

UNDERSTANDING HABITAT USE AND ITS DRIVERS

FOR SMALL CARNIVORES IN THE NILGIRIS

by

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Under the supervision of

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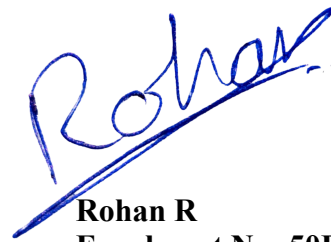
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I hereby declare that the work conducted under the thesis entitled **“UNDERSTANDING HABITAT USE AND ITS DRIVERS FOR SMALL CARNIVORES IN THE NILGIRIS”**, is a record of original and independent research work done by me and subsequently submitted for the award of the degree of **Master’s in Wildlife Science** at the **Academy of Scientific and Innovative Research**. This research work has been carried out under the guidance and supervision of **Dr. Shrushti Modi, Scientist - C**, and co-supervision of **Dr. Bilal Habib, Scientist - F**, and **Dr. Ayan Sadhu, Research Scientist** of Wildlife Institute of India, Dehradun. The work has not formed the basis for the award of any other degree, diploma, or any other qualification. I also declare that the thesis embodies my own work, analysis, observation, understanding and the particulars given in it are true to the best of my knowledge.



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This is to certify that the thesis by **Rohan R** entitled “**UNDERSTANDING HABITAT USE AND ITS DRIVERS FOR SMALL CARNIVORES IN THE NILGIRIS**” is an original and independent research work submitted to the **Academy of Scientific and Innovative Research**, for the award of the degree of **Master’s in Wildlife Science**.

Rohan R has put one semester of research work embodied in this thesis under my guidance and supervision. The work presented in this thesis has not been submitted to any other University or Institute for the award of any degree, diploma or distinction.

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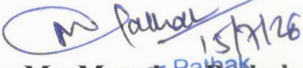
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Executive Summary

1. Small carnivores play a critical ecological role but remain historically understudied, particularly within highly modified landscapes like the Indian subcontinent. This study investigates the habitat use, and structural drivers of the small carnivore assemblage, along with spatial and temporal patterns in the Nilgiris, a high-altitude biodiversity hotspot in the Western Ghats
2. Using a paired camera-trap deployment of 64 stations yielding 2477 trap nights across a 100 km² matrix, spatial ecology was evaluated for focal species groups—Leopard Cat, Mongoose, and Civet—using Generalized Linear Models (GLMs) against PCA-derived environmental gradients representing remoteness and habitat complexity.
3. To overcome low empirical detection rates of the endemic Nilgiri marten (*Martes gwatkinsii*), semi-structured social surveys (N=110) were conducted to synthesize traditional knowledge and community perceptions among local stakeholders.
4. The fitted models indicated non-linear associations between photographic capture counts and the PCA-derived gradients of remoteness and habitat complexity. Predicted intensity of use was generally higher at intermediate to moderately high values of these gradients. To minimize

intra-guild competition, the sympatric carnivore community exhibited distinct temporal and spatial niche partitioning.

5. Social surveys provided crucial baseline data for the Nilgiri marten, revealing strong community associations with Shola forest canopies and frugivory, alongside the discovery of two previously undocumented local names ("Karumverugu" and "Peshku"). Furthermore, social data indicated an absence of perceived human-wildlife conflict and near-unanimous community support for the species' conservation. Ultimately, these findings highlight the necessity of retaining native structural complexity within modified matrices and demonstrate the efficacy of integrating traditional knowledge into predictive spatial ecology for cryptic endemics.

1. Introduction

2.1. The Global Paradigm of Small Carnivores

The mammalian order of Carnivora has a diverse array of species, yet an overwhelming majority of its diversity is represented by small carnivores. Spanning families such as Felidae, Viverridae, Herpestidae, and Mustelidae, small carnivores are defined as species weighing less than 21.5 kg (Hunter & Barrett, 2018). These mesopredators occupy critical nodes within global food webs, connecting the lower trophic levels to the highest ones. Unlike large apex predators, small carnivores often exhibit high morphological and behavioral plasticity, allowing them to exploit varied ecological niches ranging from primary forests to highly modified agricultural matrices (Roemer et al., 2009).

Small carnivores are invaluable members of forest systems (Jathanna, 2014). They often outnumber larger apex predators. This allows them to occupy specialized niches which are overlooked by the larger predators. Small carnivores also outnumber the large predators in diversity as well. The same patch of forest can support higher small carnivore diversity when compared to large carnivores diversity. Ecologically, small carnivores play crucial roles in controlling small mammal populations

Recent studies have suggested that small carnivores influence both sides of the trophic chain, called the “Middle-Out” ecological role. Through their large

numbers, they not only influence the lower trophic levels (the prey) but also the higher trophic levels as well, by being the prey for larger carnivores, while also acting as biological pest and disease control (Marneweck et al., 2022).

Many small carnivores are opportunistic omnivores. During certain seasons, they prioritize fruits over prey, helping in dispersing seeds throughout their habitat, aiding in habitat regeneration. Their dietary and niche plasticity also enables them to persist in human-modified landscapes (Roemer et al., 2009)

Widespread land-use change, driven by agriculture and urban expansion, often subsidize small carnivores, through agricultural/household waste. This could lead to unnatural hyper-abundances in some generalist species while simultaneously driving specialized, forest-dependent mesocarnivores toward extinction (Prugh et al., 2009). The hyper-abundances in some generalist species leads to “functional redundancy” in large ecosystems, where multiple species occupy very similar ecological niches and perform very similar ecological functions (Rosenfeld., 2002). Fragmented tropical ecosystems often lack this functional redundancy. Consequently the loss of even a single specialized species may cause ecological collapse, wiping out a large percentage of associated biodiversity. The loss of a frugivorous, or insectivorous small carnivore can trigger cascading effects across all lower trophic levels (McConkey et al., 2012).

