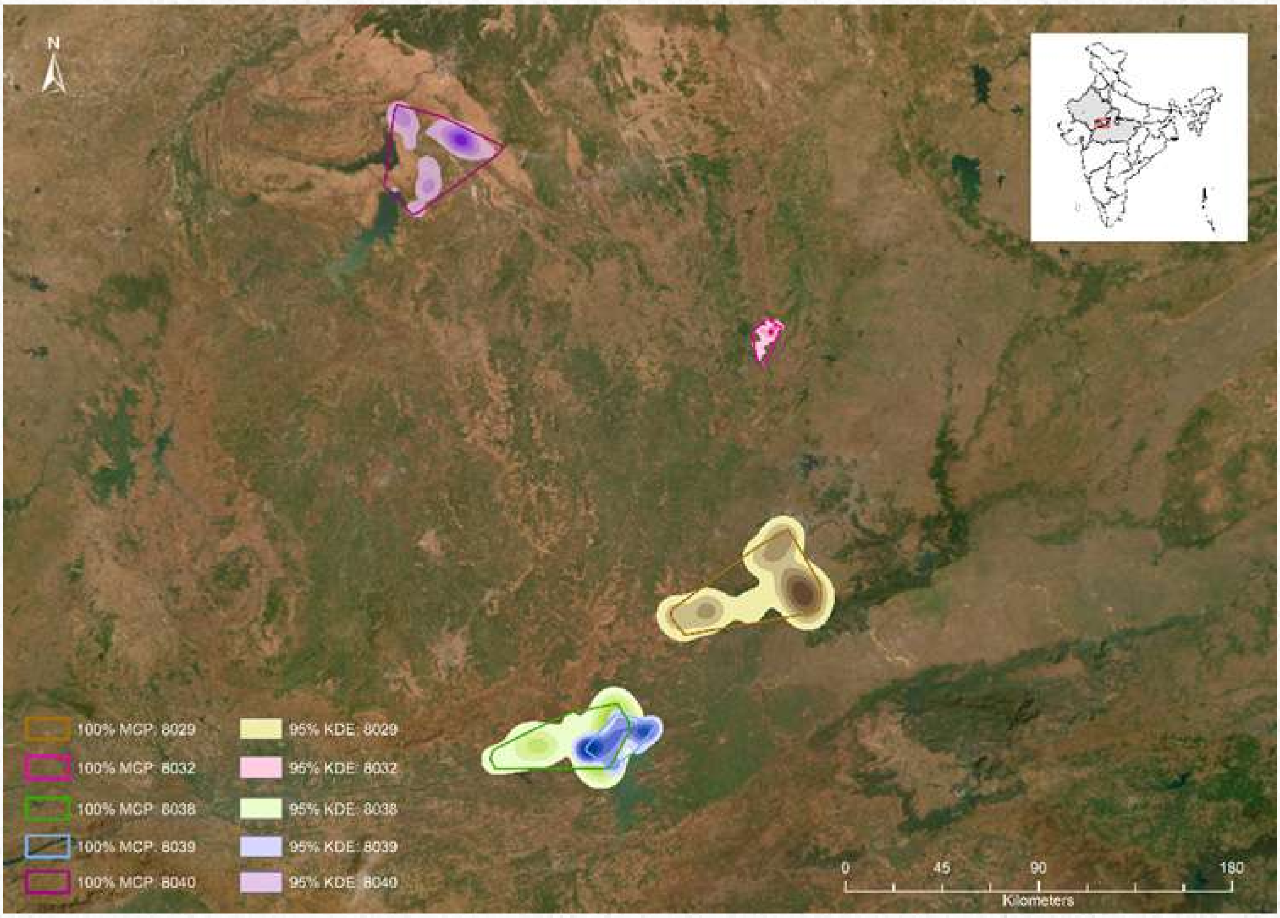


Figure 3.7.1.
Home ranges (100% MCP and 95% KDE) of the five radio-collared leopards in Gandhi Sagar landscape

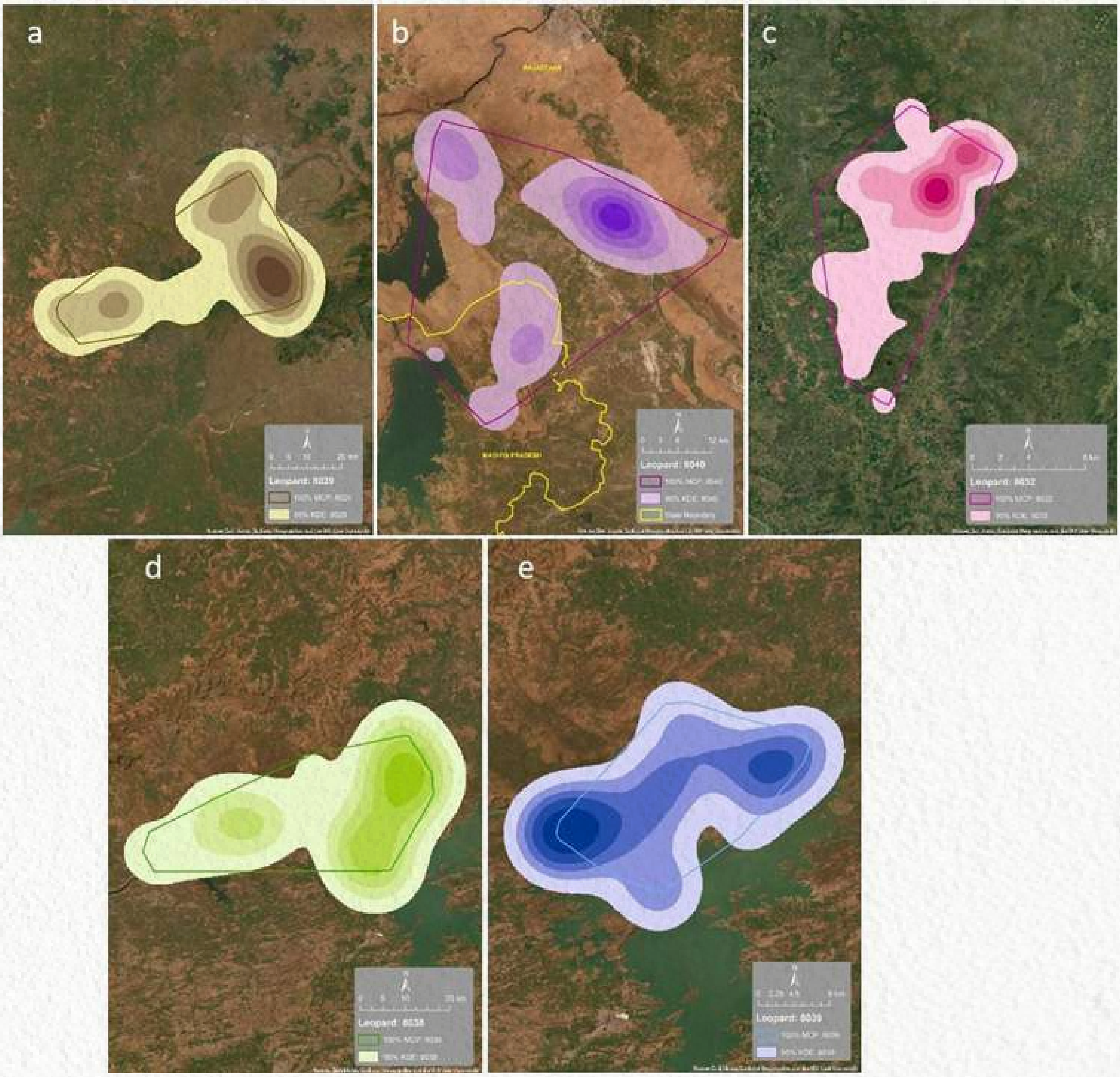


Figure 3.7.2.
Home ranges using 100% Minimum convex polygon (MCP) and 95% Kernel Density Estimator (KDE), of radio-collared leopards a) TagID:8029, b) TagID:8040, c) TagID:8032, d) TagID:8038, & e) TagID:8039 in and around Gandhi Sagar Wildlife Sanctuary.

3.7.1.4. Habitat selection of radio-collared leopards in Gandhi Sagar Wildlife Sanctuary

Habitat selection analyses, based on Resource Selection Functions (RSF) and Ivlev's Electivity Index, showed clear preferences for forested and open habitats, while human-modified landscapes were consistently avoided. Leopards strongly selected dry mixed deciduous forest, Khair–Sissu Forest, *Terminalia pendula* forest, and open natural ecosystems, with RSF coefficients indicating positive associations. In contrast, agriculture, Boswellia-dominated patches, and built-up areas were avoided, with negative selection values. Ivlev's Index further emphasized this pattern, with *Terminalia pendula* forest and Dry mixed deciduous habitats showing the highest electivity values (up to +0.7 to +0.8), with strong avoidance for agriculture and built-up areas. Habitat-use frequency data reinforced these findings, with Dry mixed deciduous forest accounting for ~40% of locations, are followed by Open Natural Ecosystems (~38%) and *Terminalia pendula* forest (~18%).

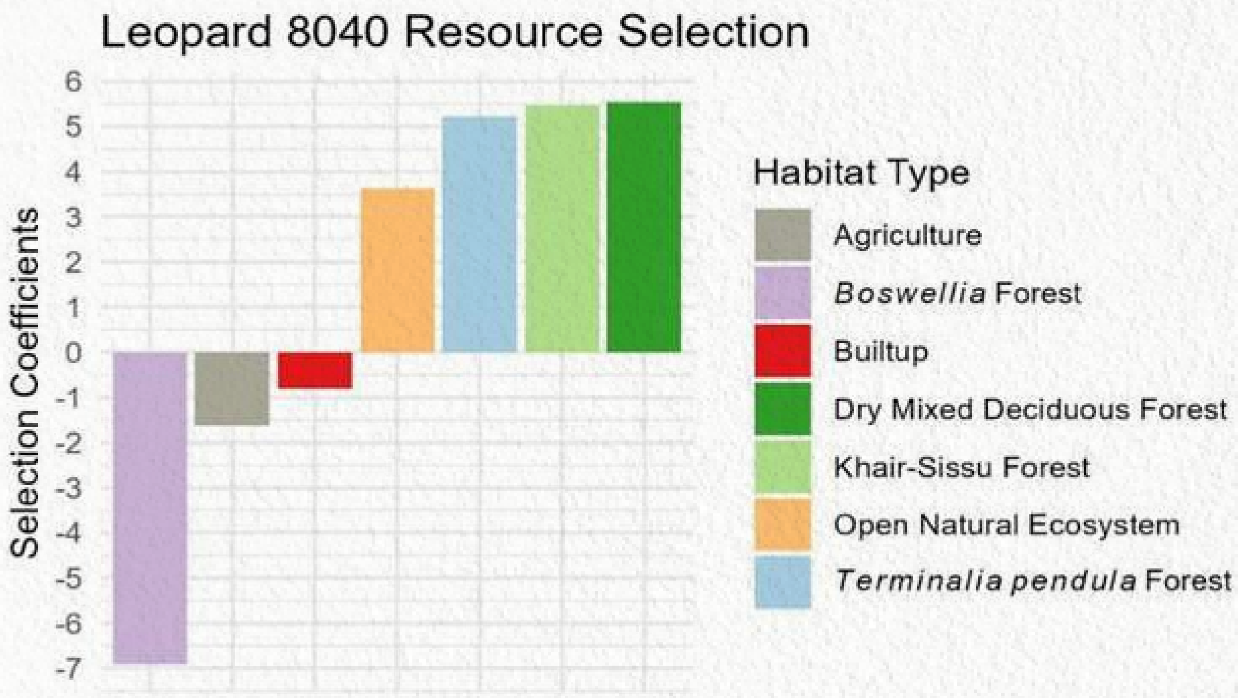


Figure 3.7.3.

Habitat selection of radio-collared leopard in Gandhi Sagar Wildlife Sanctuary using the Resource Selection Function

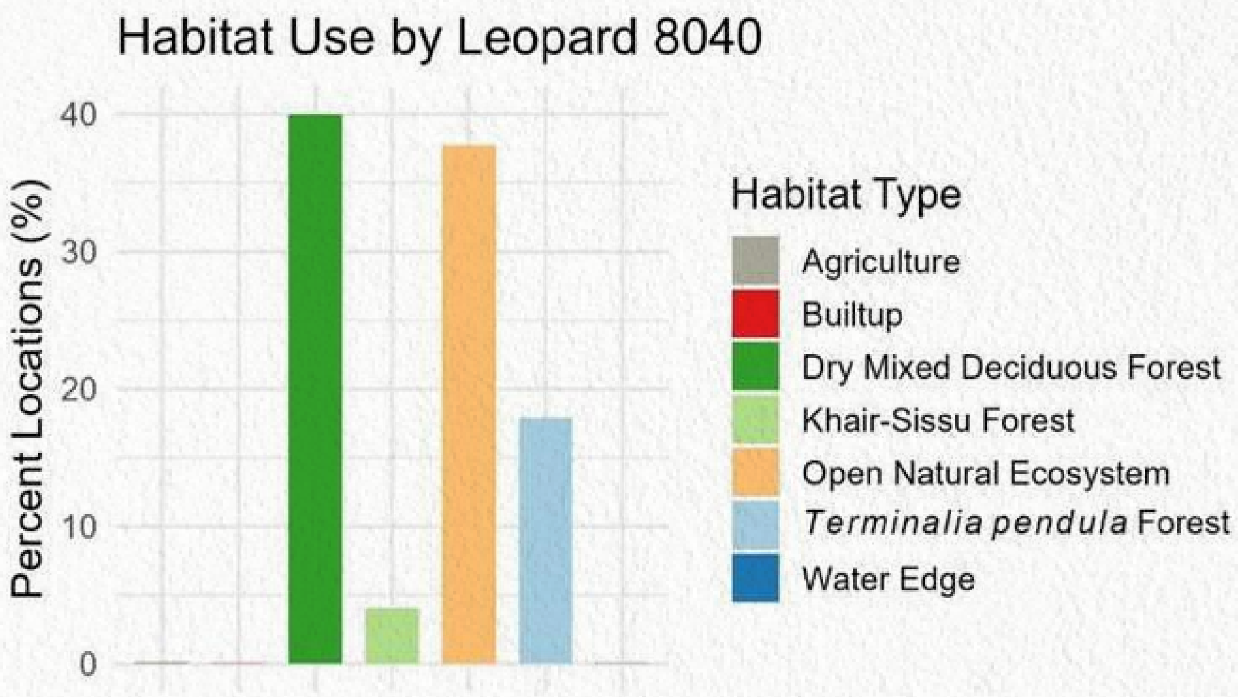


Figure 3.7.4.

Habitat use of radio-collared leopard in Gandhi Sagar Wildlife Sanctuary using the percentage of locations in each habitat type

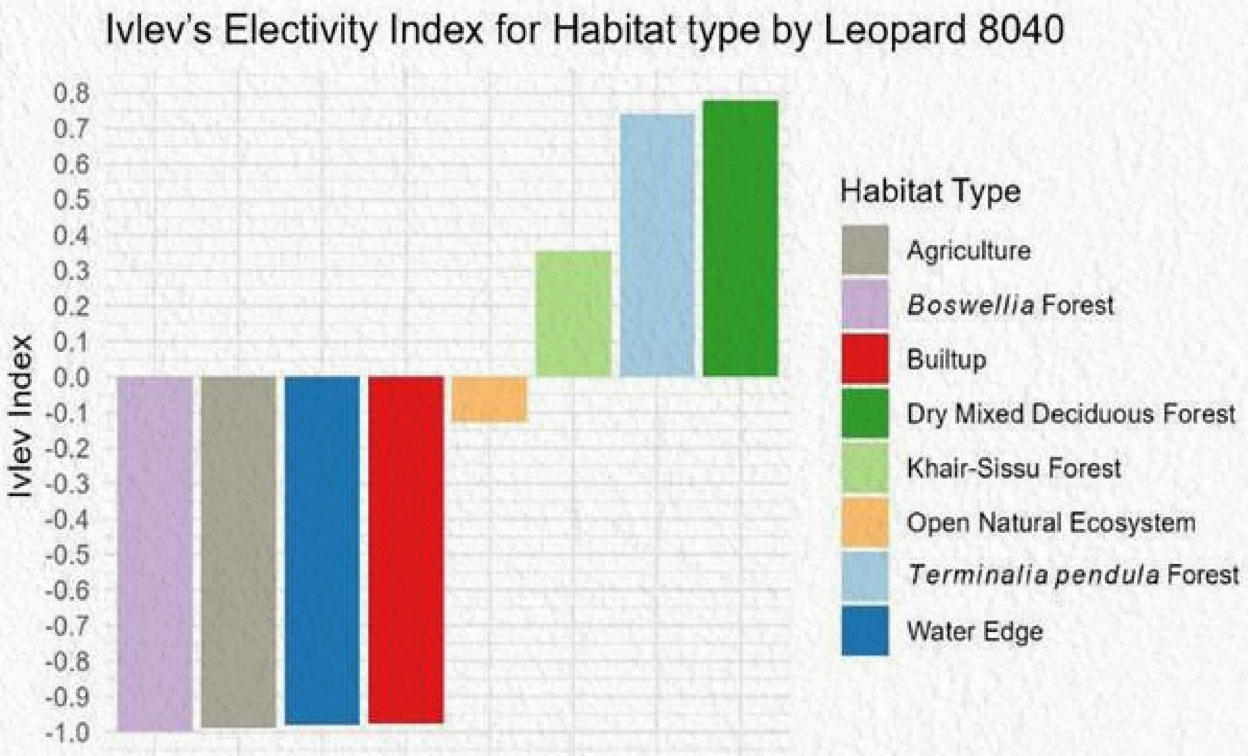


Figure 3.7.5.
Habitat use of radio-collared leopard in Gandhi Sagar Wildlife Sanctuary using the Ivlev's index

4. Prey Monitoring

4.1. Prey assessment in Kuno National Park

4.1.1. Methodology

As part of ecosystem monitoring in Kuno NP and Gandhi Sagar WLS, the distance sampling-based line transect method was employed to estimate the population density of wild prey species (Buckland *et al.* 2001). Line transects were laid in a random orientation, with each forest beat considered as a sampling unit. Since forest beats are administrative units that cover the entire protected area, this framework ensured representative sampling across various habitat types. Within each beat, at least one line transect of 2 to 2.5 km in length was positioned randomly to meet the assumption that their placement across the study area is independent of animal distribution. Three temporal replicates of each transect were surveyed by walking. Sampling was conducted early in the morning by a team consisting of a WII researcher, a forest guard, and a local watcher. During the sampling walks, clusters or groups of animals encountered were recorded along with species identity, group size, sighting distance, and bearing. Accurate measurements were ensured using a digital laser range finder for distance and a see-through (SUUNTO) compass for bearing.

Data during the sampling of line transects were recorded on the mobile app of Monitoring System for Tigers-Intensive Protection and Ecological Status (M-STrIPES), a software-based monitoring system as per the All-India Tiger Estimation protocol, and subsequently processed on the M-STrIPES desktop platform (Jhala *et al.* 2021; Qureshi *et al.* 2025). The processed dataset included line transect tracks and walking effort, bearing of transects and bearing of the sighted animals, observer-to-animal distances, cluster and group size information, and geographic coordinates of the sightings. This dataset was structured and analyzed using DISTANCE software v.8 (Thomas *et al.* 2010). The DISTANCE framework estimates detection probabilities based on perpendicular distances while correcting for biases arising from habitat variability, body size of the species, or group size. Multiple candidate models (half-normal, hazard rate, and uniform with cosine adjustments) were evaluated, with model selection guided by Akaike's Information Criterion (AIC), goodness-of-fit tests, and visual inspection of the detection function. Outlier truncation was applied where necessary to improve model fit before density estimates were derived for each prey species (Buckland *et al.* 2001; Karanth & Nichols, 2017).

To quantify the habitat features and anthropogenic activities, vegetation plots were sampled systematically along the transect line at 400 m intervals on alternate sides of the transect line. Within each plot, trees were quantified in circular plots of 15 m radius, shrubs were sampled in 5 m radius plots, and grasses were enumerated in 1 m radius plots. Human disturbance indicators such as wood cutting, lopping signs, bamboo cutting, fire incidence, and livestock presence (direct or indirect evidence) were recorded. Additionally, ungulate pellet counts were conducted in plots measuring 2 m × 20 m, laid opposite to vegetation plots, to capture indirect prey presence (Jhala *et al.* 2021). The enumeration in these plots was conducted subsequent to completing the prey sampling walk.

Kuno NP (area ~748 km²) is situated within the larger Kuno Wildlife Division (area ~1235 km², recently expanded to 1777 km²). The area was formally designated as a National Park in 2018 after the inclusion of two additional ranges (area ~404 km²) with the previously existing Kuno Wildlife Sanctuary (area ~344 km²). The Sanctuary had historically been subject to a distinct management regime, with systematic monitoring of prey populations and habitat characteristics initiated since 2005. Current monitoring therefore continues to present prey density estimates across two key management categories: (1) the erstwhile Wildlife Sanctuary area of Kuno NP and (2) the rest of Kuno National Park (Qureshi *et al.* 2024).

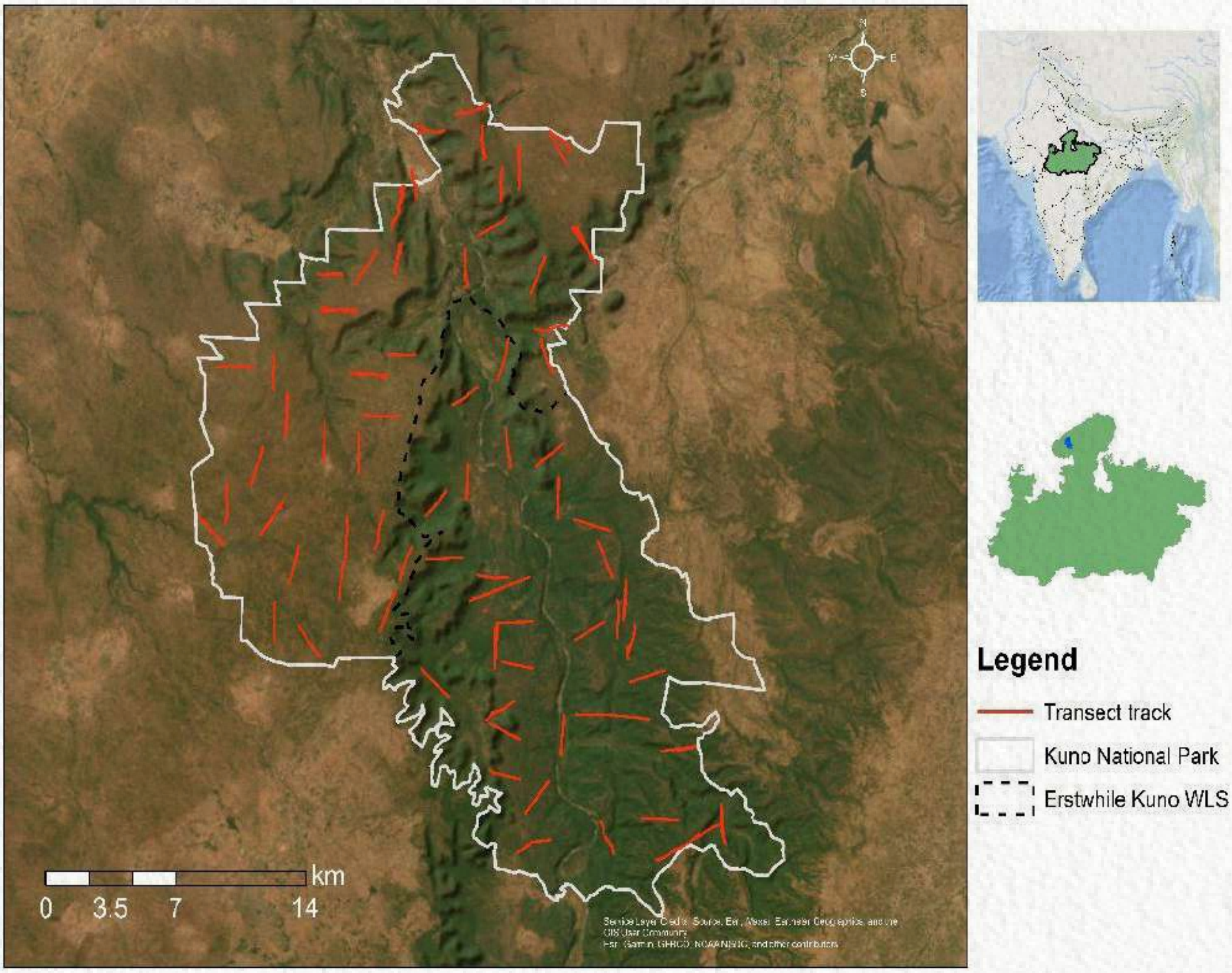


Figure 4.1.1.
Map of the line transects sampled in each beat of Kuno National Park to assess the status of prey in 2025

Line transect sampling to assess prey populations in Kuno NP was conducted during April - May 2025, covering a total of 73 beats corresponding to 73 transects walked thrice with an overall sampling effort of 478.12 km on foot, spanning nine days. During the survey, species such as chital, sambar, nilgai, Indian hare, Indian peafowl, grey langur, and Indian wild pig, as well as domestic and feral cattle, were recorded. In addition, 438 vegetation plots were sampled along these transects to evaluate habitat characteristics.

Table 4.1.1.
Species-wise observations of prey during the line transect-based distance sampling conducted in Kuno National Park (Area ~ 748 km^2) during April-May 2025

	Erstwhile Wildlife Sanctuary Area of Kuno National Park (Area - 344.69 km^2)	**Rest of Kuno National Park (Area - 404.07 km^2)**
Effort	240.61 km	237.51 km
Species	**No. of observations – Groups (individuals)**	**No. of observations – Groups (individuals)**
Chital	73 (516)	8 (42)
Sambar	18 (37	5 (9)
Nilgai	6 (16)	11 (53)
Indian wild pig	15 (40)	7 (19)
Indian hare	2 (2)	8 (8)
Indian peafowl	18 (36)	2 (2)
Grey langur	21 (231)	2 (8)
Domestic or Feral cattle	2 (2)	1 (4)

Post-stratification using a global detection function was employed in DISTANCE software v.8 (Thomas *et al.* 2010) to estimate species-specific densities of chital, nilgai, sambar, Indian wild pig, Indian hare, Indian peafowl, grey langur, and cattle across two management units: the erstwhile WLS area of Kuno NP and the rest of Kuno NP. In addition to distance sampling, density distribution of chital was mapped using density surface modelling (DSM). Here the detection function is fitted against various ecologically relevant environmental covariates. This results in a density surface map that shows the abundance distribution within the study area (Miller *et al.* 2013).

4.1.2. Results

Chital, sambar, Indian wild pig, Indian peafowl, and grey langur were the frequently observed species. (Table 4.1.1.). Due to very few observations of hare and domestic or feral cattle, density estimation was not possible for them; their encounter rates have been reported (Table 4.1.2.). DSM for chital was mapped as it had an adequate number of observations, and its detection function model was robust and responded well for co-variates-distance to built-up (Karra *et al.*, 2021) and pre-monsoon and pre-post monsoon difference in NDVI (Vermote *et al.* 2016).

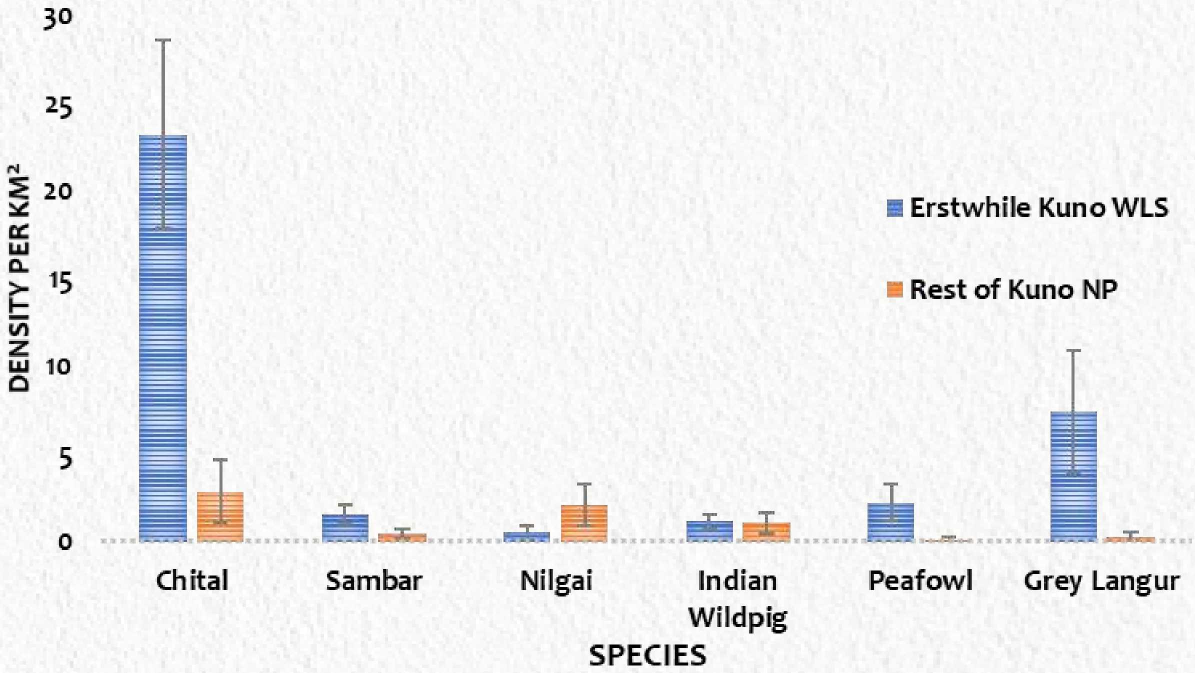


Figure 4.1.2.
Density (per km^2) of prey species in Kuno National Park obtained from distance sampling-based line transects during 2025. Error bars represent standard errors.

The density of chital estimated for the erstwhile Kuno WLS area is 23.22 (5.35 SE) individuals per km^2, while in the rest of the Kuno NP area, the estimated density was 2.87 (1.78 SE) individuals per km^2 (Figure 4.1.2). The pattern of spatial distribution is shown in the Density Surface Model (DSM) map for chital (Figure 4.1.3).

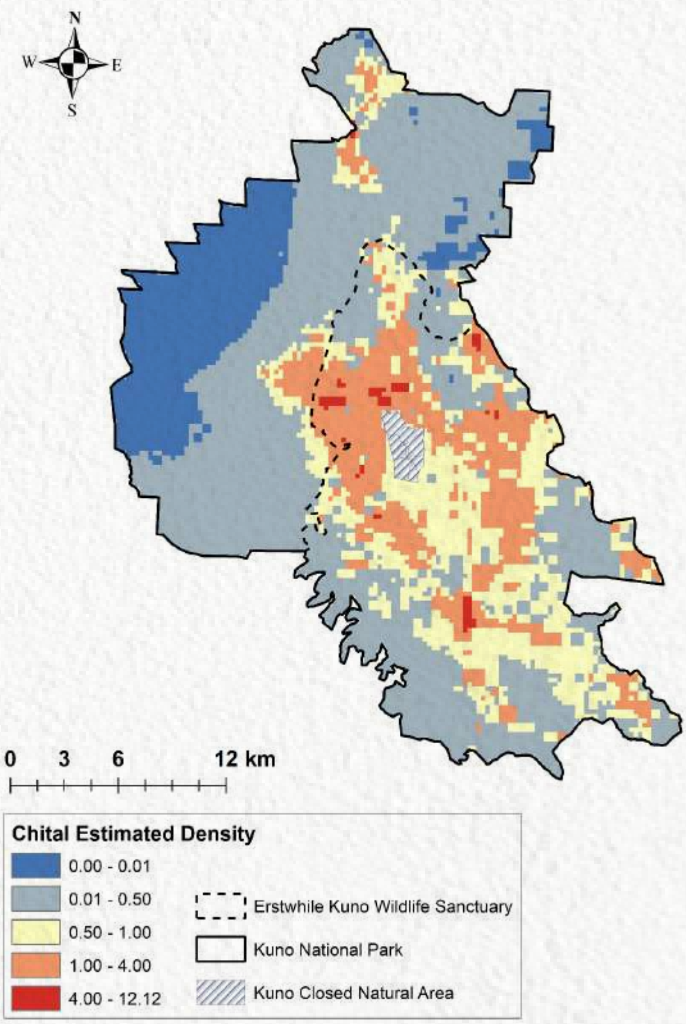


Figure 4.1.3.
Density distribution or Density Surface Model (DSM) map of chital in Kuno National Park

Table 4.1.2.

Summary of estimated prey densities obtained from line transect based distance sampling conducted in April - May 2025 for the erstwhile Kuno Wildlife Sanctuary (Area - 344.69 km^2) and rest of Kuno National Park (Area - 404.07 km^2)

Species	Site	Group Encounter rate per km	Density (SE) per km^2	%CV	MCS	ESW	Model	Adjustment key	Estimated population in Kuno National Park
Chital	Erstwhile Kuno WLS	0.29	23.22 (5.35)	23.05	7.27	53.56	Half- normal	Hermite-polynomial	8004
	Rest of Kuno NP	0.03	2.87 (1.78)	62.01	5.25	53.56	Half-normal	Hermite-polynomial	1160
Sambar	Erstwhile Kuno WLS	0.07	1.54 (0.52)	33.73	2.06	61.10	Half-normal	Hermite-polynomial	531
	Rest of Kuno NP	0.02	0.45 (0.28)	61.77	1.80	61.10	Half-normal	Hermite-polynomial	182
Nilgai	Erstwhile Kuno WLS	0.02	0.51 (0.39)	75.70	2.80	50.14	Half-normal	Hermite-polynomial	176
	Rest of Kuno NP	0.05	2.09 (1.23)	58.67	4.82	50.14	Half-normal	Hermite-polynomial	845
Indian wild pig	Erstwhile Kuno WLS	0.05	1.13 (0.44)	38.56	1.55	22.56	Half-normal	Hermite-polynomial	389
	Rest of Kuno NP	0.03	1.05 (0.6)	56.77	2.71	22.56	Half-normal	Hermite-polynomial	424
Peafowl	Erstwhile Kuno WLS	0.07	2.23 (1.02)	45.82	2.00	39.25	Hazard-rate	Simple-polynomial	769
	Rest of Kuno NP	0.01	0.11 (0.11)	103.12	-	39.25	Hazard-rate	Simple-polynomial	44
Grey langur	Erstwhile Kuno WLS	0.09	7.4 (3.51)	47.48	11.00	59.76	Half-normal	Hermite-polynomial	2551
	Rest of Kuno NP	0.01	0.28 (0.22)	78.20	4.00	59.76	Half-normal	Hermite-polynomial	113
Indian hare	Erstwhile Kuno WLS	0.01	-	-	-	-	-	-	-
	Rest of Kuno NP	0.03	-	-	-	-	-	-	-
Domes-tic or Feral cattle	Erstwhile Kuno WLS	0.01	-	-	-	-	-	-	-
	Rest of Kuno NP	0.004	-	-	-	-	-	-	-
SE- Standard Error, CV- Coefficient of Variation, MCS- Mean Cluster Size, ESW- Effective Strip Width									

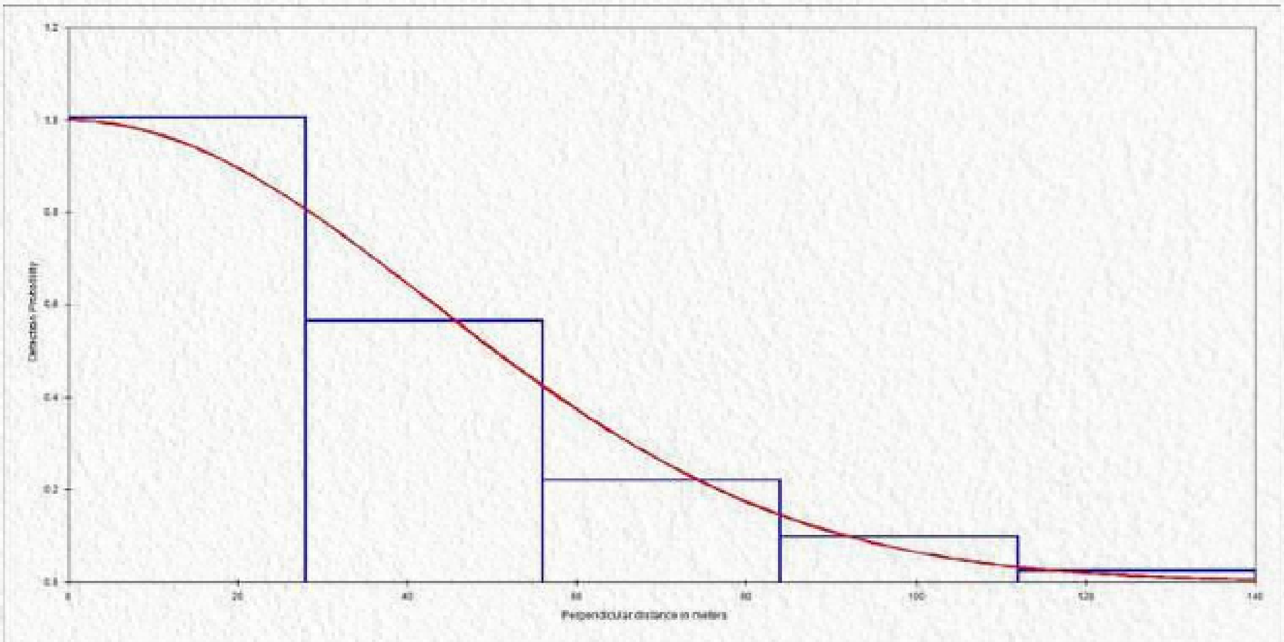


Figure 4.1.4.
Distance sampling detection function plot using the model-half normal with simple polynomial adjustment key for chital (goodness of fit $\chi 2$ - p = 0.74)

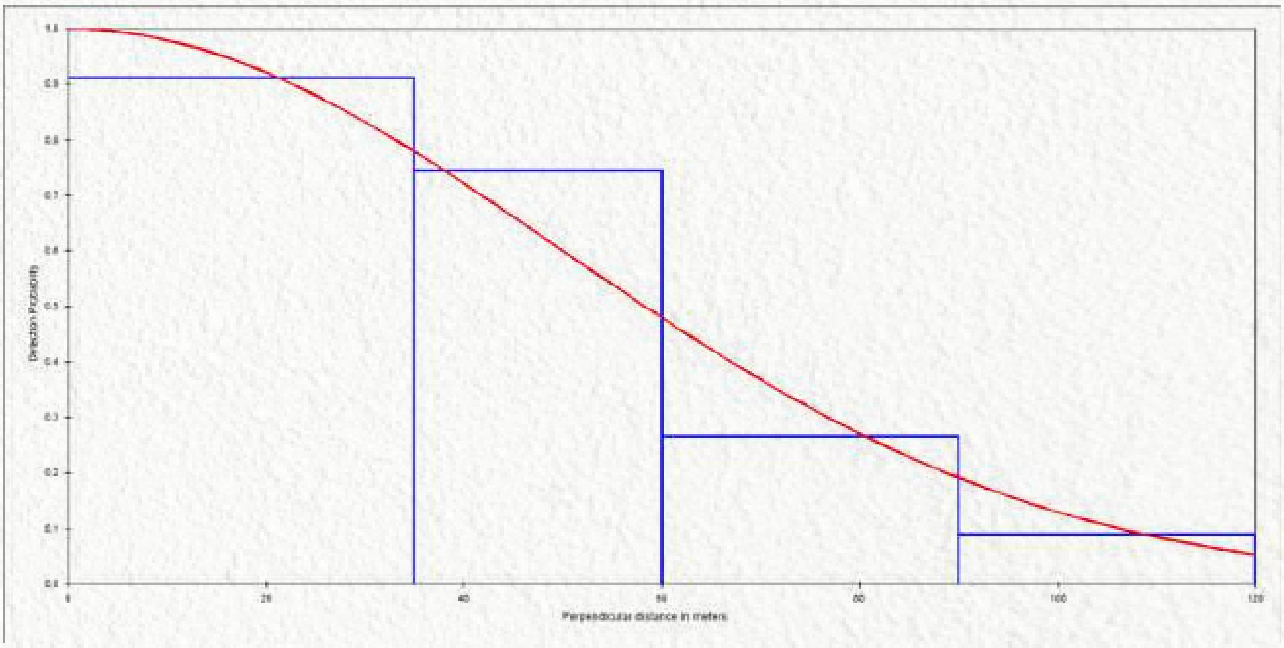


Figure 4.1.5.
Distance sampling detection function plot using the model- half normal with hermite polynomial adjustment key for Sambar (goodness of fit $\chi 2$ - p = 0.83)

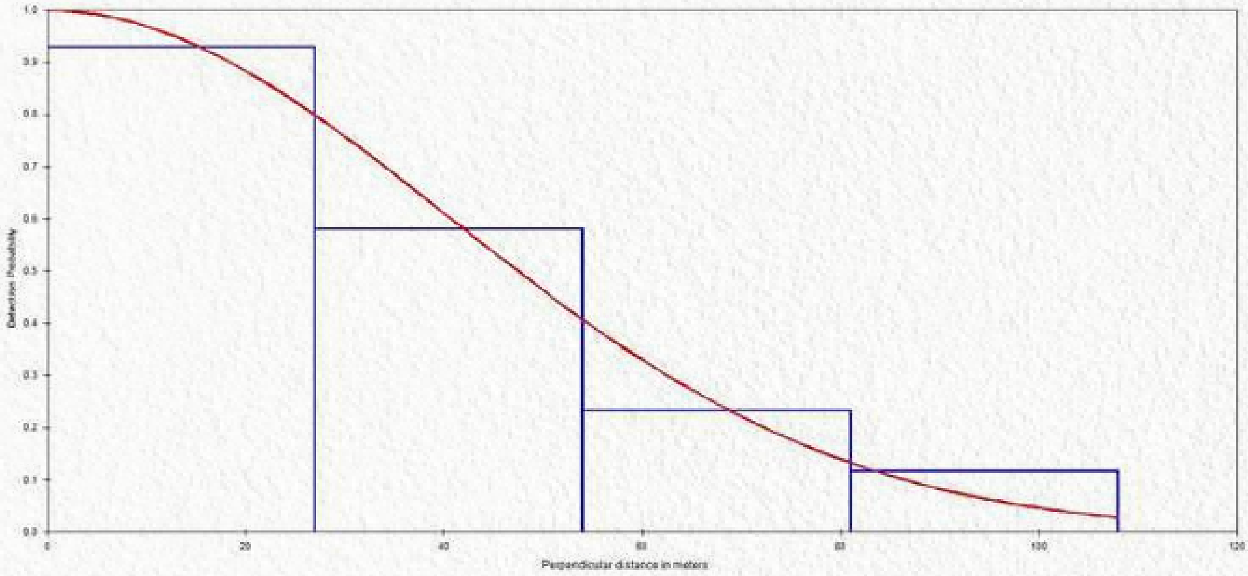


Figure 4.1.6.
Distance sampling detection function plot using the model- half normal with hermite polynomial adjustment key for Nilgai (goodness of fit χ2 - p = 0.86)

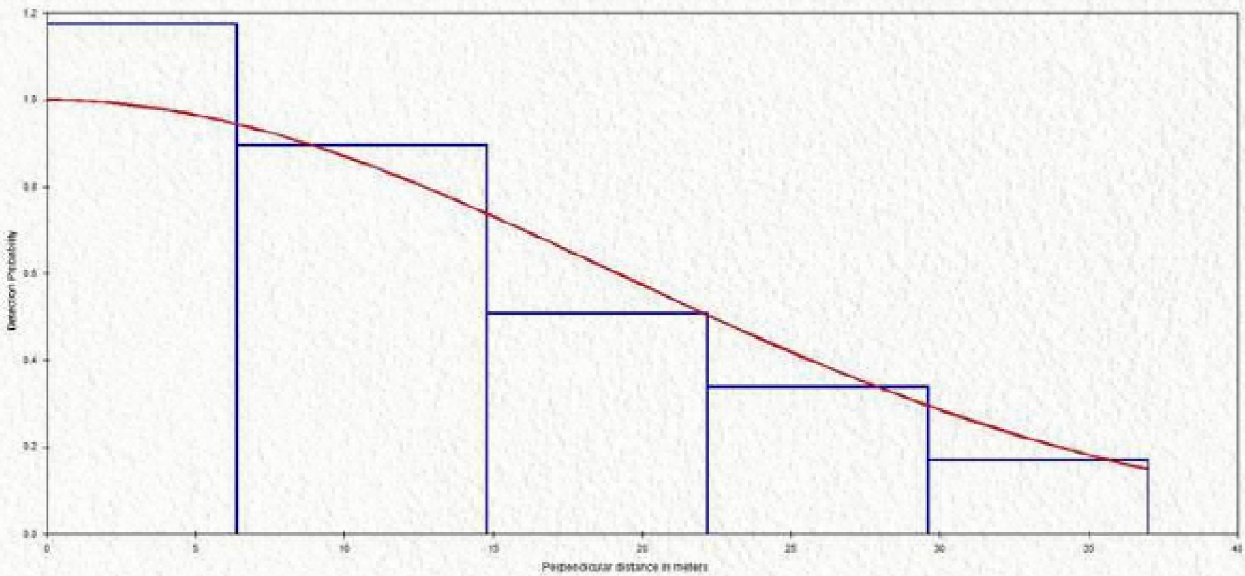


Figure 4.1.7.
Distance sampling detection function plot using the model- half normal with hermite polynomial adjustment key for Indian wild pig (goodness of fit χ2 - p = 0.93)

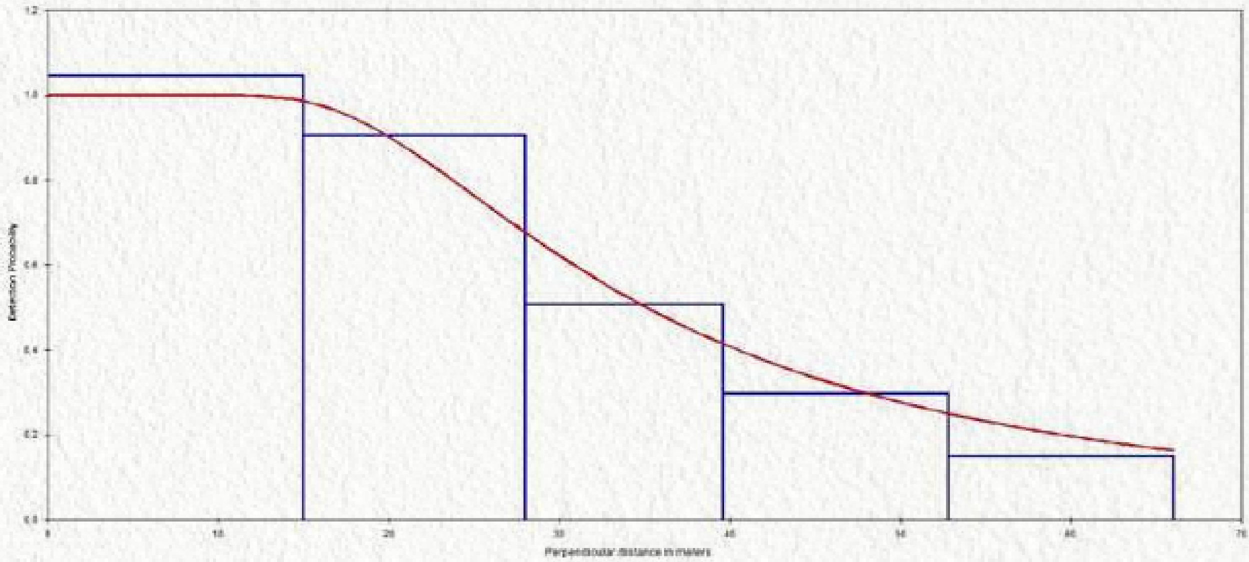


Figure 4.1.8.
Distance sampling detection function plot using the model- hazard rate with simple polynomial adjustment key for Indian peafowl (goodness of fit χ2 - p = 0.92)

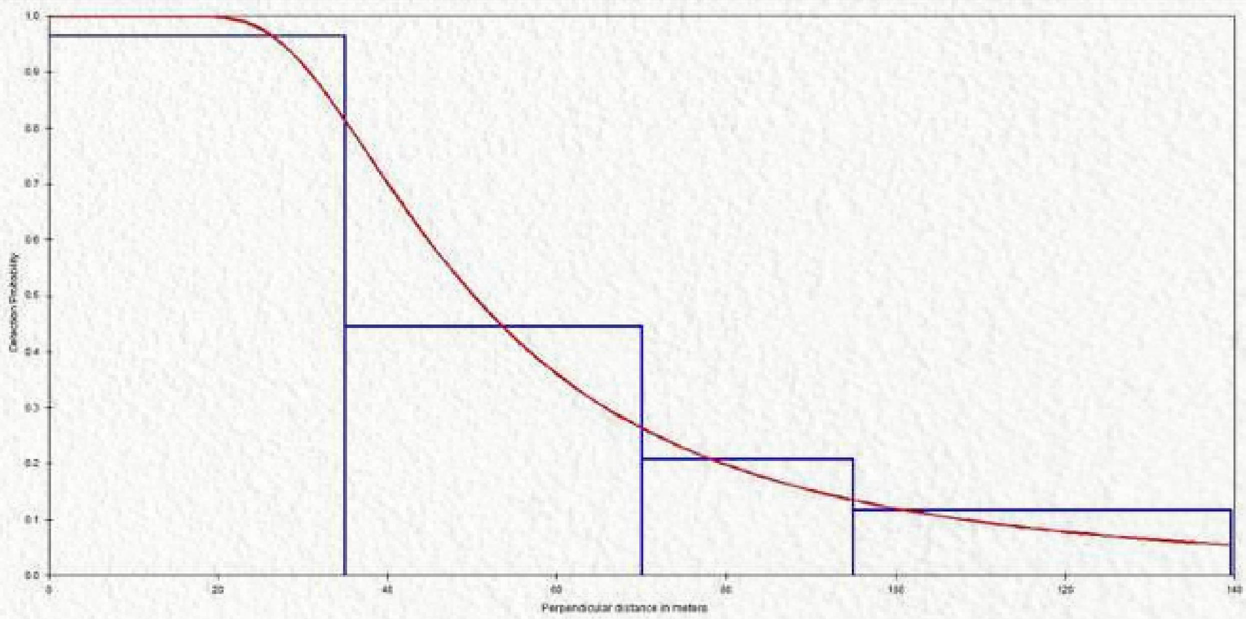


Figure 4.1.9.
Distance sampling detection function plot using the model-hazard rate with simple polynomial adjustment key for grey langur (goodness of fit χ2 - p = 0.61)

4.2. Relative Abundance Index and spatial distribution of prey in the erstwhile Wildlife Sanctuary area of Kuno National Park

4.2.1. Introduction

The Capture–Mark–Recapture (CMR) framework is widely applied for estimating carnivore populations; however, its applicability is limited in species lacking distinctive individual markings (Carbone *et al.* 2001). In such cases, relative abundance indices (RAI) are often employed as surrogates for abundance (Bridges & Noss, 2011; O'Brien *et al.* 2003; Sollmann *et al.* 2013). RAIs are based on the assumption of a linear relationship between the index values and true population abundance, thereby serving as indicators of both spatial distribution and relative density (Güthlin *et al.* 2014).