Despite their ecological importance, high diversity and global distribution, small carnivores have historically been sidelined in global conservation

science, often overshadowed by the more charismatic species (Marneweck et al., 2022). This bias, although globally relevant, is particularly evident in highly biodiverse countries like India.

2.2. Small Carnivores of the Indian Subcontinent

India is home to a large number of small carnivores. India's vast geographic range acts as evolutionary crossroads, supporting high diversity of small carnivores from distinct lineages (Nameer et al., 2015). From the Himalayan Weasels and Yellow-Throated martens in the Himalayas to the Asian Golden Cats and Marbled Cats in the Northeast to the Brown Palm Civets and Nilgiri martens in the Western Ghats, India hosts a large, diverse array of small carnivores (Kalle et al., 2013). India is home to 38 species of small carnivores.

Wildlife conservation in India has historically leveraged the concept of umbrella species. Through this approach, many internationally acclaimed conservation projects, have taken root throughout the years, and has led to widespread, landscape level changes in policy and conservation outlook. However, the larger, landscape level conservation attention afforded by this approach often overlooks the fine-scale, micro-habitat level approach necessary for small carnivore conservation. Small carnivores frequently rely on micro-habitat features like terrestrial deadwood and understory complexity. Such micro-habitat features are often overlooked in landscape level approaches. Landscape-level conservation must be augmented with targeted

micro-habitat management for effective conservation of the carnivore guild (Srivathsa et al., 2019).

The fallacy of umbrella species receiving all conservation attention is also relevant when we look at how human-wildlife conflict is managed. Mainstream conflict management is often focused on conflict between humans and larger wildlife, such as tigers, leopards and megaherbivores. The more frequent human-mesocarnivore conflicts, such as poultry depredation by wild cats often does not receive the attention it requires. The retaliatory killings as a result of this never gain mainstream attention, and are very often completely missing from conversations regarding human-wildlife conflict (Inskip, C., & Zimmermann, A., 2009).

Consequently, the current baseline knowledge regarding Indian mesocarnivores remains largely descriptive rather than predictive. Historically, the literature has been focused on opportunistic presence records, roadkill inventories, and rudimentary dietary analyses derived from scat. This data deficiency is further compounded by ambiguities in taxonomic and morphological traits—particularly within the *Urva* (mongoose) and viverrid groups—which makes historical observational data prone to misidentification. Furthermore, while India's extensive, nationwide camera-trapping networks for large felid monitoring capture massive volumes of small carnivore imagery, these taxa are frequently treated as non-target 'by-catch.' It is often possible to collate vital occurrence records for poorly understood taxa from large-scale surveys targeted at apex species (Jathanna et al., 2020). However, their spatial

and temporal data is frequently underutilized, relegated to simple presence checklists rather than being leveraged for robust, multi-species spatio-temporal modeling.

India, being a predominantly agrarian country, has massive agricultural footprint. Agricultural expansion, often encroaching into natural habitats has caused massive shifts in the habitat use of mesocarnivores. In many parts of the country, human-dominated agrarian landscapes are no longer transient corridors, but permanent, primary habitats requiring extreme behavioral plasticity (Athreya, et al., 2013).

2.3. The Western Ghats

The Western Ghats is one among the 36 biodiversity hotspots in the world (Myers et al., 2000). It is home to countless endemic species, such as the brown palm civet (*Paradoxurus jerdoni*), and the Nilgiri marten (*Martes gwatkinsii*) among small carnivores (Rajamani et al., 2002). The brown mongoose (*Urva fuscua*) and the stripe-necked mongoose (*Urva vitticolla*) are endemic to the Western Ghats and Sri Lanka, and are found extensively across the forests of Western Ghats (Mudappa et al., 2015., Mudappa et al., 2024).

However, the current scientific understanding of these regional endemics remains critically underdeveloped. For specialized, upper-elevation species such as the Nilgiri marten, historical literature has been constrained by data scarcity, relying almost entirely on opportunistic, short-duration sightings and

localized range extensions (Krishna & Karnad., 2010). While recent modeling efforts have begun to map their macro-distribution across the wider Western Ghats ridge (Shameer et al., 2023), rigorous, fine-scale studies on their structural micro-habitat drivers, exact temporal overlap with sympatric generalists, and fine-scale diel activity patterns remain conspicuously absent, severely limiting targeted conservation planning.

In addition to specialized mustelids, the Western Ghats supports highly restricted viverrids, most notably the endemic brown palm civet. Unlike many opportunistic, omnivorous mesocarnivores, brown palm civet exhibits intense dietary specialization. Literature indicates that it is predominantly frugivorous—with native fruits comprising up to 97% of its diet—making it a critical mammalian seed disperser for the region's tropical rainforests (Mudappa., 1998). Because of its reliance on large, fruit-bearing canopy trees and specific diurnal resting sites (such as Indian giant squirrel nests), the brown palm civet's ability to persist in modified landscapes is heavily dictated by the retention of native shade trees within coffee and tea plantations (Rajamani et al., 2002).

The largest Asiatic mongoose species, stripe-necked mongoose, is endemic to the Western Ghats and Sri Lanka. Ecologically, it functions as a strictly diurnal, terrestrial predator heavily associated with riparian habitats and deciduous forest floors (Menon, 2014).