4.2.1.1 Methodology

In this study, RAI was computed as the total number of independent photo-capture events per unit sampling effort, scaled by 100. An independent capture event was defined as any detection separated by at least 10 minutes from the preceding record (Carbone *et al.* 2001; O'Brien *et al.* 2003). The details of camera-trap sampling in the erstwhile WLS area of Kuno NP during 2024-25 are described in Section 3.1. Spatial distribution patterns of photo-captured species were visualized by mapping RAI values across camera-trap locations. Spatial distribution maps illustrating species detections were created using the RAI values from each camera trap. These maps were generated by applying kernel density estimation in ArcGIS.

For wildlife monitoring in the erstwhile WLS area of Kuno NP, 262 camera traps were deployed within 2 km^2 grids at 131 locations. The presence of nine prey species was documented through those camera trap photographs (Table 4.2.1) and their corresponding RAI values were calculated. RAI offers a way to compare relative abundance across species or sites without direct animal counts (O'Brien *et al.* 2003). It measures the number of independent detections per unit effort. RAI of the species was calculated per camera trap and then averaged.

The RAI values indicate that chital is the most frequently detected species, with the highest RAI of 39.60, followed by Indian hare (RAI 37.07) and sambar (RAI 20.53), suggesting their higher relative abundance or activity within the study area. In contrast, the chousingha, or four-horned antelope (*Tetracerus quadricornis*), exhibited the least RAI of 0.98, suggesting it is the least detected or potentially rarest among these species. Chousingha were not detected during line transect sampling. Spatial distribution maps of species detections using the RAI values obtained from each camera trap are shown in Figure 4.2.1.

Table 4.2.1.
Relative Abundance Index (RAI) of prey species obtained during the camera trap survey conducted in Kuno National Park during Dec 2024 – Jan 2025

Species (Prey)	Total no. of photographs	Total no. of independent events	RAI
Chital	35702	2064	39.6
Indian hare	3210	1946	37.1
Sambar	5824	1098	20.5
Nilgai	5915	1046	19.7
Indian peafowl	6810	726	13.7
Indian wild pig	4848	673	12.9
Indian crested porcupine	812	620	11.7
Grey langur	3203	118	2.21
Chousingha	266	50	0.98

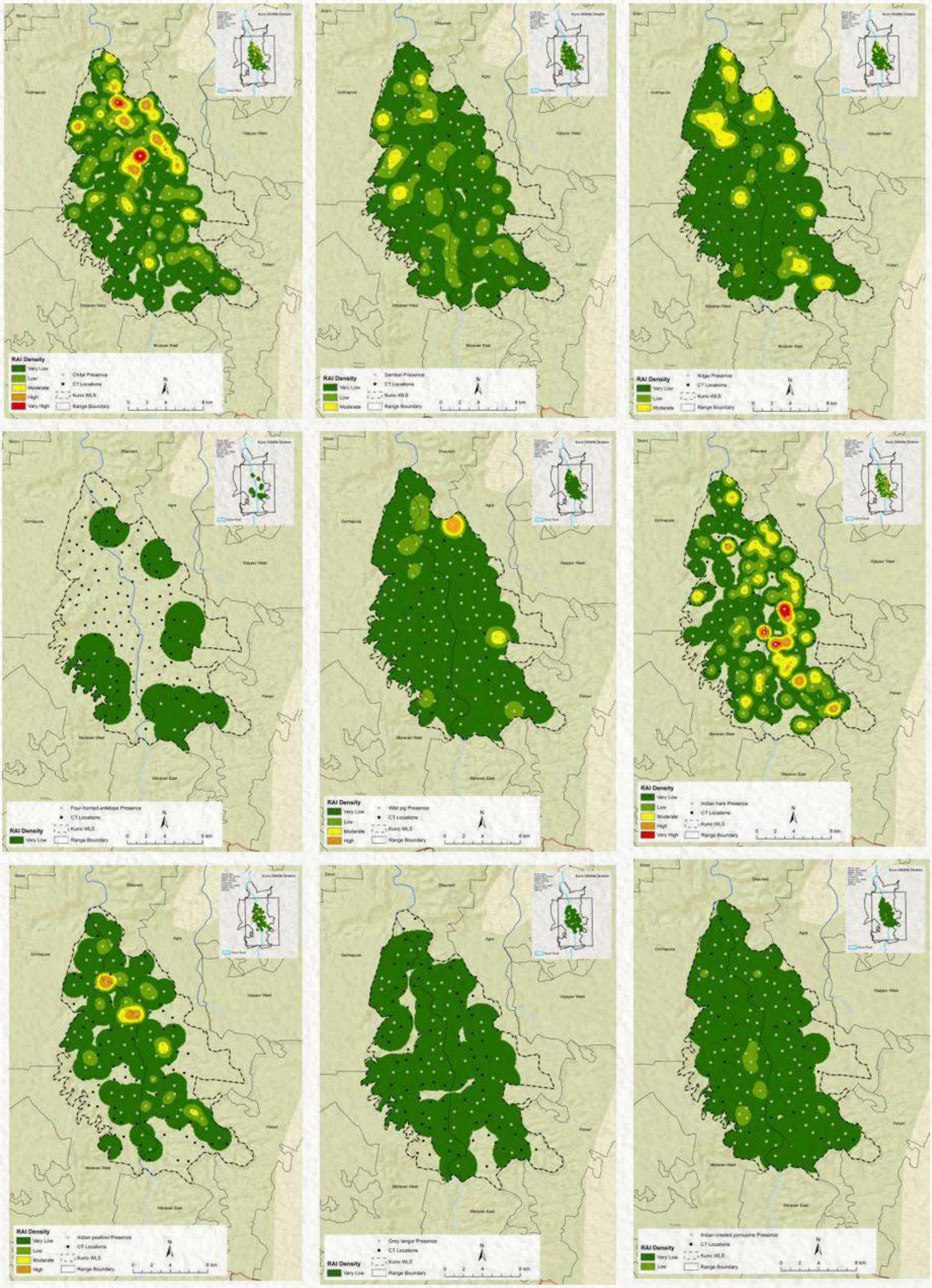


Figure 4.2.1.

Spatial distribution of prey species using Relative abundance index (RAI) obtained from camera trap sampling in the erstwhile Wildlife Sanctuary area of Kuno National Park. Chital, sambar and nilgai (top row L-R), chowsingha, wild pig and hare (middle row L-R), peafowl, grey langur and porcupine (bottom row L-R)

4.2.2. Activity pattern of prey species in Kuno National Park

The activity pattern of a species describes how its physical activity and sedentary behaviour are distributed across the circadian cycle, reflecting periods of movement, foraging, rest, and other behaviours such as feeding and social interactions (Vallejo-Vargas *et al.* 2022; Vazquez *et al.* 2019). Species may exhibit distinct diel activity patterns such as being nocturnal (active at night), diurnal (active during the day), crepuscular (active at twi-light), or cathemeral (active sporadically throughout the 24 hours) (Vallejo-Vargas *et al.* 2022).

From the data obtained from camera trap sampling, the time of each independent photo capture (minimum 10 min interval between two successive photos of the same species) was used in the 'overlap' package in the R platform to create a temporal activity pattern based on the kernel density function (Meredith & Ridout, 2014). The resulting graphs illustrate the activity patterns of nine prey species: chital, sambar, nilgai, Indian peafowl, Indian wild pig, Indian crested porcupine, grey langur, Indian hare, and chousingha, or four-horned antelope, in Figure 4.2.2.

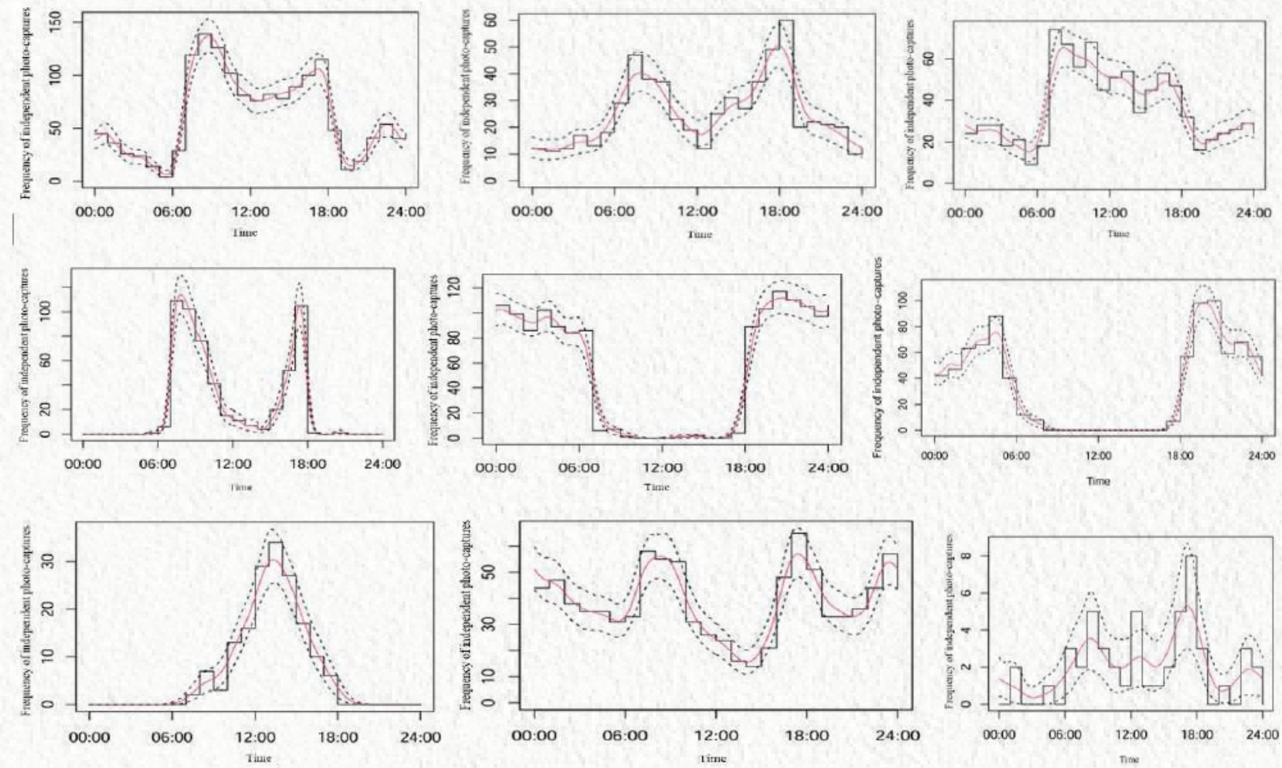


Figure 4.2.2.
Activity pattern of prey species obtained from camera trap sampling in Kuno National Park. Chital, wild pig, and nilgai (top row L-R), peafowl, porcupine and hare (middle row L-R), grey langur, sambar and chowsingha (bottom row L-R)

The graphs suggest distinct diel activity patterns and likely temporal niche preferences among the species. Chital and the Indian wild pig primarily show a crepuscular-diurnal routine, with a bimodal pattern of peak activity occurring in the early morning and late afternoon and minimal activity at night. Nilgai also showed a crepuscular-diurnal pattern but with a maximum activity peak in the morning and gradually declining over daytime till dusk. The Indian peafowl exhibited a pronounced crepuscular pattern, with activity peaks at dawn and dusk. The Indian hare and Indian crested porcupine are strictly nocturnal, while the grey langur demon-strates a strictly diurnal pattern. In contrast, sambar displays a crepuscular-nocturnal pattern, with activity peaks during dusk, dawn, and night hours. Chousingha shows a low-frequency, scattered activity throughout the day like nilgai, but with a peak at dusk.

4.2.3. Temporal overlap of wild prey with predators in Kuno National Park

Temporal overlap describes the degree to which two or more species share a similar period of activity within the daily cycle, quantifying how much their activity patterns coincide over time. This metric is estimated using a coefficient (Dhat). Camera trap images were used to develop a record table, and R package activity overlap is used to create activity overlap among mammalian predators and with prey species. The resulting graphs are presented in the following figures (Figures 4.2.3-4).

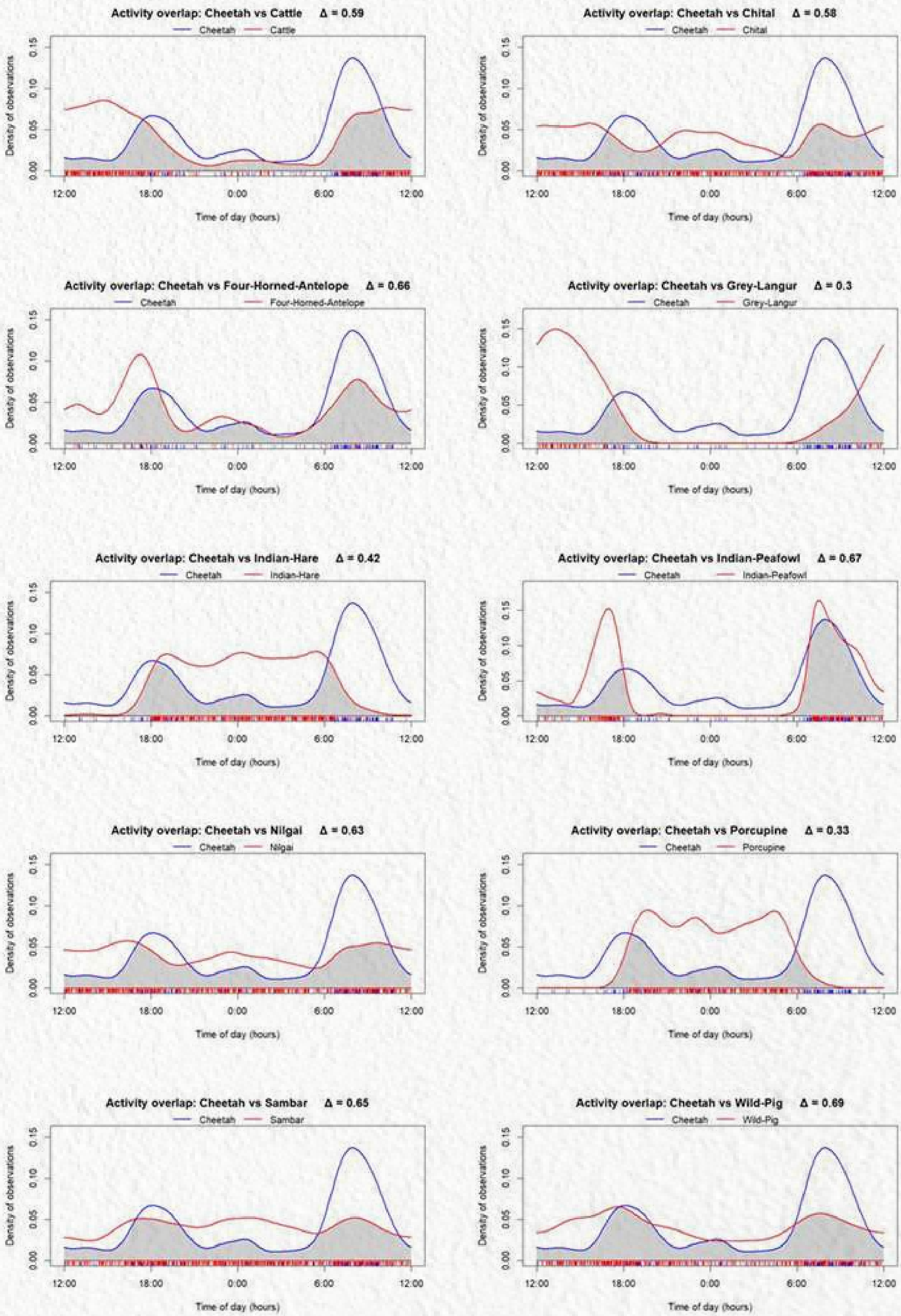


Figure 4.2.3.
Activity overlap of cheetah with prey species

These overlapping graphs between the cheetah and the prey species display extreme to moderate overlaps, depending on the prey species. Among all the prey species, nilgai, sambar, chital, and wild pig show pronounced overlaps. Whereas, with langurs and peafowl, it shows minimal overlap and temporal avoidance.

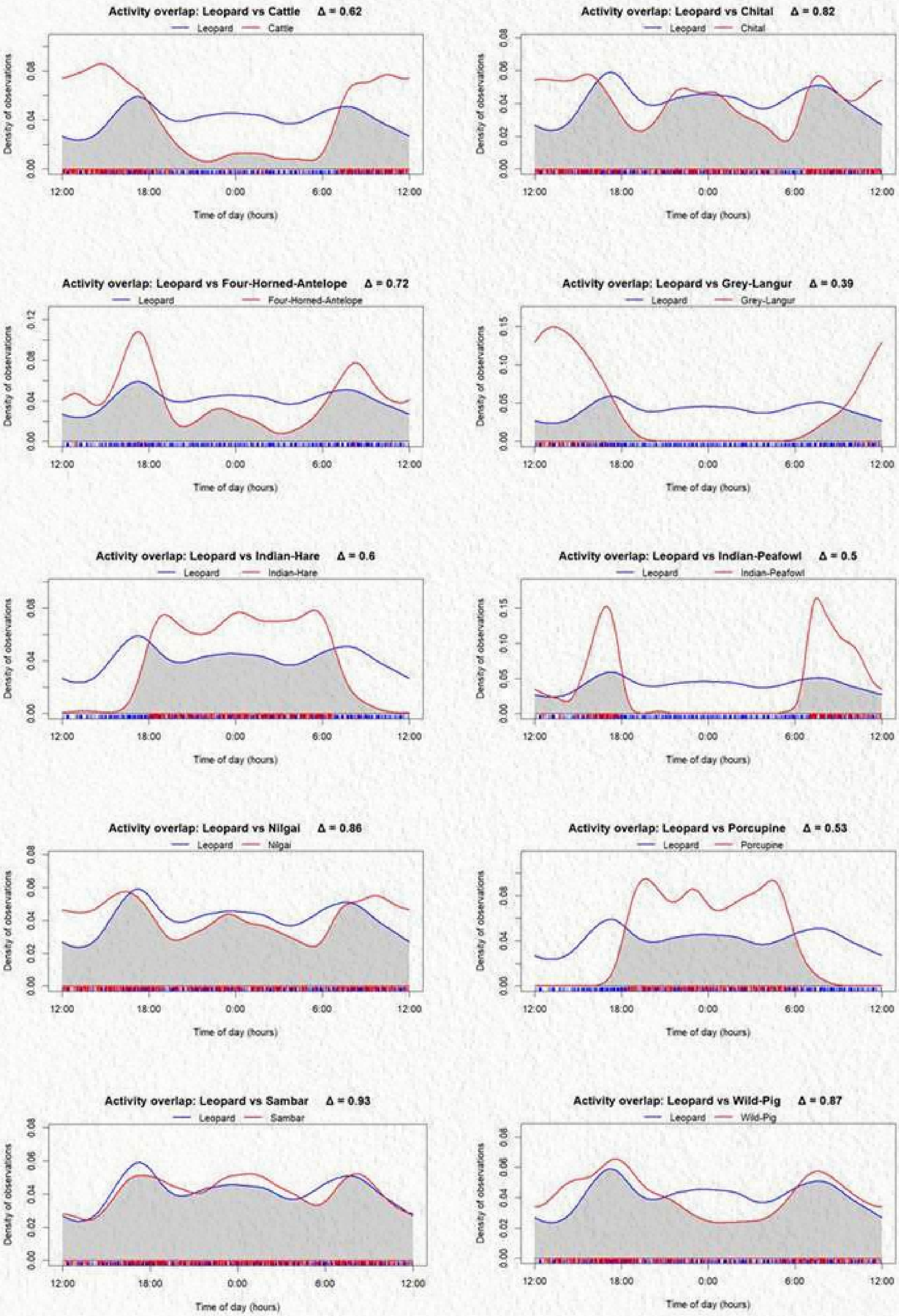


Figure 4.2.4.
Activity overlap of leopard with prey species

Prey species such as sambar, chital, wild pig, and nilgai exhibit pronounced overlap with leopards, indicating their effectiveness in hunting these prey species. This predator also exhibits moderate overlap with other species such as the grey langur, porcupine, and peafowl, indicating adaptive avoidance.

4.3. Space use of chital in Kuno National Park

4.3.1. Home range and movement of chital in Kuno National Park

A home range is defined as the geographic area utilized by an individual animal or a group of animals over a specific period, encompassing their routine activities such as foraging, resting, and mating. In chital, the size of the home range varies with habitat type, resource availability, and population density (Bhat & Rawat, 1995). Previous studies have reported that female chital in forested habitats maintain home ranges of approximately 0.5-1.2 km^2, while males may occupy ranges up to 2.5 km^2 (Johnsingh, 1983). In semi-arid landscapes with limited resources, home ranges may extend over larger areas to meet foraging requirements (Khan, 1994). The data presented here are preliminary, and further investigations are necessary for a more comprehensive understanding of prey–predator interactions.

In the present study, home range estimation was conducted using location data obtained from two female chitals deployed with UHF collars. Analyses were carried out using the adehabitatHR package (Calenge, 2024) in the R platform. Home ranges were quantified using two standard methods: The Minimum Convex Polygon (MCP) and the Kernel Density Estimator (KDE). MCP analysis delineates the smallest polygon encompassing all recorded animal locations, thereby providing an estimate of the total area used by an individual. Alternatively, the kernel method estimates the utilization distribution, representing the probability of space use (Worton, 1989). The home range and movement of two radio-collared female chitals are shown in Table 4.3.1 & Figure 4.3.1.

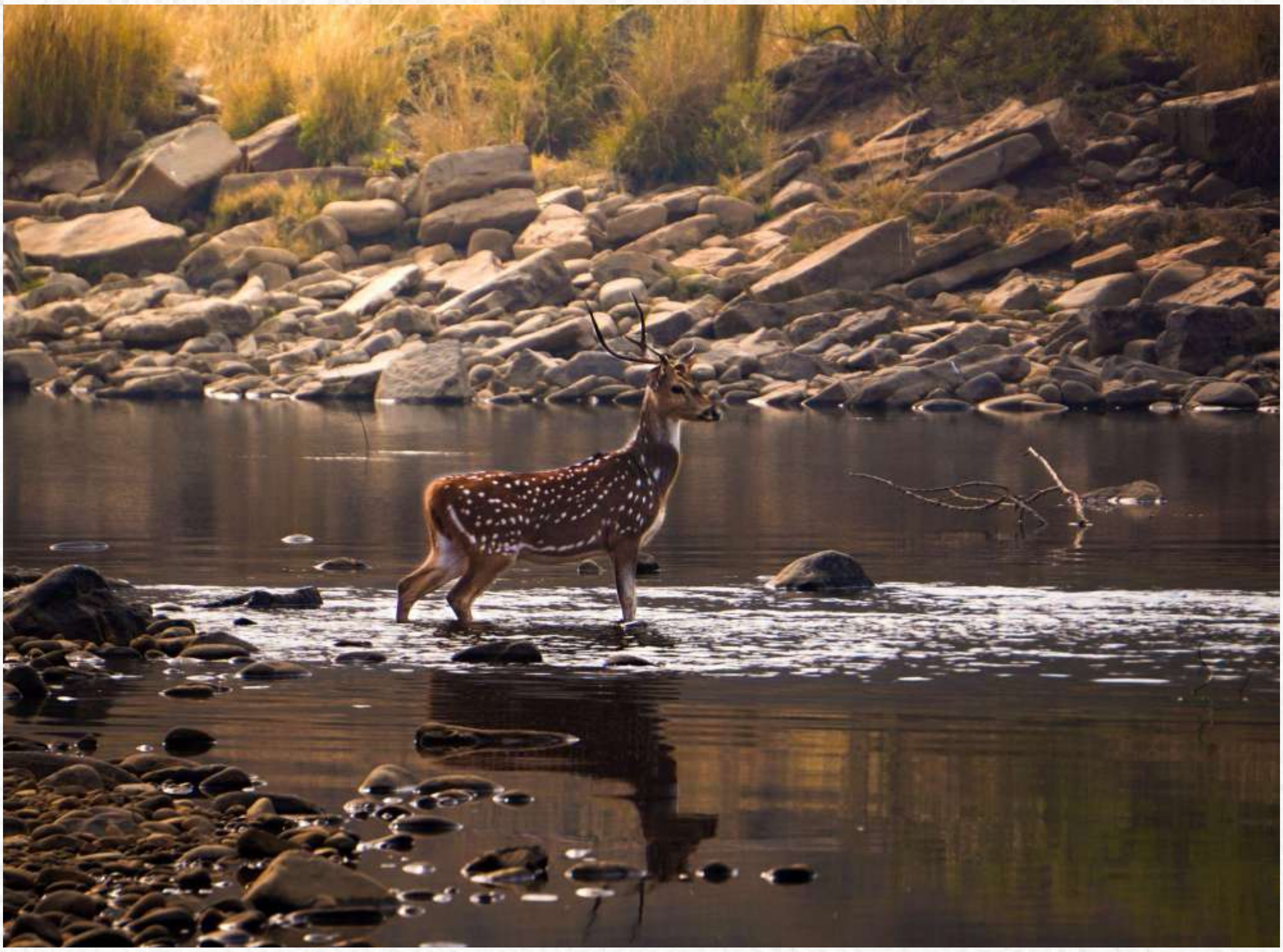


Table 4.3.1.
Home range and movement of chital in Kuno National Park

Animal ID	Age & Sex	100% MCP (Area km²)	95% KDE (Area km²)	50% KDE (Area km²)	Average Daily Distance Moved (km)	Days
Chital 6 (UHF 6800)	Adult Female	6.41	4.02	0.86	2.10 (0.08 SE)	110
Chital 8 (UHF 6798)	Adult Female	6.31	3.91	0.88	1.63 (0.05 SE)	175

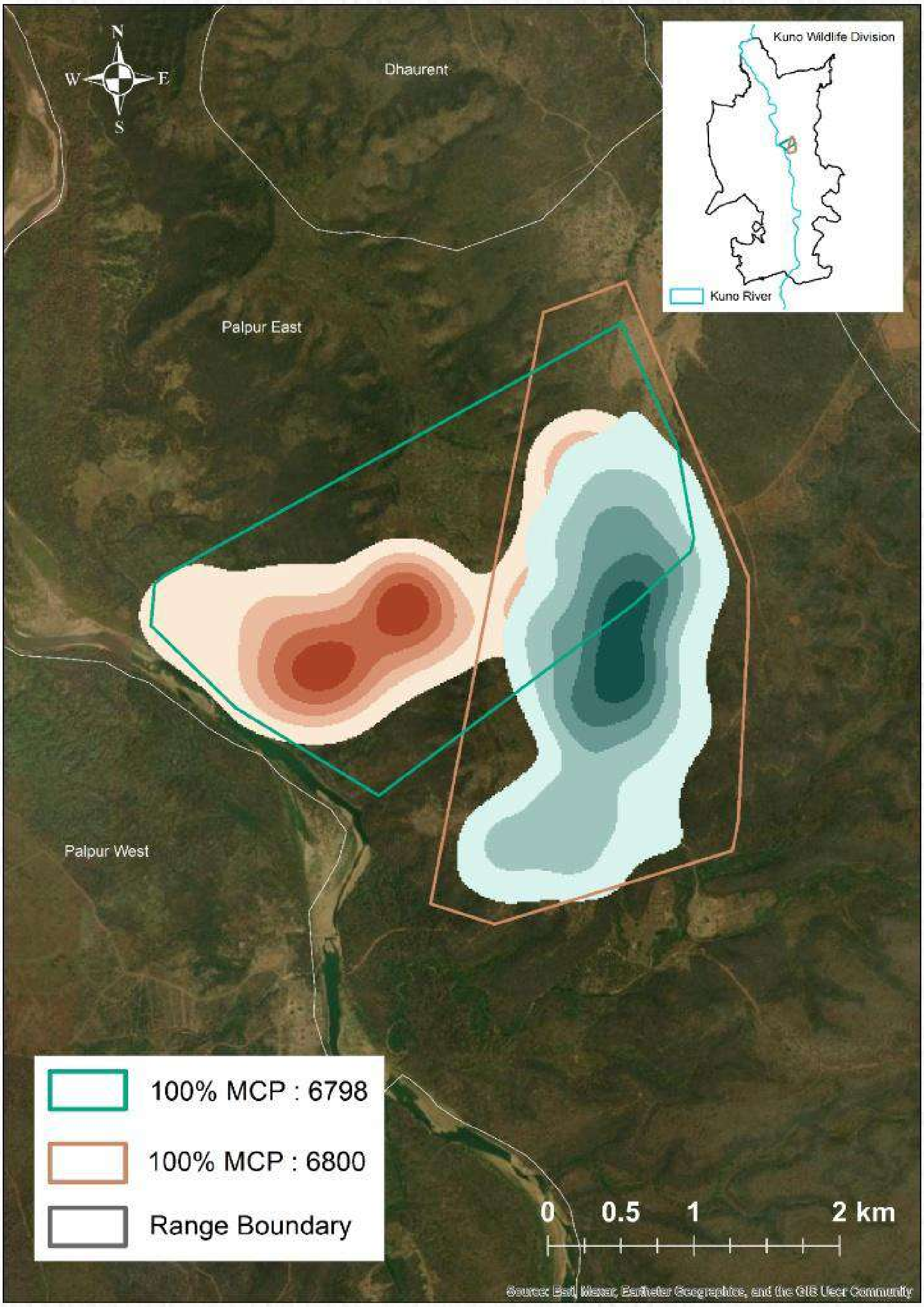


Figure 4.3.1.
Home ranges using 100% Minimum Convex Polygon (MCP), of two radio-collared (UHF) female chital in Kuno National Park

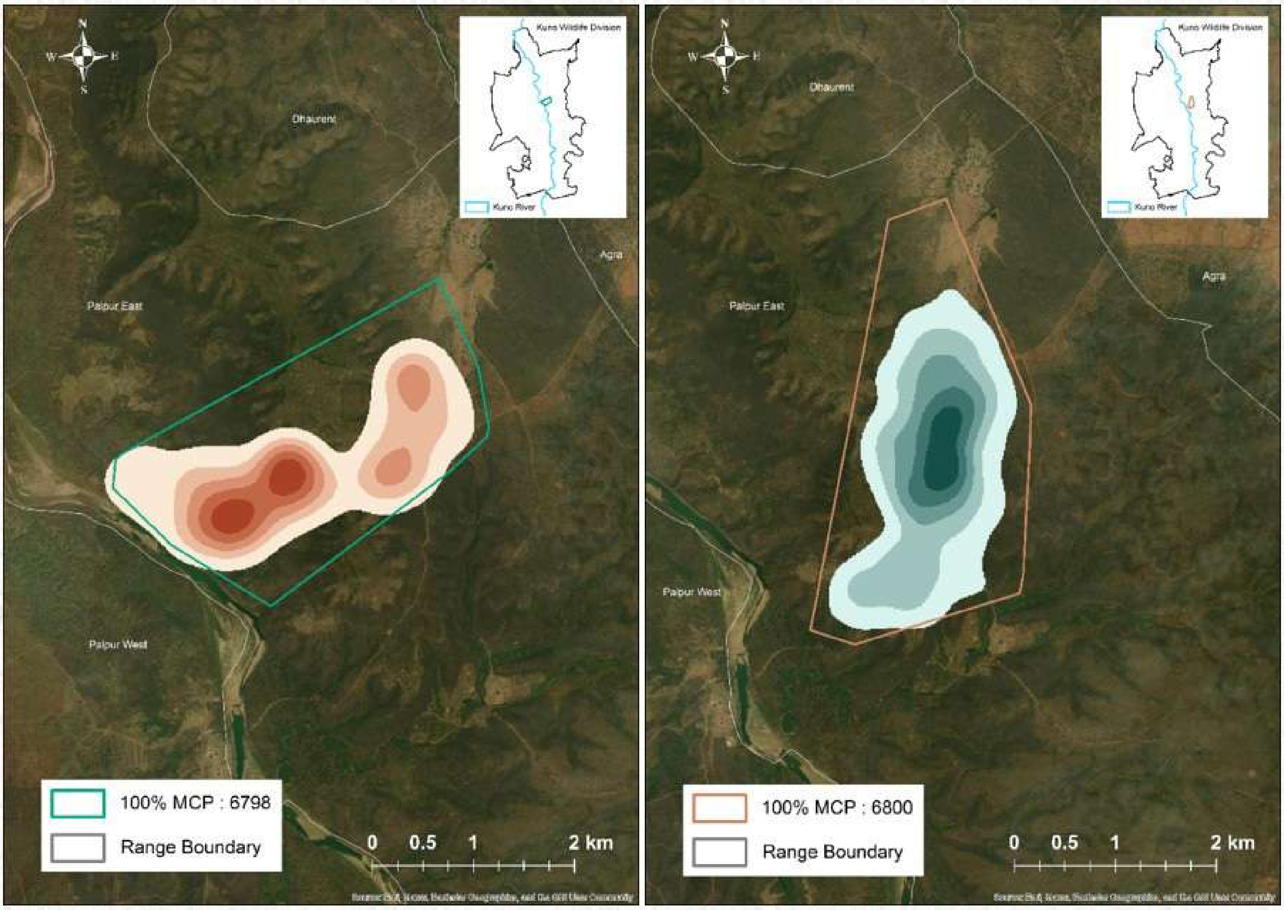


Figure 4.3.2.
Home ranges using 100% Minimum Convex Polygon (MCP), of radio-collared chital individual UHF: 6798 (left) & UHF: 6800 (right) in Kuno National Park

4.3.2. Habitat selection of radio-collared chital in Kuno National Park

Chital is known to be a forest-dwelling species mostly residing on the interface of wooded areas and open patches (Schaller, 1967; Eisenberg, 1972; Mishra, 1982). Habitat preferences of radio-collared chital in Kuno NP were assessed using the Resource Selection Function (RSF), which evaluates how specific habitat features influence the likelihood of habitat use (Manly, 2002). RSF models were developed in the R platform using the 'amt' package (Signer *et al.* 2024), applying logistic regression to compare the characteristics of used versus available but unused habitats (Johnson *et al.* 2006). The land-use/land-cover (LULC) classes considered in the analysis included water bodies/areas closer to water, agriculture, built-up areas, dry mixed deciduous forest, Open Natural Ecosystem, *Terminalia pendula* forest, Boswellia forest, Butea forest, khair-sissu forest, and tropical thorn forest.

Second-order habitat selection was examined for the radio-collared individuals. Selection ratios were calculated at the home-range level to assess the relative probability of habitat use compared to its availability. For this, the proportion of each LULC class available within the 100% Minimum Convex Polygon (MCP) was compared with the proportion of radio locations recorded within these habitats for each individual. We also calculated Ivlev's electivity index using the proportion of locations recorded for every individual in each LULC category using the R package adehabitatHS. The calculated ratios range between -1 and +1, where preference for a particular habitat is suggested by higher positive values.

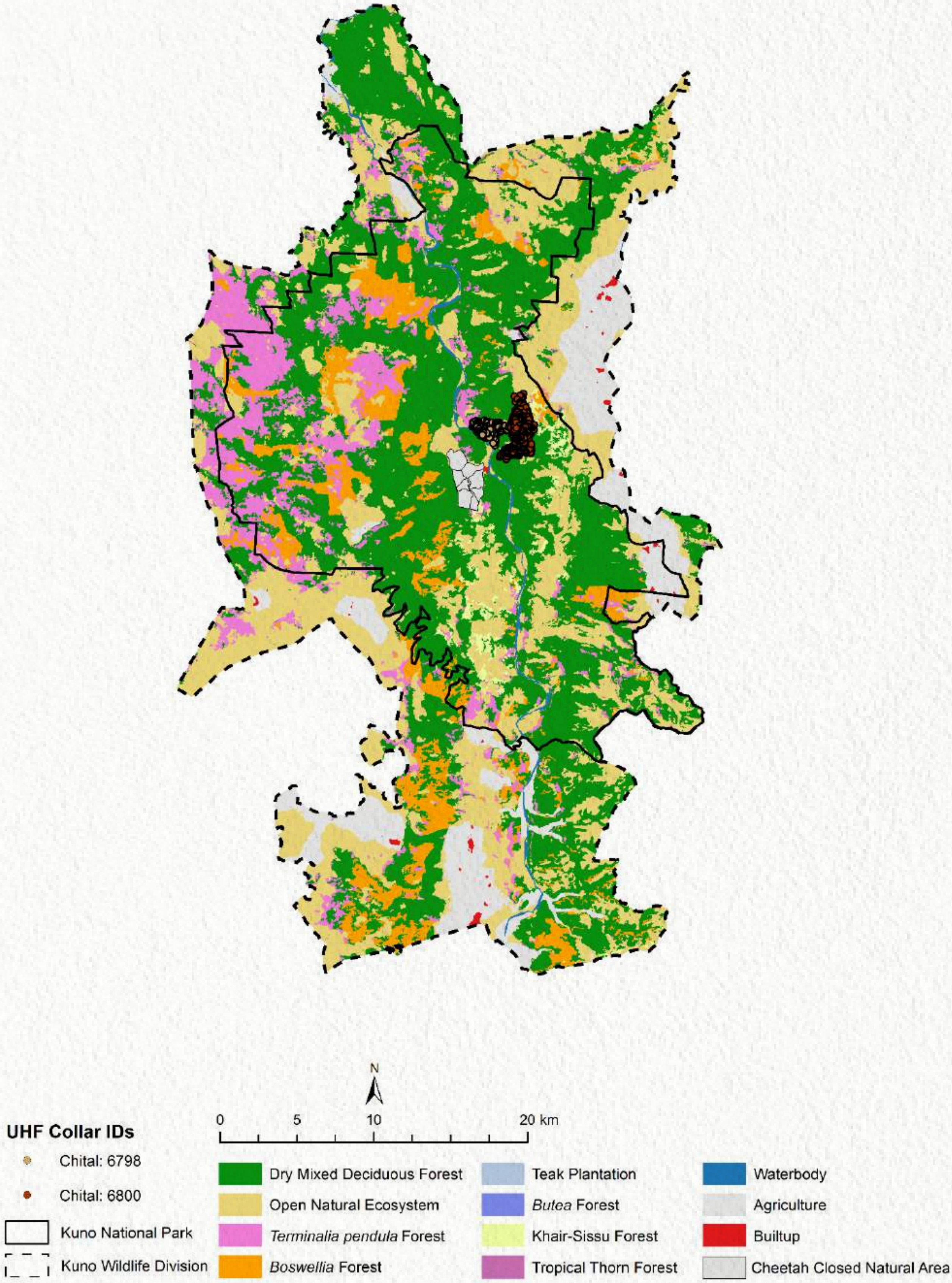


Figure 4.3.3.
Locations of radio-collared chital overlaid on the forest type map of Kuno Wildlife Division

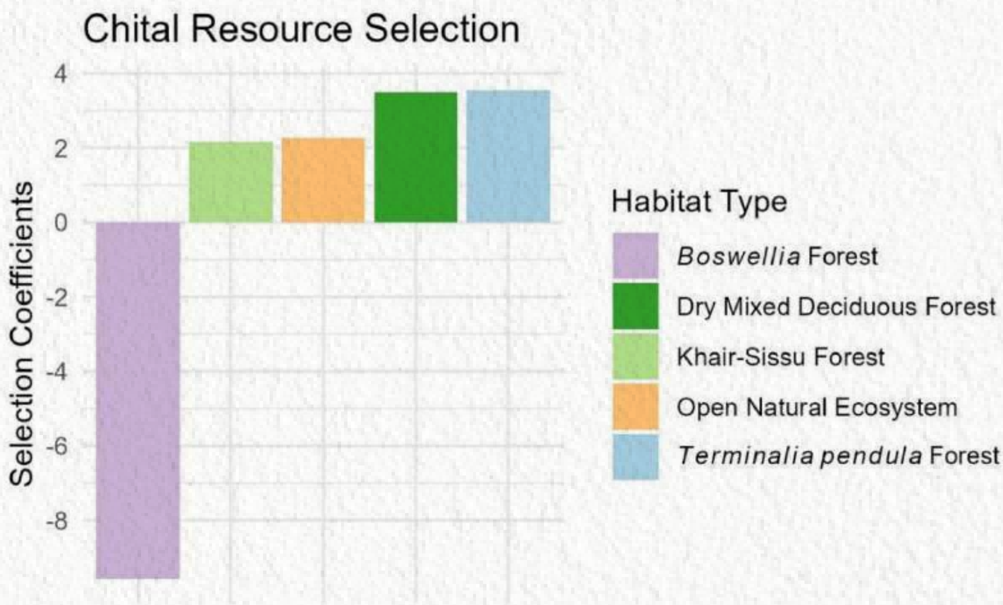


Figure 4.3.3.
Resource Selection Function (RSF) of radio-collared chitals in Kuno National Park

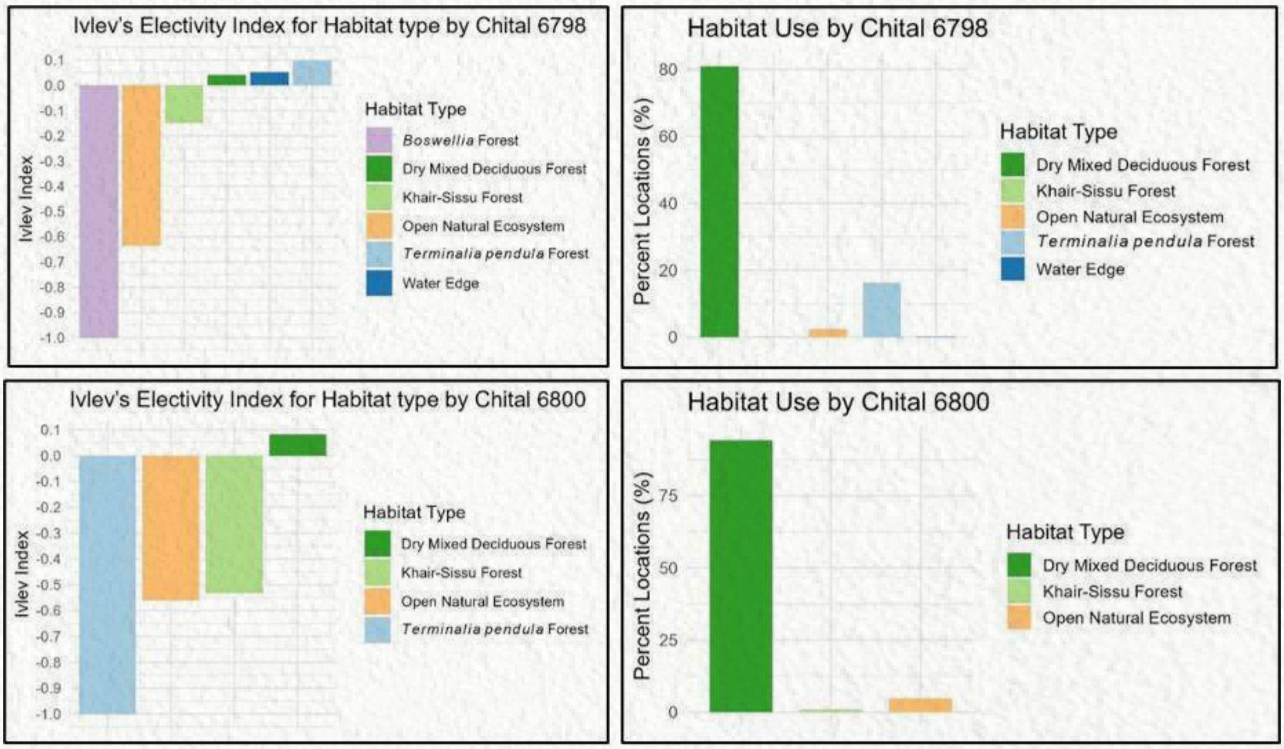


Figure 4.3.4.
Habitat selection of radio-collared chital (ID 6800 & ID 6789) adult female using Ivlev's selectivity index (left) and percentage of locations in each habitat type (right)

From RSF analysis, it was seen that *T. pendula* forest, along with dry mixed deciduous forest, followed by open natural ecosystem and khair-sissu forest, was selected by adult female chitals. Using Ivlev's index, one adult female selected *T. pendula* forest, followed by areas close to water and dry mixed deciduous forest, whereas the other female selected dry mixed deciduous forest.

4.4. Sex-specific seasonal comparison in activity patterns of chital (*Axis axis*) in Kuno National Park

4.4.1. Introduction

Ungulate activity patterns are predominantly governed by ecological pressures, particularly predation risk, and are modulated by intrinsic behavioural trade-offs between foraging and vigilance, which are critical to individual fitness and survival (Creel *et al.* 2014). As a social ungulate, chital (*Axis axis*) engage in foraging, social interactions, movement, and anti-predator behaviors, all of which are influenced by seasonal factors (Sharatchandra & Gadgil, 1980; Schaller, 1967). Chital serves as one of the primary prey species and contributes significantly to the ecosystem's biomass within the Kuno NP (Jhala *et al.* 2021). The study investigates seasonal behavioural differences between male and female chital in Kuno NP.

4.4.2. Methodology

Individual behaviour was recorded using a focal animal sampling rule with continuous recording (Altman, 1974) for 10 minutes with a 2-minute interval between consecutive sampling events. During the sampling events, the recorded behaviour of males or females for various activities. The data was grouped based on season, sex, and activity. The dataset is categorized by season (monsoon, post-monsoon, and pre-monsoon), sex (male and female), and activity type (foraging, grooming, ruminating, and walking). For each observation, the total duration of time spent on a given activity was recorded, and the proportion of time of each activity was calculated relative to the total duration per sex and season. The non-parametric Mann-Whitney U test was used to compare the distributions of activity durations between sexes across seasons. Significance level: $p < 0.05$ (*), $p < 0.01$ (**), $p < 0.001$ (***), and not significant (ns).

4.4.3. Results

The pre-monsoon season exhibited the most pronounced sex-based differences in activity. Males spent significantly more time foraging than females. Males also significantly walked more than females during pre-monsoon, likely due to the energetic demands of mate searching and territorial defense. These findings suggest that males increase their energetic investment during this season, likely in preparation for the rut. Grooming, ruminating, and vigilance did not differ significantly between the sexes. This indicates that walking and foraging are influenced by sex-specific strategies, while other maintenance behaviours remain consistent.

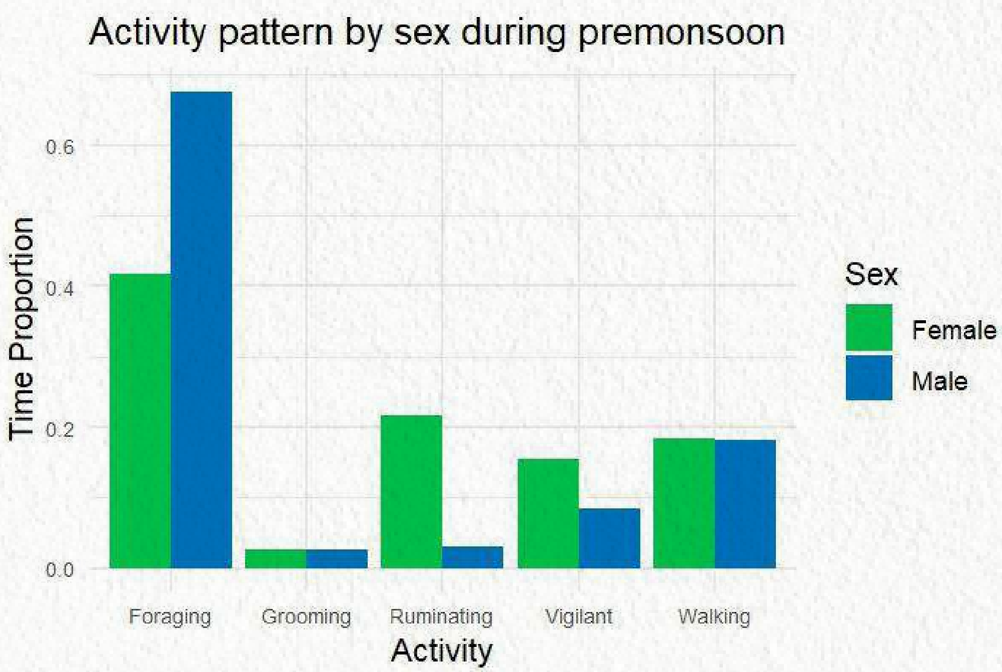


Figure 4.4.1.
Proportion of time spent on various activities observed in male and female chital during pre-monsoon

Table 4.4.1.
Mann-Whitney U test results showing the level of significance between male and female activities during pre-monsoon season

Activity	P_value	Median male	Median female	Significance level
Foraging	0.00000012	37	20	***
Grooming	0.99	9	10	ns
Ruminating	0.28	10	15	ns
Vigilant	0.38	7	9	ns
Walking	0.002	14	10	**

During the monsoon season, a sex-based significant difference was observed in foraging behaviour. Females spent a significantly greater proportion of their time foraging compared to males. This suggests that females may increase foraging effort during monsoon season, possibly to meet nutritional demands associated with reproduction or lactation. Other activities, including grooming, ruminating, vigilance, and walking, did not show statistically significant differences between sexes.