The landscape is also inhabited by the rusty-spotted cat, the world's smallest felid and a species endemic to the Indian subcontinent. Protected under Schedule I of the Indian Wildlife (Protection) Act, this near-threatened species remains one of the least studied felids globally. While their presence has been documented across multiple-use forests and agricultural boundaries in the Western Ghats (Kumara & Singh, 2007), their population dynamics are severely threatened. Beyond simple habitat fragmentation, literature highlights that small wild cats in these agrarian landscapes face the unique threat of genetic hybridization with feral domestic cats (Bandyopadhyay et al., 2024, Bandyopadhyay et al., 2026).

The Western Ghats also comes into relevance when discussing global climate change. Being one of the world's oldest mountain ranges, these mountains play a key role as refugia during climate change. The role of Western Ghats as climatic refugia is well accepted (Bossuyt et al., 2004). This refugia is widely considered to be one the main drivers of high biodiversity in this region. As climate changes, lower elevation species gets pushed higher up, paired with changes in vegetation, affecting high altitude species (Sukumar et al., 1995).

2.4. The Conservation Imperative

The need of the hour is establishing baseline ecological data on mesocarnivores. Understanding the spatial and temporal mechanics of these carnivores is the prerequisite to the successful rehabilitation of degraded habitats. It is also imperative in sustainably mitigating human-wildlife conflict at the agricultural interface. Furthermore, large-scale conservation and habitat

restoration initiatives will fail if they only focus on planting trees. Conservation programs require baseline ecological and structural data at the micro-habitat level to engineer functional landscapes capable of supporting complex predator assemblages.

To generate this precise structural data, modern wildlife research must transition from descriptive natural history to predictive spatial ecology (Guisan & Zimmermann., 2000). The increasing use of passive infrared camera trapping provides the ideal mechanism to overcome the historical barriers of studying nocturnal, cryptic, and low-density species without observer bias (Burton et al., 2015). When large datasets of continuous camera-trap imagery are paired with advanced analytical frameworks, we can decode the complex spatial drivers and temporal avoidance strategies of sympatric guilds.

It is within this intersection of critical conservation need and modern technological capability that this study is situated. By utilizing passive monitoring across the highly modified shola-tea mosaic of the Nilgiris, this research seeks to address the limited availability of fine-scale information on the habitat associations of mesocarnivores in the Nilgiris.

2.5. Aims and objectives:

1.5.1. Questions:

- i. **Habitat Use** – Which habitat types (e.g., shola forests, evergreen patches, plantations, farmlands) are most frequently used by small carnivores in the Nilgiris landscape?
- ii. **Ecological and Anthropogenic Drivers** – How do natural habitat variables (e.g., canopy cover, elevation, vegetation type) and anthropogenic factors (e.g., proximity to settlements, roads, agricultural land) influence small carnivore detection and spatial distribution?
- iii. **Guild-Level Interactions** – To what extent does the habitat use of different small carnivores overlap spatially and temporally with each other in the landscape, and what patterns emerge from these interactions?
- iv. **Status, Awareness, and Perceptions of the Nilgiri marten** – What is the current status of Nilgiri martens in the Nilgiris landscape? What is the level of awareness, perception, and local ecological knowledge about the Nilgiri marten among communities living in and around the study area, and how might this influence future conservation strategies?

1.5.2. Objectives:

- I. To understand the habitat use patterns of small carnivores in the Nilgiris, a heavily human-dominated region of the Western Ghats, by identifying key drivers.**
- II. To identify spatial and temporal patterns of small carnivore occurrence within the Nilgiris landscape:**
- III. To synthesize terrestrial detections of the endemic Nilgiri marten (*Martes gwatkinsii*) to establish baseline spatial occurrence and natural history records within the modified landscape.**

2. Study Area and Study Species

2.1. Study Area

The study was conducted over a study area of 100km² (11.2776723°N to 11.395565°N, 76.548911°E to 76.6592033°E) in the Nilgiri Wildlife division, Tamil Nadu. The Nilgiris is situated at an elevation of 900 to 2636 meters above MSL. The Nilgiris is bounded on North by the state of Karnataka, on the East by Coimbatore District and Erode District of Tamil Nadu, on the South by Coimbatore District and the state of Kerala and on the West by the state of Kerala. The Nilgiris Biosphere Reserve was established in 1986, recognizing its conservation importance as a critical node in the high biodiversity of Western Ghats (Daniels., 1992). It is India's first Biosphere Reserve. This landscape is one of the most biodiverse regions in the Western Ghats biodiversity hotspot (Shobha., 2015). Elevations vary drastically in the Nilgiris, ranging from about 900 meters in the lower valleys to over 2,600 meters on the upper plateau. The Nilgiris hills also act as a link between the Western Ghats and the Eastern Ghats, further enhancing its conservation importance.

The Nilgiris are characterised by high altitude pristine Shola Grassland and Shola Forest mosaics called Sky Islands. Bound by deep rifted valleys, these Sky Islands act like naturally fragmented habitats, providing excellent conditions for high endemism, which is reflected across most taxa (Robin & Nandini., 2012).

The landscape is defined by a skyline of at least 24 peaks exceeding 2,000 meters. The highest peak is the Doddabetta Peak, which stands at 2,637 meters. Other prominent peaks include Mukurthi (2,554 meters) and Kolaribetta (2,630 meters).

The mountains are formed from ancient Archaean crystalline rocks, predominantly charnockites. The topography features steep escarpments, deep valleys, and rolling high-altitude plateaus.

The climate in the Nilgiris is Subtropical Highland climate throughout the year (Von Lengerke., 1977). There is an average temperatures drop of roughly 6.5°C for every 1,000 meters of ascent. Further, the region receives dual monsoons due to its unique topology, which intercepts both the incoming Southwest monsoon, and the outgoing Northeast monsoon, maintaining high annual moisture levels critical for the montane evergreen ecosystems (Sukumar et al., 1995).