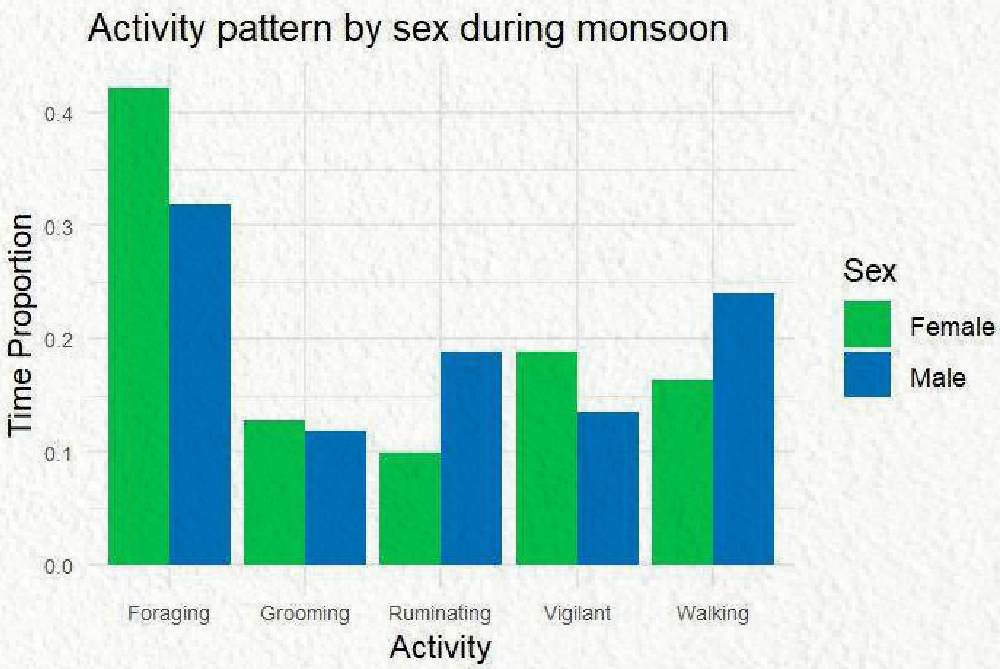


Figure 4.4.2.
Proportion of time spent on various activities observed in male and female chital in monsoon season

Table 4.4.2.
Mann-Whitney U test results showing the level of significance between male and female activities during monsoon season

Activity	P_value	Median male	Median female	Significance level
Foraging	0.0005	10	17	***
Grooming	0.96	9	8	ns
Ruminating	0.30	14	10.5	ns
Vigilant	0.11	8	9	ns
Walking	0.38	9	10	ns

In the post-monsoon season, no significant differences were detected between males and females for any of the five activities. Although males showed slightly higher durations for foraging and females for walking, these differences were not statistically significant. Grooming, ruminating, and vigilance also showed slightly comparable proportions between sexes. This convergence in activity budgets suggests that post-monsoon conditions may promote behavioural uniformity, possibly due to stable resource availability or reduced reproductive pressures.

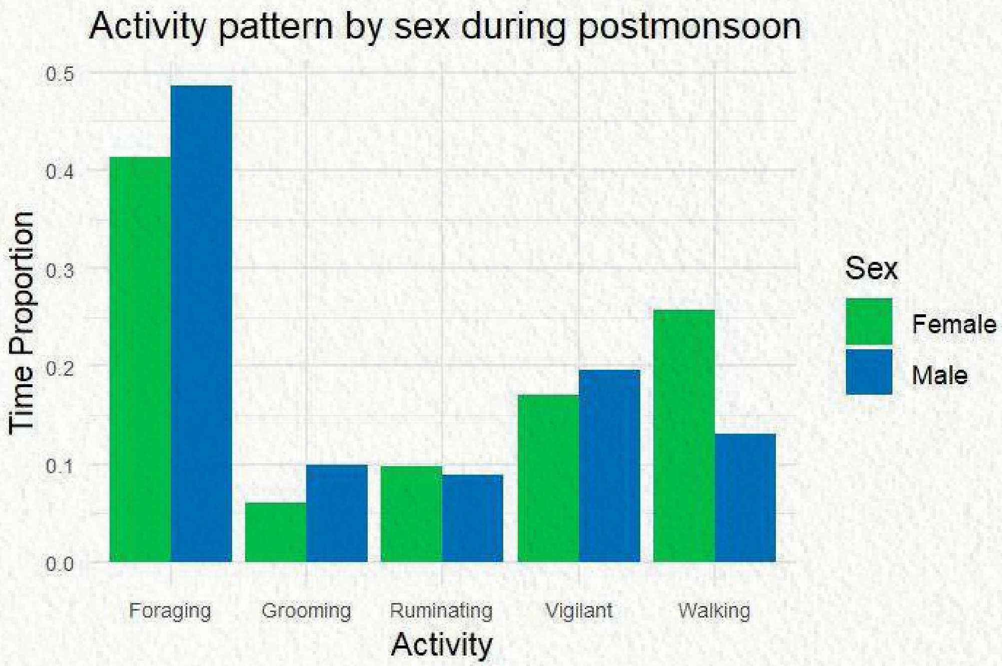


Figure 4.4.3.
Proportion of time spent on various activities observed in male and female chitals during post-monsoon season

Table 4.4.3.
Mann-Whitney U test results showing the level of significance between male and female activities during post-monsoon season

Activity	**P-value**	**Median male**	**Median female**	**Significance level**
Foraging	0.09	18	15	ns
Grooming	0.63	7.5	8	ns
Ruminating	0.50	9	9	ns
Vigilant	0.61	11	11	ns
Walking	0.24	11	14	ns

The study demonstrates that chital exhibits flexible and seasonally dynamic activity patterns that are distinctly influenced by sex-specific behavioural strategies. The behavioural time budgets of males and females vary across seasons, reflecting underlying ecological and reproductive pressures. This research will contribute to a broader understanding of predator-prey dynamics and species adaptation within a rapidly changing ecological framework.

4.5. Prey assessment in Gandhi Sagar Wildlife Sanctuary

4.5.1. Methodology

Prey assessment was conducted in Gandhi Sagar Wildlife Sanctuary (area ~ 397 km^2) using the distance sampling-based line transect method during March-May 2025. A total of 39 beats were sampled, accounting for 49 transects walked thrice with a total sampling effort of 373.5 km. Species such as chinkara, nilgai, chital, cattle, Indian hare, Indian peafowl, Indian wild pig, and grey langur were observed during the sampling period. Along these transects, a total of 294 vegetation plots were also sampled.

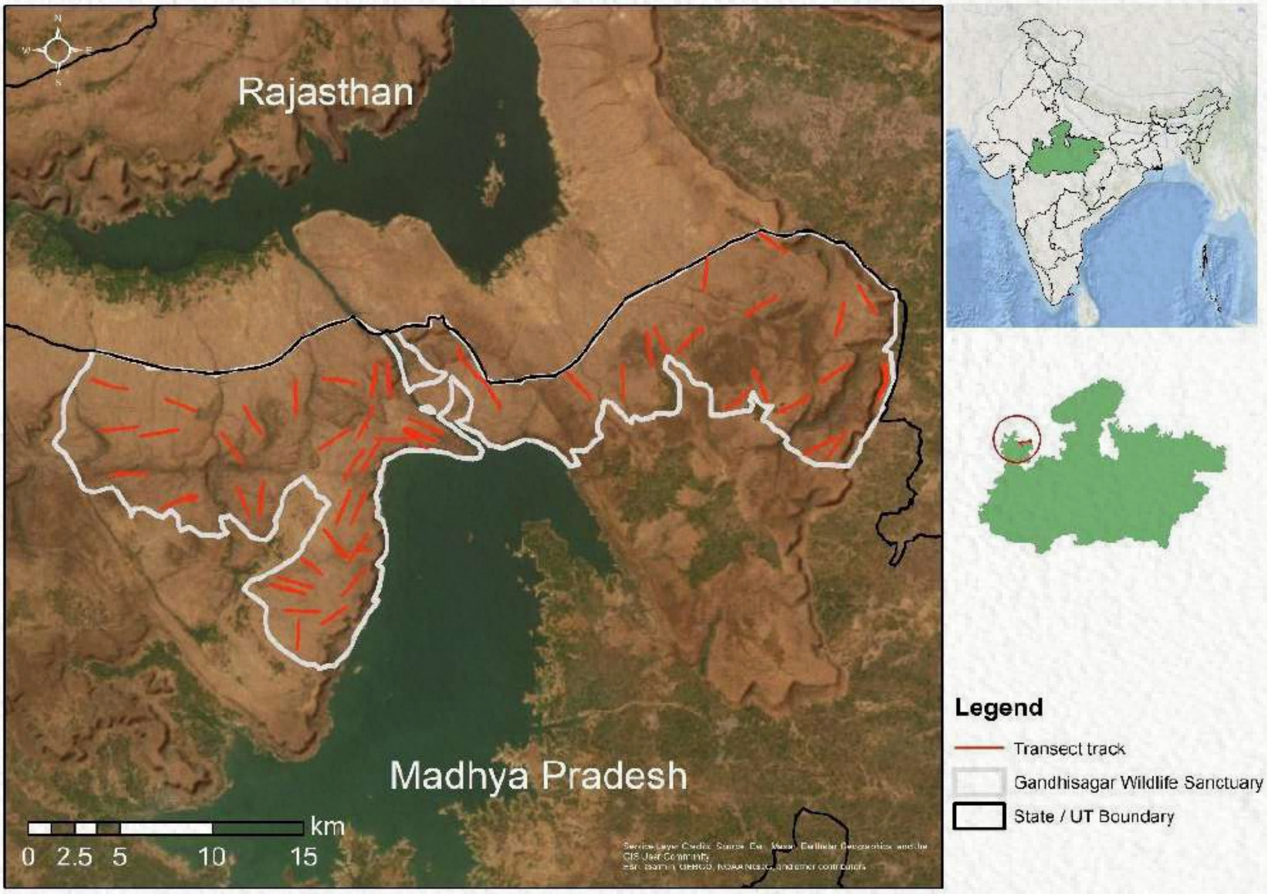


Figure 4.5.1.
Map of line transects sampled in each beat of Gandhi Sagar Wildlife Sanctuary to assess the status of prey in 2025

The East and West Ranges of Gandhi Sagar Wildlife Sanctuary are separated by the deep gorge of the Chambal River and the associated large reservoir of the dam, with minimal opportunities for animal movement between the two ranges. Within the West Range, a large Closed Natural Area of approximately 64 km^2 has been made predator-proof (fenced) for the purpose of initial cheetah release. Therefore, prey assessment survey data was analyzed using post-stratification with a global detection function to estimate the densities of chinkara, nilgai, cattle, Indian hare, Indian peafowl, and Indian wild pig across three distinct zones: the Closed Natural Area (CNA) in the West Range (area 64.4 km^2), Outside the CNA in the West Range (area 145.6 km^2), and the entire East Range (area 187.2 km^2) of the Sanctuary.

During line transect sampling, chinkara and nilgai were the most frequently observed species (Table 4.4.1). Due to very few observations, density estimation was not possible for chital and langur. Density Surface Model (DSM) maps were generated for chinkara and nilgai, as their detection function models were robust and responded well for covariates-elevation above sea level (Earth Resources Observation and Science (EROS) Center, 2000) and pre-post monsoon difference in NDVI (Vermote *et al.* 2016). These covariates best explained the density distribution of chinkara and nilgai.

Table 4.5.1.
Species-wise observations of prey during the line transect-based distance sampling conducted in Gandhi Sagar Wildlife Sanctuary (Area ~ 397.2 km²) during March - May 2025

	Gandhi Sagar West Range - Closed Natural Area	**Gandhi Sagar West Range - Outside**	**Gandhi Sagar East Range**
Effort	153.6 km	90.5 km	123.7 km
Species	**No. of Observations – Groups (individuals)**	**No. of Observations – Groups (individuals)**	**No. of Observations – Groups (individuals)**
Chinkara	60 (149)	11 (18)	31 (84)
Nilgai	35 (73)	17 (39)	30 (72)
Cattle	10 (21)	1 (1)	7 (48)
Chital	2 (6)	2 (5)	-
Indian hare	8 (8)	4 (4)	13 (14)
India peafowl	7 (19)	4 (18)	2 (3)
Indian wild pig	4 (9)	3 (13)	5 (60)
Grey langur	2 (10)	3 (7)	1 (1)

4.5.2. Results

The highest density of chinkara was observed within the Closed Natural Area of Gandhi Sagar West Range - 4.04 (1.32SE) individuals per km², while the rest of this range has a relatively very low density of chinkara. In Gandhi Sagar East Range, estimated chinkara density is 3.02 (1.43SE) individuals per km². The pattern of density distribution is shown in the DSM map for chinkara (Figure 4.5.9.). Higher densities of nilgai occur in Gandhi Sagar East Range, with 3.49 (1.03 SE) individuals per km², while densities are almost similar in CNA and outside of it in Gandhi Sagar West Range. The pattern of density distribution is depicted in the DSM map for Nilgai (Figure 4.5.10).

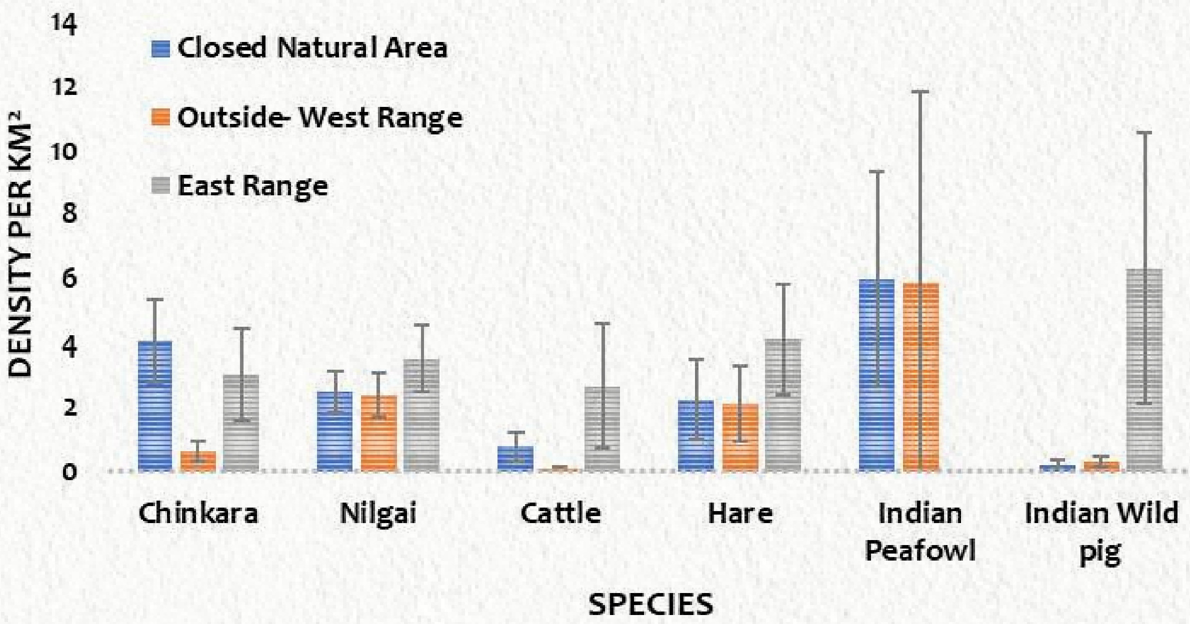


Figure 4.5.2.
Density (per km²) of prey species in Gandhi Sagar Wildlife Sanctuary obtained from distance sampling-based line transects during 2025. Error bars represent standard errors.

Table 4.5.2.

Summary of prey densities in Gandhi Sagar Wildlife Sanctuary obtained from line transect-based distance sampling in the Closed Natural Area (CNA) in Gandhi Sagar West Range (Area-64.4 km²), outside the CNA (Outside) in Gandhi Sagar West Range (Area-145.6 km²), and Gandhi Sagar East Range (Area-187.2 km²).

Species	Site	Group encounter rate per km	Density (SE) per km²	%CV	MCS	ESW	Model	Adjust-ment key	Estimated population
	CNA	0.38	4.04(1.32)	32.84	2.47				260
Chinkara	Outside	0.12	0.61(0.32)	53.03	1.64	101.90	Half-normal	Cosine	89
	East	0.24	3.02(1.43)	47.35	2.67				565
	CNA	0.23	2.46(0.63)	25.63	1.88				159
Nilgai	Outside	0.21	2.36(0.68)	28.67	2.38	87.28	Uniform	Cosine	343
	East	0.21	3.49(1.03)	29.33	2.60				654
	CNA	0.06	0.75(0.45)	60.47	2.11				48
Cattle	Outside	0.01	0.06(0.06)	73.12	-	116.63	Half-normal	Cosine	8
	East	0.06	2.64(1.93)	99.59	6.86				494
	CNA	0.04	2.22(1.25)	56.47	-				143
Indian hare	Outside	0.04	2.10(1.17)	55.78	-	9.25	Hazard-rate	Simple polynomial	306
	East	0.08	4.10(1.71)	41.58	1.11				768
	CNA	0.05	5.98(3.35)	56.00	2.71				385
Indian peafowl	Outside	0.02	5.88(5.94)	101.12	5.50	10.33	Half-normal	Cosine	856
	East	0.02	-	-	-				-
	CNA	0.03	0.21(0.15)	70.12	-				14
Indian wild pig	Outside	0.04	0.30(0.17)	55.36	-	63.87	Half-normal	Hermite polynomial	44
	East	0.04	6.31(4.21)	66.67	19.00				1181
	CNA	0.01	-	-	-	-	-	-	-
Grey langur	Outside	0.04	-	-	-	-	-	-	-
	East	0.01	-	-	-	-	-	-	-
	CNA	0.02	-	-	-	-	-	-	-
Chital	Outside	0.02	-	-	-	-	-	-	-
	East	-	-	-	-	-	-	-	-
SE- Standard Error, CV- Coefficient of Variation, MCS- Mean Cluster Size, ESW- Effective Strip Width									

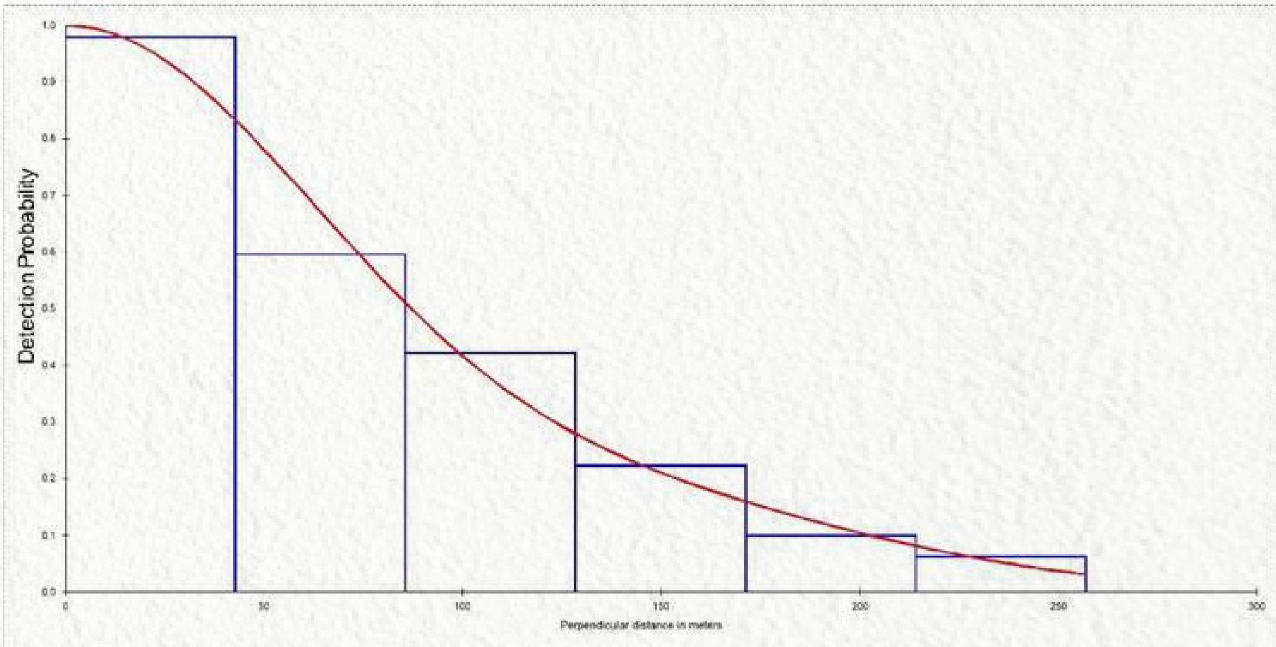


Figure 4.5.3.

Distance sampling detection function plot using the model-half normal with cosine adjustment key for chinkara (goodness of fit $\chi 2$ - p = 0.76)

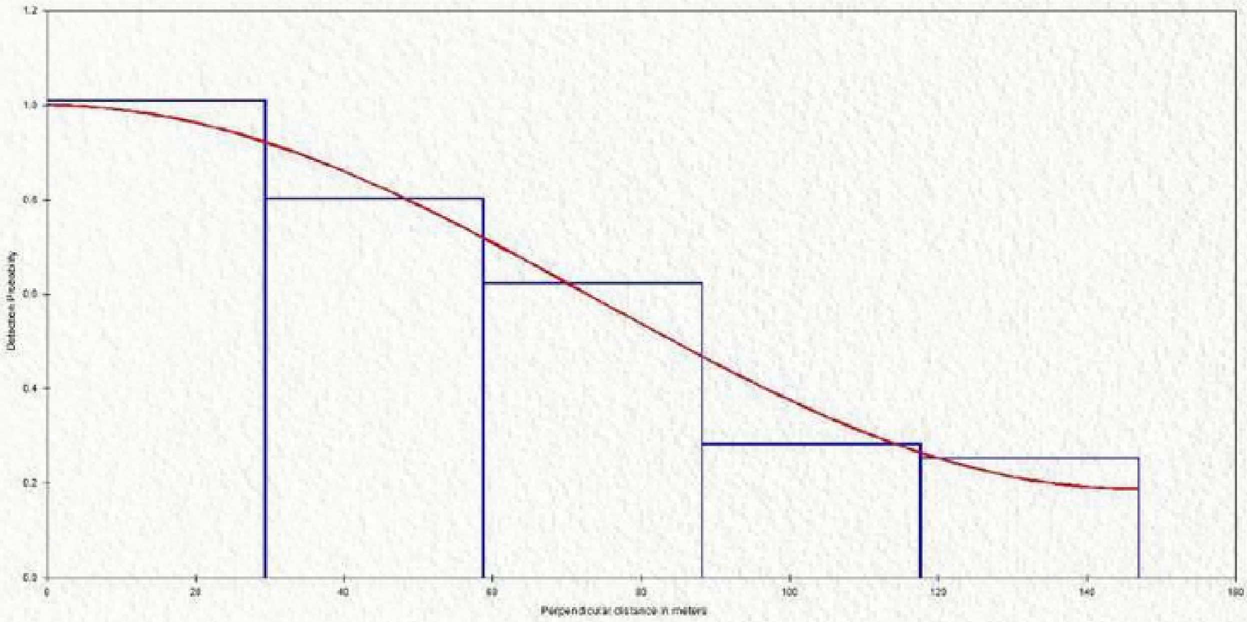


Figure 4.5.4.
Distance sampling detection function plot using the model uniform with cosine adjustment key for nilgai (goodness of fit $\chi2$ - p = 0.6)

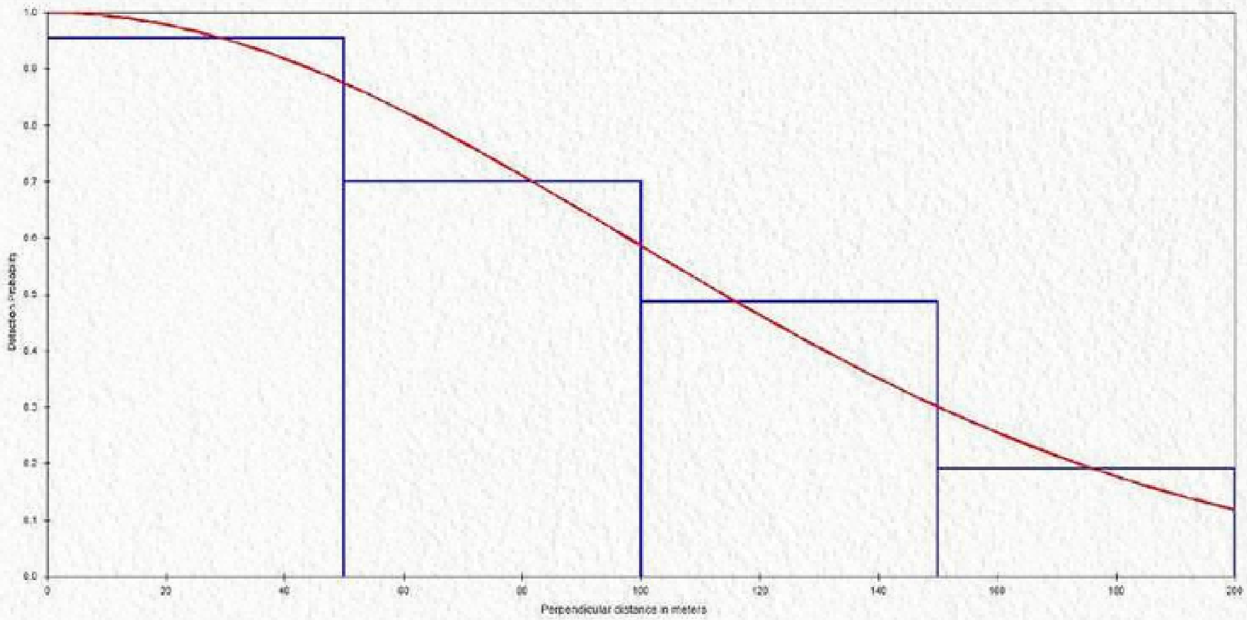


Figure 4.5.5.
Distance sampling detection function plot using the model- half normal with cosine adjustment key for cattle (goodness of fit $\chi2$ - p = 0.82)

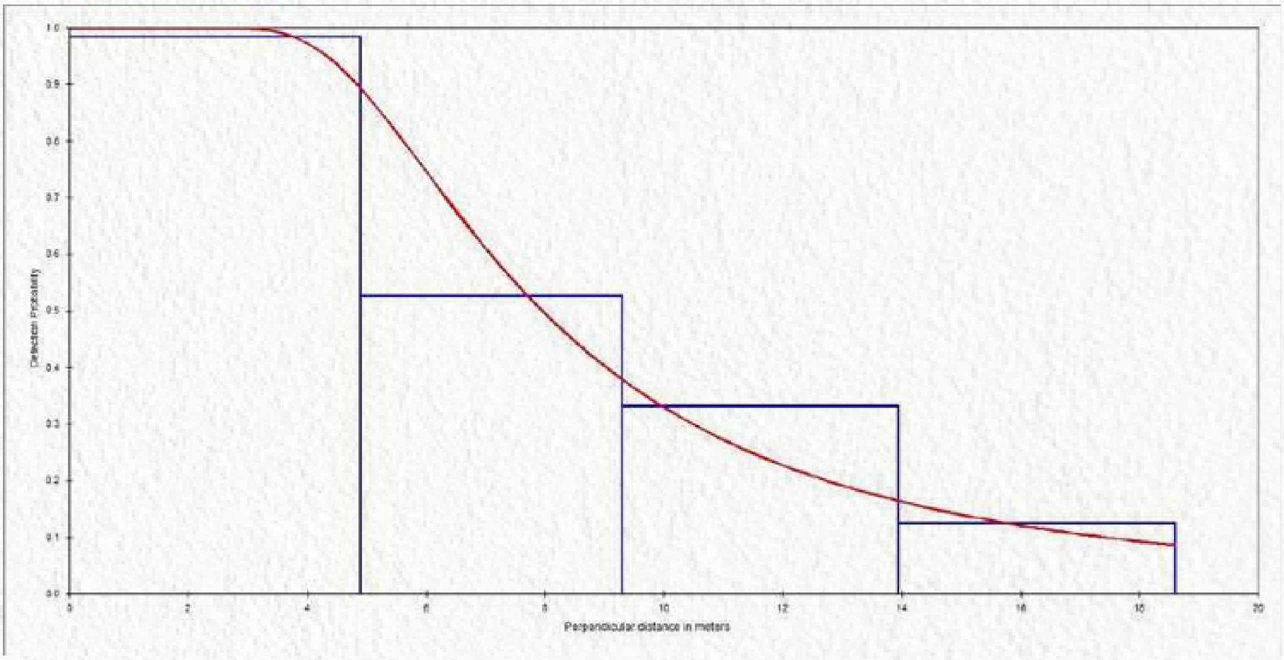


Figure 4.5.6.
Distance sampling detection function plot using the model- hazard rate with simple polynomial adjustment key for Indian hare (goodness of fit $\chi 2$ - p = 0.34)

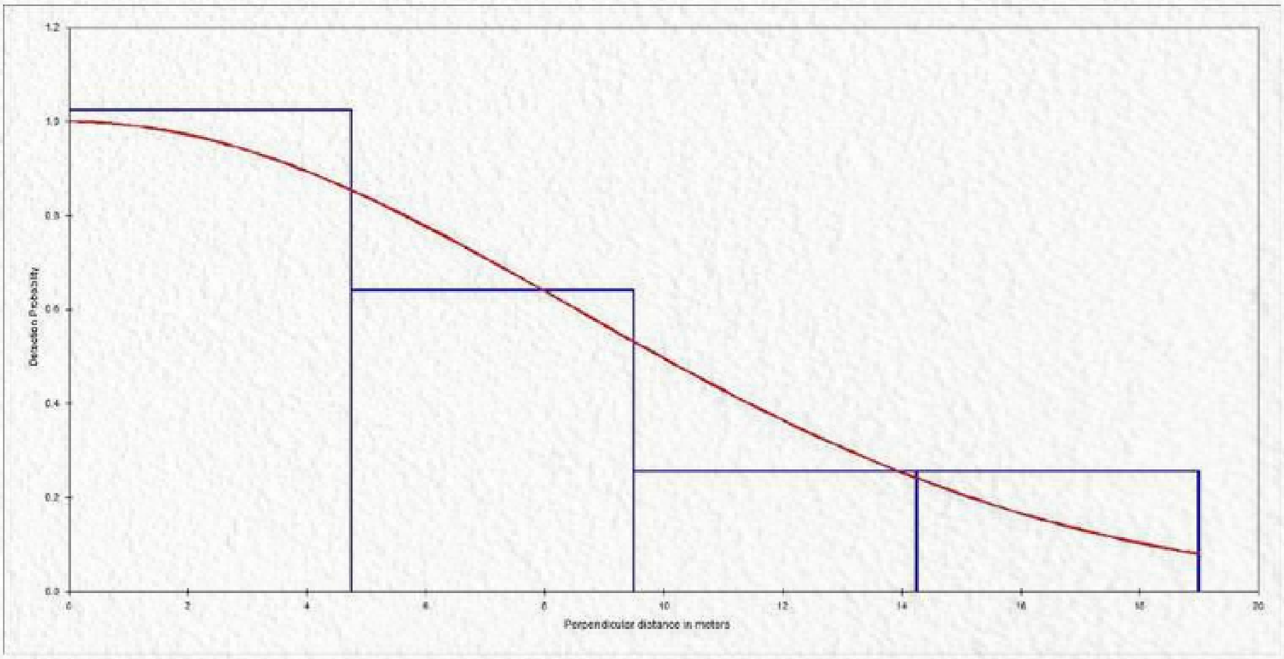


Figure 4.5.7.
Distance sampling detection function plot using the model- half normal with cosine adjustment key for Indian peafowl (goodness of fit $\chi 2$ - p = 0.61)

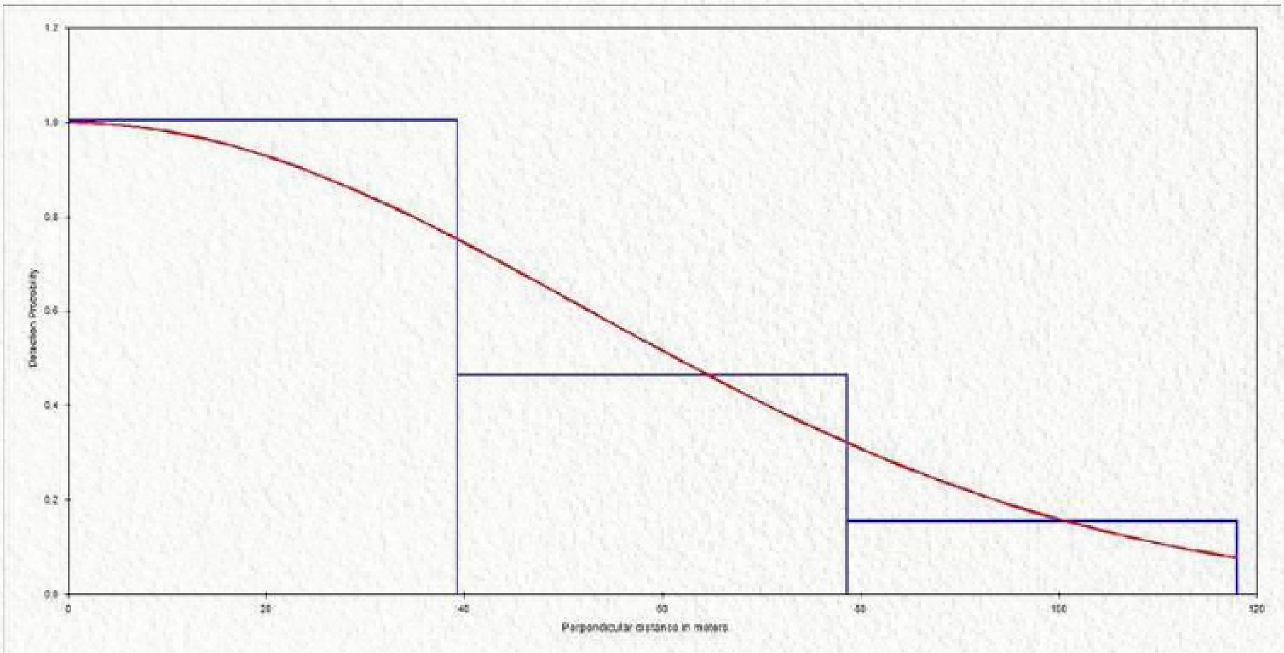


Figure 4.5.8.
Distance sampling detection function plot using the model- half normal with hermite polynomial adjustment key for Indian wild pig (goodness of fit $\chi 2$ - p = 0.6)

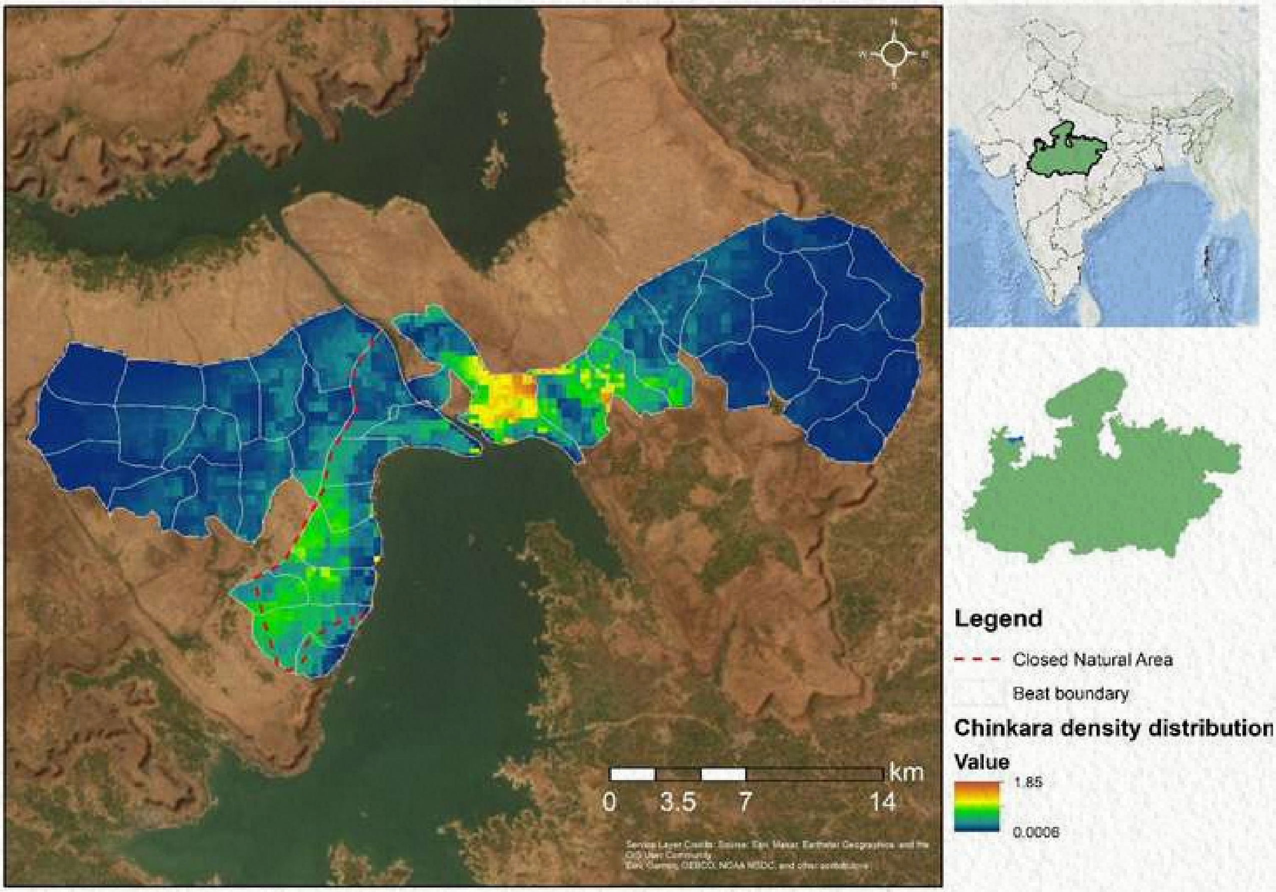


Figure 4.5.9.
Density distribution or Density Surface Model (DSM) map of chinkara in Gandhi Sagar Wildlife Sanctuary

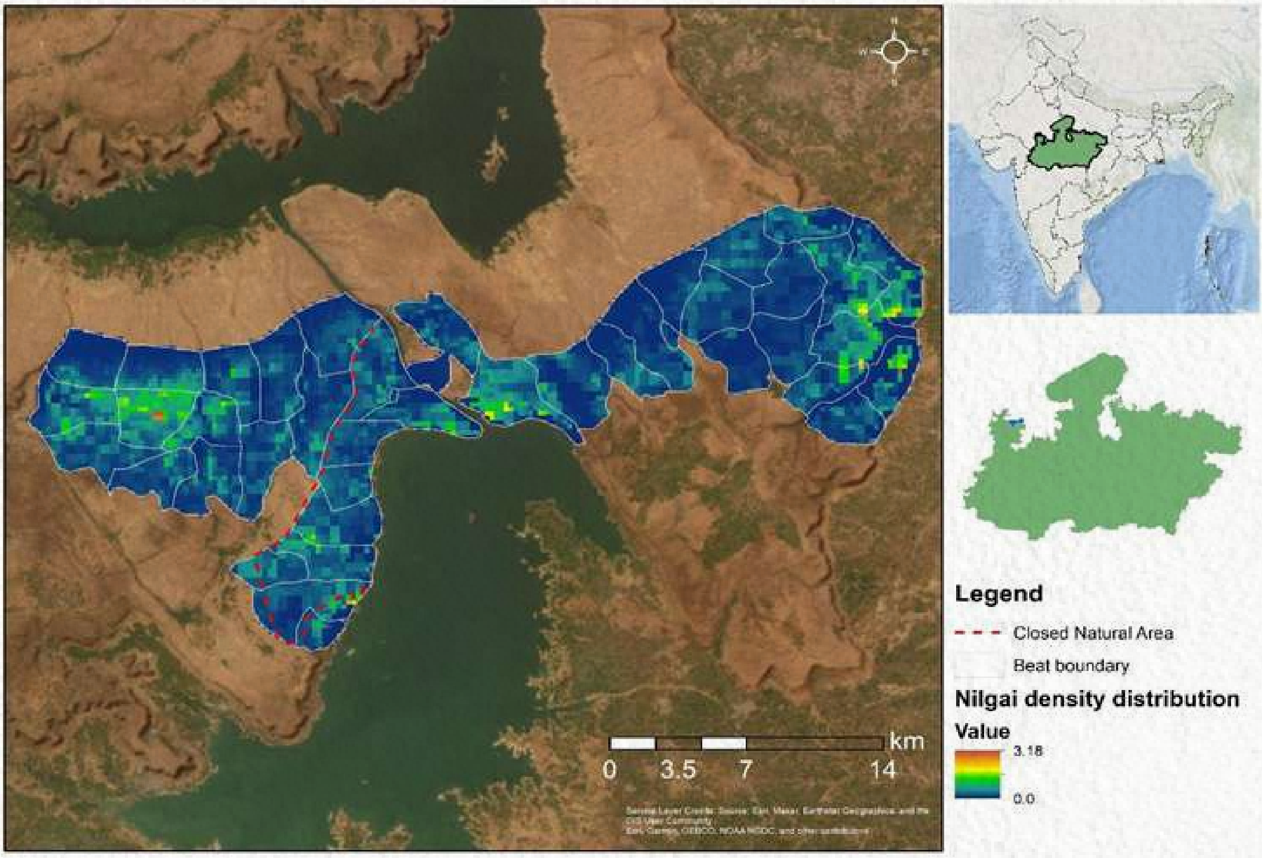


Figure 4.5.10.
Density distribution or Density Surface Model (DSM) map of nilgai in Gandhi Sagar Wildlife Sanctuary

4.6. Prey assessment using camera trap-based distance sampling in Gandhi Sagar Wildlife Sanctuary

4.6.1. Methodology

Distance sampling theory applied to camera-trap data is a fast-emerging method to estimate unmarked animal densities by treating each camera trap as a point transect (Howe *et al.* 2017). Camera trap-based distance sampling was conducted in the closed natural area of Gandhi Sagar Wildlife Sanctuary (area ~ 64 km²) between December 2024 and March 2025. A total of 54 motion-activated camera traps (Cuddyback C1) were deployed across a systematic sampling design where the entire study area was partitioned into 1 km² grid cells. Each camera trap was positioned at the centroid of each grid cell to minimize bias in animal movement in front of the camera. Traps were mounted at a height of 45 cm above ground, oriented primarily towards the north or south to minimize sun exposure. In locations where dense vegetation obstructed the view, cameras were adjusted to ensure a clear field of view. Cameras were set to capture three consecutive images per trigger event.

The calibration was performed for each camera trap using a standardized protocol with a whiteboard and a 2-meter pole marked at 10 cm intervals. The calibration was conducted in the centre and along both sides of the field of view at 1-meter intervals to ensure accurate distance measurements for subsequent density analysis. Vegetation plots were sampled at each camera location, tree counts by species within a 15-meter radius, shrub cover within a 5-meter radius, and grass species composition within a 1-meter radius were noted. Human disturbance was also recorded, including the number of woodcutting and lopping signs, bamboo and grass cutting, presence of fire, and domestic cattle presence. Ungulate pellet counts were conducted in a 2 m × 20 m strip in front of each camera trap.

Each camera trap was monitored every 10-15 days for SD card and battery replacement, and if the camera trap angle was disturbed, it was recalibrated following the same protocol. Data obtained from the cameras were properly archived, organized, and geo-tagged using the CaTRAT software program (Cheema *et al.* 2018). The geo-tagged images were manually sorted into species-specific folders for subsequent analysis.

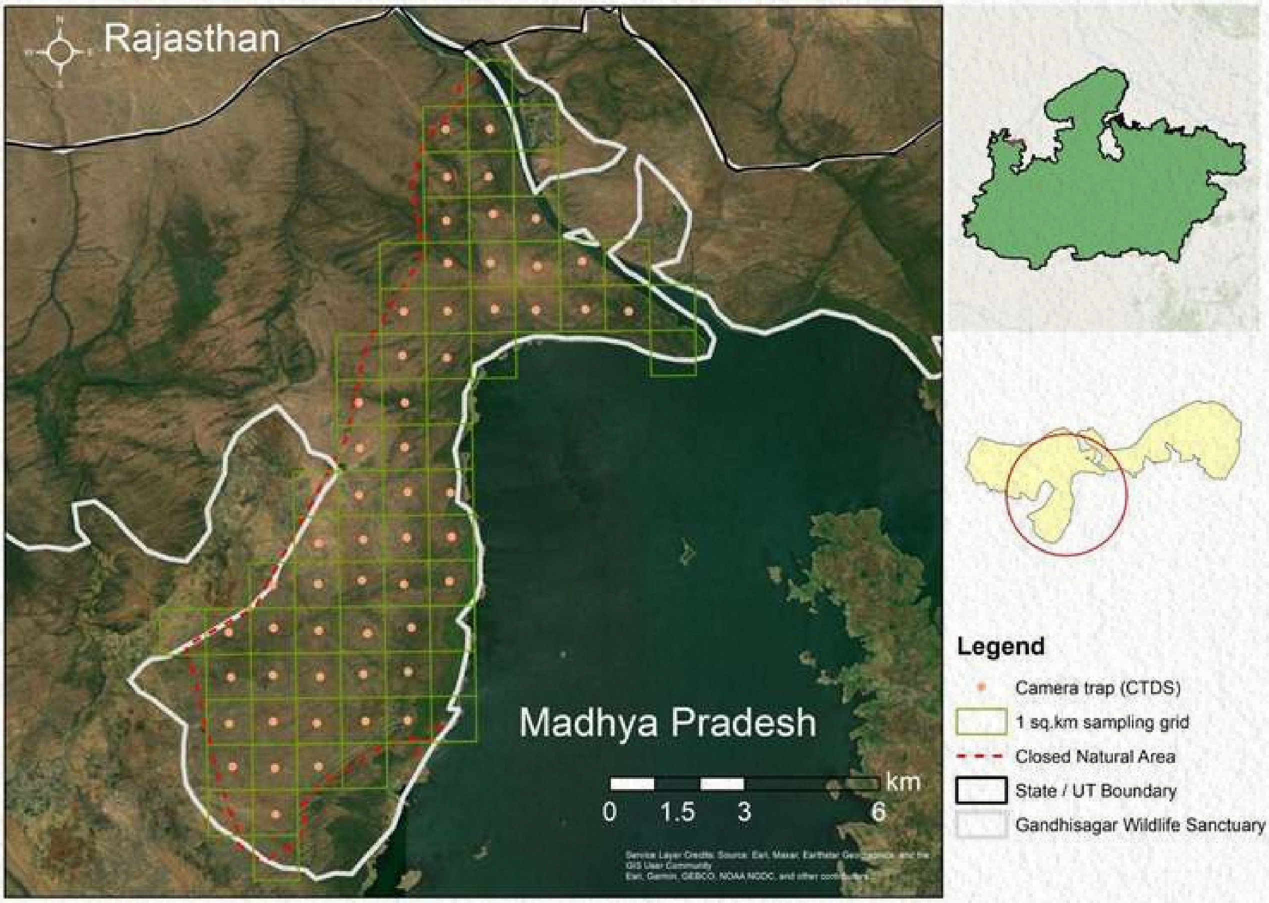


Figure 4.6.1.
Map of the camera trap distance sampling design in the Closed Natural Area of Gandhi Sagar Wildlife Sanctuary for prey assessment

4.6.2. Data analysis

Analysis of data obtained after species-wise segregation involved several steps to estimate densities of individual species. The camera trap was deployed at a point 'k', which is independent of animal movement for a period of time 'Tk'. The temporal effort was calculated by multiplying by the total number of trap occasions (24×60×60×sampling session) and transformed into seconds (Howe *et al.* 2017). The distances of species in each photograph were extracted from the Timm Haucke distance estimation tool (Haucke *et al.* 2022). The effective detection radius (EDR) was estimated using Distance software v7.5 (Thomas *et al.* 2010). The spatial coverage was calculated using the fraction of the circle, *i.e.*, Θ, which is the field of view of the camera trap. The density estimation follows standard point transect methods (Buckland *et al.* 2001) using the EDR. The area was calculated using temporal and spatial effort, and mean density was calculated by dividing encounter rate by area.

4.6.3. Results

During the camera trap-based distance sampling survey, a total of 8,14,805 images were recorded. Among the prey species, chinkara, nilgai, chital, Indian wild pig, grey langur, Indian peafowl, Indian hare, feral cattle, and Indian crested porcupine were photo-captured.

Due to low detections during the sampling, density could not be estimated for grey langur, cattle, and porcupine. The density of chinkara was the highest in the sampled area with 5.20 individuals per km² (95% CI: 4.33-6.24), followed by nilgai and peafowl. Chital and wild pig had the least densities, with nearly 1 individual per km² each. Density of chital could be estimated with adequate detections using this method, whereas line transect sampling did not yield enough detections of the species. For most of the prey species, the densities estimated using the CTDS approach were very similar to the estimates obtained from line transects.

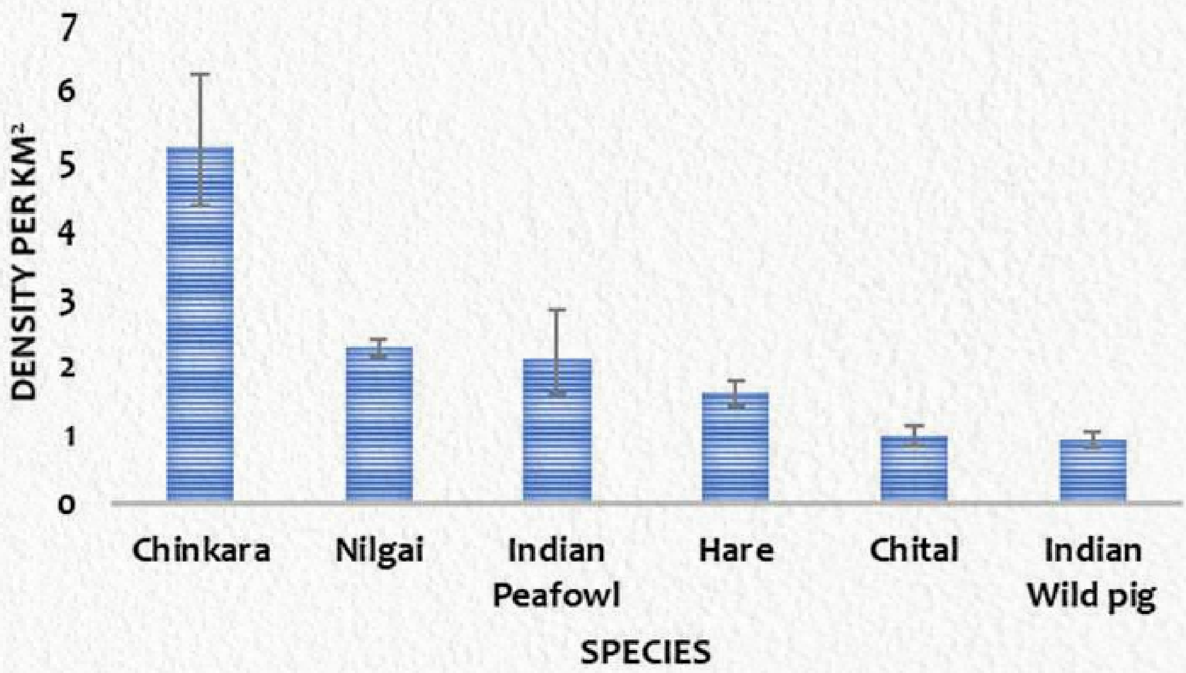


Figure 4.6.2.
Density (per km²) of prey species in the West Range of Gandhi Sagar Wildlife Sanctuary obtained from camera trap distance sampling during 2025. Error bars represent standard errors.

Table 4.6.1.
Summary of prey densities obtained from camera trap-based distance sampling in the Closed Natural Area (CNA) in the West Range of Gandhi Sagar Wildlife Sanctuary.

Species	**Independent Encounters**	**Mean Effective Detection Distance (m)**	**Encounter Rate (detections per sec)**	**Estimated Density (individuals per km²)**	**95% Confidence Interval (individuals per km²)**
Chinkara	4939	7.59 (0.35 SE)	1.13×10^{-5}	5.20	4.33-6.24
Nilgai	1651	6.64 (0.09 SE)	3.77×10^{-5}	2.27	2.14-2.40
Indian peafowl	445	4.51 (0.32 SE)	1.63×10^{-5}	2.10	1.59-2.81
Indian hare	588	6.68 (0.20 SE)	2.68×10^{-5}	1.60	1.42-1.80
Chital	1350	9.05 (0.32 SE)	3.03×10^{-5}	0.98	0.85-1.13
Indian wild pig	1348	9.36 (0.28 SE)	3.08×10^{-5}	0.93	0.82-1.05
SE- Standard Error					

5. Habitat Monitoring

5.1. Vegetation structure and composition in Kuno National Park

5.1.1. Introduction

Vegetation plays a critical role in maintaining the ecological integrity, habitat quality, and overall functioning of any ecosystem (Alberti, 2010). It influences soil stability, nutrient cycling, and microclimatic regulation and provides essential resources such as food and shelter for a wide range of fauna (Sylvain & Wall, 2011; Otieno, 2024). Understanding vegetation diversity is particularly important for assessing ecosystem health, identifying conservation priorities, and monitoring long-term ecological changes. Such information also supports habitat management, restoration planning, and biodiversity conservation efforts (Dale *et al.* 2024). Recognizing its ecological significance particularly in the context of habitat consolidation and improved protection subsequent to cheetah introduction, a systematic vegetation survey was undertaken to establish a robust baseline of vegetation diversity and distribution across Kuno NP.

5.1.2. Methodology

A grid-based sampling approach using 2 km^2 grids, with vegetation sampling conducted at the centroid of each grid (Figure 5.1.1). Quadrat-based sampling was designed for different vegetation strata, *viz.*, 10×10 m quadrats for trees, saplings, and invasive species; 5×5 m quadrats for shrubs; and 1×1 m quadrats for herbs and grasses. In total, 276 quadrats were sampled across the NP comprising four forest ranges. All tree species encountered during the sampling were identified and standardized to prevent duplication arising from spelling inconsistencies. To evaluate vegetation structure and composition, diversity indices, *viz.*, Shannon's Diversity Index (H′) to measure overall species diversity, Simpson's Index of Diversity (1 − D) to estimate the probability that two randomly selected individuals belong to different species, Pielou's Evenness (J′) to assess the uniformity of species distribution, and Fisher's Alpha (α) to quantify species richness independently of sample size, were calculated.

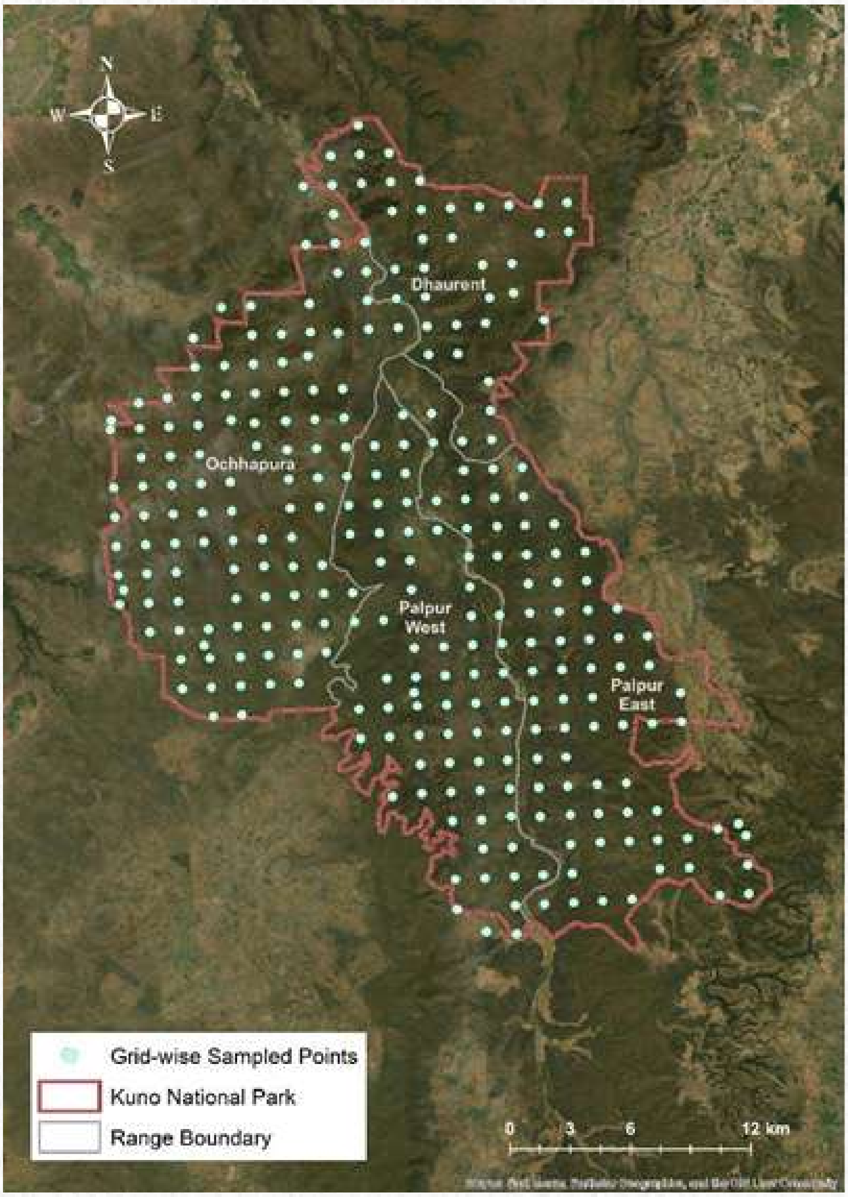


Figure 5.1.1.
Map showing sampling points in a 2x2 km^2 grid framework across the forest ranges of Kuno National Park.

5.1.3. Results

During the grid-based vegetation sampling, a total of 44 tree species, 16 shrub species, 15 invasive species, 17 grass species, and 30 herb species were recorded in the four forest ranges of Kuno NP. This comprehensive inventory provides a strong baseline for understanding the vegetation structure of the PA and its role in sustaining ecological processes and biodiversity. The results are presented for each forest range, which is an administrative boundary within the NP for ease of management.

The tree diversity analysis revealed notable spatial variation across the ranges (Table 5.1.1 & Figures 5.1.2-5.1.4). At the landscape level, Kuno NP exhibited a Shannon Diversity Index (H′) of 2.57 and an evenness value (J′) of 0.68, indicating moderate overall diversity with partial dominance by a few tree species. The Simpson's Index of Diversity (1 − D) of 0.86 highlighted a high probability that two randomly selected individuals belong to different species, while the Fisher's Alpha (α) value of 7.67 confirmed substantial richness relative to the sample size.

Among the different forest ranges, Occhapura forest range on the northwest of the Park emerged as the most diverse range, with a Shannon Index (H′) of 2.88, Simpson's Index (1 − D) of 0.93, and high evenness (J′ = 0.84), suggesting a balanced distribution and the presence of numerous rare species contributing to richness. Dhaurent forest range on the north also showed high diversity, with H′ = 2.59, 1 − D = 0.88, and a Fisher's Alpha (α) of 7.12, indicating a heterogeneous and evenly distributed tree community.

In contrast, the Palpur East and Palpur West forest ranges recorded comparatively lower diversity. Palpur East showed a Shannon Index (H′) of 1.88 with evenness (J′) of 0.58 and Fisher's Alpha (α) of 5.39, reflecting moderate richness but reduced uniformity. Palpur West exhibited the lowest diversity, with H′ = 1.83, J′ = 0.62, and α = 3.65, indicating localized dominance patterns.

Across the park, *Terminalia pendula* (34%) emerged as the most dominant species, followed by *Senegalia catechu* (11%), *Ziziphus xylopyrus* and *Holarrhena pubescens* (9% each), and *Diospyros melanoxylon* (5%) (5.1.5). The dominance of these species, especially in the Palpur forest ranges, accounts for the moderate evenness values observed across the landscape.

Overall, the findings indicate that Occhapura and Dhaurent forest ranges are more diverse, whereas Palpur East and West forest ranges exhibit lower diversity, characterized by the dominance of a few species. This baseline assessment provides essential data for future monitoring and management of vegetation in Kuno NP.

Table 5.1.1.
Summary of diversity indices, diversity level, and evenness of tree species

Administrative Boundary	**Species Richness (S)**	**Shannon Index (H′)**	**Diversity Level**	**Evenness (J′)**	**Evenness Level**	**Simpson's Index (1 − D)**	**Fisher's Alpha (α)**
Kuno National Park	44	2.57	Moderate-High	0.68	Moderate	0.86	7.67
Palpur East Range	26	1.88	Moderate	0.58	Moderate	0.7	5.39
Palpur West Range	19	1.83	Moderate-Low	0.62	Moderate	0.74	3.65
Occhapura Range	31	2.88	High	0.84	High	0.93	6.68
Dhaurent Range	28	2.59	High	0.77	Moderate-High	0.88	7.12

Shannon Index (H′) (<2.0 = Low; 2.0–2.5 = Moderate; 2.5 = High); Evenness (J′) (<0.60 = Low uniformity (dominance by few species); 0.60–0.75 = Moderate uniformity; 0.75 = High uniformity (balanced species distribution)).

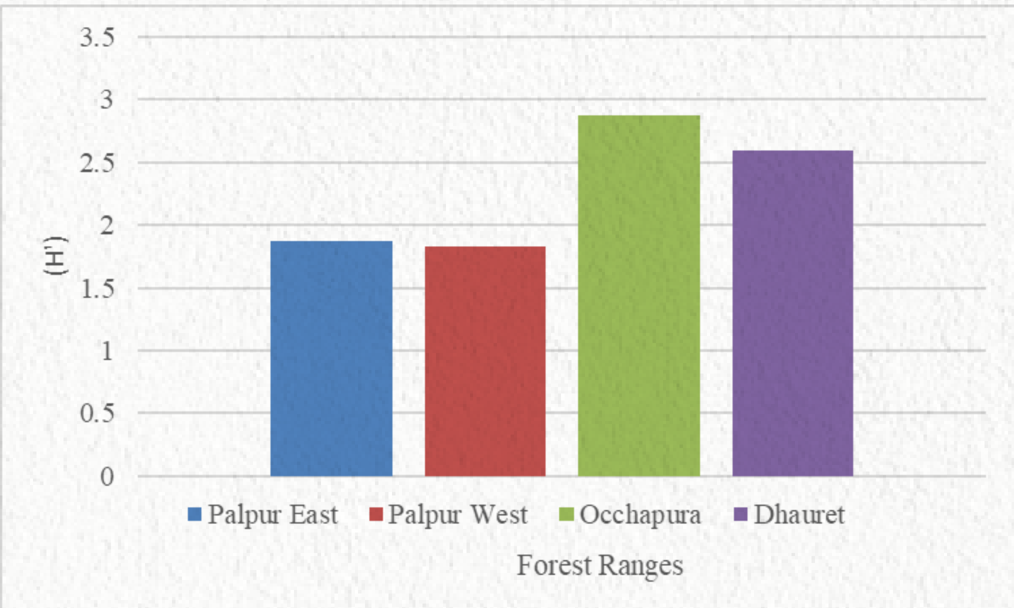


Figure 5.1.2.
Shannon Diversity Index (H′) in the four forest ranges of Kuno National Park

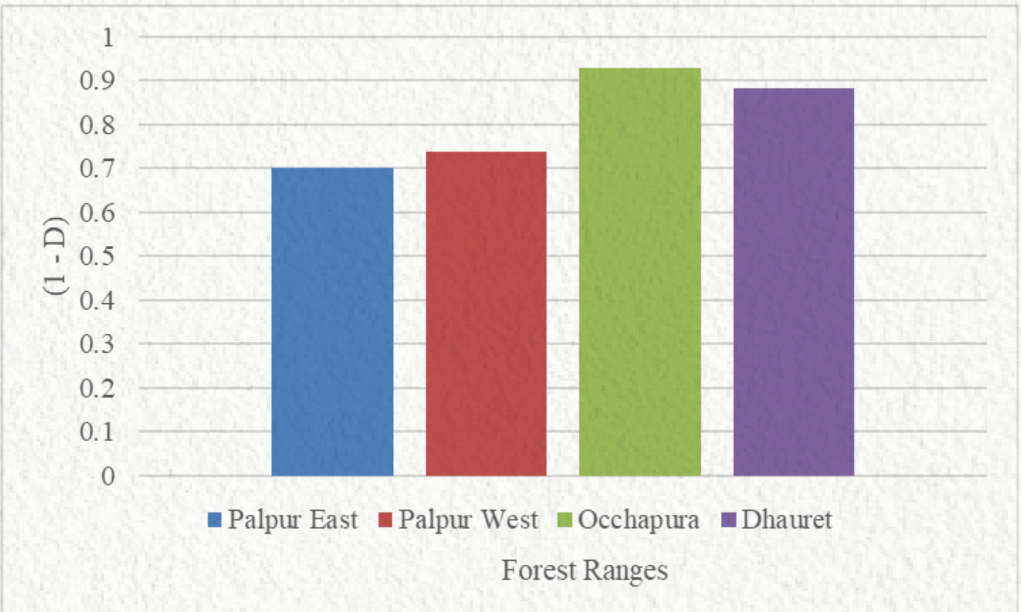


Figure 5.1.3.
Range-wise comparison of Simpson's Index (1 – D) in the four forest ranges of Kuno National Park

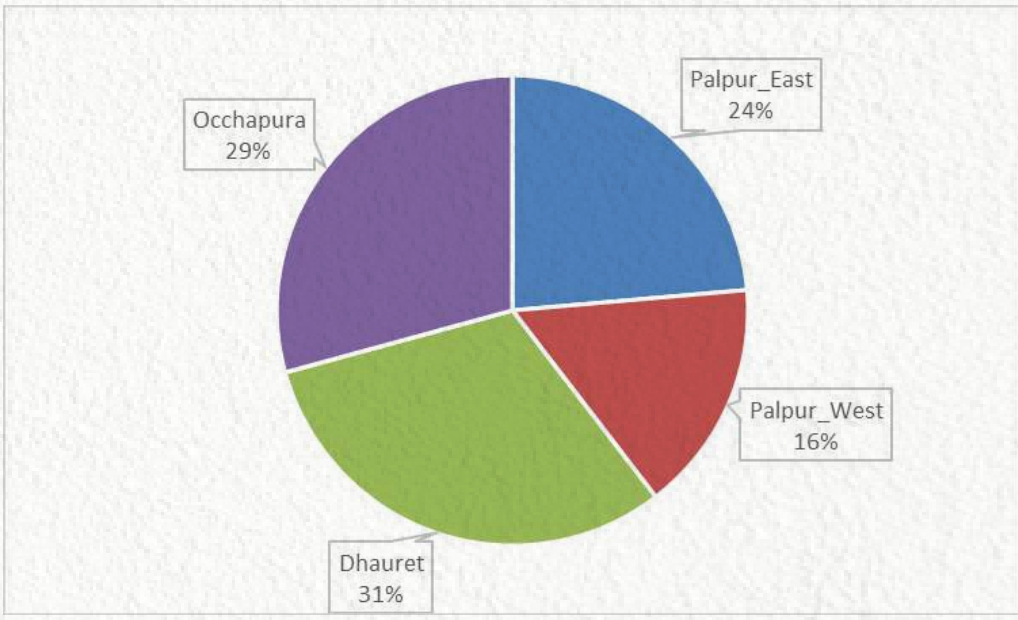


Figure 5.1.4.
Proportion of Fisher's Alpha (α) diversity in the four forest ranges of Kuno National Park

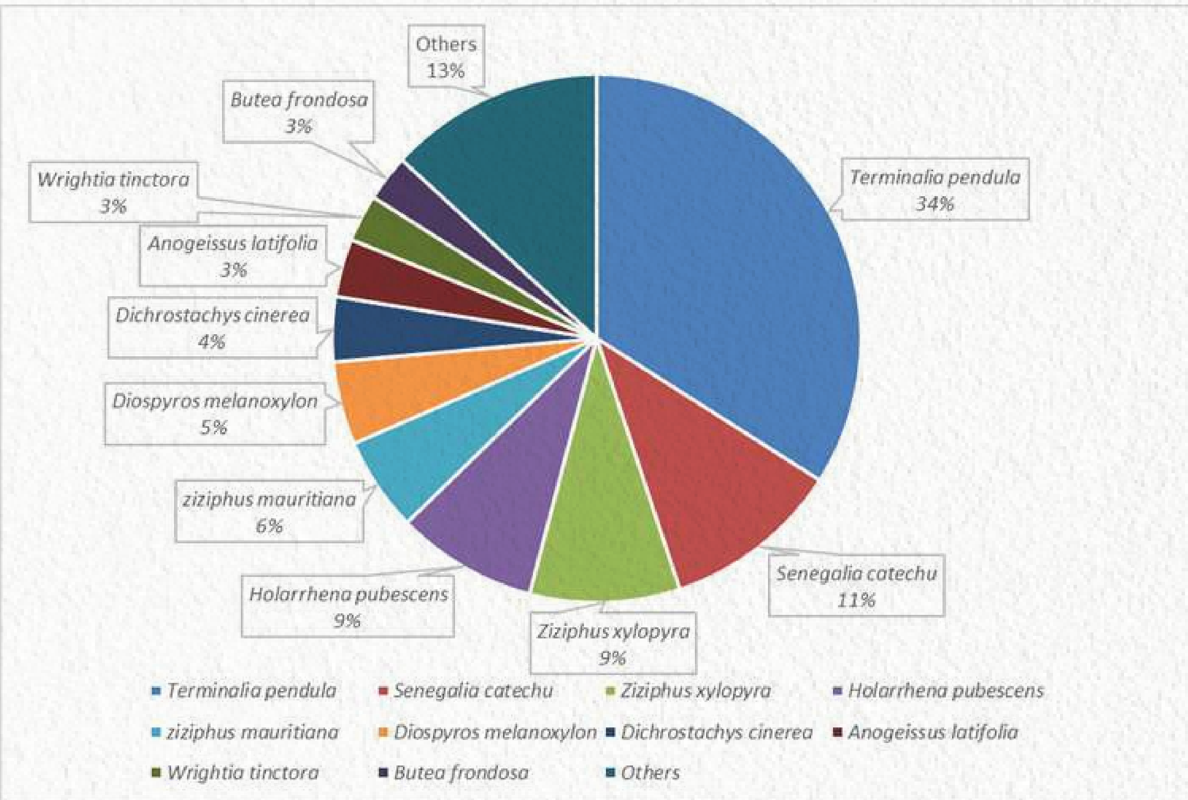


Figure 5.1.5.
Proportional (pi) abundance of individual tree species in the four forest ranges of Kuno National Park

Further, to develop a comprehensive checklist of plant species, the systematic collection is underway in both cheetah introduction sites (Kuno NP & Gandhi Sagar WLS), following standard herbarium methods. A total of 51 grass specimens, 27 herbs, 6 shrubs, and 12 trees were collected so far from Gandhi Sagar WLS. Similarly, in Kuno NP, 26 grass specimens were collected. It will result in a comprehensive, well-documented reference collection that supports vegetation monitoring, taxonomic research, and habitat assessment across the cheetah introduction sites.

5.2. Distribution of invasive species in Kuno National Park

The invasion pattern across the four forest ranges in Kuno NP was analyzed using the ratio of abundance (A) and frequency (F), wherein an A/F ratio below 0.025 signifies regular (uniform) distribution, values between 0.025 and 0.05 suggest a random distribution, and ratios exceeding 0.05 indicate a contagious (clustering) distribution (Cottam & Curtis, 1956), unveiling the intricacies of plant spatial arrangement and providing ecologists with a quantitative lens through which to understand the ecological dynamics of diverse ecosystems. Against this backdrop, this study examines the distribution patterns of invasive species across the Palpur East, Palpur West, Dhaurent, and Occhapura forest ranges of Kuno NP. In the Palpur East forest range, *Mesosphaerum suaveolens*, *Senna tora*, and *Lantana camara* were observed as prominent invasive species, displaying densities of 9064 individuals ha^{-1}, 5049.33 individuals ha^{-1}, and 173.33 individuals ha^{-1}, respectively. *Mesosphaerum suaveolens* (A/F=2.74), *Senna tora* (0.59), *Lantana camara* (0.08), *Parthenium hysterophorus* (0.62), and *Ageratum conyzoides* (0.21) showed contagious distribution across the entire range. Other prevailing invasive species, namely *Ageratum houstonianum* (0.01) and *Argemone maxicana* (0.03), exhibit varying densities of 2.67 and 10.67 individuals ha^{-1} and show regular and random distribution respectively. Within the Palpur East forest range, the A/F ratios point to a predominantly contagious distribution for most of the species.

In the Palpur West forest range, *Senna tora*, *Mesosphaerum suaveolens*, and *Ageratum conyzoides* were observed as prominent invasive species, displaying densities of 5108.55 individuals ha^{-1}, 4331.34 individuals ha^{-1}, and 320.89 individuals ha^{-1}, respectively. *Mesosphaerum suaveolens* (0.026) showed random distribution, while *Senna tora* (0.008), *Ageratum conyzoides* (0.005), *Ageratum houstonianum* (0.003), *Argemone mexicana* (0.006), and *Parthenium hysterophorus* (0.001) showed regular distribution across the forest range. Within the Palpur West forest range, the A/F ratios point to a predominantly regular distribution for most of the species.

In the Dhaurent forest range, *Mesosphaerum suaveolens*, *Senna tora*, and *Ageratum conyzoides* were observed as prominent invasive species, displaying densities of 8818.42 individuals ha^{-1}, 4144.74 individuals ha^{-1}, and 31.58 individuals ha^{-1} respectively. Similarly, *Parthenium hysterophorus* (28.95 individuals ha^{-1}) and *Lantana camara* (21.05 individuals ha^{-1}) were present but at comparatively lower densities. All recorded invasive species - *Mesosphaerum suaveolens* (0.0151), *Senna tora* (0.0063), *Ageratum conyzoides* (0.0009), *Parthenium hysterophorus* (0.0008), and *Lantana camara* (0.0003) exhibited a regular distribution pattern across the range. The A/F ratios in the Dhaurent forest range indicate that the invasive species are predominantly regularly distributed, suggesting a relatively uniform spatial spread throughout the area.

In the Occhapura forest range, *Mesosphaerum suaveolens* emerged as the most dominant invasive species, exhibiting a high density of 10,907.22 individuals ha^{-1}, followed by *Senna tora* (2,073.20 individuals ha^{-1}) and *Parthenium hysterophorus* (46.39 individuals ha^{-1}). Lower densities were observed for *Ocimum americanum* (15.46 individuals ha^{-1}), *Argemone mexicana* (5.15 individuals ha^{-1}), and *Lantana camara* (4.12 individuals ha^{-1}). Distribution analysis revealed that *Mesosphaerum suaveolens* (1.27), *Senna tora* (0.29), and *Parthenium hysterophorus* (0.17) exhibited a contagious distribution pattern, indicating aggregated clusters within the range. In contrast, *Argemone mexicana* (0.02) showed a regular distribution, while *Lantana camara* (0.03) and *Ocimum americanum* (0.06) exhibited a random distribution pattern. Overall, the Occhapura forest range reflects a mixed invasion pattern, with dominant species forming clusters while others are scattered in random or uniform patterns.

5.2.1. Hotspot mapping of major invasive species

Species presence and individual counts recorded across grid-based and opportunistic 10×10 m quadrats were used to generate kernel density heat maps (Figure 5.2.1.1a). Using ArcMap's Kernel Density Estimation (KDE) tool, interpolated density surfaces for major invasive species, *viz*., *Mesosphaerum suaveolens*, *Senna tora*, *Lantana camara*, *Parthenium hysterophorus*, *Ageratum conyzoides*, *Solanum incanum*, *Argemone mexicana*, and *Neltuma juliflora*, were developed. KDE computes the magnitude of occurrences per unit area by weighting counts at each location and smoothing based on distance to neighboring points. The raster outputs visually emphasize spatial abundance: darker tones represent invasion hotspots, while lighter shades indicate areas of lower density, adapted from Hannah *et al.* (2019). The KDE analysis revealed heterogeneous spatial patterns of invasion across Kuno NP, with hotspots concentrated in disturbed habitats, riparian corridors, and open or semi-open canopy areas, underlining how anthropogenic activities and habitat variation facilitate invasive dynamics.

Mesosphaerum suaveolens was dominant in the partially open dry mixed deciduous forests of Occhapura and Dhaurent forest ranges (canopy cover 10–40%) (Figure 5.2.1.1b). Its clustering along forest edges and semi-open understory indicates a preference for intermediate light conditions. Further, its prolific seed production and strong regenerative ability contribute to dense monospecific stands that suppress native herbaceous diversity and forest regeneration.

Management intervention: Prioritize early detection and control in semi-open and degraded forest tracts to prevent understory dominance.

Parthenium hysterophorus had invasion hotspots in the north-eastern Palpur West range, especially near former crop fields, degraded forests, and riparian zones offering moist, nutrient-rich, disturbed conditions (Figure 5.2.1.1c). Its rapid spread is facilitated by prolific seed output and the vulnerability of disturbed habitats.

Management intervention: Target removal in riparian zones, forest–crop agriculture interfaces, and road edges to limit further spread.

Senna tora was prevalent in open scrublands, dry savannah forests, and grassland patches but scarce in dense canopy zones. Its tolerance for nutrient-poor soils, drought resilience, and effective dispersal allow it to dominate degraded landscapes (Figure 5.2.1.1d).

Management intervention: Undertake manual removal before seed dispersal, particularly in savannah-like vegetation patches.

Lantana camara formed hotspots in central, southeastern, and northern forest ranges, especially along riparian areas within open to moderately dense canopy forests (10-70%) (Figure 5.2.1.1e). Field observations further revealed that, at present, the invasion is largely concentrated in the Palpur East forest range, where it dominates riparian zones, forest edges, and disturbed patches.

Management intervention: Focus early-stage control on riparian areas and disturbed edges.

Ageratum conyzoides clustered toward central and southern parts, notably along riverbanks, forest margins, and canopy gaps, favouring semi-open (10-70%) light environments consistent with its rapid colonization (Figure 5.2.1.1f).

Management intervention: Monitor riparian zones and canopy gaps; control infestations near disturbance-created openings.

Argemone mexicana spreads widely in the southern, central, and western ranges, especially along roads, streams, and crop agriculture boundaries in open canopy (<40%) dry forests. (Figure 5.2.1.1g).

Management intervention: Prioritize eradication at roadsides and peripheries of crop fields to mitigate ecological and socio-economic threats.

Neltuma juliflora displayed limited presence inside the PA, with clusters near human structures, though it remains abundant just beyond Park boundaries due to deliberate planting for fuel and fencing (Figure 5.2.1.1h).

Management intervention: Implement early eradication inside Park limits and engage communities to curb planting around boundaries.

Senna occidentalis was clustered in central and southern zones near disturbed edges and scrublands, largely absent in dense canopy areas. Its presence in vulnerable habitats like *Terminalia pendula* forests raises ecological and wild ungulates nutrition concerns, as dense stands can suppress native vegetation (Figure 5.2.1.1i).

Management intervention: Prioritize removal in open/scrub zones near to reduce ecological and with ungulate nutrition and subsequent health issues.

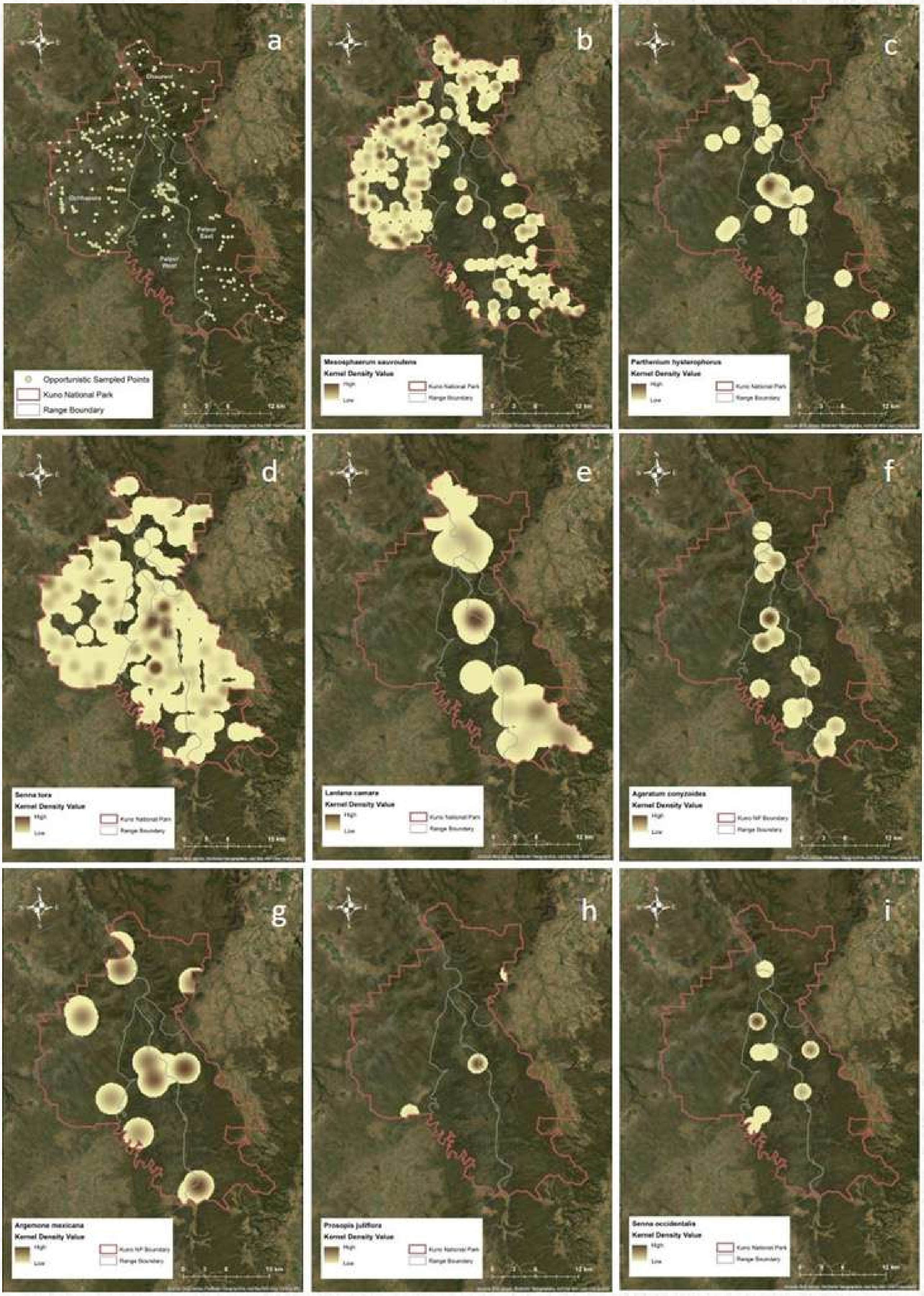


Figure 5.2.1.1.

a) Map showing opportunistic sampling points, Hotspots of b) *Mesosphaerum suaveolens*, c) *Parthenium hysterophorus*, d) *Senna tora*, e) *Lantana camara*, f) *Ageratum conyzoides*, g) *Argemone mexicana*, h) *Neltuma juliflora*, & i) *Senna occidentalis* in the four forest ranges of Kuno NP

KDE-based mapping confirms that invasive species in Kuno NP are spatially concentrated, primarily in disturbed, riparian, and open-canopy regions, aligning with ecological principles that link invasion to disturbance and resource availability (Sharma *et al.* 2005; Hiremath & Sundaram, 2013). Key landscape-transforming invaders include *Lantana camara* and *Parthenium hysterophorus*, which are dominant along forest edges and riparian interfaces. Herbaceous invaders such as *Ageratum conyzoides* and *Senna tora* are exploiting gaps in the herb layer, thereby reducing available forage and native flora. Additionally, tree and shrub invaders like *Neltuma juliflora* and *Senna occidentalis* are currently localized but pose significant future risks if not managed proactively. Priority zones requiring immediate intervention include riparian corridors, which act as critical pathways for invasion; crop agricultural and grazing interfaces, which are socio-ecologically sensitive areas; and open or semi-open dry deciduous forests, which are highly vulnerable to biodiversity loss. Without timely and targeted control measures, the spread of invasive species is expected to advance into core forest tracts, undermining native biodiversity, altering natural fire regimes, and reducing overall ecosystem resilience (Shackleton *et al.* 2017).

5.3. Vegetation dynamics in former village sites of Kuno National Park: A pilot survey

The incentivized voluntary relocation of villages from PAs is a critical conservation intervention aimed at restoring wildlife habitats, reducing anthropogenic pressures, and enhancing biodiversity (Karanth *et al.* 2018). In Kuno WLS, a large-scale incentivized voluntary relocation initiative was implemented between 1998 and 2003 under the Beneficiary Oriented Scheme for Tribal Development, a Centrally Sponsored Scheme of the Ministry of Environment and Forests, Government of India (Kabra, 2009). This program, led by the Madhya Pradesh Forest Department, was envisioned to create a conducive environment for the reintroduction of the Asiatic lion and to improve the overall ecological integrity of the Park (Ranjitsinh & Jhala, 2010).

Kuno NP represents a unique socio-ecological landscape characterized by low village density due to historical issues with dacoity and the habitation of tribal communities such as the Mogiyas, Sahariyas, and Bhils (Choudhary, 2001). These communities have traditionally relied heavily on forest resources, contributing to a complex interplay between human activities and ecosystem dynamics.

Between 1998 and 2003, 24 villages were voluntarily relocated outside the Sanctuary (Johnsingh *et al.* 2007). Recent field assessments, however, have expanded this list to 37 villages, comprising 25 villages recorded by the Forest Department and 12 additional settlements that had moved out on their own more than four decades ago. These sites have created a rare opportunity to study the long-term ecological impacts of such interventions on soil and vegetation dynamics within the park.

To address this knowledge gap, a pilot survey was conducted to lay the groundwork for a detailed ecological assessment. The survey involved the identification and mapping of relocated villages, documentation of their relocation history, characterization of dominant habitat types, and preliminary terrain mapping. Out of the 37 identified village sites, 35 villages were visited during the pilot phase, which included 24 villages as per official records and 11 additional sites revealed through consultations with villagers and field staff (Table 5.3.1; Figure 5.3.1).

Table 5.3.1.
Details of the sites of former villages in Kuno National Park

S.no.	Period of relocation	Village name	Habitat type	Terrain
1	1970s	Garhi	Pendula forest	Slope, Hill top
2	1970s	Old Barred	Pendula forest	Slope, Hill top
3	1970	Old Basantpura	Mixed forest	Slope, Valley
4	1975s	Rampura	Woody savannah	Plain
5	1975s	Jhankiyapur	Mixed forest	Plain
6	1978-1980	Khemchatal	Woody savannah	Plain
7	1980s	Old Jakhoda	Mixed forest	Undulating
8	1980s	Patera	Mixed forest	Plain
9	1980s	Tongra	Pendula forest	Slope, Valley
10	1980s	Basera	Pendula forest	Plain
11	1985-90	Setakheda	Woody savannah	Plain
12	1980s	Aakoda	Mixed forest	Plain
13	1999-2000	Khalai	Woody savannah	Plain
14	1999-2000	Barred	Woody savannah	Plain
15	2000-2001	Palpur	Scrub land	Plain
16	2000-2001	Pandari	Woody savannah	Plain
17	2000-2001	Ladar	Woody savannah	Plain
18	2000-2001	Bawanpura	Woody savannah	Plain
19	2000-2001	Pipal Babdi	Open grassland	Plain
20	2000-2001	Nayagaon	Woody savannah	Plain
21	2000-2001	Parond	Woody savannah	Plain
22	2000-2001	Silpura	Woody savannah	Slope, Valley
23	2000-2001	khaira	Woody savannah	Plain
24	2000-2001	Ahirwani	Woody savannah	Plain
25	2000-2001	Taparpura	Woody savannah	Plain, Valley
26	2000-2001	Meghpura	Woody savannah	Plain
27	2000-2001	Paira	Woody savannah	Plain
28	2000-2001	Durendi	Woody savannah	Plain
29	2000-2001	Masawani	Woody savannah	Plain
30	2000-2001	Chak Masawani	Woody savannah	Plain
31	2000-2001	Chak Parond	Woody savannah	Moderate slope
32	2000-2001	Chapret	Scrub land	Slope
33	2000-2001	Khajuri Khurd	Woody savannah	Plain
34	2000-2001	Khajuri Kalan	Woody savannah	Plain
35	2000-2001	Jakhoda	Woody savannah	Plain
36	2000-2001	Basantpura	Woody savannah	Plain
37	2023-2024	Bagcha	Scrub land	Plain

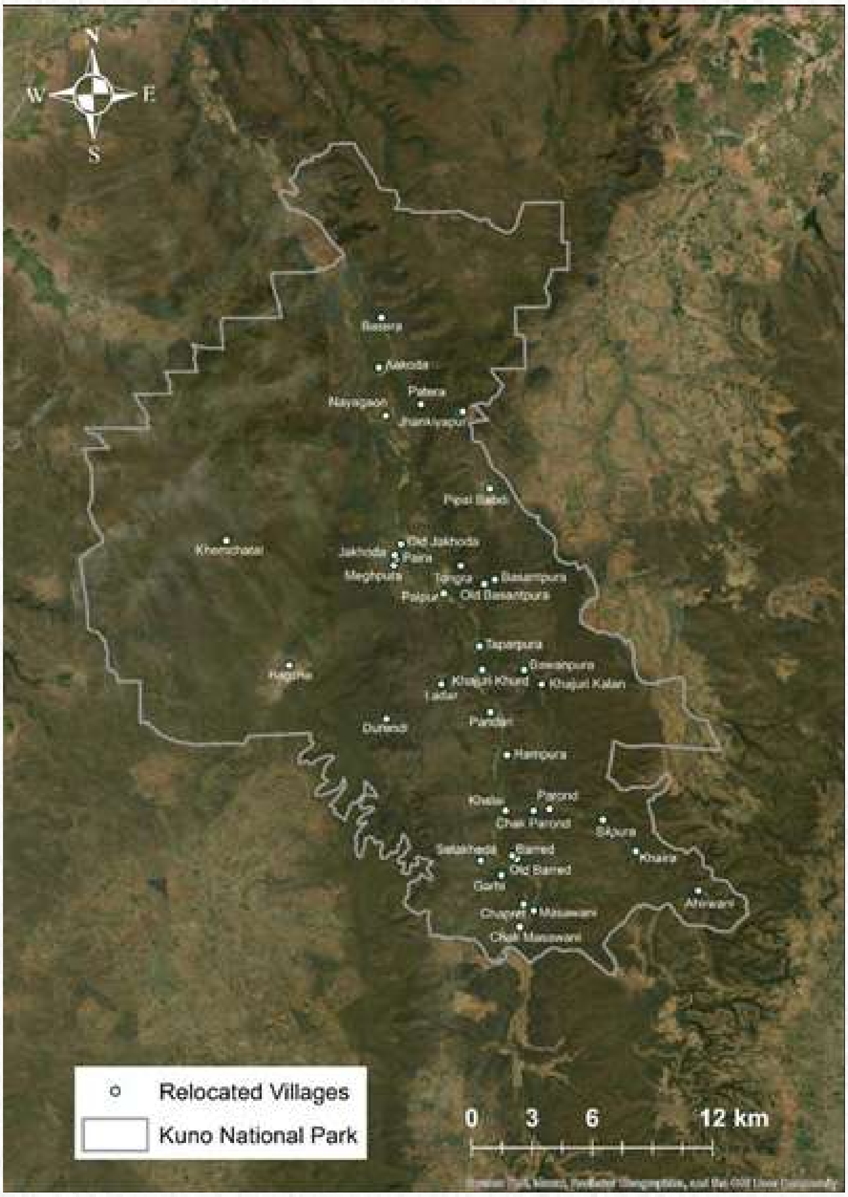


Figure 5.3.1.
Map showing sites of former villages in Kuno National Park

5.3.1. Drone-based habitat and terrain assessment

To understand the habitat structure and terrain of the sites of former villages, a drone survey was conducted. Field observations combined with aerial imagery revealed that the extent of invasive species varied across these villages, largely influenced by the year of relocation and the duration of site abandonment (Figures 5.3.2-5.3.4). Relocated villages exhibited a gradient of invasion intensity, ranging from low to high (oldest to newest relocated village), depending on the recovery stage of the habitat. The major invasive plant species recorded in these areas include *Parthenium hysterophorus*, *Argemone mexicana*, *Senna tora*, and *Mesosphaerum suaveolens*. These findings indicate that the relocated village sites have become significant hotspots for invasive species within Kuno NP. highlighting the need for targeted management and restoration interventions to facilitate native vegetation recovery and maintain ecological integrity.

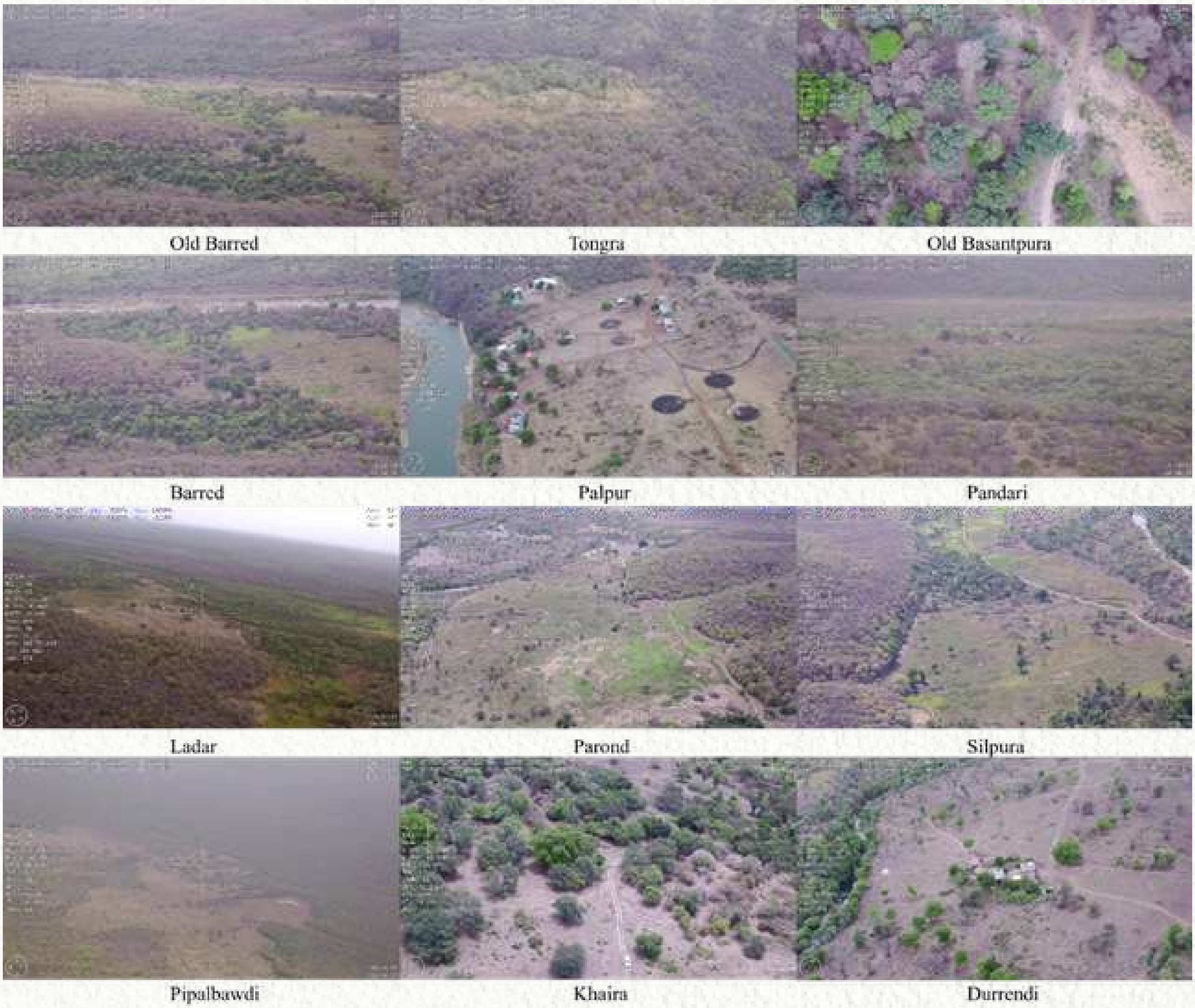


Figure 5.3.2.
Drone photographs of relocated villages from Kuno National Park.

Figure 5.3.3.
The oldest and middle-aged sites of former villages (Old Paira, Paira & Meghpura, and Chapret) in Kuno National Park

Figure 5.3.4.
Sites of the recently voluntarily relocated village (Bagcha) in Kuno National Park

Further, a detailed assessment will be conducted on soil properties and vegetation parameters across relocated sites and corresponding control sites within Kuno NP. The study will aim to quantify the extent of ecological recovery and succession following the cessation of human activities such as agriculture, grazing, and construction. The findings will provide baseline data for long-term ecological monitoring, informing evidence-based biodiversity conservation and adaptive habitat management strategies in Kuno NP.

5.3.2. Future course of action

1. Conduct comprehensive baseline vegetation surveys at identified cheetah introduction sites to establish reference data for habitat and species composition.

2. Carry out detailed pilot surveys at additional village relocation sites to document habitat types, terrain characteristics, and preliminary vegetation dynamics.

3. Regularly update and digitize the herbarium specimens to build a centralized, user-friendly database that can serve as a reference for researchers, managers, and conservation planners.

4. Assess the spread, distribution, and seasonal patterns of invasive species across different habitats and relocated sites to guide targeted management and control measures.

5. A detailed assessment of soil properties and vegetation parameters across relocated and control sites in Kuno NP will be undertaken to quantify ecological recovery and succession, providing baseline data for long-term monitoring and evidence-based habitat management.

5.4. Vehicle Movement in Gandhi Sagar Wildlife Sanctuary

5.4.1. Introduction

Linear infrastructure traversing PAs are a significant conservation challenge worldwide. India's PA network is increasingly intersected by linear infrastructure such as roads, leading to ecological challenges. Though roads enable connectivity and contribute to economic development, without proper mitigation measures, they fragment habitats, cause direct wildlife mortality, and disturb the ecological processes. Gandhi Sagar WLS, Madhya Pradesh, is bisected by a state highway (SH-31A), which is a conduit for heavy trucks, local traffic, and two-wheelers. Gandhi Sagar experiences mixed-use vehicular pressure with limited regulation. (NTCA *et al.* 2024). The Sanctuary harbors species such as chinkara, nilgai, leopard, jungle cat, golden jackal, and striped hyena, as well as a range of avifauna.