The Nilgiris harbour countless species endemic to the Western Ghats. Among small carnivores are the brown palm civet (*Paradoxurus jerdoni*), and the Nilgiri marten (*Martes gwatkinsii*) (Rajamani et al., 2002). The brown mongoose (*Urva fuscua*) and the stripe-necked mongoose (*Urva vitticolla*) which are endemic to the Western Ghats and Sri Lanka, are found extensively across the forests of Nilgiris (Mudappa et al., 2015., Mudappa et al., 2024).

Beyond mesocarnivores, the Nilgiris landscape forms a crucial stronghold for threatened megafauna. As a core component of the Western Ghats, the landscape supports some of the largest contiguous populations of the Asian elephant (*Elephas maximus*) and the Bengal tiger (*Panthera tigris*) globally. The apex predator guild is further supplemented by sympatric populations of the leopard (*Panthera pardus*) and the dhole (*Cuon alpinus*), which exert top-down pressures across the Nilgiris (Daniels., 1992).

The unique altitudinal gradients and rugged topography also harbor highly specialized, range-restricted mammalian herbivores. The high-altitude montane grasslands provide critical habitats for the endangered Nilgiri tahr (*Nilgiritragus hylocrius*), while endemic primates such as the Nilgiri langur (*Semnopithecus johnii*) are found in the Shola forest canopies (Sukumar et al., 1992).

The upper elevations of the Nilgiris landscape are characterized by a highly distinct, dual-component vegetative matrix: the native montane 'Shola-grassland' mosaic and the heavily modified anthropogenic plantation zones. The natural climax vegetation of the upper plateau consists of stunted, tropical montane evergreen forests, known as Sholas, tightly restricted to the sheltered valleys, folds, and depressions of the mountains where moisture is retained. These Shola patches are characterized by a dense, closed canopy with high structural complexity, with high diversity of epiphytes, mosses, and lichens, which provide crucial micro-habitats for arboreal taxa. Key native floral

species include *Syzygium* sp., *Michelia nilagirica*, and the endemic *Rhododendron arboreum* var. *nilagiricum* (Robin & Nandini., 2012). Historically, these forest patches were set within a vast matrix of undulating, frost-resistant montane grasslands, dominated by *Chrysopogon* and *Arundinella* species, and globally renowned for the mass-blooming *Strobilanthes kunthiana* (Kurinji) shrub (Thomas & Palmer., 2007).

Beginning in the mid-19th century, this native floral architecture was drastically altered. The vast stretches of natural montane grasslands were systematically replaced by commercial monocultures, fundamentally altering the structural permeability of the landscape. Today, the matrix outside the native Shola fragments is heavily dominated by vast, commercial tea (*Camellia sinensis*) estates. Furthermore, historical forestry practices introduced fast-growing exotic timber species—primarily Australian wattles (*Acacia mearnsii*), eucalyptus (*Eucalyptus globulus*), and pines (*Pinus* sp.)—which have heavily invaded the grassland edges and fundamentally altered soil hydrology and understory density (Thomas & Palmer., 2007). Consequently, the modern flora of the study area represents a heavily fragmented patchwork of dense, native Shola refugia embedded within a simplified, exotic agricultural matrix.

2.2. Study Species

The small carnivore assemblage in the Nilgiris consists of highly diverse and complex guild of small carnivores, encompassing multiple evolutionary lineages across four mammalian families: Felidae, Viverridae, Herpestidae, and Mustelidae. The guild consists of leopard cat (*Prionailurus bengalensis*), jungle cat (*Felis chaus*), rusty-spotted cat (*Prionailurus rubiginosus*), brown palm civet (*Paradoxurus jerdoni*), small Indian civet (*Viverricula indica*), Nilgiri marten (*Martes gwatkinsii*), stripe-necked mongoose (*Urva vitticollis*), brown mongoose (*Urva fuscus*), Asian small-clawed otter (*Aonyx cinereus*), and smooth-coated otter (*Lutrogale perspicillata*).

While the regional biodiversity is high, species distribution within the Nilgiris is heavily dictated by severe altitudinal gradients and specific hydrological requirements. The Asian small-clawed otter and smooth-coated otter are obligate riparian species primarily restricted to major riverine networks in the lower valleys. Similarly, the rusty-spotted cat exhibits a strong spatial preference for lower-elevation dry deciduous tracts and scrublands (Menon., 2014). Because this study's sampling design is strictly constrained to the upper-elevation montane plateau and Shola-tea matrices, these three lower-elevation species fall outside the spatial scope of the target landscape and were subsequently excluded from the focal analytical group.

The Focal Groups

The remaining upper-elevation assemblage, which forms the core focus of this study, exhibits remarkable functional diversity and varying degrees of endemism:

The Felids: The small wild cat assemblage is represented by the leopard cat and the jungle cat. The leopard cat is a highly adaptable, forest-dwelling mesopredator documented to successfully exploit modified agricultural edges, whereas the jungle cat is a highly adaptable terrestrial hunter frequently associated with open matrices and human-dominated agrarian landscapes (Srivathsa et al., 2015).

The Viverrids: The civet group includes the widespread small Indian civet, a terrestrial and semi-arboreal generalist, and the endemic brown palm civet. The latter is a globally threatened, strict frugivore heavily reliant on the retention of native canopy connectivity and mature fruit-bearing trees within the matrix (Mudappa., 1998).

The Herpestids: The mongoose assemblage comprises two predominantly diurnal foragers endemic to the Western Ghats and Sri Lanka: the stripe-necked mongoose and the brown mongoose. The stripe-necked mongoose is the largest Asiatic mongoose and frequently utilizes forested wetlands and intact forest floors (Mudappa et al., 2015).