5.4.2. Methodology

To examine the pattern and intensity of vehicular activity along the highway, camera traps (Cuddeback – C1) were deployed at three strategic sites: Rampura Pathar on the northern part of the road traversing the Sanctuary, Ravlikudi on the south, and Kuekheda dirt road (crosses Madhya Pradesh–Rajasthan border), which were monitored 24/7. All the camera traps were fitted with IR flash to also monitor vehicular movement during the night. All the cameras were regularly monitored, and data was retrieved frequently. The vehicles photographed were categorized into "Heavy Motor Vehicle," "Light Motor Vehicle," and "Two-Wheeler."

- Heavy Motor Vehicle (truck, bus, tractors, and other goods and services vehicles)
- Light Motor Vehicle (car, jeep, auto, and other modified vehicles)
- Two-Wheeler (motorcycle and bicycle)

The data were segregated based on the above-mentioned categories using "FastStone" and "ExifPro" software, and metadata were extracted from the segregated files. The times of vehicles photographed were converted into a 24-hour format to assess the vehicular movement using the R program, and the package "circular" (Lund *et al.* 2017) was used to generate the temporal distribution of vehicle movement. A "rose diagram" in 24-hour clock format was generated for better visual representation.

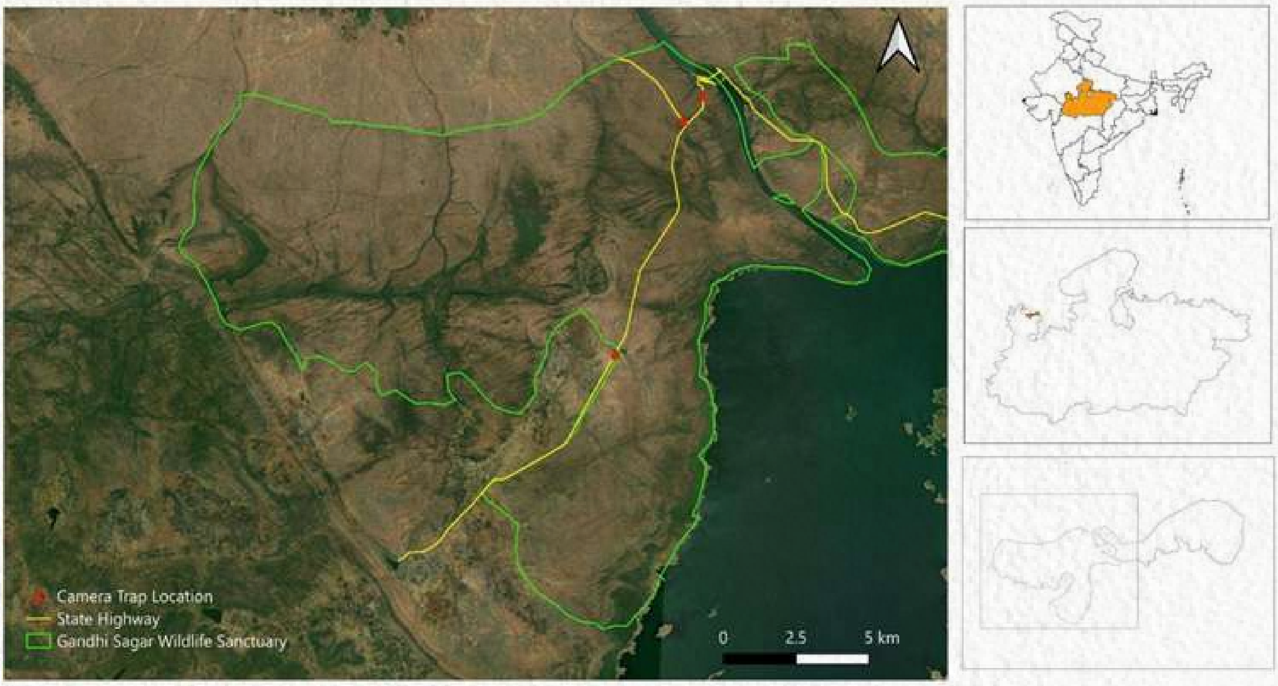


Figure 5.4.1.
Map of camera trap locations on the state highway passing through Gandhi Sagar Wildlife Sanctuary

5.4.2. Results

5.4.2.1.

Vehicle Movement Patterns in Rampura Pathar

Heavy Vehicles

Movement is low during late night and early morning hours (21:00–05:00) and increases after 06:00. Major activity occurs during the daytime till late evening (07:00–20:00), with clear peaks around 09:00, 11.00 and 17.00 HRS indicating increased transport during morning or early evening. Activity gradually declines thereafter, suggesting that heavy vehicle movement is mainly associated with working hours and transport operations.

Light Vehicles

Light vehicle movement increases from 09:00 and reaches its peak between 15:00 and 17:00. Activity declines after 18:00 and remains minimal during late-night hours. This pattern reflects daily commuting and local travel, particularly during the afternoon and early evening periods.

Two-Wheelers

Two-wheelers show the highest daytime activity among all vehicle categories. Movement increases from 07:00, peaking between 11:00 and 14:00, and remains relatively high until 16:00 before declining toward evening. This suggests extensive use of two-wheelers for short-distance commuting and local mobility.

Overall Pattern

All vehicle categories exhibit a clear diurnal pattern, with movement increasing after sunrise and decreasing at night. Two-wheelers dominate midday movement, light vehicles peak during the afternoon, and heavy vehicles show a late-afternoon peak. These temporal patterns indicate varying traffic intensities that may influence wildlife disturbance and road-related risks in the landscape.

5.4.2.2. Vehicle Movement Patterns in Kudikheda

Heavy Vehicles

Movement remains low during late evening and early morning hours (19:00–05:00) and increases after 07:00. Moderate activity occurs during the morning (08:00–11:00), with a clear peak around 17:00, indicating higher transport activity during the late afternoon or early evening. Movement gradually declines afterward, suggesting that heavy vehicles mainly operate during daytime transport and evening return trips.

Light Vehicles

Light vehicle movement increases after 09:00, with peak activity between 15:00 and 17:00. Activity decreases after 18:00 and remains low during night-time. This pattern reflects commuting and local travel, particularly during the afternoon and early evening hours.

Two-Wheelers

Two-wheelers show the highest daytime activity. Movement increases after 07:00, peaks between 11:00 and 14:00, and remains moderate until 16:00 before declining toward evening. This suggests extensive use of two-wheelers for short-distance commuting and daily travel.

Overall Pattern

All vehicle categories exhibit a diurnal traffic pattern, with movement increasing after sunrise and decreasing at night. Two-wheelers dominate midday activity, light vehicles peak during the afternoon, and heavy vehicles show a late-afternoon peak. These patterns indicate varying traffic intensity that may influence wildlife disturbance and road-related risks in the landscape.

5.4.2.3. Vehicle Movement Patterns in Rawlikudi

Heavy Vehicles

Movement is low during late night and early morning hours (22:00–05:00) and gradually increases after 06:00. A clear increase occurs between 08:00 and 12:00, with the highest activity around 09:00–10:00. Moderate movement continues during the afternoon (13:00–16:00), followed by a second increase between 17:00 and 19:00. This pattern reflects daytime logistics and goods transport, while reduced night-time activity likely relates to operational schedules and lower transport demand.

Light Vehicles

Light vehicle activity increases rapidly after sunrise, with a strong peak around 08:00–09:00. Movement gradually declines after 10:00–11:00, though moderate traffic continues during the afternoon. Another moderate increase occurs during the evening hours (18:00–20:00). This pattern reflects daily commuting cycles, including travel related to work, school, and routine activities.

Two-Wheelers

Two-wheelers show the earliest and sharpest morning peak, occurring between 07:00 and 09:00, with the highest activity around at 07:00. Movement declines after 09:00, though moderate activity persists during the afternoon (13:00–17:00). Night-time movement remains minimal, indicating their primary use for short-distance commuting and local travel.

Overall Pattern

All vehicle categories exhibit a clear diurnal traffic pattern, with activity increasing after sunrise and decreasing toward night. Two-wheelers show the earliest peak, light vehicles display morning and evening commuting peaks, and heavy vehicles maintain broader daytime activity associated with freight transport. These patterns highlight temporal variations in traffic that may influence wildlife disturbance and road-related risks in the landscape.

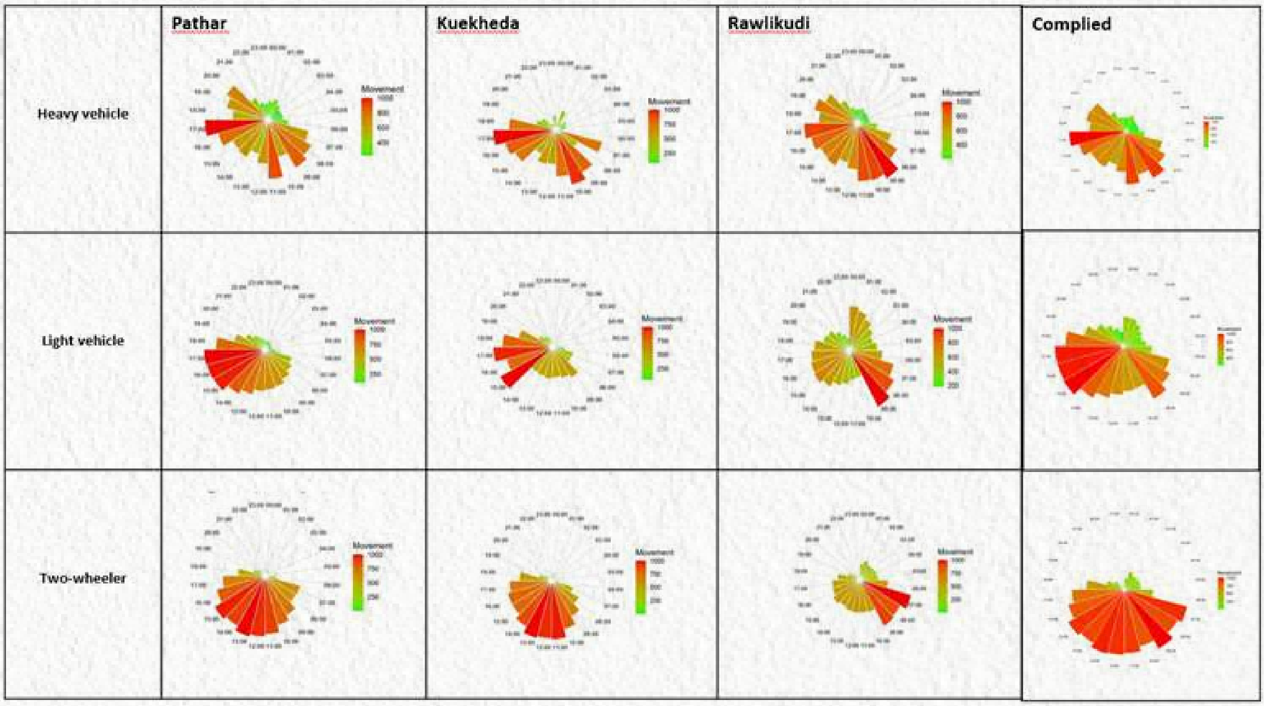


Figure 5.4.2.
Temporal distribution of vehicle movement at different locations on the state highway in Gandhi Sagar Wildlife Sanctuary

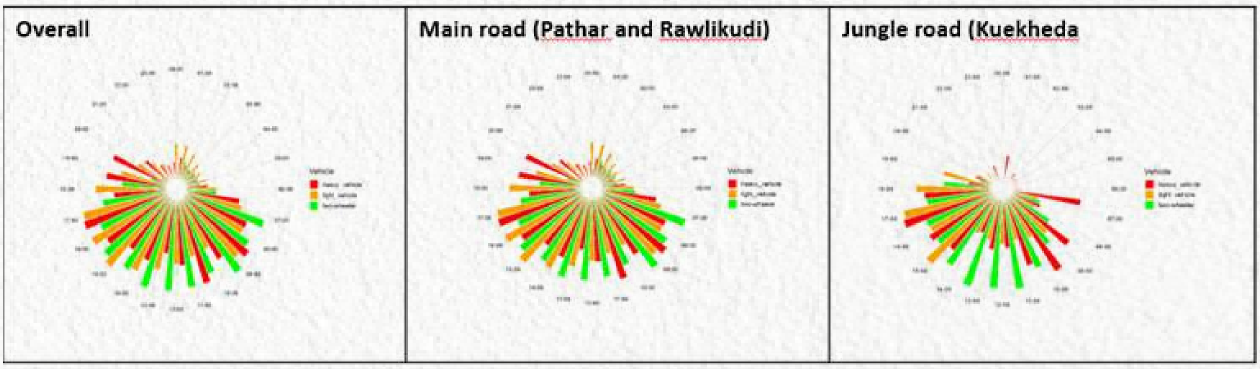


Figure 5.4.3.
Overall comparison of temporal distribution of vehicle movement between main road (state highway) and dirt road in Gandhi Sagar Wildlife Sanctuar

Table: 5.4.1.
Pattern of vehicular traffic movement in Gandhi Sagar Wildlife Sanctuary

Vehicle Type	Active Time Period	Traffic Condition	Remarks
Heavy Vehicles (truck, bus, tractor, and other goods and services vehicles)	09:00 – 11:00 &17:00	Peak (Rush Hours)	Heavy vehicles are allowed mainly in the morning, supporting transportation to the nearby town, schools, and working/office hours.
	08:00, 10:00 and 16:00	Moderate (Daytime)	Proper public transportation creates a moderate level of traffic during these hours of the day.
Light Vehicles (car, jeep, auto, and other modified vehicles)	15:00 – 17:00	Peak (Evening)	During evening hours, light vehicle traffic increases, creating considerable damage to the wildlife.
	08:00 and 14:00	Moderate (Morning and noon)	In these hours, villagers travel to work in modified vehicles. Small goods
Two-Wheelers (Bikes, bicycles)	07:00, 09:00, 11:00-13:00 & 15:00	Peak (Daytime)	High density in the whole day (daytime) office commute hours; often bypasses congested roads.
	08:00, 10:00, 14:00 & 16:00	Moderate (Morning and evening)	During these, people go to the workplace and in the evening return from the workplace to their homes.

5.4.3. Discussion

The vehicle movement patterns recorded from the 24-hour camera trap indicate a clear diurnal traffic pattern at these three locations.

Heavy vehicles show low activity during late night and early morning hours (22:00–06:00), with movement increasing after 07:00 and peaking between 08:00 and 12:00, particularly around 09:00 and 11:00, followed by moderate activity in the afternoon and a secondary rise during 17:00. This pattern likely reflects daytime logistics and goods transport operations.

Light vehicles exhibit a pronounced commuter pattern, with a strong peak around 15:00 - 17:00 in the evening, corresponding to routine work and school travel, moderate activity during the morning and afternoon (08:00 and 14:00).

In contrast, t**wo-wheelers** display throughout the daytime movement from (07:00 to 16:00), especially in the morning (07:00, 09:00, and 11:00) and afternoon (12:00-13:00 and 15:00), with peak activity of two-wheelers. This suggests that two-wheelers are primarily used for short-distance commuting and local mobility.

Overall, the results highlight temporal differences among vehicle categories, where two-wheelers dominate daytime traffic, light vehicles reflect typical commuting cycles, and heavy vehicles maintain broader daytime activity associated with freight transport. Such patterns are important for understanding temporal human disturbance and potential road-related risks to wildlife, particularly during peak traffic periods.

5.4.4. Site-specific movement

The data analysis across Rampura Pathar, Kuekheda, and Rawlikudi reveals distinct vehicle movement. **At Pathar**, heavy vehicles dominate, with continuous activity and moderate during the afternoon and peak in the evening hours (11:00 and 17:00). This pattern confirms Pathar's main traffic check-post, where heavy vehicles prefer evening travel long distances. Light vehicles are prominent during the day, particularly during rush hours, creating overlaps with freight flows that pose safety and risk. The presence of two-wheelers is limited relative to other sites, but their exposure to mixed traffic, particularly heavy trucks, increases accident risk.

In Kuekheda, the traffic mix is more balanced. Heavy vehicles are present but not overwhelming, showing peaks aligned with market supply schedules. Light vehicles are the dominant category during evening hours

(15:00 and 17:00), reflecting their role as a border and dirt road. Two-wheelers form the strongest category overall, with sharp late morning and afternoon peaks, showing reliance on two-wheelers for short- to medium-distance mobility for the nearby villages from Rajasthan and M.P. border. This multi-directional and multi-modal flow indicates Kuekheda's importance as a local connectivity road.

In Rawlikudi Heavy vehicles are at their peak in the morning and evening hours (09:00 and 17:00) and moderate on 10:00 - 11:00, and some peak confirming local transportation for work and residential function. Two-wheelers are clearly the dominant mode, with sharp peaks (07:00) and moderate (08:00 - 09:00) for local transportation. This reflects strong dependence on motorcycles and scooters for short daily travel.

Each of these sites have specific -pattern as well as types of vehicle movement and thus require targeted mitigation interventions to reduce the barrier effect alongside potential collisions with wildlife.

5.5. Seroprevalence studies for understanding major carnivore diseases

5.5.1. Introduction

Conservation translocations, encompassing reintroductions, introductions, and reinforcements (with the former two often being contextually interchangeable), involve the deliberate movement of organisms to achieve specific ecological objectives (Osborne & Seddon, 2012; Novak *et al.* 2021). Projects such as the current cheetah introduction in India represent ecologically complex interventions that require an in-depth understanding of species ecology, behavior, and associated challenges, necessitating a systematic and adaptive management approach (Berger-Tal *et al.* 2020). Historically, many translocation programs were conducted with limited attention to disease risks (Davidson & Nettles, 1992; Hartley & Sainsbury, 2017; Girling *et al.* 2019). However, growing recognition of the potential impact of diseases on wildlife has led to the wider adoption of structured disease risk analyses (Woodford & Rossiter, 1994; Cunningham, 1996; Kock *et al.* 2010; Sainsbury *et al.* 2017; Vaughan-Higgins *et al.* 2021). Such assessments are now considered not only critical for improving translocation success and ensuring long-term population viability but also an established best-practice standard (Girling *et al.* 2019).

Cheetahs in captivity are susceptible to various disease conditions, however, are rarely detected in wild cheetahs. As per the IUCN status assessment of cheetahs in 2014, infectious diseases were unlikely to be much of a threat to cheetah populations in the wild (Tordiffe *et al.* 2022). Indian carnivores, on the other hand, are affected by a wide array of debilitating pathogens (Arora, 2003; Nayak *et al.* 2020), many of which are either native to the region or easily transmissible from domestic species. While published literature documents numerous disease accounts in captive settings, information on free-ranging carnivores is scarce, and a nationwide active disease surveillance program has yet to be initiated. To address this gap, a comprehensive Disease Risk Analysis (DRA) for the introduction of cheetahs (*Acinonyx jubatus*) to India was conducted prior to the translocation (Tordiffe *et al.* 2022). This DRA catalogued potential communicable hazards and disease-management actions, identifying pathogens hazardous to cheetahs in southern Africa and those known to be present in large felids in India.

Building upon this foundational risk assessment, a seroprevalence study was initiated to ascertain the disease status at the introduction sites (*viz*., Kuno NP and Gandhi Sagar WLS). Samples from co-predators, opportunistically collected during the Wildlife Institute of India's (WII) telemetry studies were analyzed. Additionally, 56 free-ranging dog samples from the vicinity of Kuno NP and 50 from near Gandhi Sagar WLS were analyzed as part of the current cheetah introduction project. Initial disease screening was performed using rapid chromatographic immunoassays (Anigen Rapid Test Kit, Bionote Inc., Gyeonggi-do, 18449, Republic of Korea). These tests allow for quick, on-field assessment without specialized equipment and provide a valuable preliminary screening tool prior to more definitive laboratory analysis, despite not being standardized for wildlife species.

The panel of pathogens screened for antibodies (Ab) or antigens (Ag) included:

- Canine-specific: Canine babesia, Anaplasma phagocytophilum, Borrelia burgdorferi, Ehrlichia canis, Dirofilaria immitis (heartworm), and Canine Parvovirus (CPV).
- Feline-specific: Feline heartworm, Feline Leukemia Virus (FeLV), Feline Immunodeficiency Virus (FIV), Fe-

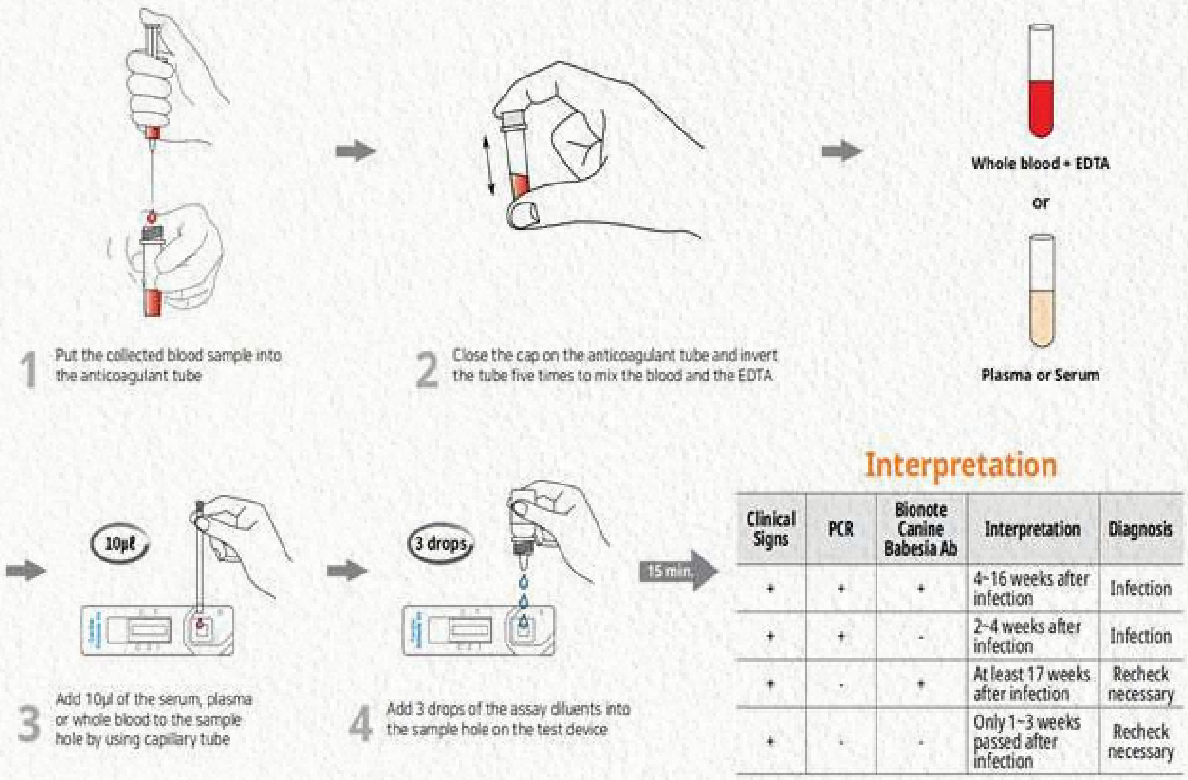
line Parvovirus (FPV), and Feline Coronavirus (FCoV).

- General: Toxoplasma gondii.

The detailed methodology and results are presented in the subsequent sections.

5.5.2. Canine babesia

- Principle used in the test: Chromatographic immunoassay for the qualitative detection of antibodies against canine babesia gibsoni
- Sample required: Whole blood, plasma, or Serum
- Procedure:



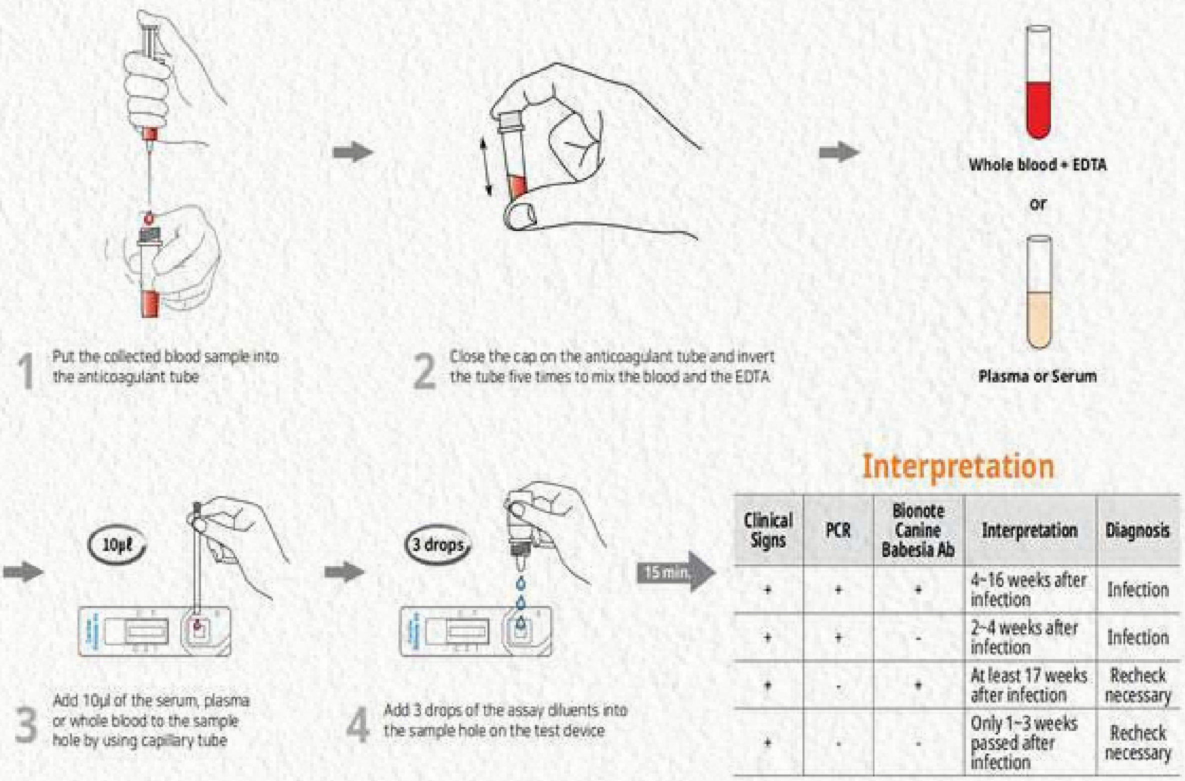
Results:

Species	n	+ve	- ve
Hyena	4	0	4
Leopard	27	0	27
Jungle cat	8	0	8
Jackal	3	0	3
Tiger	1	0	1
Cheetah	4	0	4
Feral dog	50	0	50

n = Total number of species samples

5.5.3. *Anaplasma spp.*:

- Principle used in the test: Chromatographic immunoassay for the qualitative detection of antibodies against Anaplasma phagocytophilum/Anaplasma platys
- Sample required: Whole blood, Plasma, or Serum
- Procedure:

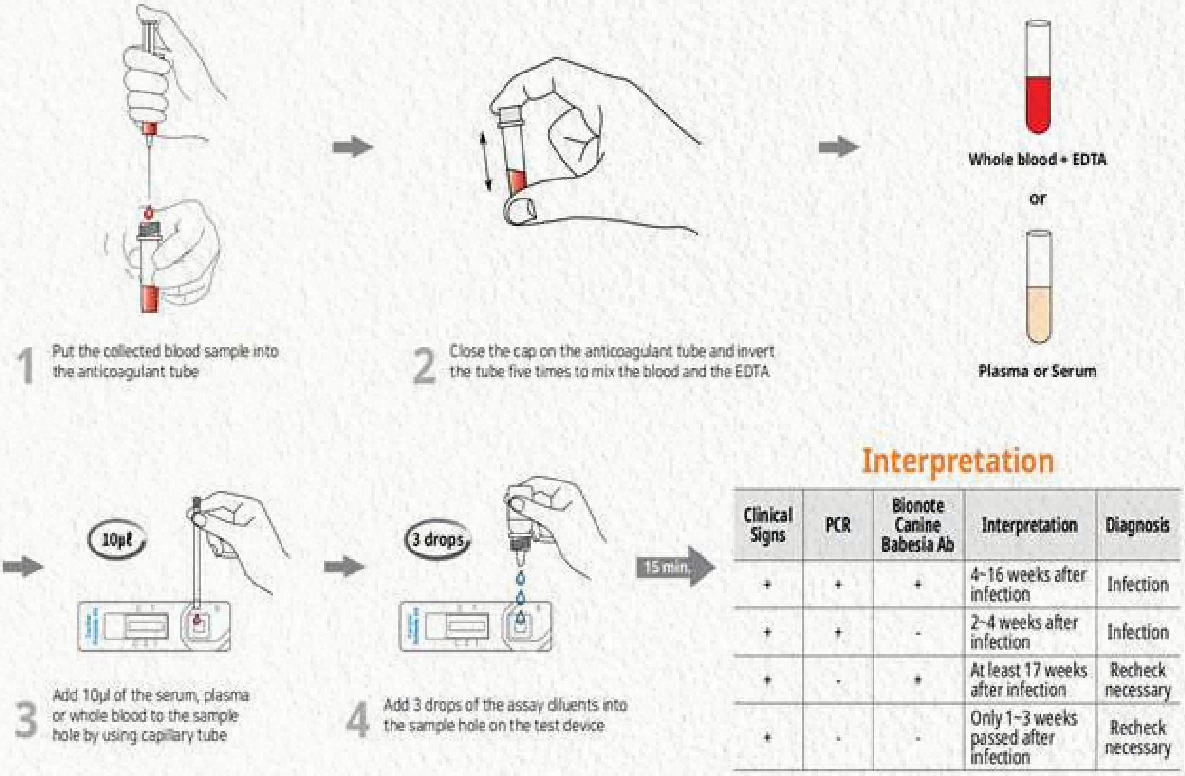


Results:

Species	*n*	+ve	- ve
Hyena	4	0	4
Leopard	27	0	27
Jungle cat	8	0	8
Jackal	3	0	3
Tiger	1	0	1
Cheetah	4	0	4
Feral dog	39	13	26

5.5.4. *Borrelia burgdorferi*

- Principle used in the test: Chromatographic immunoassay for the qualitative detection of antibodies against Borrelia burgdorferi
- Sample required: Whole blood, Plasma or Serum
- Procedure:

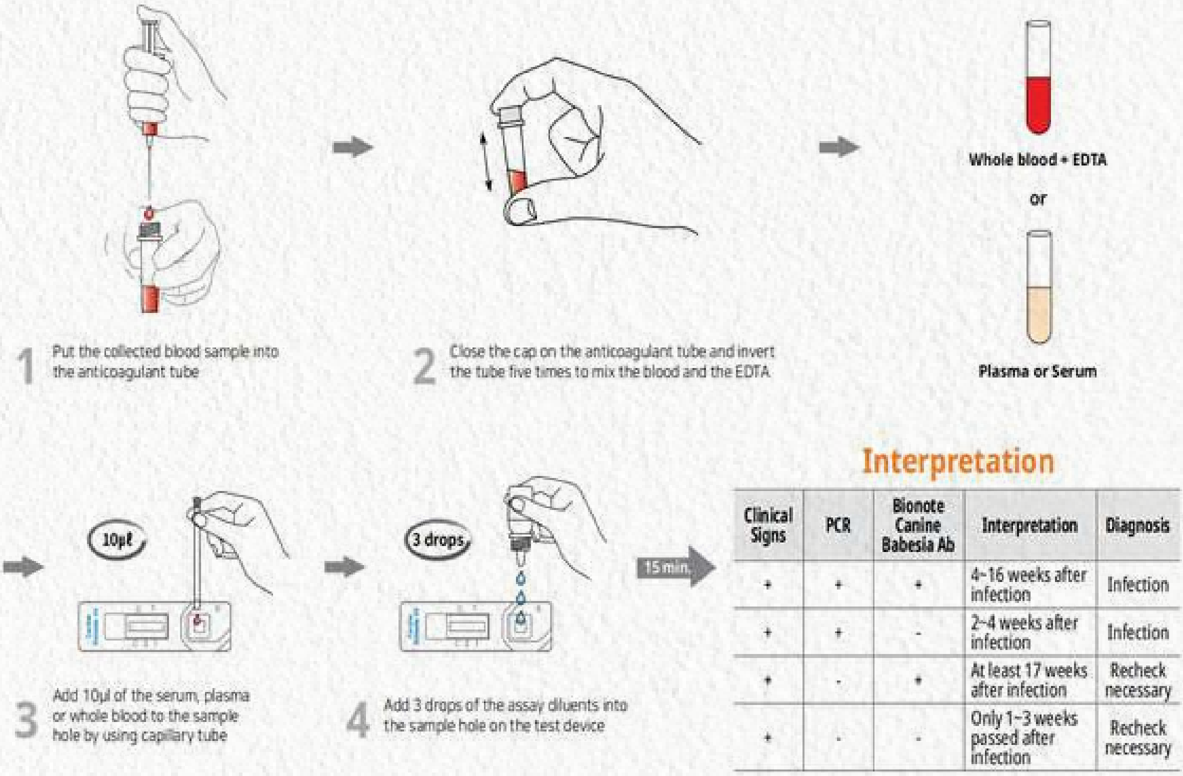


Results:

Species	*n*	+ve	- ve
Hyena	4	0	4
Leopard	27	0	27
Jungle cat	8	0	8
Jackal	3	0	3
Tiger	1	0	1
Cheetah	4	0	4
Feral dog	39	0	39

5.5.5. Ehrlichia canis

- Principle used in the test: Chromatographic immunoassay for the qualitative detection of Ehrlichia canis antibody
- Sample required: Whole blood, Plasma or Serum
- Procedure:



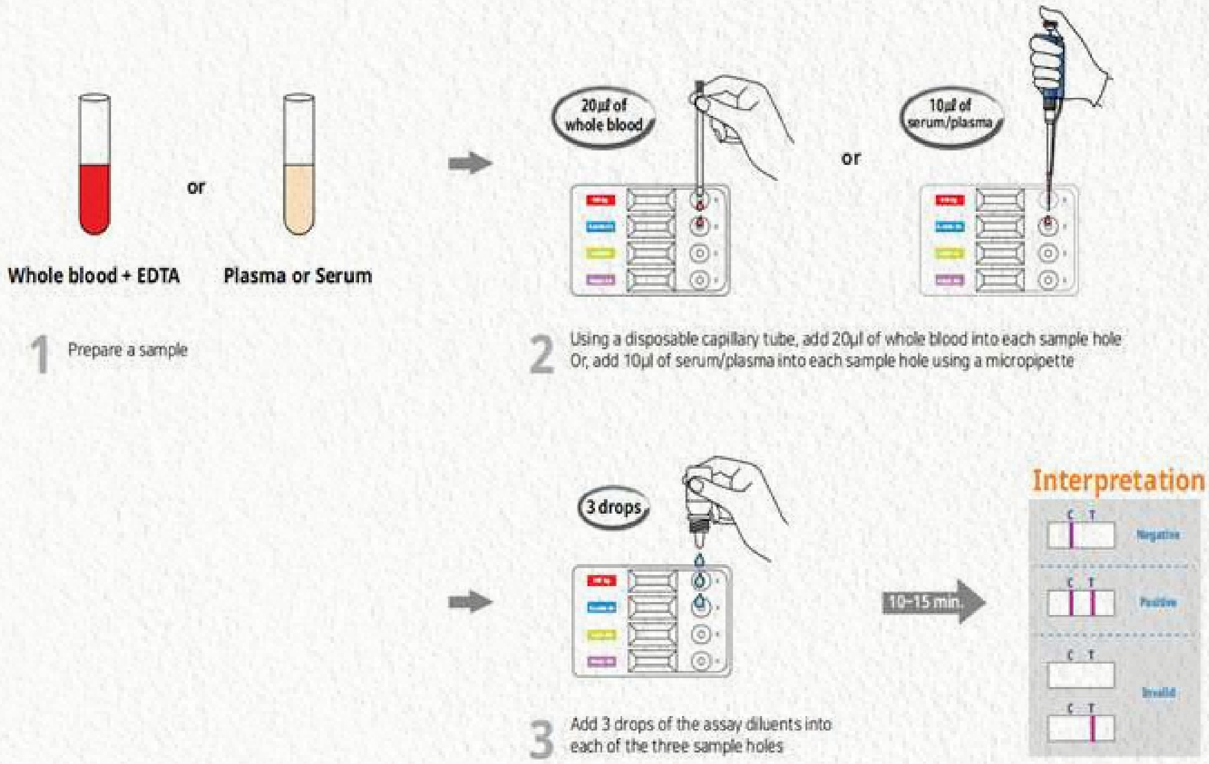
Clinical Signs	PCR	Bionote Canine Babesia Ab	Interpretation	Diagnosis
+	+	+	4~16 weeks after infection	Infection
+	+	-	2~4 weeks after infection	Infection
+	-	+	At least 17 weeks after infection	Recheck necessary
+	-	-	Only 1~3 weeks passed after infection	Recheck necessary

Results:

Species	*n*	+ve	- ve
Hyena	4	0	4
Leopard	27	0	27
Jungle cat	8	0	8
Jackal	3	0	3
Tiger	1	0	1
Cheetah	4	0	4
Feral dog	39	4	35

5.5.6. Dirofilaria immitis

- Principle used in the test: Chromatographic immunoassay for the qualitative detection of Dirofilaria immitis antigen
- Sample required: Whole blood, Plasma or Serum
- Procedure:

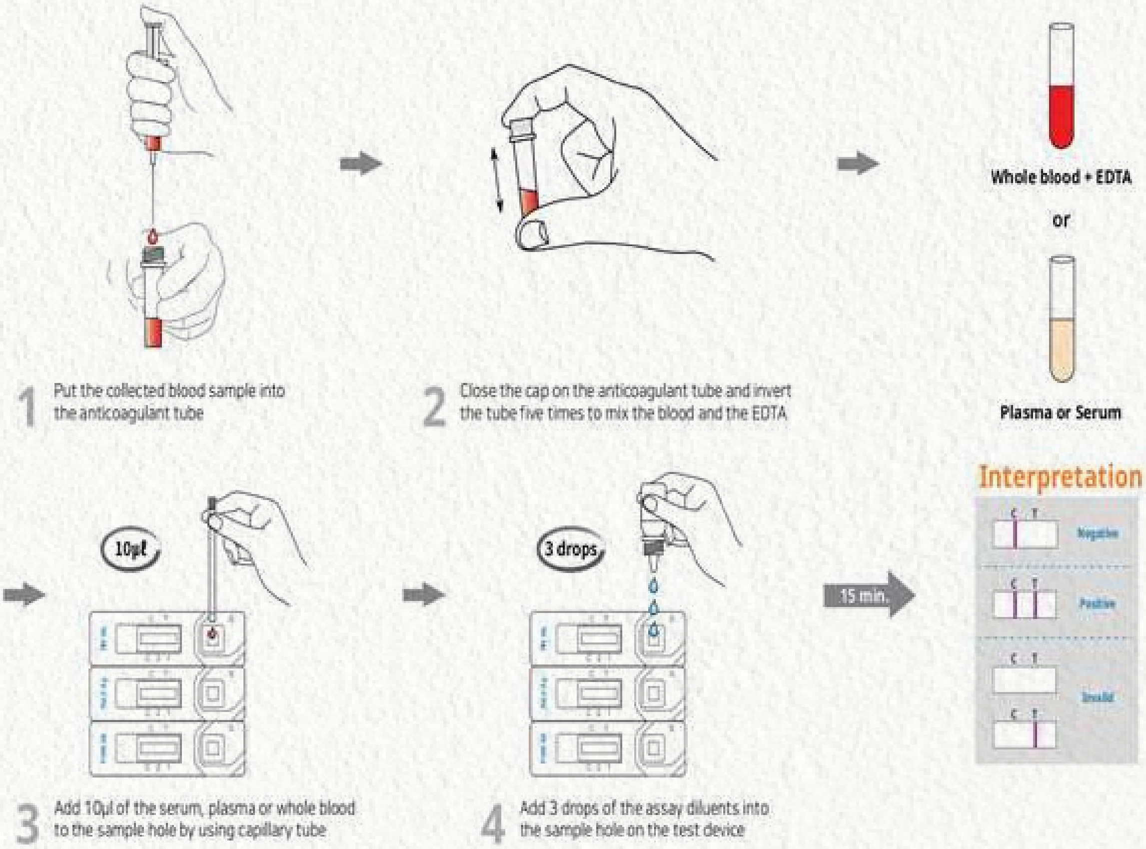


Results:

Species	*n*	+ve	- ve
Hyena	4	0	4
Leopard	27	0	27
Jungle cat	8	0	8
Jackal	3	0	3
Tiger	1	0	1
Cheetah	4	0	4
Feral dog	39	0	39

5.5.7. Feline heartworm

- Principle used in the test: Chromatographic immunoassay for the qualitative detection of feline heart-worm antibody (FHW Ab)
- Sample required: Whole blood, Plasma or Serum
- Procedure:

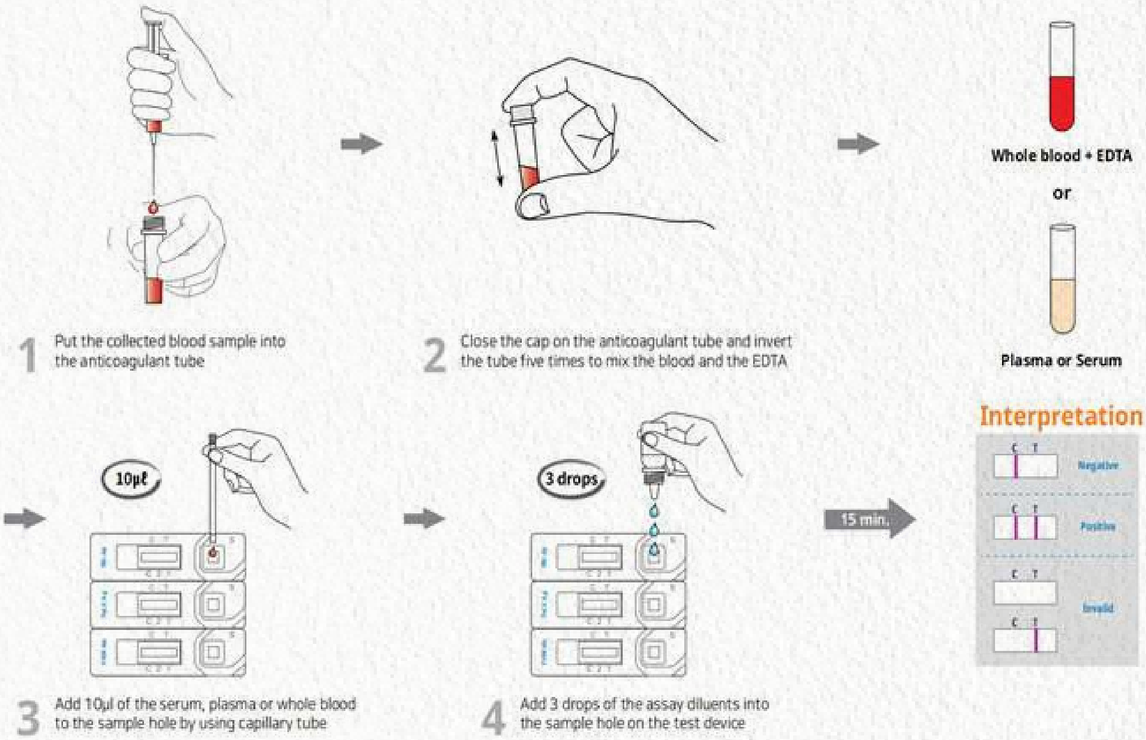


Results:

Species	*n*	+ve	- ve
Hyena	4	0	4
Leopard	27	0	27
Jungle cat	8	0	8
Jackal	3	0	3
Tiger	1	0	1
Cheetah	4	0	4

5.5.8. Feline leukemia Virus

- Principle used in the test: Chromatographic immunoassay for the qualitative detection of feline leukemia virus antigen (FeLV Ag)
- Sample required: Whole blood, Plasma or Serum
- Procedure:

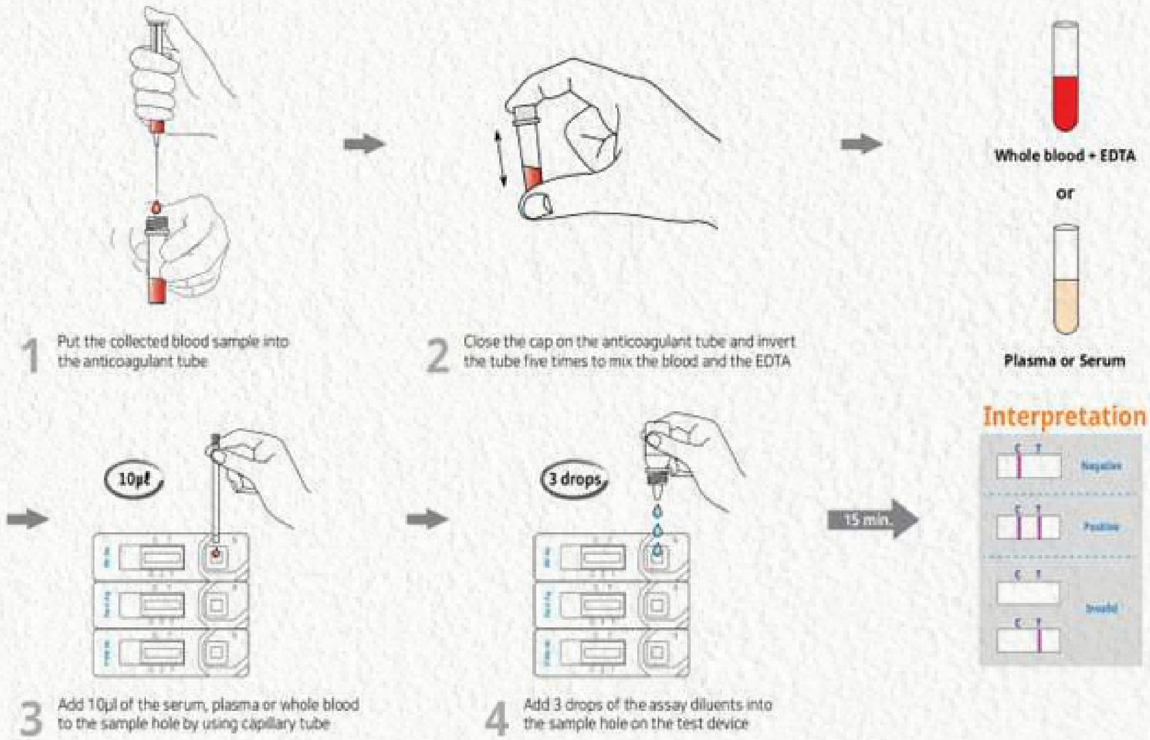


Results:

Species	*n*	+ve	- ve
Hyena	4	0	4
Leopard	27	0	27
Jungle cat	8	0	8
Jackal	3	0	3
Tiger	1	0	1
Cheetah	4	0	4

5.5.9. Feline immunodeficiency virus

- Principle used in the test: Chromatographic immunoassay for the qualitative detection of feline immunodeficiency virus antibody (FIV Ab)
- Sample required: Whole blood, Plasma or Serum
- Procedure:

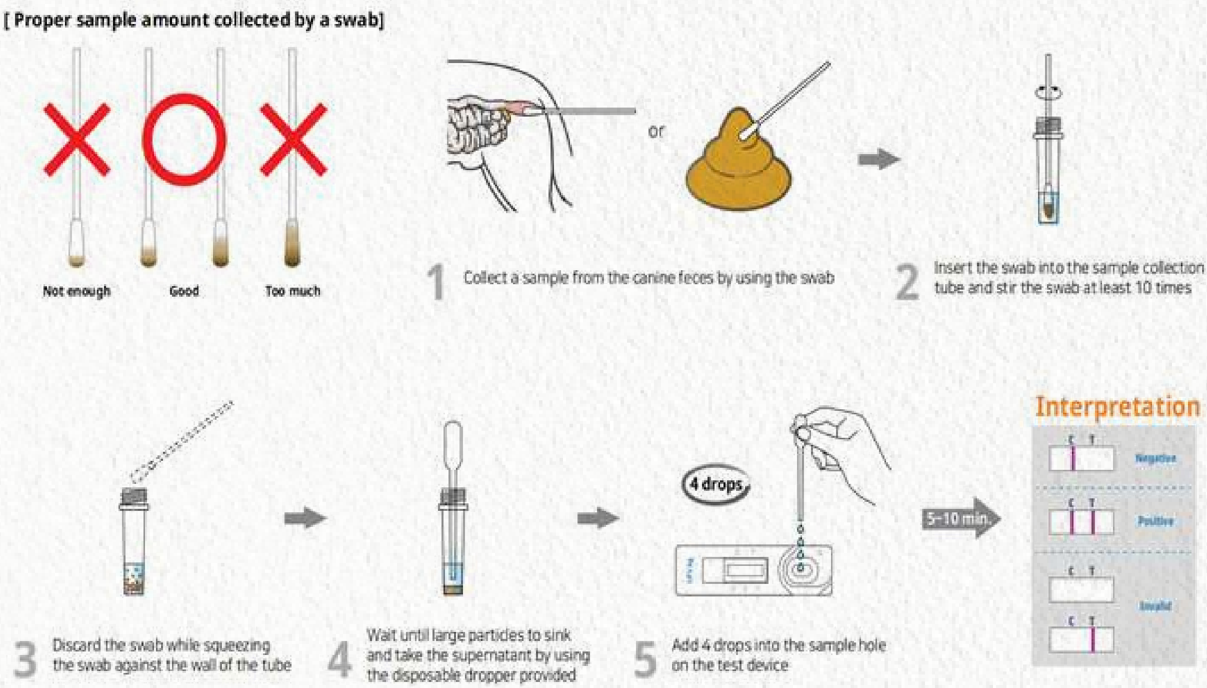


Results:

Species	*n*	+ve	- ve
Hyena	4	0	4
Leopard	27	0	27
Jungle cat	8	0	8
Jackal	3	0	3
Tiger	1	0	1
Cheetah	4	0	4

5.5.10. Canine Parvovirus (CPV)

- Principle used in the test: Chromatographic immunoassay for the qualitative detection of Canine Parvovirus antigen (CPV Ag)
- Sample required: Canine feces
- Procedure:

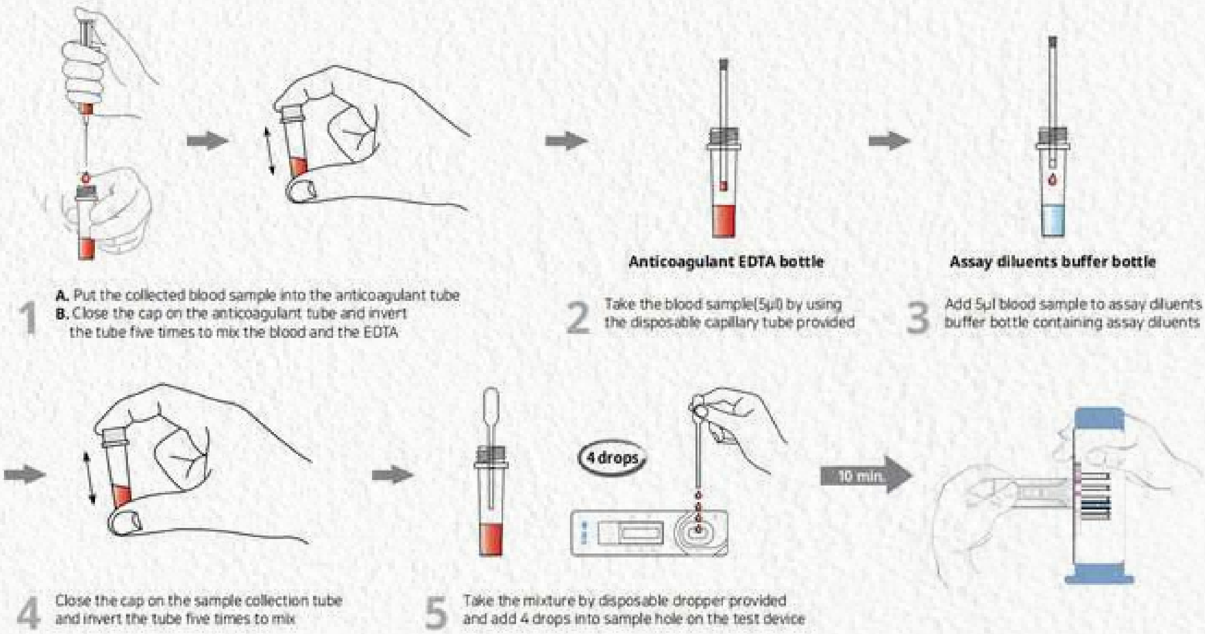


Results:

Species	*n*	+ve	- ve
Hyena	4	0	4
Leopard	19	17	2
Jungle cat	8	2	6
Jackal	3	0	3
Cheetah	4	0	4

5.5.11. Canine Parvovirus (CPV)

- Principle used in the test: Chromatographic immunoassay for the qualitative detection of Canine Parvovirus antibody (CPV Ab)
- Sample required: Whole blood, Plasma or Serum
- Procedure:

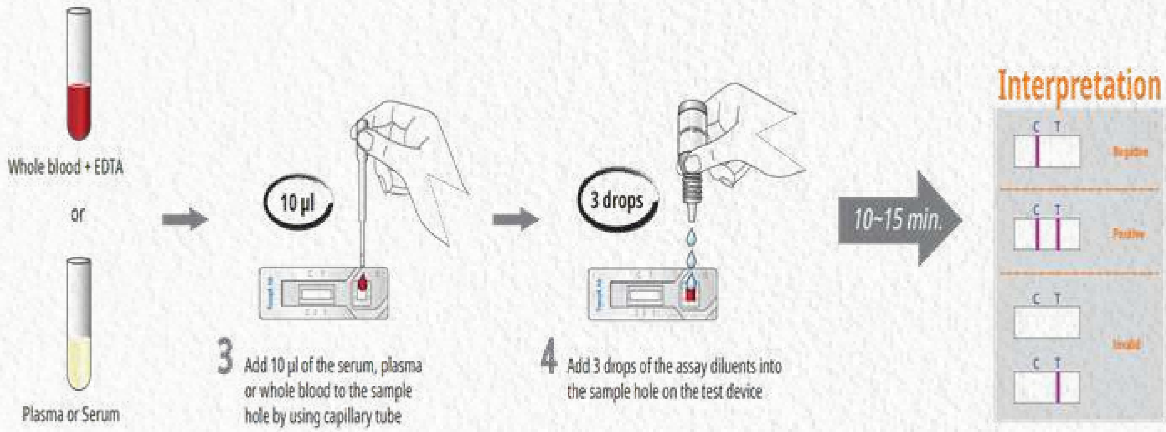


Results:

Species	n	+ve			-ve
		Low titer (Below 1:40 as HI titer)	Medium titer (1:80 as HI titer)	High titre (Above 1:160 as HI titer)	0
Feral dog	50	32	2	16	

5.5.12. Toxoplasma:

- Principle used in the test: Chromatographic immunoassay for the qualitative detection of Detection of Toxoplasma gondii antibody
- Sample required: Whole blood, Plasma or Serum
- Procedure:

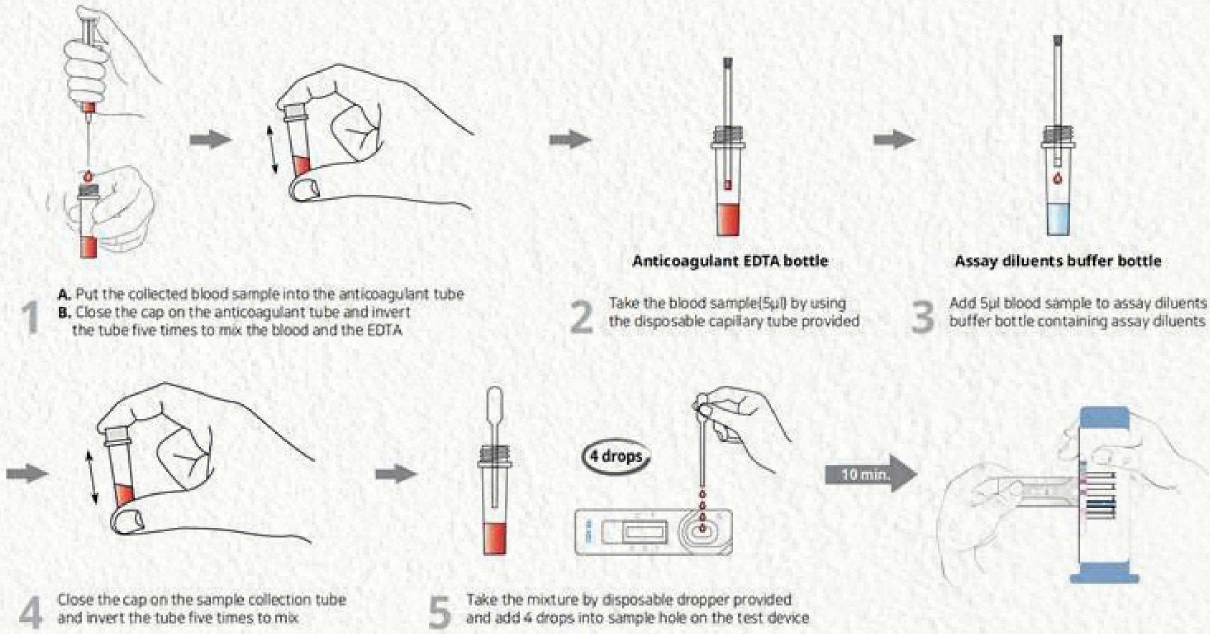


Results:

Species	*n*	+ve	- ve
Hyena	4	0	4
Leopard	19	3	16
Jungle cat	8	2	6
Jackal	3	1	2
Cheetah	4	3	1
Feral dog	50	4	46

5.5.13. Canine distemper virus (CDV)

- Principle used in the test: Chromatographic immunoassay for the qualitative detection of canine distemper virus (CDV) antibody
- Sample required: Whole blood, Plasma or Serum
- Procedure:

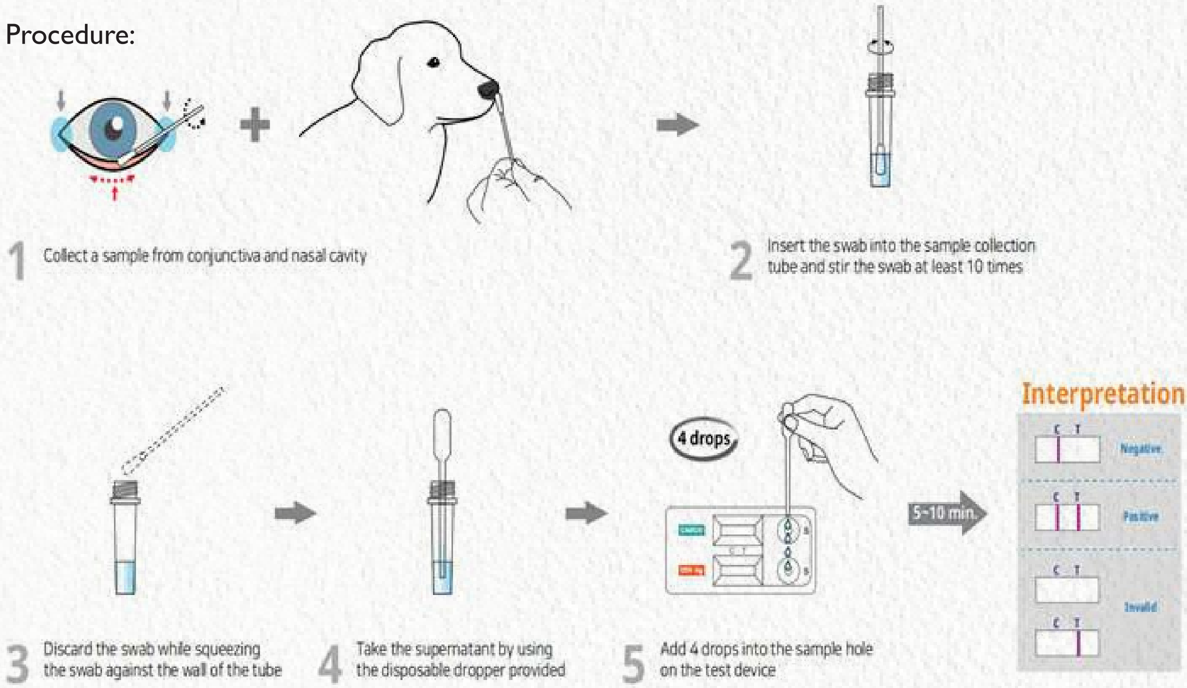


Results:

Species	n	+ve			-ve
		Low titer (Below 1:40 as HI titer)	Medium titer (1:80 as HI titer)	High titre (Above 1:160 as HI titer)	
Feral dog	41	29	7	5	0

5.5.14. Canine distemper virus (CDV)

- Principle used in the test: Chromatographic immunoassay for the qualitative detection of canine distemper virus (CDV) antigen
- Sample required: Conjunctiva Swab
- Procedure:

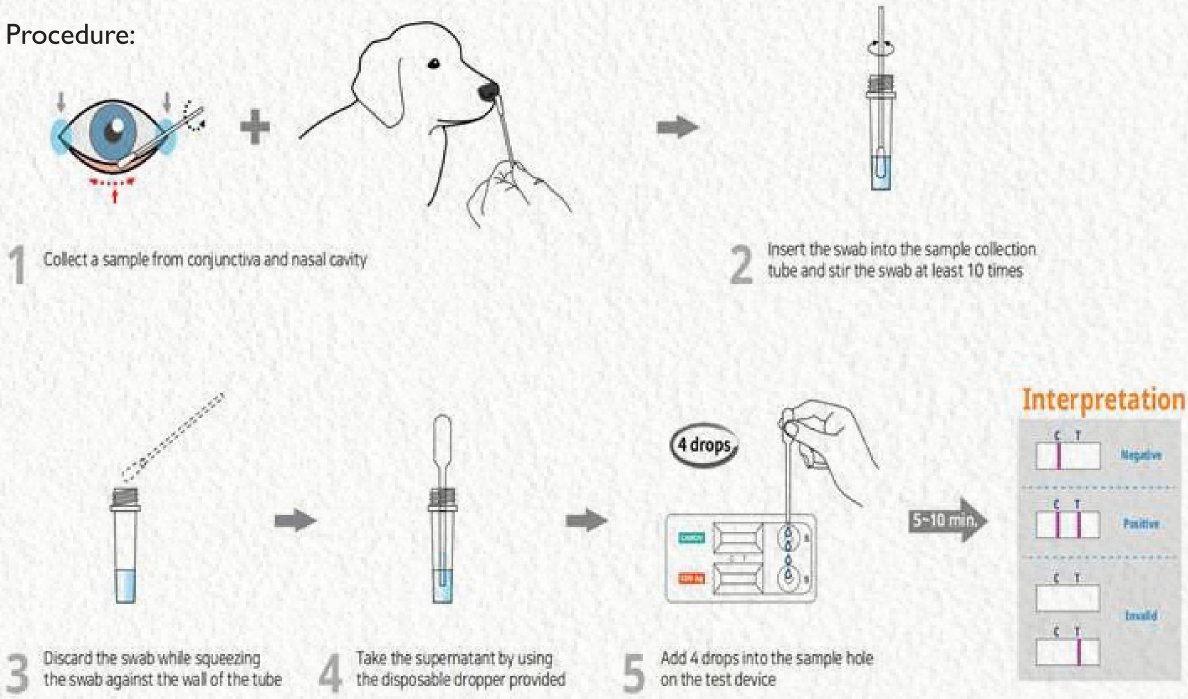


Results:

Species	*n*	+ve	- ve
Feral dog	50	0	50

5.5.15. Canine influenza virus (CIV)

- Principle used in the test: Chromatographic immunoassay for the qualitative detection of canine influenza virus strain antigen
- Sample required: Nasal Fluid
- Procedure:

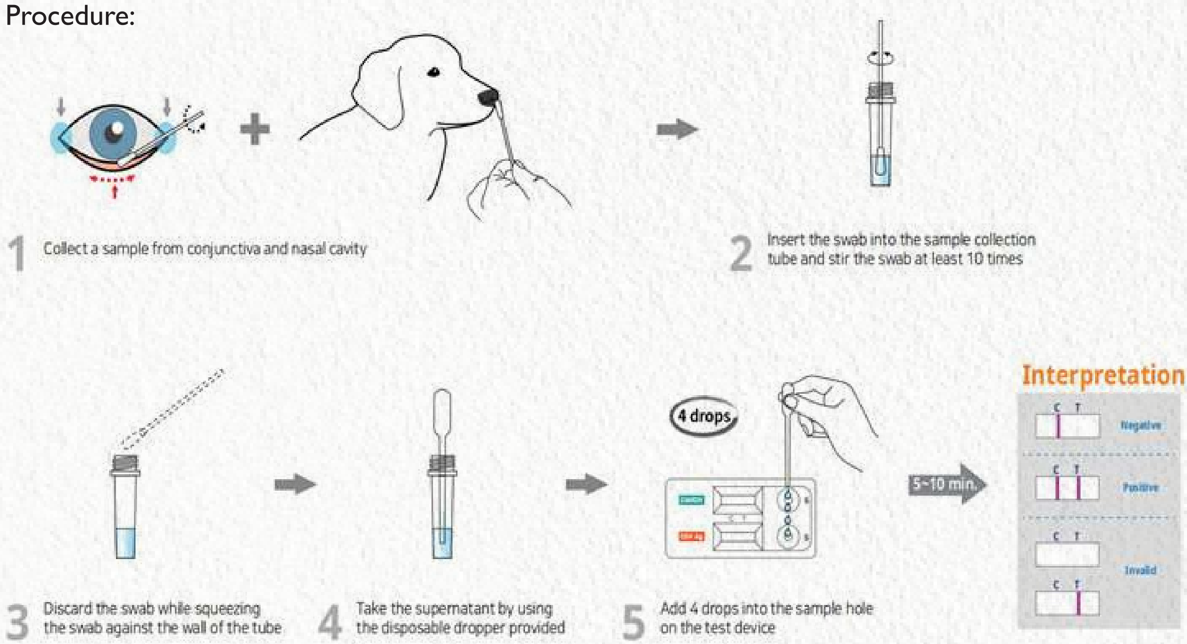


Results:

Species	*n*	+ve	- ve
Feral dog	50	0	50

5.5.16. Canine Adenovirus (CAV)

- Principle used in the test: Chromatographic immunoassay for the qualitative detection of canine adeno-virus strain antigen
- Sample required: Nasal Fluid
- Procedure:

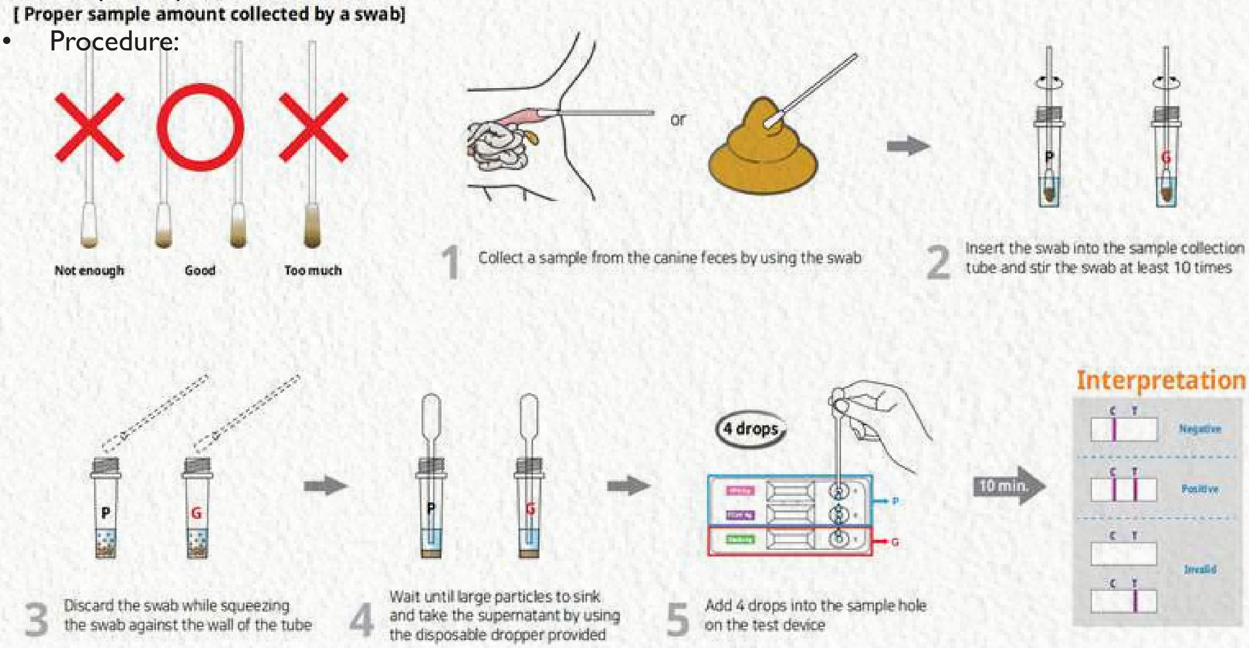


Results:

Species	*n*	+ve	- ve
Feral dog	50	0	50

5.5.17. Feline parvovirus (FPV)

- Principle used in the test: Chromatographic immunoassay for the qualitative detection of Feline Parvovirus antigen (FPV Ag)
- Sample required: Feline feces
- Procedure:



Results:

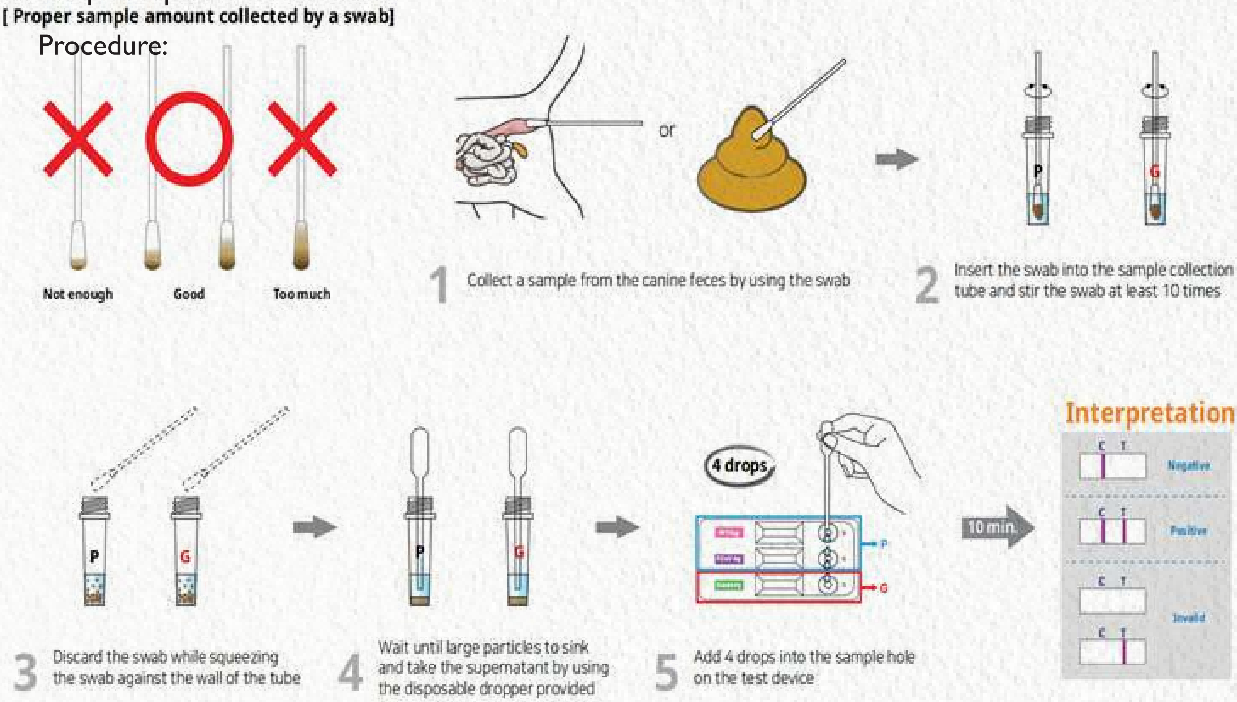
Species	*n*	+ve	- ve
Leopard	3	0	3

5.5.18 Feline corona virus (FCV)

- Principle used in the test: Chromatographic immunoassay for the qualitative detection of Feline corona virus antigen (FCV Ag)

- Sample required: Feline feces

- Procedure:

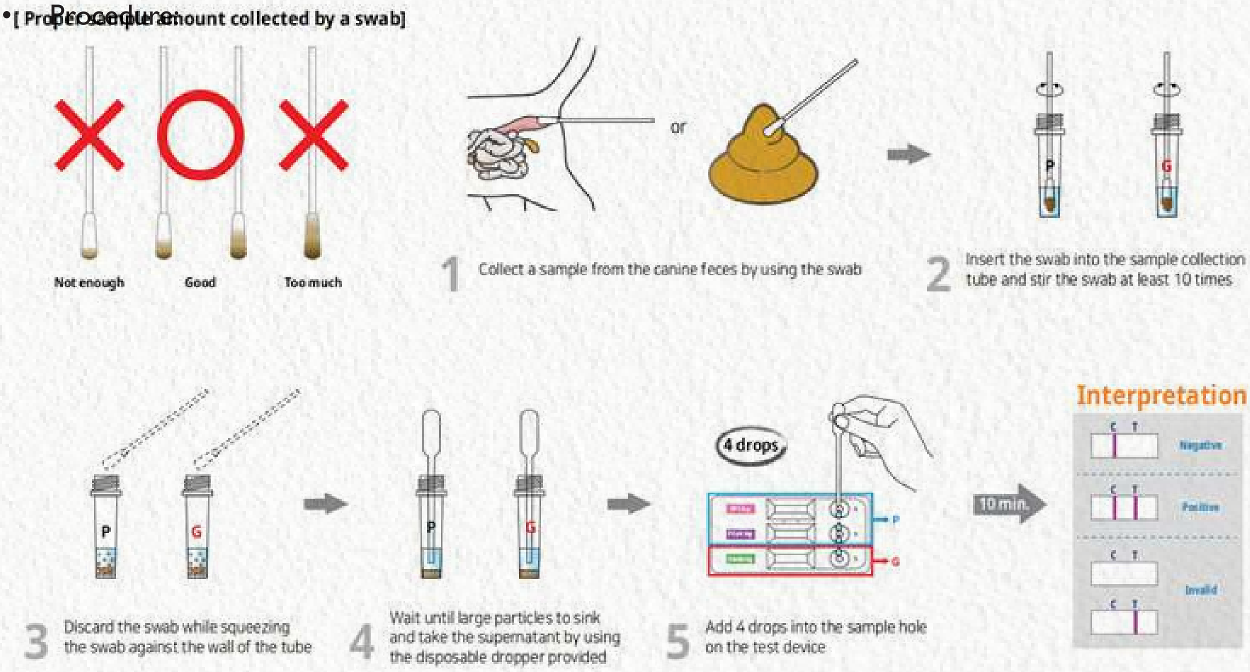


Results:

Species	*n*	+ve	- ve
Leopard	3	0	3

5.5.19 Giardia:

- Principle used in the test: Chromatographic immunoassay for the qualitative detection of Giardia antigen
- Sample required: Canine feces
- Procedure:



Results:

Species	*n*	+ve	- ve
Leopard	3	0	3

Table 5.5.1.
Consolidated results of seroprevalence studies for understanding major carnivore diseases

Infectious Disease	**Hyena**			**leopard**			**Jungle cat**			**Jackal**			**Cheetah**			**Tiger**		
	n	**-**	**+**	***n***	**-**	**+**	***n***	**-**	**+**	***n***	**-**	**+**	***n***	**-**	**+**	***n***	**-**	**+**
***Canine babesi**a*	4	4	0	27	27	0	8	8	0	3	3	0	4	4	0	1	1	0
Anaplasma	4	4	0	27	27	0	8	8	0	3	3	0	4	4	0	1	1	0
Borrelia burgdorferi	4	4	0	27	27	0	8	8	0	3	3	0	4	4	0	1	1	0
Ehrlichia canis	4	4	0	27	27	0	8	8	0	3	3	0	4	4	0	1	1	0
Dirofilaria immitis	4	4	0	27	27	0	8	8	0	3	3	0	4	4	0	1	1	0
Feline heartworm	4	4	0	27	27	0	8	8	0	3	3	0	4	4	0	1	1	0
Feline leukemia Virus	4	4	0	27	27	0	8	8	0	3	3	0	4	4	0	1	1	0
Feline immunodefi-ciency virus	4	4	0	27	27	0	8	8	0	3	3	0	4	4	0	1	1	0
Canine Parvovirus	4	4	0	19	2	17	8	6	2	3	3	0	4	4	0	-		
Toxoplasma	4	4	0	19	16	3	8	6	2	3	2	1	4	1	3	-		
Feline parvovirus	-			3	3	0	-			-			-			-		
Feline corona virus	-			3	3	0	-			-			-			-		
Feline corona virus	-			3	3	0	-			-			-			-		

* n = Total number of species samples; - = Negative; + = Positive

Table 5.5.2.
Consolidated results of seroprevalence studies in feral/free-ranging dogs in the vicinity of Kuno National Park and Gandhi Sagar Wildlife Sanctuary

Infectious disease	**Free Ranging Dogs**					
	Gandhi Sagar WLS			**Kuno NP**		
	n	**-ve**	**+ve**	**n**	**-ve**	**+ve**
Canine babesia	50	50	0		-	
Anaplasma	39	26	13	56	56	0
Borrelia burgdorferi	39	39	0	56	56	0
Ehrlichia canis	39	35	4	56	55	1
Dirofilaria immitis	39	39	0	56	56	0
Toxoplasma	50	46	4		-	
Canine Adenovirus	50	50	0	56	54	2
Canine distemper virus Ag	50	50	0	56	54	2
Canine influenza virus	50	50	0		-	
Canine Parvovirus Ab		-		56	55	1

While this initial serological screening provides crucial field-based data, it represents the first tier of a comprehensive diagnostic strategy. To obtain a more definitive diagnosis, characterize pathogen strains, and identify novel or unexpected agents, samples will be subjected to advanced laboratory-based analyses in the near future. This would include next-generation sequencing (NGS) and other sophisticated molecular techniques, such as PCR and metagenomics, which offer higher specificity and sensitivity for a detailed understanding of the pathogen landscape in these ecosystems.

5.6. Management activities undertaken in Kuno National Park & Gandhi Sagar Wildlife Sanctuary

5.6.1. Habitat management in Kuno National Park

The details of the habitat improvement work particularly vegetation management undertaken in Kuno NP is provided in Table 5.6.1.

Table 5.6.1.
Habitat improvement in Kuno National Park

Sl. No.	Work	Area in ha (2024-25)	Area in ha (2025-26) (Work in progress)
1.	Weed eradication	1400	1190
2.	Brushwood removal	2555	1165
3.	Lantana uprooting	300	0
4.	Unpalatable grass removal	50	0

5.6.2. Grassland restoration in Gandhi Sagar Wildlife Sanctuary

For grassland management inside the cheetah closed natural area, an eradication program of invasive plant species *Lantana camara* & *Neltuma juliflora* to increase the available grassland area has been initiated. Proposals for the eradication of these species and the development of grasslands are regularly sent under various Annual Plans of Operations (APOs). During the year from September 2024 to September 2025, 1065 ha of area was treated under various budget heads. The activities that have been carried out under habitat restoration and grassland management includes eradication of *L. camara* & *N. juliflora* with other weeds (*Cassia tora*, *Hyptis spp*., *Achyranthes aspera*, *Parthenium hysterophorus*), soil and moisture conservation works such as clearing of loose boulders and brushwood, building of check dams on small streams, and construction of percolation tanks. After uprooting the weeds, grass seeds were sprayed in the vacant area, increasing the grassland area available for ungulate prey.

Table 5.6.2.
Year-wise area managed for grassland restoration in Gandhi Sagar Wildlife Sanctuary

Grassland development work	2023-2024	2024-2025
Area	870 ha	1065 ha
Total Area	1935 ha	

Image 5.6.1. Grassland management undertaken in Gandhi Sagar Wildlife Sanctuary ©Madhya Pradesh Forest Department

Table 5.6.3.
Species of grasses being promoted in Gandhi Sagar Wildlife Sanctuary

Species	Species	Species	Species	Species
1.*Apluda mutica*	6.*Chrysopogon fulvus*	11.*Dimeria spp.*	16.*Heteropogon contortus*	21.*Themeda quadrivalvis*
2.*Aristida hystrix*	7.*Cynodon dactylon*	12.*Echinochloa spp.*	17.*Imperata cylin-drica*	22.*Themeda triandra*
3.*Bothriochloa pertusa*	8. *Cyperus spp.*	13.*Eleusine indica*	18.*Iseilema laxum*	
4.*Bothriochloa odorata*	9.*Dichanthium annula-tum*	14.*Eragrostis tenella*	19.*Setaria pumila*	
5. *Chloris barbata*	10.*Digitaria ciliaris*	15.*Eragrostis uni-oloides*	20.*Sorghum halep-ense*	

5.6.3. Habitat management in Gandhi Sagar Wildlife Sanctuary

The Closed Natural Area (~64 sq km) for cheetahs was divided into three partitions, and several roads and fire lines were created to prevent the spread of fire. Protection is enhanced to minimize fire incidents. No fire incidents took place after the arrival of cheetahs in Gandhi Sagar WLS.

The fenced area for cheetah release has a sufficient number of water sources. In addition to the existing water sources, two 10 HP solar water pumps and two 5 HP solar water pumps have been installed at the Kunamata and Karanpura sites. A new pipeline of approximately 7 km was laid in the fenced area to make water available for quarantine bomas, prey augmentation enclosures, and all three compartments of the Closed Natural Area designated for cheetah release. Additionally, nine ponds and seven saucers have been constructed to make water available for wildlife during hot summers, as well as to maintain moisture in grassland areas to sustain green grass around the year. To facilitate vehicle mobility during patrolling and monitoring, nearly 37.33 km of road upgradation work was taken up during September 24-25. The large compartment of the Closed Natural

Area with cheetahs (Khemla, Area-15.8 km^2) was augmented with wild prey. Further, three enclosures were constructed for natural breeding of prey and subsequently augmented with chital.

On the recommendation of the committee for overseeing the preparations before cheetah release, to maintain biosecurity and follow the disinfection procedure in the quarantine bomas, a wheel dip disinfectant, foot dip, waste disposal system, and a dedicated changing room were created. To avoid external interaction of animals during the quarantine period, an outside fence was constructed.

Image 5.6.2. Training on grassland management conducted in Gandhi Sagar Wildlife Sanctuary ©Madhya Pradesh Forest Department

Image 5.6.3. Water management with installation of a 10 HP solar-powered pump at Karanpura in Gandhi Sagar Wildlife Sanctuary ©Madhya Pradesh Forest Department

5.6.4. Preparations for cheetah introduction in Gandhi Sagar Wildlife Sanctuary

5.6.4.1. Veterinary infrastructure

An old dormitory building located in the Rampura Pathar area, within the Closed Natural Area designated for the release of cheetahs, has been renovated and converted into a veterinary hospital. The hospital is equipped with five major facilities, *viz.*, a diagnosis room (lab), a treatment room, veterinarian accommodation, a mobile veterinary unit, and a kraal area.

Image 5.6.4. Wildlife health unit at Gandhi Sagar Wildlife Sanctuary ©Madhya Pradesh Forest Department

A diagnosis room (lab) for laboratory testing, imaging studies, and other diagnostic procedures to identify health issues; a treatment room (ICU) for critical cases requiring close monitoring and care; administration of medications, therapies, and various other treatments to manage diseases as well as health issues; and surgical procedures and injuries were prepared. A mobile veterinary unit was formed for on-the-spot medical services for cheetahs, vaccination of livestock and feral dogs in surrounding areas, prophylactic measures, and rescue operations. The kraal area is designed to provide a safe and nurturing environment for injured as well as young wildlife and veterinarian accommodation for emergency stays of staff and during regular monitoring. Equipment and supplies include medical equipment for immobilization (darting gun), essential anesthetic medicines and other important medical equipment, *etc.*; surgical instruments and kits, such as specialized instruments for various surgical procedures; a range of medications; bandages; and other supplies. A trained veterinarian experienced in wildlife medicine and surgery has been appointed, and staff recruitment and training are underway. A solar grid (5 kW) is provided in the hospital for uninterrupted 24/7 electricity supply.

Image 5.6.5. Kraal area of wildlife health unit at Gandhi Sagar Wildlife Sanctuary ©Madhya Pradesh Forest Department

5.6.4.2. Vaccination of peripheral village animals (cattle, buffalo, and dogs) and field staff

To prevent the transmission of zoonotic and infectious diseases between domestic animals (such as cattle, buffaloes, and dogs) and wildlife, thereby safeguarding both animal health and biodiversity, regular vaccinations against Foot and Mouth Disease (FMD), Hemorrhagic Septicemia (HS), Black Quarter (BQ), *etc*., were carried out, and a total of 2500 animals (cattle & buffaloes) were vaccinated in the surrounding villages of Gandhi Sagar WLS. Additionally, 62 dogs were administered with rabies, canine distemper, and parvovirus vaccinations. Villages located near the PA within a 5–10 km radius were targeted for this intervention. As a precautionary measure, 60 field staff were vaccinated with human pre-rabies vaccines in collaboration with the local Primary Health Centre.

Image 5.6.6. Livestock vaccination program conducted in villages around Gandhi Sagar Wildlife Sanctuary ©Madhya Pradesh Forest Department

5.6.4.3. Preparation of the closed natural area in Gandhi Sagar Wildlife Sanctuary

The committee formed by the Department of Animal Husbandry and Dairying (DAHD) to inspect the quarantine facility recommended several improvements, including a disinfection procedure, waste disposal system, change room, and personal protective equipment. All the recommendations were complied with by the park management in the quarantine boma, the feeding chamber, gatekeeper room, and outer fencing (to avoid external interaction of the cheetah) were constructed.

Image 5.6.7. Inspection visit of committee from the Department of Animal Husbandry and Dairying ©Madhya Pradesh Forest Department

Closed Natural Area ~64 km² with predator-proof fencing is divided into three compartments, *viz.*, Karanpura (21 km²), Neemchauk (27.6 km²), and Khemla (15.8 km²), for better management. It was very difficult to install the fence along the Chambal River side lined with cliffs and rifts, so to make it predator-proof, a line of fence was created between the river and the start point. At all five entry points in the fence, a single gate has been upgraded to a double gate. To improve water availability in the fenced area within which quarantine bomas, prey augmentation enclosures are enclosed, a 25,000 ltr capacity tank was constructed at Konamata Point, and an 8 km water distribution pipeline was deployed. Additional water saucers and ponds were constructed to improve water availability in the summer season. Habitat assessments, ungulate, and carnivore population assessments were carried out with the collaborative efforts of the WII and the Forest Department. A new dog squad was established in the Gandhi Sagar WLS to improve the protection as well as detection of wildlife crime. The MP Forest Department involved local people in ongoing construction and habitat development work to garner community support and to provide them with employment locally. All the necessary preparation for the cheetah release program was completed timely. For better accommodation facilities for staff, new construction and repair works of the existing buildings are being done. The progress of preparations was continuously monitored by the senior officials of the Madhya Pradesh State Forest Department, NTCA, and Project Cheetah.

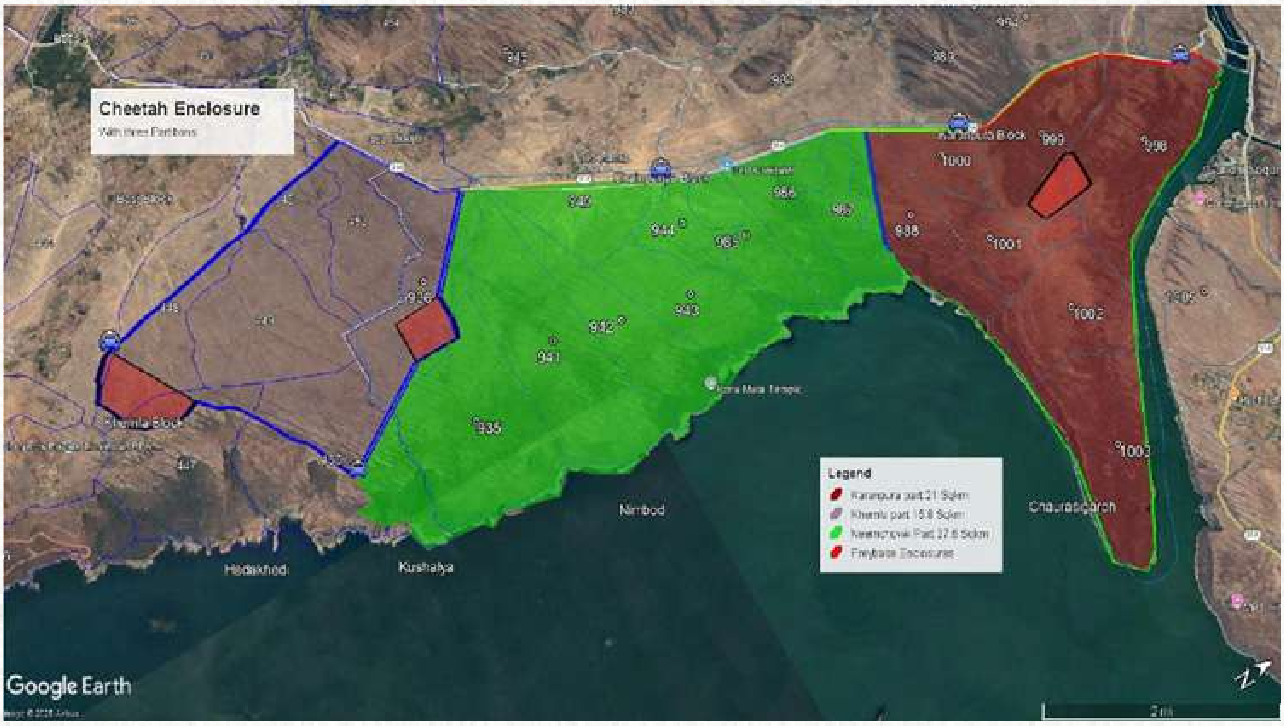


Image 5.6.8. Closed Natural Area (Size ~64 km²) with three compartments for initial phase of cheetah introduction in Gandhi Sagar Wildlife Sanctuary ©Madhya Pradesh Forest Department

Image 5.6.9. Dog Squad in Gandhi Sagar Wildlife Sanctuary ©Madhya Pradesh Forest Department

Image 5.6.10. Inspection visit by NTCA and Project Cheetah officials ©Madhya Pradesh Forest Department

Image 5.6.11. Inspection visit by senior officials of Madhya Pradesh State Forest Department ©Madhya Pradesh Forest Department

5.6.5. Management of leopards inside the Closed Natural Area for cheetah release

As outlined in the Action Plan for the introduction of cheetahs (NTCA *et al.* 2024), proactive interventions are being implemented in the Closed Natural Area to minimize prey competition and reduce the potential for conflict between cheetahs and leopards. Being subordinate carnivores, cheetahs are highly vulnerable to displacement and mortality when competing with stronger predators such as leopards, which not only exploit similar prey resources but may also kill cheetahs or their cubs (Laurenson, 1995). To mitigate these risks and create an optimal environment for cheetah acclimatization, a systematic program for the removal of leopards from the designated fenced area cheetah for cheetah release has been initiated.

Standard protocols involving safe and humane capture, immobilization, and translocation are strictly adhered to, ensuring animal welfare throughout the process. As of August 2025, leopards have been successfully captured and relocated outside the fenced area, substantially reducing interspecific competition and enhancing the prospects for cheetah establishment.

Table 5.6.4.
Details of leopards shifted outside the Cheetah Closed Natural Area in Gandhi Sagar Wildlife Sanctuary

Animal ID	**Date of capture**	**Age class**	**Sex**
GSF-06	02/10/2024	Sub- adult	Female
GSF-07	10/10/2024	Adult	Female
GSF-08	02/01/2025	Adult	Female
GSM-07	03/01/2025	Adult	Male
GSF-09	05/01/2025	Adult	Female
GSF-10	09/02/2025	Adult	Female
GSF-11	08/03/2025	Sub- adult	Female
GSM-08	04/04/2025	Adult	Male
GSF-12	03/05/2025	Sub- adult	Female
GSF-13	05/05/2025	Sub- adult	Female
GSM-09	06/05/2025	Adult	Male
GSM-10	25/05/2025	Adult	Female
GSM-14	13/06/2025	Sub- adult	Female
GSM-11	25/08/2025	Adult	Male
GSM-12	11/09/2025	Adult	Male

Image 5.6.12. Immobilization of an adult female leopard in Cheetah Closed Natural Area at Gandhi Sagar Wildlife Sanctuary

5.6.6. Miscellaneous veterinary activities in Gandhi Sagar Wildlife Sanctuary

In addition to routine health monitoring of cheetahs, several miscellaneous veterinary activities are being undertaken in Gandhi Sagar WLS to support the larger ecological management and research objectives. One of the key interventions includes the radio-collaring of prey species such as nilgai and chital. These activities are carried out under the supervision of veterinarians in coordination with the NTCA and Madhya Pradesh Forest Department.

Table 5.6.5.
Details of ungulates radio-collared in Gandhi Sagar Wildlife Sanctuary

S. No.	Date	Species	Age class	Sex	Collar ID
1.	23-09-2024	Nilgai	Adult	Female	NILA06
2.	26-09-2024	Chital	Adult	Male	IR-SAT 6799

Radio-collaring of ungulates provides valuable insights into habitat use, ranging behaviour, movement ecology, and prey availability within the Sanctuary, which are critical for assessing the prey base and its sustainability for supporting cheetah populations. Data obtained from these activities contribute significantly to adaptive management strategies, ecological research, and conservation planning, thereby complementing the overarching goal of establishing a healthy ecosystem in the Gandhi Sagar landscape.

Image 5.6.13. Radio-collared Nilgai in Gandhi Sagar Wildlife Sanctuary

6. Human Dimensions

6.1. Human dimensions of cheetah introduction in India

The successful introduction of cheetahs (*Acinonyx jubatus*) in India is closely linked to the economic well-being and cooperation of local people in the vicinity of the release sites. The cheetah introduction program, primarily a conservation initiative, is also a catalyst for social upliftment and economic development of local communities. Of the five main objectives of the programme, two specifically address human dimensions in cheetah conservation areas:

- To harness and connect opportunities for eco-development and eco-tourism as a means of enhancing community livelihoods, and
- To effectively manage the human-wildlife interface through timely ex-gratia payment, outreach programmes, and scientific interventions, thereby strengthening community support.

Livelihood-based interventions have been initiated with a focus on eco-tourism, generating employment opportunities for local youth as guides, drivers, and tracking staff. Skill development and training programmes were conducted for villagers as well as school students, enhancing community capacities to engage in conservation-linked enterprises. Mechanisms for ex-gratia payment for loss of livestock due to wildlife were operationalized, ensuring timely redress and reducing antagonism. Awareness programmes reached households through outreach camps, workshops, and school-based activities, developing positive attitudes towards cheetah conservation.

Active engagement and participation of local communities remain central to the long-term success of the program. By creating livelihood opportunities through ecotourism and building trust via proactive activities by the park management, the initiative is laying the foundation for sustained community management in cheetah conservation landscapes.

6.1.1. Humans of the cheetah landscape

The delineated contiguous cheetah landscape spans 32 districts, majorly in the states of Madhya Pradesh and Rajasthan, with parts of it in Uttar Pradesh, encompassing approximately 17,000 km^2. In India, elevated human population density results in the unintentional co-occurrence with wild species within most forested areas. Given the escalating anthropogenic footprint and the cheetah's status as a wide-ranging carnivore, the likelihood of their interactions remains significant. In such cases, it is essential to comprehend the nuances of societal dynamics of the local communities through the individuals residing on the margins of protected regions delineated for cheetah protection. This enables management authorities to determine public reception of a previously absent large carnivore, hence informing management strategies and future policy development.

6.1.1.1 Methodology

To gain a deeper insight into the lives and activities of local communities, social surveys employing both quantitative and qualitative methodologies were carried out to thoroughly analyze community dynamics and socio-economic conditions. The quantitative component was a systematic household survey designed to analyze socio-economic situations, estimate forest dependency, and comprehend local opinions of wildlife. This was conducted to provide a comprehensive overview of the communities residing around the protected area. The qualitative component comprised comprehensive interviews to explore cultural and religious beliefs, traditional behaviours, and community narratives related to forests and wildlife. This methodology revealed deeper insights into local views, beliefs, and historical ties to the landscape, enhancing a comprehensive understanding of human components in the context of nature and wildlife conservation.

A systematic sampling methodology was employed for precision and validity. The sample size includes a minimum of 5% of homes in bigger villages or communities. In smaller settlements with fewer than 50 households, a greater proportion, specifically at least 10%, of households were polled. This strategy guaranteed that smaller, potentially underrepresented communities received appropriate consideration. Households were randomly picked with a stratified sampling technique. The team attempted to secure participation from diverse socio-economic and cultural groups within each village to mitigate the potential for bias during the survey.

The sampling was conducted around Kuno NP and Gandhi Sagar WLS to examine social dynamics and understand local communities, their livelihoods, dependence on forests, traditional knowledge, and attitudes towards wildlife. More than 40 villages and settlements within a 5 km radius of the Kuno NP boundary were surveyed (Figure 6.1.1.), while 11 villages and settlements around Gandhi Sagar WLS were surveyed (Figure 6.1.2.).