The Mustelids: This assemblage is anchored by the study's primary high-altitude endemic, the Nilgiri marten. As the only native marten species in southern India, it is a rare, canopy-dwelling species strictly confined to the upper-elevation Shola-grassland mosaics and high-altitude evergreen tracts of the Western Ghats (Shameer et al., 2023).

3. Methods

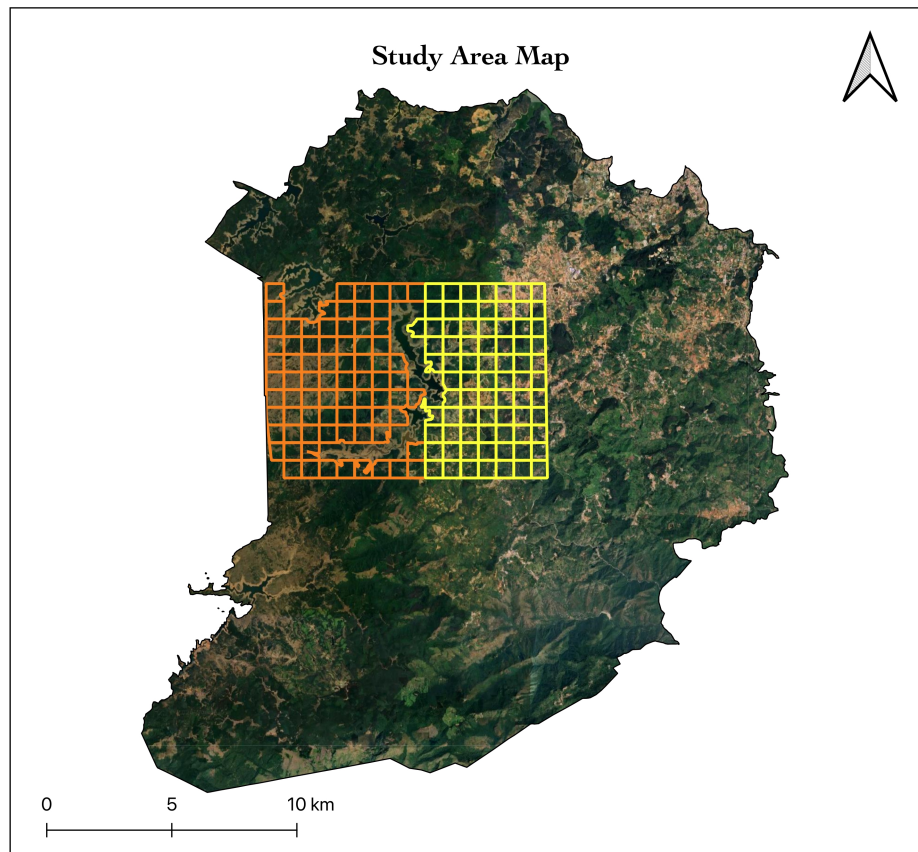
This study was aimed at understanding the patterns of habitat use, and the factors driving it, among small carnivores in the Nilgiris. To achieve this, photo-capture data was tested against various ecologically meaningful environmental variables. Data on environmental variables was collected during fieldwork. All this information was analyzed using appropriate analytical techniques to understand the patterns of and factors affecting habitat use of small carnivores.

3.1. Selection of Study Area and Reconnaissance

To understand the habitat use of small carnivores, it was necessary to select a study area which had a high diversity of small carnivores. After a thorough review of literature to find such sites, the following two sites were shortlisted: 1. Munnar Forest Division and Eravikulam National Park of Kerala, and 2. Nilgiris Forest Division of Tamil Nadu. Nilgiris Forest Division offers high diversity of small carnivores. This coupled with a clear and distinct human disturbance gradient across the landscape, and logistic feasibility rendered this area to be selected as the study area.

A reconnaissance survey was carried out in September 2025 to ascertain the suitability of the study area to meet the objectives. Certain changes were made to the original objectives based on observations during this survey. The gradient of human disturbance was visually examined and then compared with remotely

sensed data to verify the gradient. The extent of the study area was decided after the reconnaissance survey.



Map 1 : Study Area Map with Two Blocks

3.2. Study Design and Field Methods

3.2.1. Land use Classes

The study area was classified using remotely sensed land cover data (Copernicus 30m resolution) and visual inspection of satellite imagery. Supervised classification was carried out on Google Earth Engine using training polygons collected on field. The resultant classified imagery of 30m spatial resolution was further validated by inspection of satellite imagery, and using ground validated points collected during fieldwork.

3.2.2. Camera Trap Deployment

The study followed a non-invasive sampling approach, using camera traps (Cuddeback X-Change™ with white flash) to detect animal presence. The 100 km² study area was divided into a sampling grid of 707x707m, with each grid having an area of 0.5km² to intensively survey the species' habitat use. A paired, dual-placement camera strategy was employed within each grid cell.

Random Placement: one camera trap was deployed at the centre of the grid. This was done to ensure unbiased baseline data, which is required for robust predictive habitat modeling. In cases where the centre of the grid was not accessible, the camera trap was placed at the nearest accessible location.

Optimized Placement: the second camera trap was deployed at a location optimized to increase captures of elusive small carnivores. Natural trails, fallen deadwood, presence of fruiting trees were some of the factors which influenced the deployment location of the second camera trap.

By employing this dual camera system, we were able to account for low detection probability of small carnivores. The camera traps were placed at a height no larger than 60 cm from the ground.

The sampling was conducted in two blocks. Block 1 consisted mostly of Shola Forests, Shola Grasslands, and Exotic tree patches. 34 camera trap stations were deployed across 17 grids in Block 1. Block 2 was comprised of agriculture land, tea plantations, Shola forests and exotic tree patches. 30 camera trap stations were deployed across 15 grids in the Block 2. Uniform number of camera trap stations could not be achieved in both blocks. Block 2, being comprised largely of agriculture land, sampling efforts in Block 2 were constrained by a lack of cooperation from local agriculture land owners, preventing the deployment of camera traps in these agro-ecosystems.

Each of the total 64 camera traps were operated for a sampling period of minimum 30 days. The camera traps were monitored and maintained at regular intervals. The traps were retrieved after the sampling period.

3.2.3. Natural and Anthropogenic Variables Survey

Natural and anthropogenic variables were collected from each camera trap station during subsequent monitoring visits.

<u>Natural</u>	<u>Anthropogenic</u>
Canopy cover percentage	Distance to road
Canopy height	Distance to settlement
Understory density	Distance to night light
Aspect	Presence of fire
Altitude	Presence of garbage
Forest Type	
Presence of fruiting trees	
Presence of fallen trees	

Table 1: Variables collected for analysis

Small carnivore assemblages exhibit high levels of vertical stratification. Variables such as canopy cover percentage and canopy height are critical predictors for arboreal obligates and semi-arboreal species (e.g., Nilgiri marten, brown palm civet), which require continuous canopy connectivity for movement and predator avoidance. Conversely, understory density and the presence of fallen trees dictate the habitat suitability for terrestrial mesopredators (e.g., mongooses, small wild cats). Dense undergrowth and deadwood provide structural complexity necessary for ambush foraging, diurnal resting sites, and refuge from larger apex predators (Bali et al., 2007; Srivathsa et al., 2019).

Altitude and aspect function as proxies for micro-climatic gradients, dictating temperature, soil moisture, and the resulting vegetation regime—factors known to tightly constrain high-altitude endemics in the Western Ghats (Sukumar et al.,

1995). Forest type distinguishes between native Sholas, exotic patches, agriculture land, and tea estates. Furthermore, the presence of fruiting trees is a vital dietary variable, directly predicting the occurrence of frugivorous viverrids (Mudappa., 1998).

Human-modified landscapes often alter carnivore dynamics through artificial inputs. The presence of garbage acts as a measure of anthropogenic resource subsidies, which can lead to unnatural hyper-abundances of opportunistic generalists (e.g., leopard cats, civets), (Prugh et al., 2009., Newsome et al., 2015). Finally, distance to night light was included to quantify Artificial Light at Night (ALAN). Recent literature demonstrates that ALAN acts as a powerful sensory pollutant, suppressing natural foraging behaviors and forcing spatial or temporal shifts in nocturnal mammalian predators (Gaston et al., 2013).

Natural variables:

Canopy height was measured using a Nikon Forestry Pro II rangefinder-hypsometer, using its three-point measurement mode, and canopy cover percentage: canopy cover percentage was measured using Percentage Cover smartphone app, utilizing its camera to measure canopy cover percentage. The smartphone was held 1.5m off the ground using a pre-measured stick to ensure consistent height during all measurements. Understory density was measured using visual estimation. Forest type of every camera trap station was also noted down during deployment. Presence of fruiting trees within a 15m radius around the camera trap station were recorded. Presence of fallen trees within a 15m radius around the camera trap station was also recorded. Altitude was measured

at every camera trap station using a Garmin GPSMap 62s handheld GPS system. Aspect was computed using RS/GIS technology.

Anthropogenic variables:

Presence of fire, and garbage within a 15m radius around the camera trap station were recorded (Oro et al., 2013). Distance to road, Distance to settlement, Distance to night light were calculated using RS/GIS technology.

3.2.4. Social Survey and Traditional Knowledge

To complement the empirical data derived from camera trap monitoring and predictive spatial modeling on Nilgiri martens, a semi-structured interview framework was deployed to capture Traditional knowledge and community perceptions. Traditional knowledge is increasingly recognized as a vital mechanism for establishing ecological baselines for cryptic or understudied species, particularly in complex topographies where systematic field surveys are logistically constrained (Berkes et al., 2000., Gilchrist et al., 2005).

The target population encompassed local stakeholders across the Nilgiris landscape, including forest department personnel, eco-tourism staff, local agriculturalists, and long-term residents. Prior to any data collection, verbal prior informed consent was obtained from all participants. Following the ethical guidelines for social science research in conservation (Newing., 2011), responses lacking explicit consent were excluded from the final analysis.

To ensure species identification accuracy, respondents were shown photographic reference material of the target species. Subsequent questions were designed to extract qualitative data across three core domains: baseline ecological knowledge (habitat use, diet, activity patterns), perceptions of human-wildlife interaction (depredation and perceived danger), and overarching conservation attitudes.

Data regarding the species' behavioral ecology—specifically diet and habitat associations—were collected as multiple-choice, open-ended variables allowing for multiple categorical associations per respondent. To systematically analyze these multi-value responses, the text strings were separated, cleaned of trailing whitespaces, and individually aggregated to determine the frequency of mention for each biological parameter. This method allowed for the construction of a ranked ecological profile (e.g., primary vs. secondary dietary items) derived entirely from local observation. Survey responses were compared descriptively with camera-trap detections and habitat characteristics.

Evaluating community tolerance and risk perception is fundamental to the long-term success of carnivore conservation initiatives (Dickman., 2010). To quantify these human dimensions, a standard five-point Likert scale (ranging from "Strongly Disagree" to "Strongly Agree") was utilized. The survey measured critical socioeconomic variables, including the perceived danger the species poses to human safety, the risk of livestock/poultry depredation, and the community's belief in the species' ecological importance.

3.3. Analytical Methods

Different techniques of comparison, modelling and ordination were used to answer specific questions relating to habitat use, factors influencing it, temporal and spatial overlapping of small carnivores.