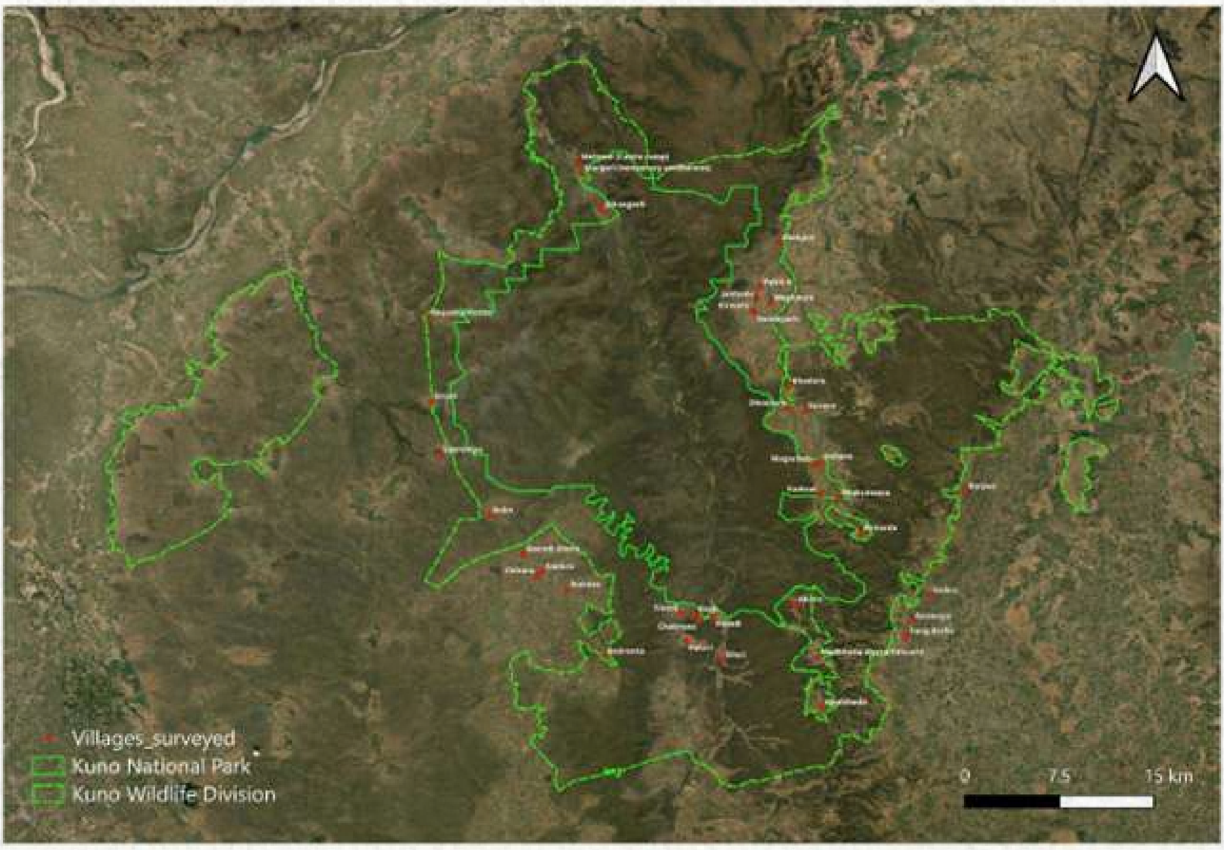


Figure 6.1.1.
Location of the surveyed villages around Kuno National Park

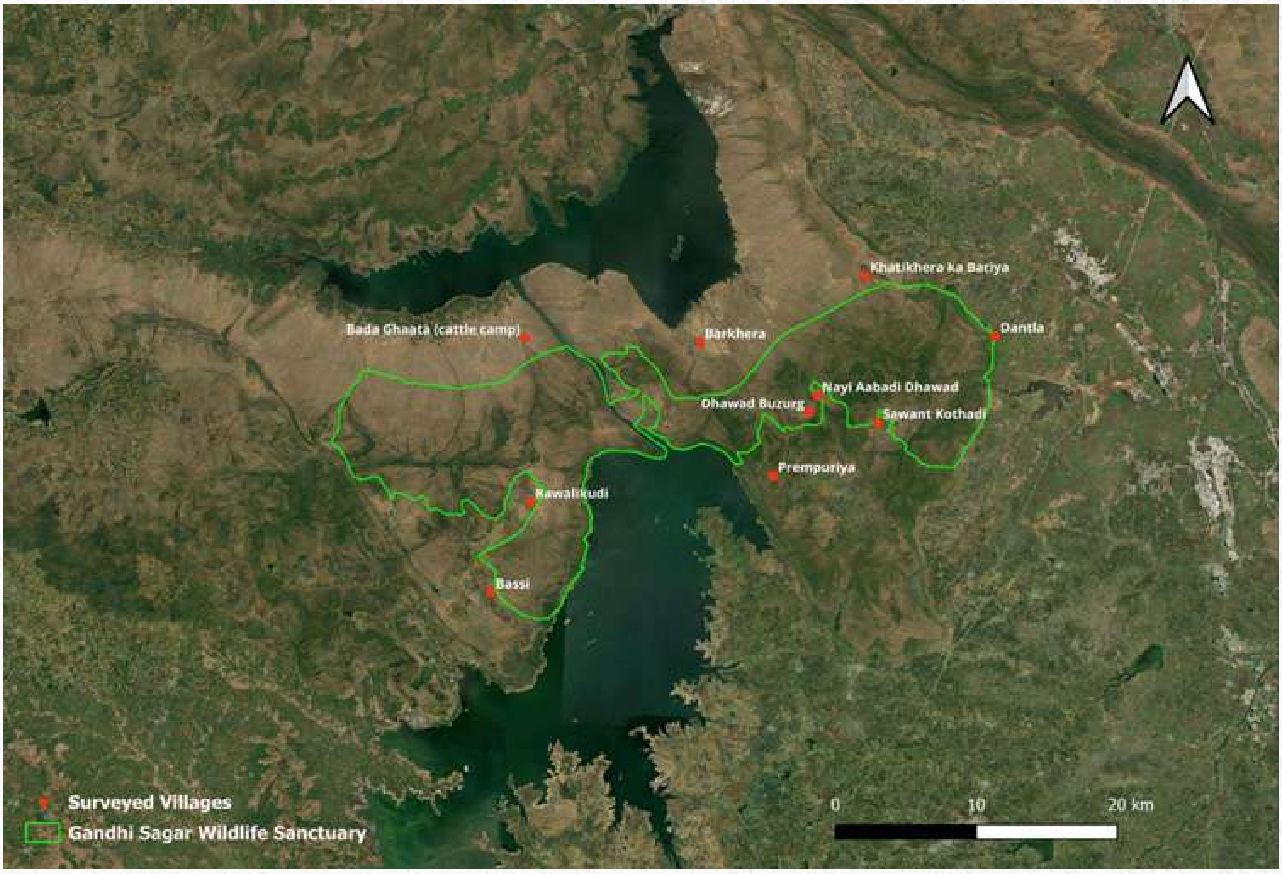


Figure 6.1.2.
Location of the surveyed villages around Gandhi Sagar Wildlife Sanctuary

6.1.1.2 Results

6.1.1.2.1. KUNO LANDSCAPE

The Kuno Wildlife Division, located in the Sheopur district (recently adjacent forest areas of Shivpuri District were added) of Madhya Pradesh, includes Kuno NP and its surrounding buffer zones. The landscape is characterized by dry deciduous forests and open savannah patches, providing a suitable habitat for various species. The PA emerged as the most suitable site among the ten evaluated for cheetah introduction in India, owing to its ecological viability. In September 2022-23, 20 cheetahs were translocated from Namibia and South Africa and released in India at Kuno NP. As the cheetahs adapt to Indian conditions and their population establishment is underway in Kuno NP, it is essential to consider the tribal and agro-pastoral communities inhabiting the landscape to promote peaceful co-occurence.

6.1.1.2.1.1. COMMUNITIES

As of the 2011 census, 23.5% of the population in Sheopur district comprises Scheduled Tribes, predominantly the Saharia. The Saharia constitute a Particularly Vulnerable Tribal Group (PVTG) mostly residing in the border districts of Madhya Pradesh and Rajasthan, with a minor presence in Uttar Pradesh. They constitute the numerically dominant population in the settlements adjacent to the PA. The other principal communities in the region include Gurjar, Yadav, Dhakad, Jatav, Kushwah, and Rawat.

While few in number, more tribal groups such as the Bhil, Bhilala, and Patelia are also present. They had shifted to this region from the districts of Jhabua and Alirajpur in Madhya Pradesh. The Mogia tribe, historically known for animal tracking and hunting skills, has moved here from various areas of Rajasthan over time.

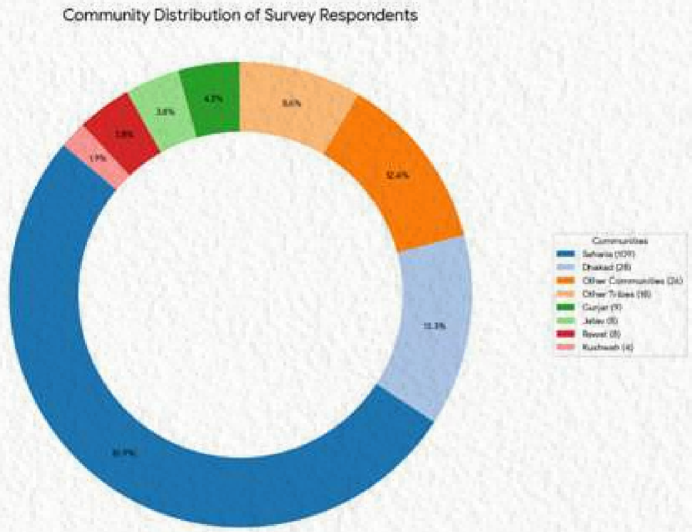


Figure 6.1.3.
Community composition in the villages surrounding Kuno National Park

6.1.1.2.1.2. EDUCATION AND LITERACY

Literacy and educational levels are important indicators of the socio-economic status of any population. In conservation initiatives, access to basic education or the lack thereof can impact a community's ability to engage with the cause and draw possible benefits.

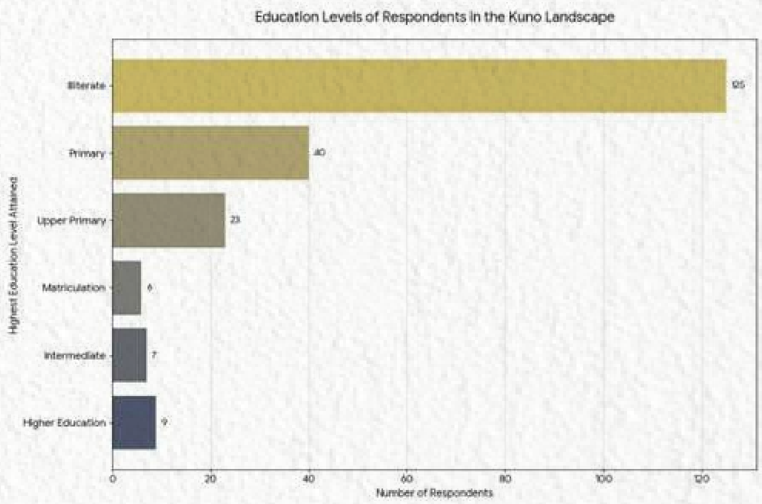


Figure 6.1.4.
Education levels of residents in the proximate villages of Kuno National Park

The responses from interview schedules conducted in the proximate villages of Kuno NP show that many respondents identified themselves as illiterate. The number of individuals with matriculation, intermediate, or higher education degrees is considerably lower, underscoring limited access and inclination towards formal education.

Although the trend of low education levels can be observed across communities, it is especially noticeable among the tribal communities in the Kuno landscape. The Saharia and the 'Other Tribes' category (Bhil, Bhilala, Patelia, and Mogiya) show the highest illiteracy rates, at ~70% and 72%, respectively.

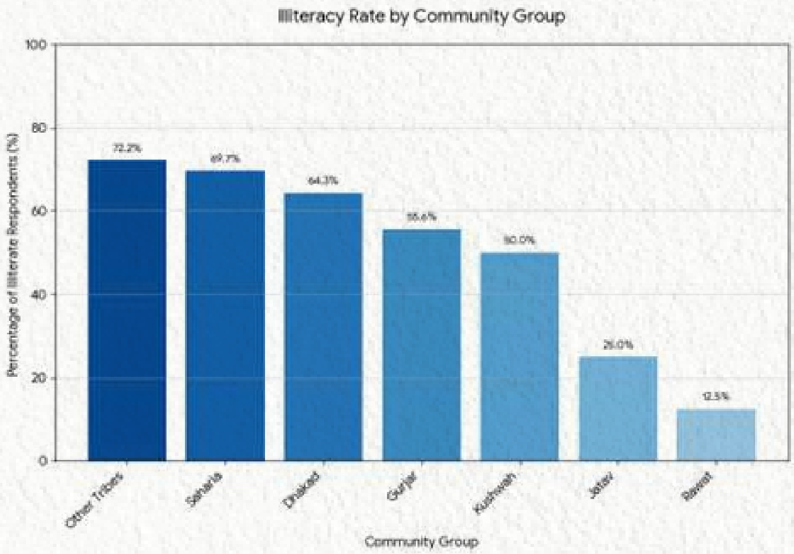


Figure 6.1.5.
Community-wise levels of literacy of the respondents in the vicinity of Kuno National Park

6.1.1.2.1.3. LIVELIHOOD

Agriculture is the region's most prevalent form of livelihood, followed by daily wages and animal husbandry. Most communities are engaged in agriculture at some level with ~69% of the respondents mentioned crop agriculture as their primary source of livelihood. The primary Kharif (monsoon) crops grown are pearl millet (Bajra) and sesame (Tilli), while the main Rabi (winter) crops are mustard (Sarso) and wheat (Gehu).

Communities like the Gurjars, Yadavs, Rawats, and Dhakads primarily engage in agropastoralism, engaging in both crop agriculture and livestock rearing. Most tribal communities in the region, *i.e.*, the Saharia, Mogiya, Bhil, Bhilala, and Patelia, also practice crop agriculture but depend on daily wage labour to earn their livelihood. The percentage of respondents who earn their livelihood primarily from daily wage labour is ~16%.

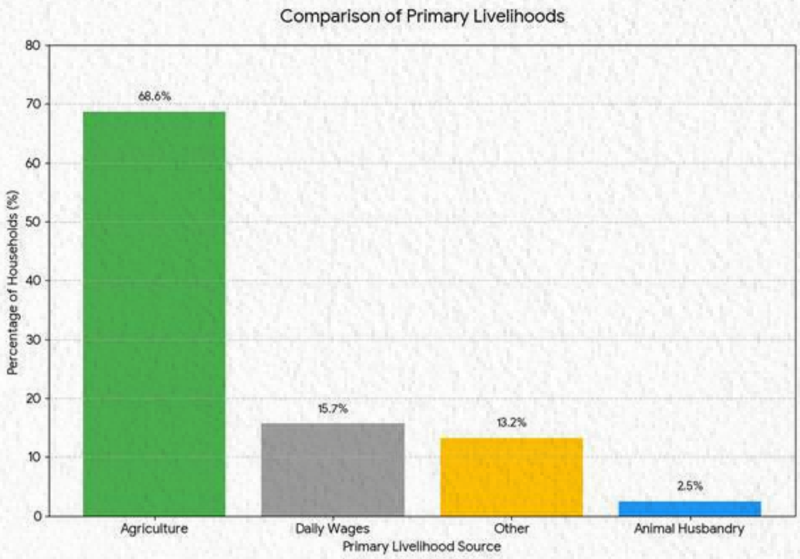


Figure 6.1.6.
A comparative plot of primary livelihood sources

Although crop agriculture is the primary source of livelihood for most communities in the region, instead of relying on just one source of livelihood, people here rely on multiple sources of livelihood. According to the responses received, ~52% of the respondents engage in daily wage labour as one of their livelihood options, making it a key economic activity for more than half the households. NTFP collection provides a supplementary source of income for ~21% of households. Meanwhile, ~16% of the respondents have reported animal husbandry or selling dairy/poultry as one of their livelihood sources.

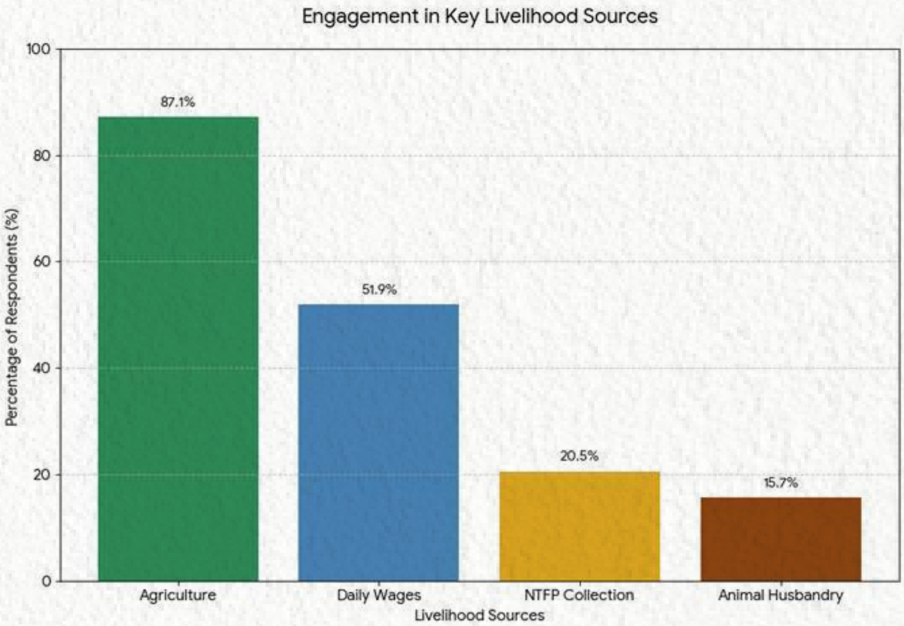


Figure 6.1.7.
Percentage of respondents engaging in the four key livelihood activities, including primary or secondary sources (Note: The percentages add up to more than 100% because most households engage in multiple activities)

6.1.1.2.1.4. DEPENDENCY ON FOREST RESOURCES

Any forested landscape is often home to communities dependent on their immediate surroundings for their subsistence. From fuelwood for cooking to collecting gum resins, fruits, and tubers, local communities living close to forests collect various forest products to meet their needs. This also applies to the people living in villages/settlements within the Kuno Wildlife Division.

Most of the (94%) households collect fuelwood from the forest, making it the primary cooking and heating energy source. Although there are restrictions on wood cutting/lopping and most people only collect dead dry wood, the dependence on fuelwood is the most significant and consistent interaction between the communities and the wildlife division's resources. It is a key area for management intervention to reduce habitat degradation.

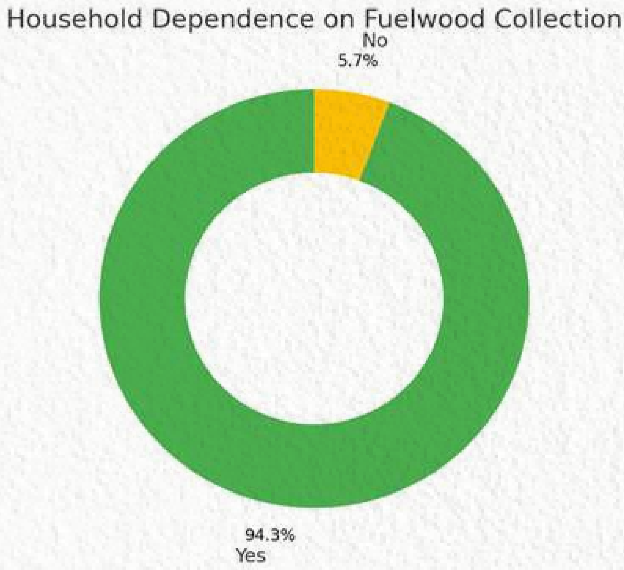


Figure 6.1.8.
Proportion of households dependent and non-dependent on dry wood as a source of cooking/heating

6.1.1.2.1.5. NON-TIMBER FOREST PRODUCTS (NTFPS)

NTFPs are a crucial supplementary livelihood strategy for many households, especially the Saharia. These products serve both subsistence and commercial purposes. Key NTFPs collected in the surveyed area are mentioned in Table 6.1.1.

Table 6.1.1.
Non-Timber Forest Products (NTFPs) collected by the local people living around Kuno National Park

Local Name	**Scientific Name**	**Product Collected**
Tendu Patta	*Diospyros melanoxylon*	Leaf
Chir Gond	*Boswellia serrata*	Resin/Gum
Khair Gond	*Senegalia catechu*	Resin/Catechu
Kakora	*Momordica dioica*	Fruit (Spiny Gourd)
Amla	*Phyllanthus emblica*	Fruit (Indian Gooseberry)
Mahua	*Madhuca longifolia*	Flowers & Seeds
Ber	*Ziziphus mauritiana*	Fruit (Indian Jujube)
Sitawar/Bilaiya	*Asparagus racemosus*	Root
Ganger	*Grewia tenax*	------
Pawar	*Senna tora*	Seeds
Bael	*Aegle marmelos*	Fruit

Collection is often a whole-family activity, and the income generated, while small, is critical for meeting household needs, particularly when agricultural income is low. The management of NTFP collection is a key area for potential collaboration between the Forest Department and local communities.

6.1.1.2.1.6. HUMAN-WILDLIFE INTERACTION

The Palpur-Kuno Wildlife Sanctuary housed several human settlements until around two decades following its establishment in 1981. The Saharia tribe, mostly engaged in hunting and gathering, generally resided in these villages alongside other caste groups, specifically the Kushwah, Jatav, Gurjar, and Yadav. Generations of these forest-dwelling societies have maintained a profound connection with the surrounding wilderness, having historically depended on the forest and continuing to rely on it to differing extents. Engagements with wild fauna are important to the existence of human groups residing in such environments. Proximity to a PA often leads to wild species moving through human habitats. Additionally, the local populace's regular excursions to the forest for fuelwood and forest resources frequently result in encounters with wildlife. Comprehending the dynamics of these interactions within the current context and the local beliefs that influence them is essential for fostering coexistence between humans and wildlife.

6.1.1.2.1.6.1. CROP DEPREDATION

Damage to crops due to various natural phenomena is a widespread concern for farmers across India. Although the main factors leading to crop loss are weather and pests, it remains one of the main human-wildlife interactions reported by communities residing and practicing close to PAs. According to respondents, stray/feral cattle were chiefly responsible for crop loss. Farmers invest significant time and resources in guarding their fields, often with limited success. The economic losses incurred can be substantial for subsistence farmers.

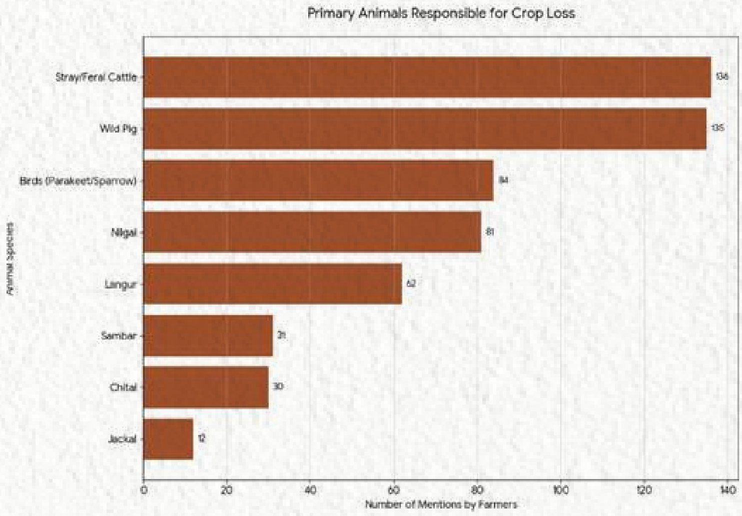


Figure 6.1.9.
Primary animals responsible for crop loss

Most farmers employ traditional methods to protect their crops, including dead hedges (thorn fencing), stone boundary walls, night-long guarding, and traditional slingshots/catapults known as gopiya to scare away birds. The sheer number of wild animals can render many of these methods ineffective against persistent ungulates like nilgai, wild pigs, and even stray/feral cattle. This can at times become a major cause of frustration and economic hardship.

6.1.1.2.1.6.2. LIVESTOCK PREDATION

While less frequent than crop raiding, the loss of livestock to carnivores represents a severe economic blow to households. The survey data indicate that the leopard is almost unanimously identified as the primary predator responsible for killing livestock, particularly goats and calves. This perception regarding leopards is a management challenge. It directly impacts local tolerance for large carnivores, a sentiment that could be transferred to cheetahs.

Respondents consistently identified large carnivores as their primary concern when asked about safety and threats from wildlife. The fear of leopards and sloth bears significantly influences how people use the landscape, often restricting movement after dark and creating anxiety. The introduction of the cheetah adds another large carnivore to this mix. While there has been no recorded instance of cheetahs attacking a human, their presence could heighten existing fears due to a lack of awareness. Proactive and transparent communication about cheetah behaviour is essential to pre-emptively address these anxieties and prevent the spread of misinformation. Most respondents stated they possess melee weapons (sticks/axes) as a safety measure, indicating a need for awareness campaigns on safe practices during wildlife encounters.

6.1.1.2.2. GANDHI SAGAR LANDSCAPE

A pilot social survey was conducted in eleven villages/settlements on the periphery of the Gandhi Sagar Wildlife Sanctuary to gain preliminary insights about the livelihoods, forest dependency, and perceptions of the local people towards wildlife. Nine of these settlements are in the Mandsaur District of Madhya Pradesh, while the remaining ones lie in Chittorgarh District, Rajasthan.

6.1.1.2.2.1. COMMUNITIES

Much like the fringe villages of the Kuno NP, the composition of communities in villages around Gandhi Sagar WLS is also a mix of agropastoral communities and erstwhile hunter-gatherer tribes. Here, communities primarily engaged in agropastoralism are Rebari, Gurjar, Charan, Rawat/Meena, Banjara, Jat, Thakur, and Dhakad. Meanwhile, the Bhil, commonly called "Bhil Thakurs," is a prominent tribal group in the region.

6.1.1.2.2.2. LIVELIHOOD

Crop agriculture and livestock rearing are the two primary livelihood sources for the region's communities. Rice, maize, soybeans, and urad are some Kharif crops that people grow here. Wheat, mustard, coriander, and gram are the major Rabi crops. Locals engaged in livestock rearing sell milk and other milk products to dairies in the urban centres of Bhanpura and Kota. Milk solids, commonly known as mawa, are prepared by many households across communities and then sold to sweet shops in Kota.

Apart from agropastoral activities, daily wage labour is another important source of livelihood for the people. Dependence on NTFP collection for supplementary income is primarily limited to the Bhil community in the landscape.

6.1.1.2.2.3. DEPENDENCY ON FOREST RESOURCES

Almost all the interviewed respondents have reported having some dependence on dry wood as a source of cooking/heating fuel. Apart from fuelwood, some of the other forest products that the locals collect are mentioned in Table 6.1.2.

Table 6.1.2.
Non-Timber Forest Products (NTFPs) collected by the people living around Gandhi Sagar Wildlife Sanctuary

Local Name	Scientific Name	Product Collected
Tendu Patta	*Diospyros melanoxylon*	Leaf
Dhawda Gond	*Terminalia anogeissiana*	Resin/Gum
Khair Gond	*Senegalia catechu*	Resin/Gum
Amla	*Phyllanthus emblica*	Fruit (Indian Gooseberry)
Naharkanta	*Asparagus racemosus*	Root
Karamdha	*Carissa spinarum*	Fruit/berry
Safed musli	*Chlorophytum borivilianum*	Root/tuber

6.1.1.2.2.4. HUMAN-WILDLIFE INTERACTION

Human-wildlife interaction around Gandhi Saga WLS mostly occurs in agricultural fields or near the edge of the village boundaries, where wild animals venture. According to the locals, ungulates like the wild pig and Nilgai are primarily responsible for crop damage, followed by stray/feral cattle. As the region sees a lot of in-migration of the pastoralist Rebari community from western Rajasthan, considerable crop damage is caused by their sheep herds as well.

As far as livestock depredation is concerned, the leopard is the primary predator in the region. Until a few years ago, the PA was under a lot of grazing pressure from livestock with leopards used to preying on them and multiple human settlements located very close to the Sanctuary enhance the chances of human-wildlife encounters.

6.1.1.3. Conclusion

6.1.1.3.1. LIVELIHOOD-SPECIFIC COMMUNITY OUTREACH AND AWARENESS

In addition to general awareness and outreach efforts, targeted campaigns are required for the setting of the cheetah project. The greater cheetah landscape encompasses a vast region inhabited by culturally and socially different human societies, necessitating the customization of community involvement to align with specific livelihood groups within the cheetah landscape. For the majority of crop agriculture-dependent households, outreach can be combined with tangible assistance to alleviate crop damage caused by wildlife and stray livestock. This would alleviate their most pressing economic issues. For pastoralist cultures such as the Gurjar and Yadav, dependent on animal husbandry, the concerns of livestock depredation must be prioritized. Likewise, for the Saharia community, whose members often venture into the forest for non-timber forest product collection, awareness should emphasize forest safety and the differentiation of cheetah behaviour from that of more feared carnivores, such as the sloth bear and leopard, which have been documented to attack humans in some cases resulting in physical harm. The project can foster confidence and illustrate a sincere cooperation by integrating cheetah awareness within the framework of these particular socioeconomic concerns.

6.1.1.3.2. TURNING CHEETAH INTO A SYMBOL OF PRIDE AND PROSPERITY

To ensure the long-term success of the cheetah introduction, it is imperative to convert the animal from becoming a potential perceived problem into a concrete advantage for the local populace. Instilling a feeling of regional pride and distinct identity among the people of the cheetah landscape will be imperative. This pride should be associated with improved livelihood opportunities, economic advancement, and consequently, affluence. The concept of eco-tourism must result in immediate, fair economic advantages. This encompasses expanding the training and employment of local youth as cheetah trackers, safari drivers, and wildlife guides. Community-operated homestays in villages with access gates can be incentivized, generating possibilities for people in the hospitality sector. By diversifying income streams and moving away from dependence on agriculture and daily salaries, the cheetah conservation will lead in economic development and social advancement as envisioned.

6.1.1.4. Future Outlook

It is accurate to assert that we have only begun to explore the human dimensions of cheetah introduction. Communities in the surroundings of Kuno NP and Gandhi Sagar WLS have participated in sociological surveys to facilitate the implementation of focused outreach and awareness initiatives aimed at securing local community cooperation through concrete incentives. The survey conducted in the peripheral villages of Gandhi Sagar WLS was merely a pilot study aimed at obtaining basic insights; hence, a comprehensive sociological investigation employing a robust research technique similar to that of the Kuno survey would be executed in the subsequent field cycle. Future sociological surveys will be conducted as new sites emerge, progressively encompassing the entire contiguous greater cheetah landscape.

6.2. Community engagement in Kuno National Park

Kuno NP management regularly carries out community outreach in the surrounding villages in the periphery of the PA, in partnership with two NGOs, Last Wilderness Foundation (LWF) and The Corbet Foundation (TCF). The following are some community outreach projects done in the past year:

1. Cheetah mitras: Around 400 cheetah mitras have been identified in nearly 70 villages, and the number is expected to increase as the coverage extends to more villages.
2. Cheetah mitra sammelan: Feb 18th, where more than 100 cheetah mitras participated.
3. More than 75 local villagers have been trained in cheetah monitoring, and they are employed in cheetah tracking duty when cheetahs are released in free-ranging condition.
4. Around 10 people from the tribal community were trained in vehicle driving to provide them with skill sets for livelihood opportunities.
5. School and hostel admissions for tribal children-around 300 enrollments last year.
6. Celebration of Wildlife Week with painting competitions, quizzes, and other engagement activities for school children.
7. Anubhuti camps for school children: Around 16 camps were conducted in which 1796 children from 26 different government schools participated and were given exposure to the forest and its importance.
8. Forest fire awareness and outreach in villages surrounding Kuno NP.
9. More than 20 people from the local community were trained as nature guides for safaris, nature trail walks, bird identification, tree identification, *etc*.
10. More than 55 farmers of the voluntarily relocated village Bagcha were trained in sustainable farming initiatives and introduced to soil testing and other modern agricultural techniques to choose a suitable crop for cultivation.

6.3. Outreach and awareness activities in Gandhi Sagar Wildlife Sanctuary

6.3.1. Capacity building in Gandhi Sagar Wildlife Sanctuary

As a capacity-building measure, grassland management training was organized by the state forest department to employ better practices in grassland management. Additionally, all the field staff were sent to Kuno NP for training and capacity building in cheetah management. Smartphones were distributed to the field staff as part of the implementation of technology-enabled patrolling using the mobile app of the MSTrIPES (Monitoring System for Tigers – Intensive Protection and Ecological Status) monitoring tool, and a training session about using the app for data collection was conducted.

Image 6.3.1. Training session on grassland improvement in Gandhi Sagar Wildlife Sanctuary © MPFD

Image 6.3.2. Smartphone distribution to field staff for technology-enabled patrolling using the mobile app of MSTrIPES tool © MPFD

6.3.2. Outreach and awareness in Gandhi Sagar Wildlife Sanctuary

Awareness and outreach campaigns were conducted regularly to sensitize local communities by the M.P. Forest Department. In May 2025, a Charwaha Sammelan (Pastoralists meet) was organized in the Sanctuary. The objective of this program was to spread awareness and increase participation of the pastoralist community in wildlife conservation.

Image 6.3.3. Charwaha Sammelan (Pastoralists meet) in Gandhi Sagar Wildlife Sanctuary © MPFD

The Madhya Pradesh Forest Department regularly conducts the Anubhuti Program for nature sensitization and experience. Around 505 students of high and higher secondary schools (through 04 events with 125 students in each) situated in the vicinity of the park have been given exposure visits to the forest area with a full-day awareness program on the cheetah introduction in Gandhi Sagar WLS.

Image 6.3.4. Anubhuti camp for school children in Gandhi Sagar Wildlife Sanctuary © FD

To create awareness and sensitization about the forests and biodiversity among the local community members, particularly children living around the PA, and to make people aware of the need to protect forests, various programs were regularly carried out. The Park management, in collaboration with an NGO-Last Wilderness Foundation, has started outreach awareness activities in and around the Sanctuary. The activities include the celebration of Wildlife Week, International Cheetah Day, and International Tiger Day in all primary, middle, high, and higher secondary schools. Regular meetings with the Eco-development committee members, making them aware of the project, engaging local people in ongoing habitat development works, and employing locals for Suraksha Shramik and other activities.

The Park management in collaboration with NGO Last Wilderness Foundation, till now has covered 12 villages (15 schools and 3 Anganwadi) and completed 180 outreach awareness activities in and around the

Sanctuary. Last Wilderness Foundation organized a nature guide training for 22 local people and 16 programs on snakes and snakebite prevention around the periphery of the Sanctuary and carried out liaison work for local people to get the benefits of government schemes.

Image 6.3.5. Park management, in collaboration with the Last Wilderness Foundation and Wildlife Institute of India conducted community-based nature conservation program in Gandhi Sagar Wildlife Sanctuary © FD

6.4. Kuno-Gandhi Sagar cheetah metapopulation management landscape

6.4.1. Introduction

As proposed by the action plan, a metapopulation approach has been adopted for managing cheetahs across key conservation sites in central India (Jhala *et al.* 2021). The primary focus of this initiative is the integration of Kuno NP and Gandhi Sagar WLS, along with their surrounding forested landscapes, into a unified management framework. Located along the M.P.-Rajasthan border, the landscape is primarily located within the Chambal River basin, which offers a varied and ecologically rich habitat for cheetah conservation. Kuno NP maintains fragmented yet functional ecological connectivity with Gandhi Sagar WLS towards the southwest. This linkage is facilitated through a series of territorial forest divisions, namely Baran, Jhalawar, Kota, and Chittorgarh, along with the Mukundara Hills Tiger Reserve (TR) in Rajasthan and the Mandsaur forest division in Madhya Pradesh. Additionally, the northwest corridor enhances landscape integration through Ranthambore TR, Kailadevi WLS, Ramgarh-Vishdhari TR, and the forest divisions of Bundi and Bhainsrodgarh WLS in Rajasthan. These interconnected forest patches will play a critical role in supporting cheetah movement, habitat continuity, and long-term metapopulation management across the broader Kuno–Gandhi Sagar landscape. These forest patches cumulatively cover an area of ~17,000 km^2 in M.P. (Area ~10,500 km^2) and Rajasthan (Area ~ 6,500 km^2). The Kuno–Gandhi Sagar landscape spans multiple districts across two states with a small portion in Uttar Pradesh. It includes Sheopur, Shivpuri, Gwalior, Morena, Guna, Ashoknagar, Mandsaur, and Neemuch Districts in M.P. In Rajasthan, the landscape encompasses the districts of Baran, Sawai Madhopur, Karauli, Kota, Jhalawar, Bundi, and Chittorgarh. In addition to the core districts currently encompassed within the Kuno–Gandhi Sagar cheetah landscape, several adjacent regions are being considered for future inclusion based on cheetah movement patterns and habitat utilization. These include the districts of Bhind and Datia in M.P, Dholpur in Rajasthan, and Lalitpur and Jhansi in Uttar Pradesh. Their incorporation into the broader conservation landscape will be contingent upon cheetah movements and ecological assessments, ensuring adaptive management aligned with species behavior and habitat connectivity.

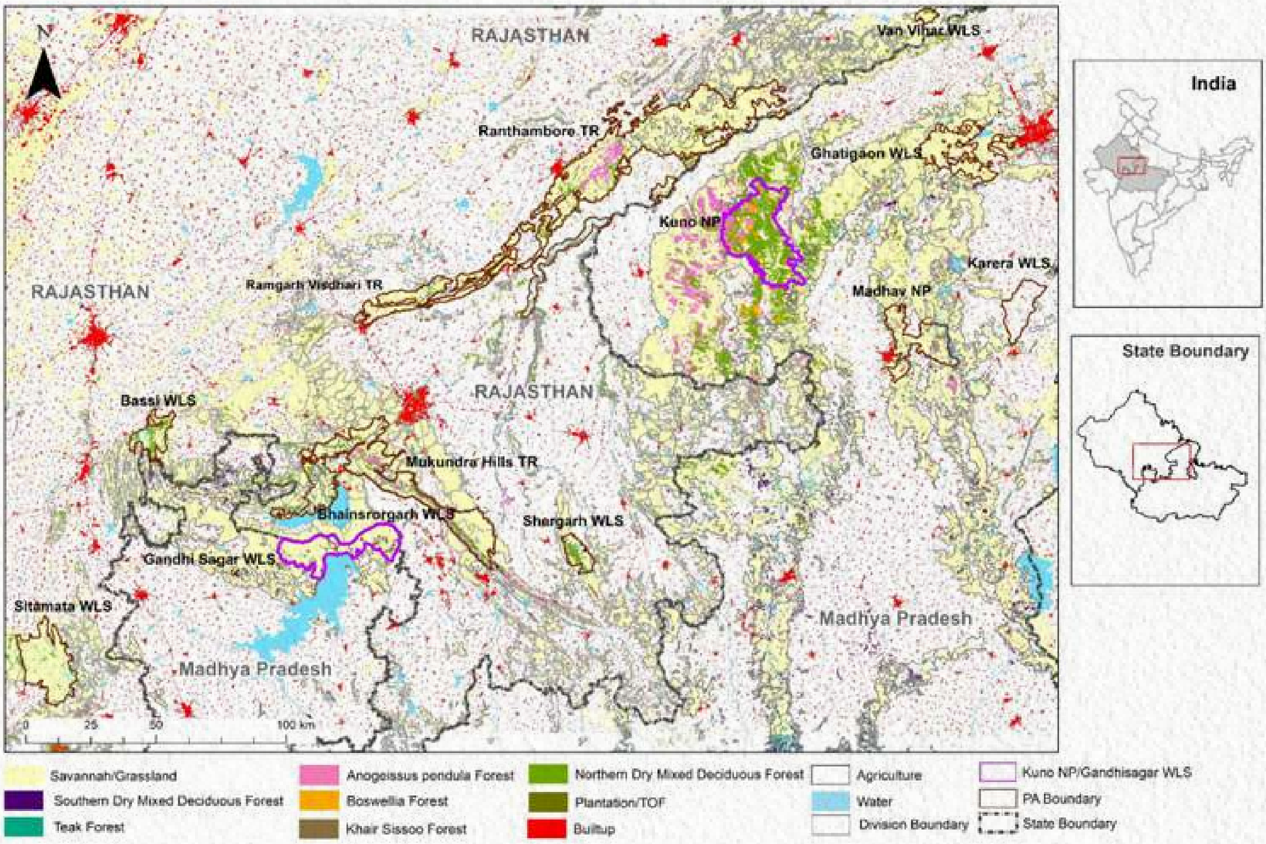


Figure 6.4.1.
Map of Kuno-Gandhi Sagar cheetah metapopulation landscape in the States of Madhya Pradesh, Rajasthan and Uttar Pradesh

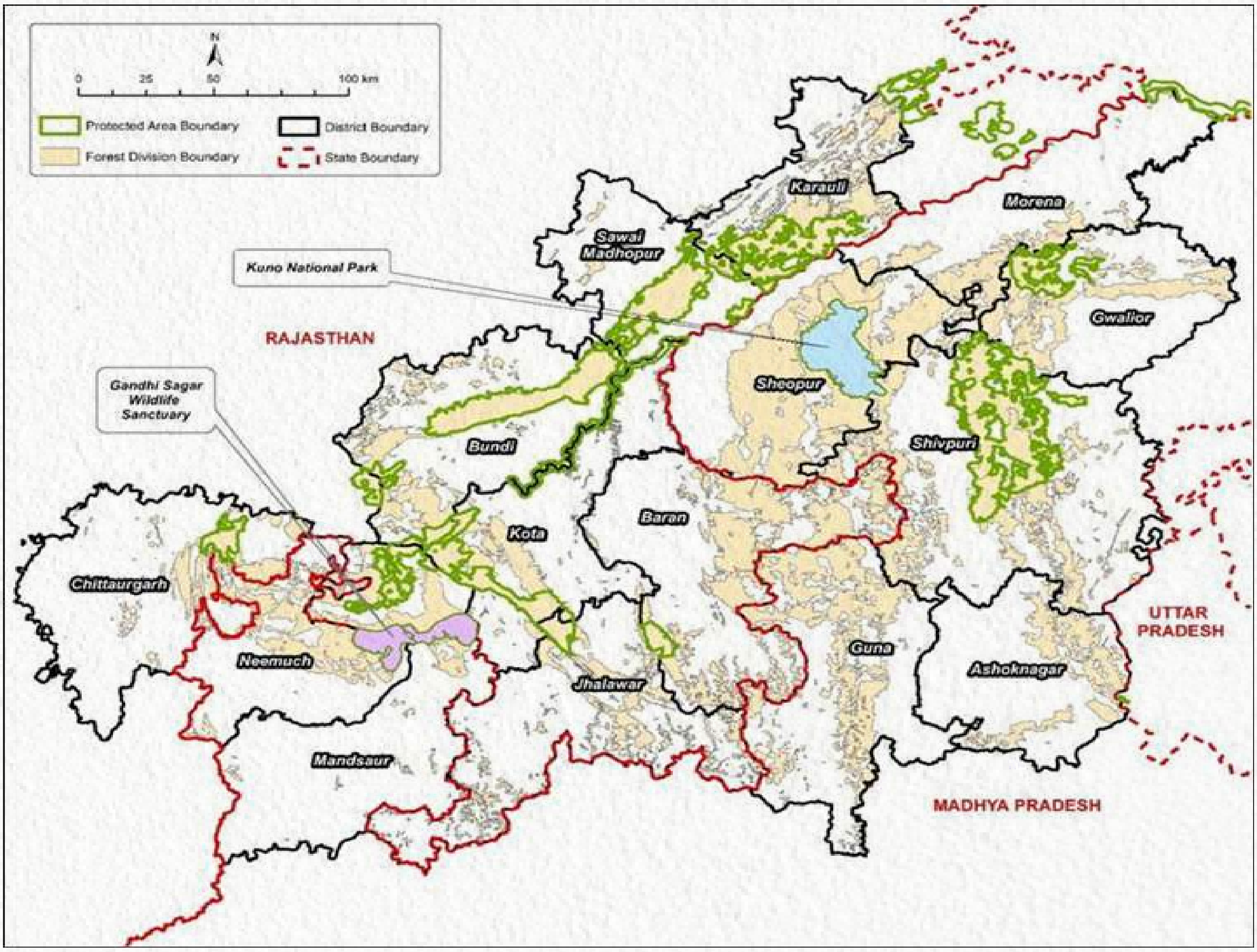


Figure 6.4.2.
Protected Areas situated in the Kuno-Gandhi Sagar cheetah metapopulation landscape

The Protected Areas situated in the landscape are National Chambal WLS, Ghatigaon WLS, Gandhi Sagar WLS, Orcha WLS, Kuno NP, Madhav TR, Shergarh WLS, Ramgarh-Vishdhari TR, Bassi WLS, Bhainsrodgarh WLS, Mukundara Hills TR, Shahbad Conservation Reserve (CR), Shahbad CR, Sorsan CR, Banjh Amli CR, Ummedganj Pakshi Vihar CR, Ramgarh CR & Ranthambore TR Divisions I & II.

6.4.2. Requirements in Kuno-Gandhi Sagar cheetah metapopulation landscape

Specific requirements for managing the Kuno-Gandhi Sagar cheetah metapopulation landscape are as follows:

Multisectoral Masterplan: A comprehensive, integrated masterplan should be developed to ensure effective coordination between the Forest Department and relevant government sectors, including district administration, law enforcement, agriculture, revenue, animal husbandry, fisheries, transportation, and rural development. The master plan should incorporate clearly defined legal, administrative, and financial mechanisms for implementation and long-term monitoring, with explicitly delegated institutional roles and accountability frameworks to ensure inter-departmental cohesion and operational efficacy.

Water Resource Management: Water availability constitutes a potentially limiting ecological resource during the dry season. Management interventions should therefore ensure a minimum spatial distribution of artificial water sources, with at least one water point available within a 4 km radius of another across the drier zones of Protected Areas and the broader landscape matrix. Such measures are anticipated to enhance prey species utilization of these areas and augment the overall carrying capacity of the landscape for target wildlife populations.

Grassland Management: Active habitat management interventions are required to suppress woody encroachment and maintain open grassland structure. The preservation and restoration of grassland habitats are critical for sustaining the natural prey base essential for cheetahs, leopards, wolves, caracal and other endangered wildlife occurring within the region.

Landscape Management Strategy: A landscape-scale management framework, modelled on guidelines established by the National Tiger Conservation Authority (NTCA), should be adopted and contextually adapted for implementation across the study landscape. Core components of this framework should include habitat restoration along with the provision of livelihood incentives and economic benefits for resident communities residing within and adjacent to PAs, the establishment of prompt and equitable compensation mechanisms for livestock depredation attributable to wildlife, the development and implementation of proactive strategies to mitigate adverse human-wildlife interactions, and the regulation and curtailment of high-impact infrastructure development and industrial activities within ecologically sensitive zones to minimize habitat degradation and landscape fragmentation.