Rather than relying on simple presence/absence ratios, we used predictive modelling to describe habitat use as a function of its drivers. Generalized linear models were utilized to quantify habitat use as a function of the natural and anthropogenic variables, which in turn helped in generating a predictive framework that maps the optimal ecological niche space (habitat use) for each focal group.

All analyses were done separately for each focal species. Multiple species had low capture rates, these were pooled together into groups for the analyses (Mongoose group and Civet group).

3.3.1. Habitat Use and its Factors

The data segregation was done for different target species. A correlation matrix was made to visualize correlation among the variables. To prevent model over-fitting and account for high correlation among the variables, Principal component analysis was conducted to compress the different habitat and anthropogenic variables into distinct axes.

Habitat use was then modeled using Poisson GLMs. Components extracted from the PCA - PC1 & PC2, and binary categorical variables for forest type (eg. Shola forest vs. Exotic) were used as predictor variables and sightings as response variable in the GLM. To test for non-linear relationship quadratic terms for the PCA gradients were integrated into the models. A null model, without any predictor variables was also computed.

To account for the inherently low detection probabilities of cryptic mesocarnivores, captures from both the random and optimized camera placements within a single grid were pooled. Consequently, GLMs evaluated habitat use at the broader grid-level resolution (0.5 km²) rather than at the micro-site level.

The explanatory power of the predictor variables was assessed using a likelihood-ratio test framework with an analysis of deviance based on a Chi-square distribution, comparing the deviance of the full parameterized models to an intercept-only null model to determine whether the addition of structural and environmental macro-gradients significantly improved the model fit.

To visualize the non-linear relationships and habitat interactions derived from the fitted generalized linear models, predictive dataframes were constructed using a grid-expansion framework (`expand.grid`) in R-Studio. Predictions were generated by varying the target continuous predictor (scaled PC1 or PC2) across its full observed range while holding the secondary principal component fixed at its mean value (=2), to isolate the effects of the individual environmental gradients.

Predicted values and their associated standard errors ($\pm$ SE) were calculated on the response scale using the delta method framework via the “predict.glm” function in R-Studio. These systematic predictions were then mapped across categorical habitat types to evaluate changes in space-use trends across divergent forest conditions.

Predictive 2D niche space maps were also created for each focal species. The plot visualizes intensity of habitat use by the focal species across the different environmental gradients.

3.3.2. Spatio-temporal partitioning

To understand spatio-temporal niche partitioning among the small carnivores, diel activity patterns, temporal overlap and spatial overlap was calculated for the focal species and groups.

To avoid temporal autocorrelation (artificially inflating data from a single animal lingering in front of the camera), only independent capture events—defined strictly as consecutive photographs of the same species separated by a minimum interval of 15 minutes—were utilized for this analysis. The timestamp of each independent capture was extracted as solar time. Timestamps were converted into radians to facilitate circular statistical analysis.

To strictly quantify the degree of temporal segregation among all potential interspecific competitors, a 7x7 pairwise overlap matrix was constructed using the overlap package in R-Studio

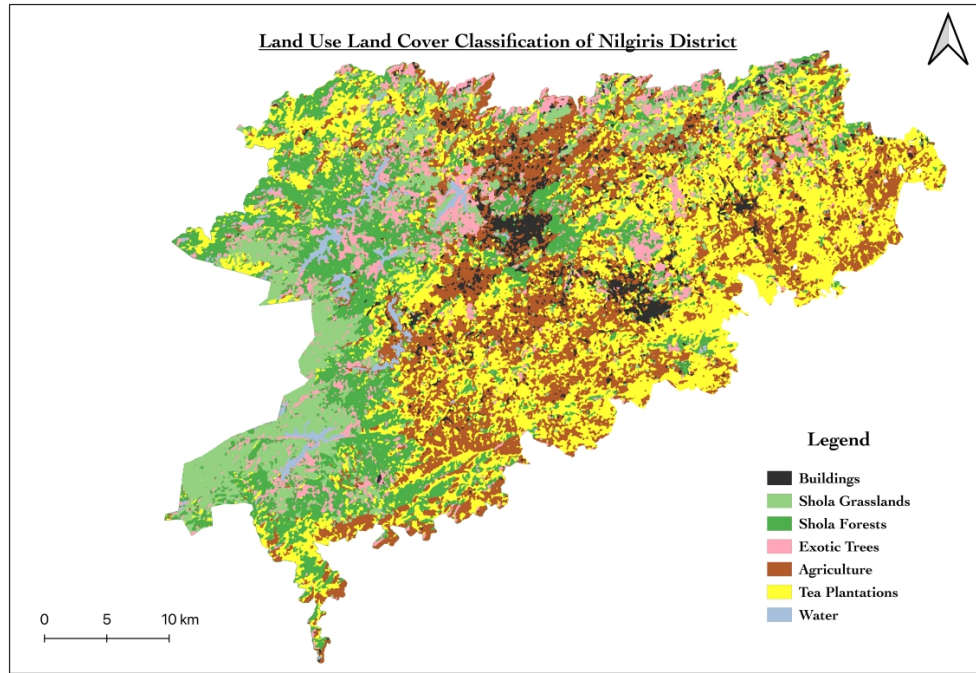
The predicted intensity of habitat use was utilized to calculate spatial overlap between the focal groups. Schoener's D metric of niche overlap was used in this analysis. Pairwise overlap matrix was constructed for spatial overlap as well.

3.3.3. Social Survey and Traditional Knowledge

All quantitative and qualitative survey data were processed and analyzed using R. Descriptive statistics were generated to establish the demographic profile of the respondents (age, occupation, residency status). For perception and attitude variables, Likert-scale responses were treated as ordinal data and visualized using diverging stacked bar charts to clearly delineate community consensus.