6.4.2.1. Kuno landscape

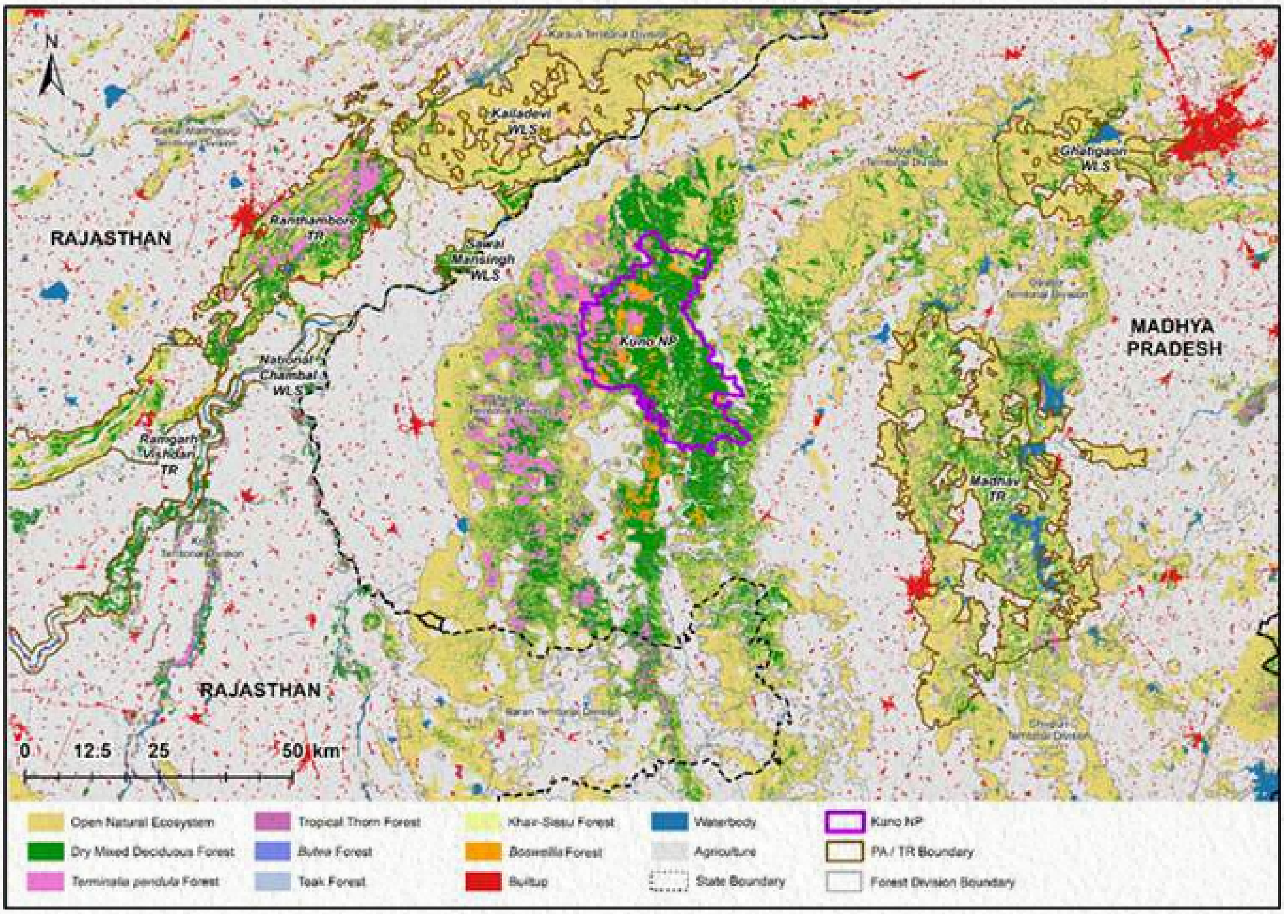


Figure 6.4.3.
Map of Kuno landscape depicted with various land use/land cover categories

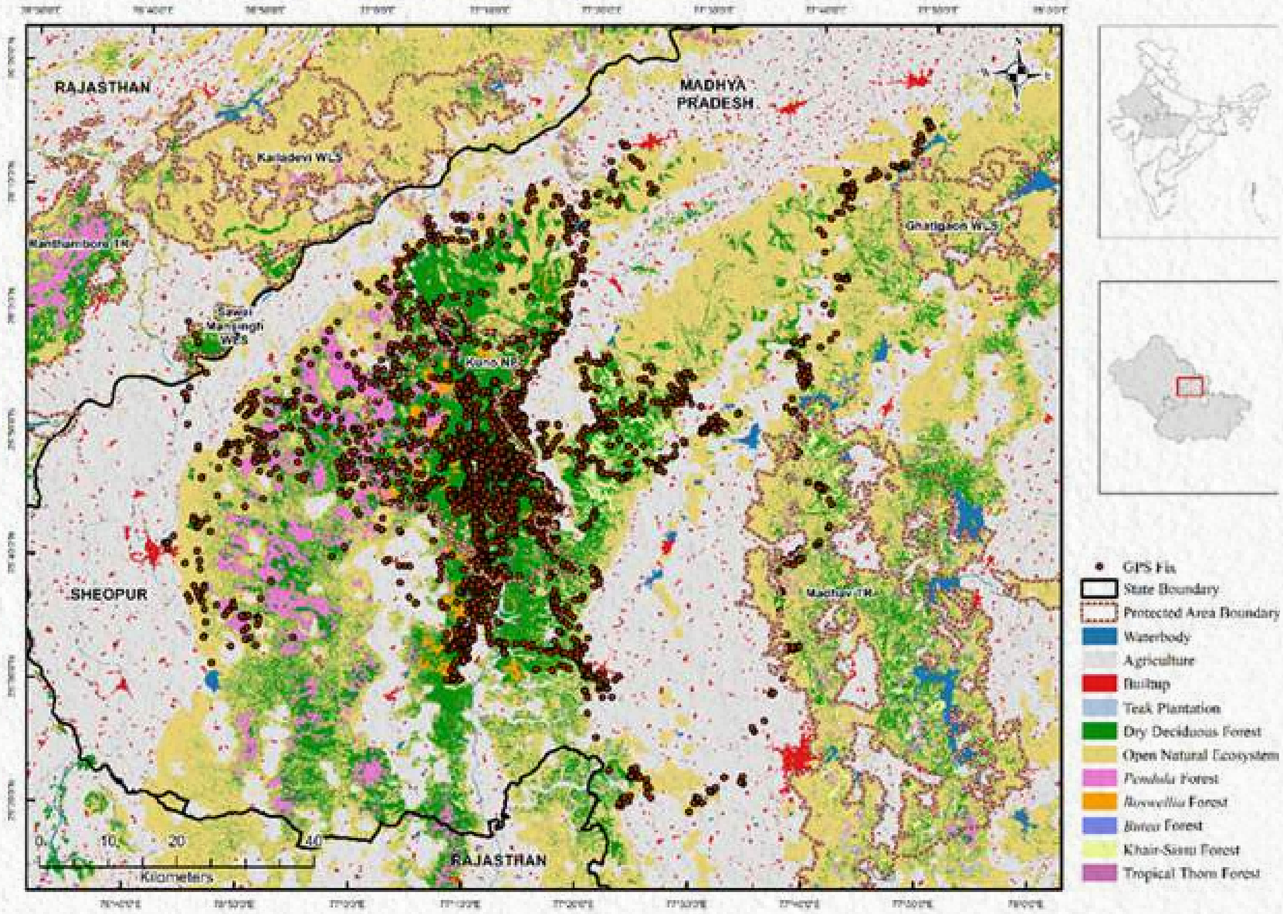


Figure 6.4.4.
Map of cheetah movement in Kuno landscape

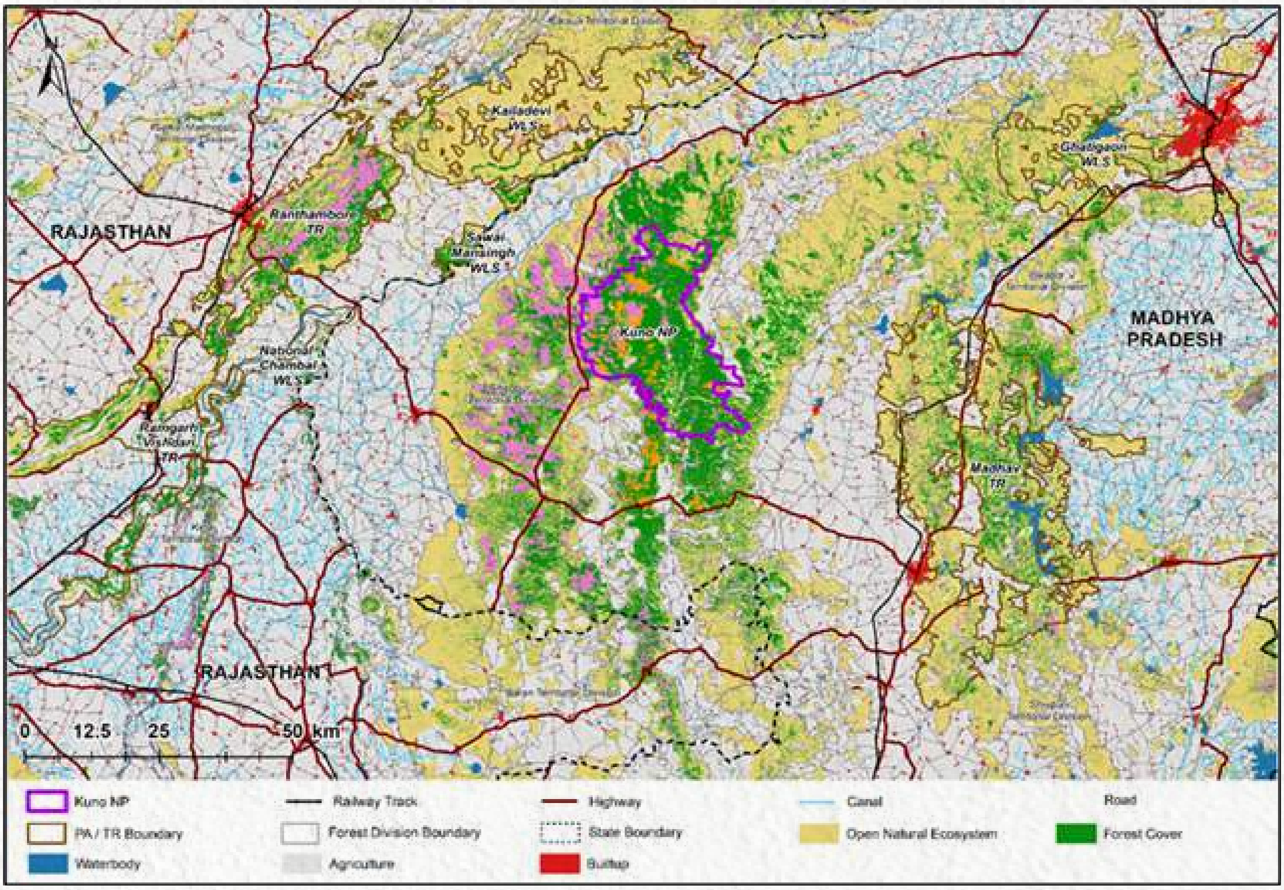


Figure 6.4.5.
Map of Road and Railway network in Kuno landscape

6.4.2.2. Gandhi Sagar landscape

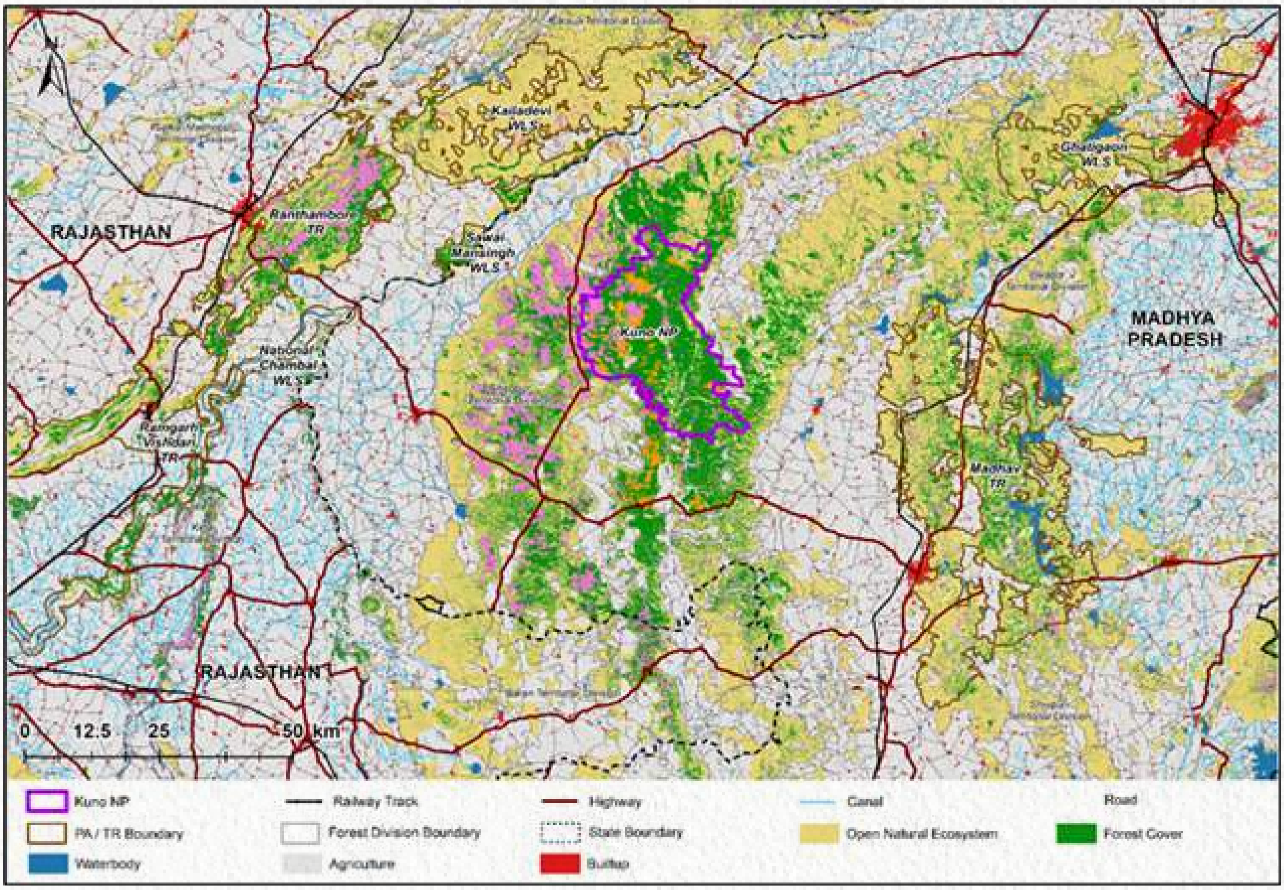


Figure 6.4.6.
Map of Gandhi Sagar landscape depicted with various land use/land cover categories

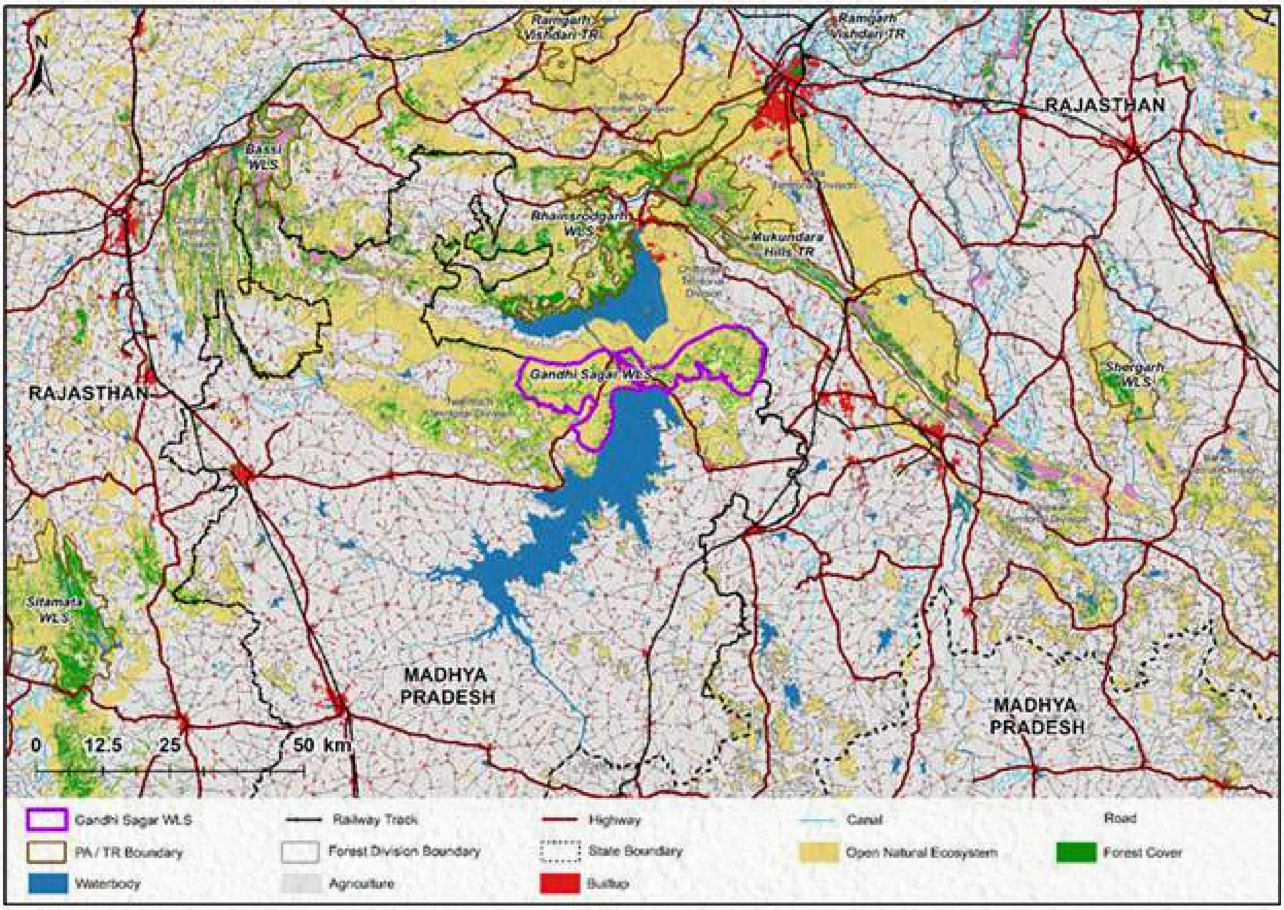


Figure 6.4.7.
Map of Road and Railway network in Gandhi Sagar landscape

6.5. Preparation of integrated landscape management plan for establishing viable cheetah metapopulation in India

6.5.1. Components of district profile

In line with the Sustainable Development Goals (SDGs), the Integrated Landscape Management Plan aims to balance biodiversity conservation with socio-economic development and climate resilience. The framework of this management plan includes various components, but before moving onto the objectives, addressing critical issues, and arriving at management recommendations, provides a brief outline of 16 districts of the landscape. This district-wise information includes important attributes starting from demographics to data on socio-economic scale and biodiversity. Collecting accurate and fine-scale data on a district level from various sources is extensive and prolonged. So far, district profiles of 5 districts, *i.e.*, Sheopur, Mandsaur, Neemuch, Gwalior, and Shivpuri, have been prepared. In each district profile, 18 attributes were decided to be incorporated and Table 6.5.1. shows the information provided for each attribute.

Table 6.5.1.
District profile attribute table

Attributes	Information given
1. General Information	Contains geographical information such as the area, formation, communities and the neighbouring districts. It also describes the number of sub-districts/ Community Development (C. D.) blocks, towns, and villages the district holds.
2. Geography and Environment	Provides the location, terrain, and describes the natural water resources (rivers) and catchment area.Aspects of the climate is briefly outlined with rainfall and temperature.
3. Demographics	This section discusses the statistics of population. It describes the total number and percentage of residents, male and female residents, population of children under 6 years of age, male and female literacy, urban and rural divide, and religious data of the district. It also discusses the population growth experienced by the district from 2001 to 2011 and the population density as of 2011.
4. Economy and Livelihoods	Emphasizes the working population of the district. Some of the districts, like Sheopur and Mandsaur, have a majority of workers in the agricultural industry. It also gives the number and percentage of main workers, marginal workers, and non-workers. It mentions the proportion of the female population participating in the working population of the district.The section provides a number of Scheduled Tribe (ST) communities that are housed by the district.
5. Infrastructure	Comprises linear infrastructure, which includes roads, railways, and canals. The presence of the river systems, natural waterways that complement the infrastructure network. Mobile coverage, electricity, drinking water sources, housing and sanitation, and fuel for cooking.
6. Agriculture and Irrigation	Number and percentage of the workers engaged in the agricultural industry under two categories, *i.e.*, agricultural labourers, and cultivators. The section mentions the principal crops of 2012, the net sown area, the total cultivable area, the net irrigated area, and sources used for irrigation, such as dug wells, tube wells, and so on. Finally, it also mentions the total area classified under agriculture and the total irrigated area.
7. Forest and Wildlife	The total forest area present in the district is given, along with the administrative units under which the forests are managed, such as NP,WLS or territorial division. In addition, the fauna present in the wildlife parks are detailed.
8. Health	Healthcare infrastructure, including Primary Health Centre (PHC), Community Health Centre (CHC), and hospital capacity. Overall medical services and especially in maternal and child health in tribal regions are provided..
9. Education and Literacy	The literacy rates of the residents are discussed. The number of male and female literates is compared. Similarly, a comparison between urban and rural literates is presented. Finally, the section mentions the number of schools and colleges/universities.
10. Public Services	Information on post offices, internet cafes, and public distribution systems. Banking services, mobile network areas, sanitation facilities, and the use of clean cooking fuel.
11. Industry and Employment	Number and percentage of persons for different categories of the working population, such as agricultural labourers, cultivators, household industry workers, and other workers. In addition, it also briefly states the employment opportunity generated by the micro- and small-scale industry sector in the district along with the one-district, one-product initiative.
12. Transport and Connectivity	Details of National and State highways, railway links, and canal systems. Public and private transport services, road quality, *etc.* Importance of the river systems contributing to the transportation network.
13. Culture and Heritage	Details on cultural and tourist attractions in the districts. Importance of tribal communities in protecting the heritage and helping the economy of the state and districts.

14. Administrative Setup	The numbers and names of the C. D. blocks, sub-districts, and constituencies are mentioned. Additionally, the number of inhabited villages and the total number of villages are also mentioned. Finally, the number of police stations present in the district is also mentioned.
15. Natural Resources and Utilities	Details the measure of groundwater using depth to water level for the month of November in the post-monsoon period. It also mentions the percentage of recharge-worthy area in the district and the amount of rainfall received in the year 2022. Finally, it mentions the names of the rivers that flow through the district.
16. Habitat and Landscape	Information on forest areas, protected zones, critical corridors, and the importance of conserving the habitat and shaping the landscape. Contribution of the PAs present in the district for sustaining the biodiversity and ecosystem.
17. Livestock and Poultry	There are a number of various poultry animals, such as cattle, buffalo, sheep, goats, and pigs. It also contains a combined total number of other livestock, which includes horses, ponies, mules, donkeys, and camels. Finally, the section contains the number of total poultry animals and total stray cattle and dogs.
18. Waste Management	Generation of solid waste and total solid waste (SW) generated in the district. SW collection and segregation, and information on dumping grounds. Outlet for wastewater drainage in both urban and rural districts.

All the information for the attributes mentioned in 6.5.1 was curated carefully and documented for each district. The Sheopur district profile mentioned below shares an idea of how the district profile data has been accumulated.

6.5.1.1. District profile of Sheopur district

1. GENERAL INFORMATION

Sheopur district, located in the northwestern part of Madhya Pradesh, spans an area of 6,605.68 km^2 and forms part of the Chambal division. It shares boundaries with the Morena and Bhind districts to the north, the Shivpuri district to the east, the Baran and Kota districts of Rajasthan to the west, and the Kota district further southwest, situating it at a strategic interface between Madhya Pradesh and Rajasthan. Administratively, Sheopur was carved out as a separate district in 1998, with Sheopur town serving as the district headquarters. The district is divided into three sub divisions/C.D. Blocks- Sheopur, Baroda, Karahal, Vijaypur and further into five tehsils/administrative units- Sheopur, Baroda, Karahal, Vijaypur and Beerpur (are also major towns) with a total of 585 revenue villages. According to the 2011 Census, the district has a population of 687,861, of which 77.37% reside in rural areas and 22.63% in urban areas, reflecting its predominantly agrarian and rural character. The Sahariya tribe, classified as a Particularly Vulnerable Tribal Group (PVTG), constitutes a significant proportion of the population, shaping the district's socio-cultural identity. Hindi is the principal language, though local dialects are widely spoken across rural settlements. The district's economy is largely dependent on agriculture, livestock, and forest-based livelihoods, while its ecological significance is underscored by the presence of Kuno National Park (NP), which has positioned Sheopur as a focal point for conservation at both state and national levels. Together, these attributes highlight Sheopur as a district where geography, demography, and ecology converge to create a unique socio-environmental landscape that requires integrated planning for sustainable development.

2. GEOGRAPHY AND ENVIRONMENT

The geography and environment of Sheopur district are defined by its location in the northwestern part of Madhya Pradesh, covering a total area of 6,605.68 km^2 between 25°15'N, 76°30'E and 26°15'N, 77°40'E. The district lies along the Vindhyan range, whose sandstone and shale formations shape its undulating terrain, rocky outcrops, and shallow soils. These geological features influence land use, vegetation patterns, and water availability, while also giving rise to the alluvial soils of the plains that sustain agriculture. Elevation ranges from a minimum of 145 m to a maximum of 517 me above mean sea level. The Vindhyan acts as a watershed, feeding the district's major rivers, *i.e.*, Chambal, Sip, and Kuno, which provide irrigation, drinking water, and ecological connectivity. The climate is marked by extremes, with mean maximum summer temperatures reaching 40°C and an overall peak of 47°C, while winters can drop to 3°C, making the district vulnerable to climatic stress, particularly in its rainfed agricultural zones. The annual average rainfall in the district is 720 mm. Ecologically, Sheopur is significant for housing Kuno NP (748.76 km^2), which, together with surrounding forests, grasslands, and riverine habitats, forms a critical conservation hub for species such as leopards, chinkara, nilgai, and the introduced cheetah. The rugged Vindhyan terrain also provides natural corridors that connect PAs across the larger Chambal-Kuno landscape, reinforcing its role in sustaining biodiversity. At the same time, the range shapes human settlement patterns and tribal livelihoods, with communities such as the Sahariya depending on forest resources for fuelwood, fodder, and non-timber forest products. However, pressures from overgrazing, deforestation, and soil erosion highlight the fragility of this environment. In essence, Sheopur's geography and environment are important not only for their natural resource base but also because the Vindhyan range serves as the ecological foundation that sustains agriculture, water systems, biodiversity, and human livelihoods, making its sustainable management central to balancing conservation and development in the district.

3. DEMOGRAPHICS

Sheopur district houses a total population of 6,87,861 people as per the 2011 Census, representing 0.95% of Madhya Pradesh's total population. The demographic composition shows 3,61,784 males (52.6%) and 3,26,077 females (47.4%), resulting in a sex ratio of 901 females per 1,000 males. The district experienced a robust population growth rate of 22.94% between 2001-2011, with population density standing at 104 persons per kilometer2. The urban-rural divide is pronounced, with 5,80,509 people (84.39%) residing in rural areas and 1,07,352 people (15.61%) in urban settlements. The child population aged 0-6 years is 1,16,63 (16.96%), with 61,490 male children and 55,149 female children, showing a child sex ratio of 897 females per 1,000 males. Educational attainment has shown significant improvement, with an overall literacy rate of 57.43% in 2011, compared to 46.40% in 2001. Male literacy stands at 69.33% while female literacy is 44.23%. The total number of literates in the district is 3,28,025, comprising 2,08,201 male literates and 1,19,824 female literates. Rural areas show a literacy rate of 54.47% while urban areas achieve 72.85%. The religious composition is predominantly Hindu, with 6,38,702 people (92.85%), followed by Muslims at 41,396 people (6.02%), Sikhs at 6,387 people (0.93%), Christians at 230 people (0.03%), Buddhists at 201 people (0.03%), Jains at 379 people (0.06%), and others comprising 40 people (0.01%).

4. ECONOMY AND LIVELIHOODS

The economy of Sheopur district is overwhelmingly agrarian, with livelihoods deeply tied to cultivation and agricultural labour. Out of a total workforce of 277,455 individuals, 106,745 are cultivators and 115,261 are agricultural labourers, together accounting for more than 80% of the working population. This heavy dependence on agriculture underscores the vulnerability of the district to climatic variability and resource constraints. Beyond agriculture, the workforce includes 4,166 household industry workers and 51,283 other workers, reflecting modest diversification into secondary and tertiary sectors. The labour force is further divided into 196,189 main workers and 81,266 marginal workers, while 410,406 people are classified as non-workers, highlighting the demographic pressure on productive employment. The district is also home to a significant tribal population, including the Sahariya and other Scheduled Tribes, whose livelihoods are closely linked to forests and non-timber forest products (NTFPs). Subsistence agriculture, wage labour, and forest-based livelihoods together form the economic base of these communities. While industrial employment remains limited, traditional crafts such as wooden toy-making and small-scale agro-processing provide supplementary income. Overall, Sheopur's economy reflects a predominantly rural and subsistence-oriented structure, where strengthening agricultural productivity, diversifying livelihoods, and integrating tribal communities into sustainable value chains are critical for enhancing resilience and reducing poverty.

5. INFRASTRUCTURE

The infrastructure profile of Sheopur district reflects a developing but uneven network of physical and social amenities that underpin both livelihoods and service delivery. The district's road network extends to 1,599.15 km across the blocks of Karahal, Sheopurkalan, and Vijaypur, forming the backbone of intra-district connectivity, while broader linkages are provided by the 8,772 km of national highways in Madhya Pradesh, of which Sheopur is a part. Railway connectivity remains limited, constraining large-scale passenger and freight movement, and canal infrastructure is present but localized, serving primarily irrigation needs. Mobile coverage and electricity have reached most villages, though reliability and quality of supply vary, particularly in remote tribal areas. Drinking water is sourced from hand pumps, wells, and piped systems, but coverage gaps persist, especially in rural settlements. Housing and sanitation infrastructure remain underdeveloped, with many households still dependent on traditional materials and lacking access to improved sanitation facilities. Similarly, reliance on biomass fuels for cooking continues to dominate, reflecting both affordability constraints and limited penetration of clean energy alternatives such as LPG. Overall, while Sheopur's infrastructure base provides essential connectivity and services, significant gaps remain in transport, sanitation, housing, and energy access, all of which require targeted investment to support inclusive development and reduce pressures on natural resources within the broader landscape.

6. AGRICULTURE AND IRRIGATION

Agriculture forms the backbone of Sheopur's economy, with the majority of the population dependent on farming and allied activities for their livelihoods. The district's agricultural profile is diverse, encompassing both food grains and horticultural crops. Principal crops include wheat, paddy, gram, jawar, bajra, tuar, and udad, which are cultivated across extensive tracts of land. Horticulture has also expanded, with 2,682 hectares under fruits producing 61,195 metric tonnes; 7,903 hectares under vegetables yielding 151,905 metric tonnes; 92 hectares under flowers producing 827 metric tonnes; 7,603 hectares under spices yielding 21,409 metric tonnes; 22 hectares under aromatic plants producing 8.8 metric tonnes; and 120 hectares under medicinal plants producing 407.5 metric tonnes. The net sown area is estimated at 1,575 km^2, while the net irrigated area is 1,422.37 km^2, and the gross irrigated area reaches 1,656.78 km^2, leaving about 938.14 km^2 as rainfed and unirrigated. Irrigation is supported by a combination of dug wells, tube wells, ponds, canals, and lift irrigation schemes, reflecting the district's reliance on both groundwater and surface water resources. The soils are predominantly alluvial and those derived from Vindhyan sandstone and shale, which influence cropping patterns and productivity. While rainfall averaging over 1,000 mm annually provides a crucial base for rainfed farming, variability in monsoon patterns makes irrigation infrastructure vital for stabilizing yields. Together, these attributes underscore the centrality of agriculture in Sheopur's socio-economic fabric, while also highlighting the need for sustainable water management and soil conservation to ensure long-term productivity and resilience in the face of climate variability.

7. FOREST AND WILDLIFE

Sheopur district administers a forest area of 3407.86 km^2 (FSI, 2023), which is almost 51% of the total area of the district and is notable for housing the prestigious Kuno National Park. The forest administration operates under two divisions: the Kuno Wildlife Division (Area~1777km^2) and the Sheopur Territorial Division. Kuno National Park, spanning 748.76 km^2, is home to diverse wildlife, including leopards, chinkaras, nilgais, and reintroduced cheetahs. Human-wildlife negative interactions and habitat change due to development are observed due to the co-occurrence of humans and animals. The Kuno River, flows through the core of the protected area, plays a pivotal role in enriching the biodiversity and maintaining the health of the ecosystem.

8. HEALTH

The health infrastructure of Sheopur district remains modest and faces significant challenges in meeting the needs of its largely rural and tribal population. The district has a network of nine primary health centres (PHCs), three community health centres (CHCs), One District Hospital and other private hospitals, with a reported capacity of around 5,150 hospital beds, yet service delivery is uneven and often constrained by shortages of staff, equipment, and medicines. A new Government medical college was recently inaugurated in Sheopur town. Mobile health units supplement fixed facilities, particularly in remote areas, but accessibility remains limited for many villages. Maternal and child health indicators highlight persistent vulnerabilities, especially among the Sahariya tribal community, where malnutrition and limited access to institutional healthcare are pressing concerns. Preventive healthcare, including immunization and awareness programs, has expanded in recent years, but gaps in coverage and quality continue to affect outcomes. Overall, while the district has made progress in expanding its health infrastructure, strengthening service delivery, improving outreach in tribal areas, and addressing nutrition and maternal health, these remain critical priorities for enhancing human well-being and supporting inclusive development in the Sheopur landscape.

9. EDUCATION AND LITERACY

The education and literacy profile of Sheopur district reflects both progress and persistent disparities. As per the 2011 Census, the overall literacy rate stands at 57.43%, marking an improvement from 46.40% in 2001, yet still below the state average. A pronounced gender gap is evident, with male literacy at 69.33% compared to only 44.23% among females, underscoring structural inequalities in educational access. The total literate population comprises 328,025 individuals, including 208,201 male literates and 119,824 female literates. Spatial differences are also significant: urban areas record a literacy rate of 72.85%, while rural areas lag behind at 54.47%, reflecting the uneven distribution of educational infrastructure and opportunities. The district hosts a network of primary, middle, and higher secondary schools, along with a limited number of colleges, but enrollment and retention rates remain lower for girls, particularly in tribal and marginalized communities. These patterns highlight the need for targeted interventions to bridge gender and rural–urban divides, expand access to secondary and higher education, and integrate skill development programs that can link education with livelihood opportunities. Strengthening education in Sheopur is thus central not only to improving human development indicators but also to enabling inclusive participation in conservation-linked development initiatives across the landscape.

10. PUBLIC SERVICES

The provision of public services in Sheopur district reflects a mixed picture of expanding access alongside persistent gaps in quality and coverage. The district has a network of post offices and public distribution system (PDS) outlets that provide essential communication and food security services, while internet cafés and mobile connectivity are gradually improving digital access, particularly in urban centers. Banking services have expanded in recent years, though rural penetration remains uneven, limiting financial inclusion for marginalized households. Mobile network coverage is widespread, yet service reliability varies across remote tribal villages. Sanitation facilities and the adoption of clean cooking fuels such as LPG are increasing but remain below state averages, with a significant proportion of households still dependent on traditional biomass fuels. These service gaps are particularly pronounced in rural and tribal areas, where infrastructure deficits intersect with socio-economic vulnerability. Strengthening public services in Sheopur is therefore critical not only for improving human development indicators but also for enabling effective implementation of conservation-linked development initiatives under the broader landscape management framework.

11. INDUSTRY AND EMPLOYMENT

The industrial and employment profile of Sheopur district is overwhelmingly agrarian, with the majority of its workforce engaged in cultivation and agricultural labour. Out of a total of 277,455 workers, 196,189 are main workers and 81,266 are marginal workers, while 221,006 individuals are directly employed as cultivators and agricultural labourers, underscoring the district's dependence on primary sector activities. Non-agricultural employment is relatively modest, with 4,166 household industry workers and 51,283 other workers engaged in small-scale enterprises and service activities. Traditional crafts such as artistic wooden toy-making continue to provide livelihood opportunities and cultural continuity, while other industries include ready-made garments and embroidery, wooden furniture, and repair and servicing units. Industrial development remains limited in scale and is largely agro-based, reflecting the district's resource profile and rural economy.

12. TRANSPORT AND CONNECTIVITY

The transport and connectivity framework of Sheopur district is shaped by a combination of road networks, limited rail links, and natural waterways that together facilitate movement of people and goods. The district is connected through national and state highways, with a total road length of 1,599.15 km across the blocks of Karahal, Sheopur, and Vijaypur, forming the backbone of intra-district connectivity. While road transport remains the dominant mode, the quality of roads varies, with rural stretches often requiring maintenance, particularly during the monsoon season. Railway connectivity is modest, restricting large-scale passenger and freight movement, and canal systems provide supplementary but localized transport and irrigation benefits. The presence of major rivers such as the Chambal and Kuno adds to the natural connectivity of the district, though inland water transport remains underdeveloped. Public and private transport services operate across the district, but accessibility gaps persist in remote tribal villages. Overall, Sheopur's transport and connectivity infrastructure, though functional, requires significant strengthening to support economic growth, improve access to markets and services, and reduce isolation of rural communities, while ensuring that linear infrastructure development is planned in harmony with ecological corridors and wildlife habitats.

13. CULTURE AND HERITAGE

The cultural and heritage landscape of Sheopur district is deeply rooted in its tribal traditions, historical monuments, and natural attractions, which together form an integral part of the region's identity. The district is home to seven major tourist sites-Dob Kund, Triveni Sangam, Kuno NP, Baroda Fort, Manpur Fort, the Sahariya Museum, and Sheopur Fort-each reflecting a blend of ecological, historical, and cultural significance. The Sahariya tribe, along with other indigenous communities, plays a vital role in preserving oral traditions, crafts, and rituals that contribute to the district's cultural richness. Traditional wooden toy-making, recognized as a local craft, continues to provide both livelihood opportunities and cultural continuity. Under the One District One Product (ODOP) initiative (https://mptradeportal.org/districtProfileOdop), Sheopur has been designated for guava fruit, linking agricultural heritage with modern economic development. These cultural and heritage assets not only sustain local identity but also hold potential for eco-tourism and heritage-based livelihoods, provided they are managed sustainably. Together, they underscore the importance of integrating cultural preservation with conservation and development strategies in the broader landscape management framework.

14. ADMINISTRATIVE SETUP

The administrative setup of Sheopur district reflects a well-defined governance structure that integrates both rural and urban units. The district is divided into five tehsils, namely Sheopur, Karahal, Vijaypur, Badoda, and Birpur, and three community development blocks, namely Sheopur, Vijaypur, and Karahal, which together account for populations of 236799, 215041, and 131800, respectively. In total, the district encompasses 585 villages, of which 516 are inhabited, and is organized into 226 Gram Panchayats that serve as the primary units of rural self-governance. Urban administration is centered around three statutory towns: Sheopur, Vijaypur, and Badoda, which function as hubs for trade, services, and governance. The district headquarters is located at Sheopur town, which also houses key administrative offices. Law and order are maintained through a network of 16 police stations, ensuring coverage across both rural and urban areas. This administrative framework not only facilitates governance and service delivery but also plays a critical role in implementing development schemes, managing natural resources, and coordinating conservation initiatives within the broader Kuno landscape.

15. NATURAL RESOURCES AND UTILITIES

The natural resources and utilities of Sheopur district are defined by a rich network of surface and groundwater systems that sustain both agriculture and biodiversity. The district is traversed by three major rivers, *i.e.*, Chambal, Sip, and Kuno, which provide critical water resources for irrigation, drinking, and ecological functions. In addition, reservoirs such as Banjara, Awda, and Barda supplement the district's water storage capacity. A detailed assessment of waterbodies reveals a diverse distribution: 146 waterbodies smaller than 0.5 ha, 97 between 0.5 and 1 ha, 76 between 1 and 2 ha, 92 between 2 and 10 ha, 28 between 10 and 50 ha, 5 between 50 and 100 ha, and 5 larger than 100 ha. This gradation highlights the importance of small and medium-sized wetlands in supporting local livelihoods, fisheries, and groundwater recharge. Groundwater resources are also significant, with aquifers providing irrigation to large tracts of cultivated land, though seasonal fluctuations and over-extraction remain concerns. Together, these natural resources form the backbone of Sheopur's agrarian economy while simultaneously underpinning the ecological integrity of the Kuno landscape. Effective management of these rivers, reservoirs, and aquifers is therefore essential not only for sustaining agricultural productivity but also for maintaining the hydrological balance that supports forests, wildlife, and human settlements across the district.

16. HABITAT AND LANDSCAPE

The habitat and landscape profile of Sheopur district reflects a mosaic of forests, agricultural lands, and protected areas that together shape its ecological character. The district supports 3407.86 km^2 of forests, which form about 51% of its total geographical area, alongside a net sown area of 1,720.91 km^2 and a total cropped area of 3,351.56 km^2 (DESA 2023). This land-use pattern highlights the dual importance of Sheopur as both an agrarian landscape and a biodiversity stronghold. The presence of Kuno NP (748.76 km^2) within this matrix underscores the district's role as a critical conservation hub, particularly for large carnivores such as leopards, wolves and the introduced cheetah. The mix of cultivated fields, rainfed agriculture, and extensive forest tracts creates a dynamic interface where human livelihoods and wildlife habitats overlap. These landscapes also function as ecological corridors, linking protected areas and sustaining species movement across the broader Ranthambor-Chambal_Kuno-Madhav landscape. However, pressures from grazing, fuelwood collection, and agricultural expansion continue to influence habitat quality, making integrated land-use planning essential. Overall, Sheopur's habitat and landscape configuration illustrate the delicate balance between sustaining rural livelihoods and conserving ecological integrity in one of Madhya Pradesh's most strategically important districts.

17. LIVESTOCK AND POULTRY

The livestock sector in Sheopur district is substantial, with a total population of 677,227 animals (20th Livestock Census, 2019), giving the district a livestock density of 10,252 animals per 100 km^2. Among these, cattle form the largest group with 264,113 head (3,998 per 100 km^2), followed by buffalo numbering 198,624 (3,006 per 100 km^2). Goats are also highly significant, with a population of 203,050 (3,073 per 100 km^2), reflecting their importance as a resilient livelihood source in semi-arid conditions. In contrast, sheep are relatively few, with 8,591 animals (130 per 100 km^2), while pigs number 2,849 (43 per 100 km^2). Other livestock, including horses, ponies, mules, donkeys, and camels, collectively account for 527 animals (8 per 100 km^2). In addition to these, the district supports a sizable poultry population of 94,587 birds, equivalent to 1,432 per 100 km^2, which contributes to both nutrition and supplementary income for rural households. A further 25,668 stray animals (388 per 100 km^2) are recorded, highlighting challenges in livestock management and the growing issue of abandoned or free-ranging cattle. This composition underscores the dual role of livestock in Sheopur as both a critical livelihood base and a factor influencing ecological dynamics, particularly in relation to grazing pressure on forests and agricultural landscapes.

18. WASTE MANAGEMENT

The waste management profile of Sheopur district highlights both achievements and persistent gaps in handling solid and liquid waste. The Sheopur municipality generates approximately 22 tonnes of solid waste per day (TPD), while the total solid waste generated across the district amounts to 32.6 TPD. In addition, the three community development blocks collectively produce around 102.5 TPD of solid waste. Collection efficiency is reported at 100%, indicating that waste is being gathered from all sources; however, there remains a 50% deficit in segregation at the source, which limits the effectiveness of recycling and scientific disposal. Liquid waste management presents an even greater challenge, with 72% of households lacking any outlet for wastewater drainage, a problem that is particularly acute in rural areas (82%) but also present in urban settlements (14%). This situation underscores the urgent need for improved infrastructure for segregation, treatment, and safe disposal of both solid and liquid waste. Without such interventions, unmanaged waste not only threatens public health but also risks contaminating soil and water resources, thereby undermining the ecological integrity of the Sheopur landscape.

After the district profiles, aims and objectives emphasizing critical issues and their solutions were prepared component-wise to keep all the necessary details present in the plan. The next sections of the landscape management plan are being drafted, but Table 6.5.2. shows the inclusion of tentative components for the rest of the plan.

Table 6.5.2.
Tentative components of the Landscape Management Plan

Components	**Information given**
1. Objectives and problems	Contains objectives of management and issues in achieving objectives.
2. Strategies and principles	Boundaries, *i.e.*, the landscape,PAs and forest divisions in all the Districts. District administrations will delineate eco-sensitive zones, prioritize habitat corridors, and ensure buffer greening.
3. Eco-tourism	The strategy promotes low-impact eco-tourism in key wildlife habitats and water bodies. Implementation involves training local guides, setting up eco-camps, and capacity-building in hospitality. District tourism cells will develop location-specific plans (*e.g.*, Gandhi Sagar floating camps, Kuno wildlife trails etc).
4. Tourism interpretation & conservation education	Interpretation centres will act as knowledge hubs. District education departments will integrate modules on wildlife and climate into schools to raise awareness about ecological values and the understanding of natural heritage among residents. Cheetah-themed awareness to be prioritized.
5. Ecodevelopment	Promote alternate livelihoods, reduce forest dependence, and incentivize conservation. Also, promote biogas, LPG, bamboo-based enterprises, and agroforestry. Funded through convergence with Viksit Bharat – Guarantee for Rozgar and Ajeevika Mission (Gramin) Act and National Rural Livelihood Mission.
6. Cheetah conservation strategy	Cheetah recovery is central to this plan. Based on the Cheetah Landscape Atlas (2024), habitat improvement, prey base augmentation, conflict mitigation, and community incentives will be implemented phasewise in the districts. GPS collaring, rapid response units, and livestock compensation schemes, social fencing will be strategized. Local schools will run 'Cheetah Clubs' to build awareness.
7. Research, monitoring, and training	Research institutes in the wildlife and forestry sector with the Forest Department will conduct landscape assessments. Districts will set up local research coordination cells. Frontline staff to be trained in SLEM (Sustainable Land and Ecosystem Management), cheetah monitoring, and ecotourism operations. Modules for schools, colleges, and PRI representatives.
8. Organisation and administration	State Landscape Cell at the Secretary level; district cells under DFOs with representation from line departments. Basic facilities for field staff (housing, digital connectivity, transport).
9. Budget	Phased budget over specific time intervals. Sources include CAMPA, CSR, GEF, Green India Mission, RKVY and others
10. Schedule of operations and miscellaneous	Review of cheetah soft release and eco-restoration at periodic intervals and the adaptive management cycle is to be documented. Eco-guides, wildlife monitors, and local artisans. Unified landscape monitoring dashboards. District Forest divisions to maintain digital compartment records.
11. List of PA's, annexures, maps	Landscape corridors and cheetah habitat zones, district-wise eco-tourism and eco-development projects, SDG alignment table, ESIP socioeconomic indicators by district, and wildlife and vegetation of cheetah landscape.

7. Way Ahead

- Development of an integrated landscape management plan incorporating legal, administrative, and financial mechanisms with delegation of roles, responsibilities, and accountability for implementation and monitoring.
- Constitution of multiple Cheetah Rapid Response teams at the district/forest division level.
- Continuous awareness, outreach, sensitization, and dissemination campaigns promoting pro-cheetah and biodiversity conservation at various fronts through multiple channels.
- Implementation of a modern smart patrol monitoring system such as MSTrIPES (Monitoring System for Tigers – Intensive Protection and Ecological Status) in the larger landscape.
- Management of human-wildlife interactions in the landscape through community involvement and technology-aided interventions, as well as capacity building of forest department staff.
- Ensuring livelihood securities of the local communities and timely disbursement of compensation/ex-gratia relief for wildlife-related damages to property and life considered as payment for ecosystem maintenance costs.
- Veterinary initiatives in coordination with the animal husbandry department for livestock vaccination of livestock and managing the dog population.
- Delineation of potential wildlife corridors as a safeguard against conservation-antagonistic land use concomitant with ecological restoration of natural areas in the larger landscape.
- Vehicular traffic management on roads traversing forest areas in coordination with the transport department, particularly in wildlife-rich areas and potential wildlife corridors.
- Selective water management in drier parts of the PA and the landscape with at least one water hole 4 km apart.
- Grassland management by deterring the growth of woody species to enable savannah grasslands as an arrested successional stage in specific areas to promote wild ungulate prey and endangered wildlife species of the region.
- Prey population augmentation through nutritional enhancement for select ungulate species with active in-situ measures at prey-depauperate wildlife areas in and around cheetah release sites.
- Continuous efforts to eradicate plant invasives and weeds from the grasslands.
- Management of fire and Non-timber Forest Produce (NTFP) collection in the forest divisions through increased surveillance and regulation.
- Restoration activity in sub-optimal habitats/natural areas by the forest departments with community support to promote forage species to enhance the productivity and carrying capacity.
- Encourage sustainable and conservative eco-tourism, compliant with biodiversity conservation so that livelihood options for the local people can be created and the conservation agenda gets adequate public goodwill.
- Exploring options to generate revenues in complete consonance with the conservation objectives through brand building, marketing, sponsorships, merchandising, *etc*.
- Incorporating guidelines similar to the one provided by the NTCA's landscape management strategy in the Tiger Conservation Plan for holistic cheetah conservation.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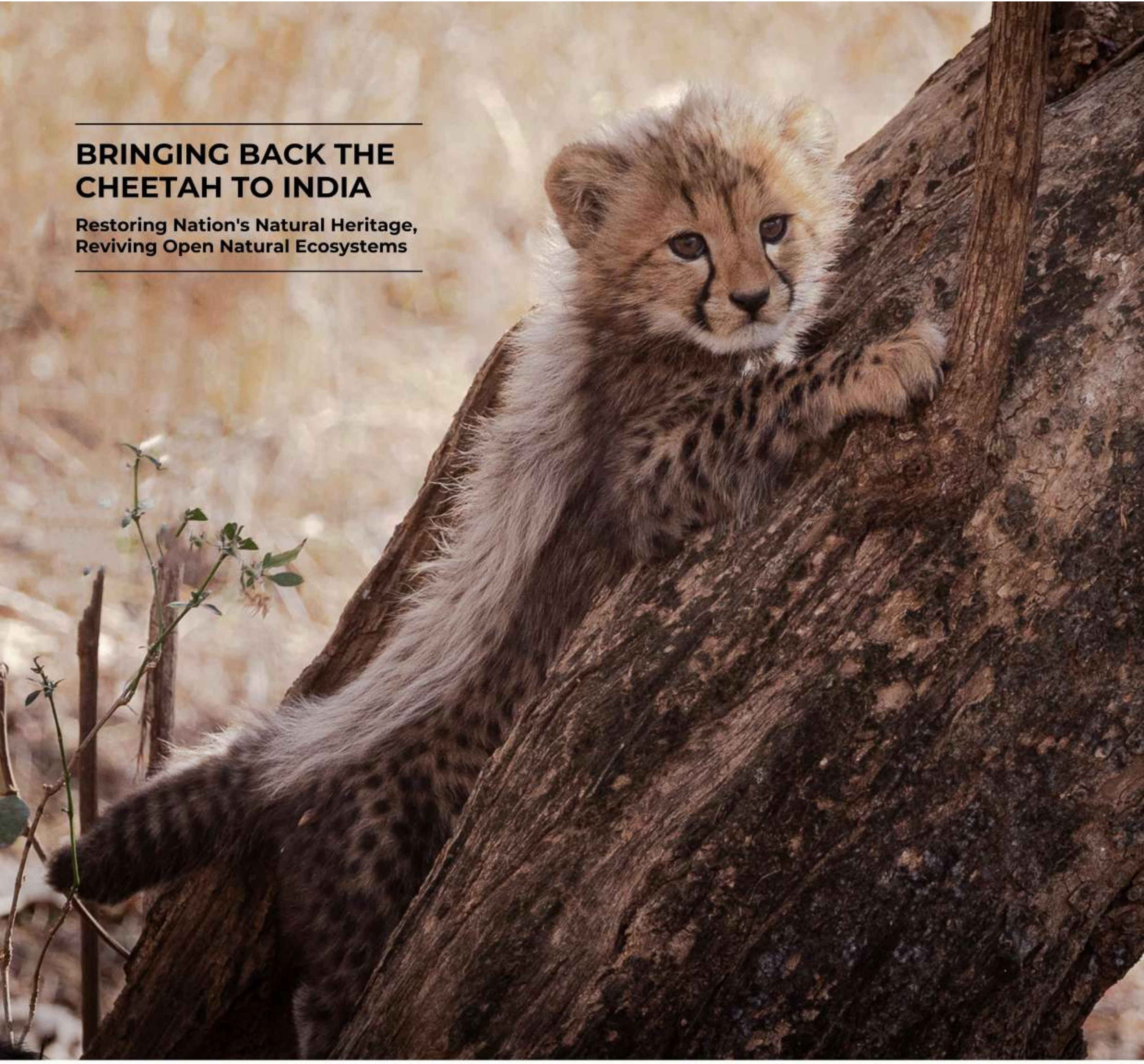
BRINGING BACK THE CHEETAH TO INDIA

Restoring Nation's Natural Heritage, Reviving Open Natural Ecosystems



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