4. Results

4.1. Land Use Land Cover Classification



Map 2: Land Use Land Cover Classification of Nilgiris District, Tamil Nadu

The classification resulted in delineation of five dominant land-use categories in the study area, which are mentioned below along with brief descriptions. (Land use classes of “Buildings” and “Water” were not considered in the analysis) (Map 1) –

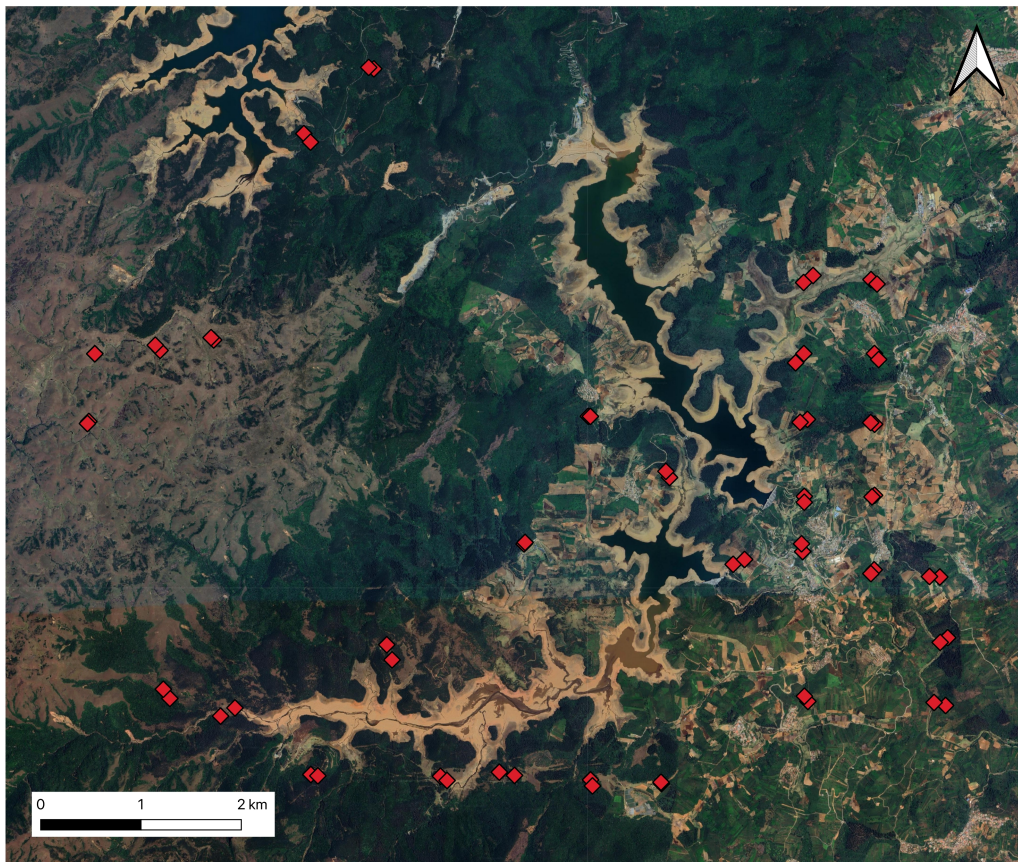
- i. **Shola Forest** (295.192 sq. Km): Stunted, tropical montane evergreen forests largely confined to sheltered valleys and topographical depressions. These native patches are characterized by a dense, closed canopy, high epiphyte load, and a complex, undisturbed understory with significant terrestrial deadwood.

- ii. **Shola Grassland** (156.367 sq. Km): Undulating, high-altitude montane grasslands that historically dominated the exposed hill slopes and plateau tops. Characterized by frost and fire resistant native grass species.
- iii. **Exotic tree patches** (125.192 sq. Km): Monoculture or mixed timber plantations comprising of introduced species, primarily *Acacia* spp. (wattle), *Eucalyptus* spp., and *Pinus* spp. Exotic plantations generally support lower native biodiversity than native forests. Older, unmanaged patches may often develop a dense secondary understory and accumulate fallen deadwood, providing an artificial physical architecture frequently utilized by structural generalists.
- iv. **Agriculture land** (264.074 sq.Km): Heavily modified land tracts used for irrigated cultivation of cash crops such as potatoes, carrots, and cabbage. These land possess very low natural canopy cover and are characterized by high anthropogenic disturbance, seasonal clearing, pesticide use and close proximity to human settlements and road networks.
- v. **Tea Plantations** (459.29 sq. Km): Consists of both large, commercially managed and smaller family managed monocultures of tea. Similar to agriculture land, tea plantations also possess very low natural canopy cover, despite providing perennial green cover. Tea plantations also have high anthropogenic disturbance, from tea plantation workers, pesticide use, and seasonal clearing

Land use classes of “Buildings” and “Water” were not considered in the analysis.

4.2. Sampling Effort and Species Accumulation

Between December 2025 and April 2026, a total of 64 camera trap stations were deployed (Map 2). After accounting for malfunctions, battery failures and a lost camera trap, the study yielded a total sampling effort of 2477 trap nights. During the sampling period, a total of 84 carnivores were captured across these camera trap stations. Out of these, 63 captures were of small carnivores (capture rate = 2.54 captures per 100 trap nights). A species accumulation curve was computed to analyse the efficiency of camera trapping. The curve did not reach a horizontal asymptote, maintaining a steady upward trajectory through the final sampling intervals. This indicates the regional species pool was not completely exhausted (Figure 1).



Map 3: Deployed camera traps. Red points indicate camera trap locations

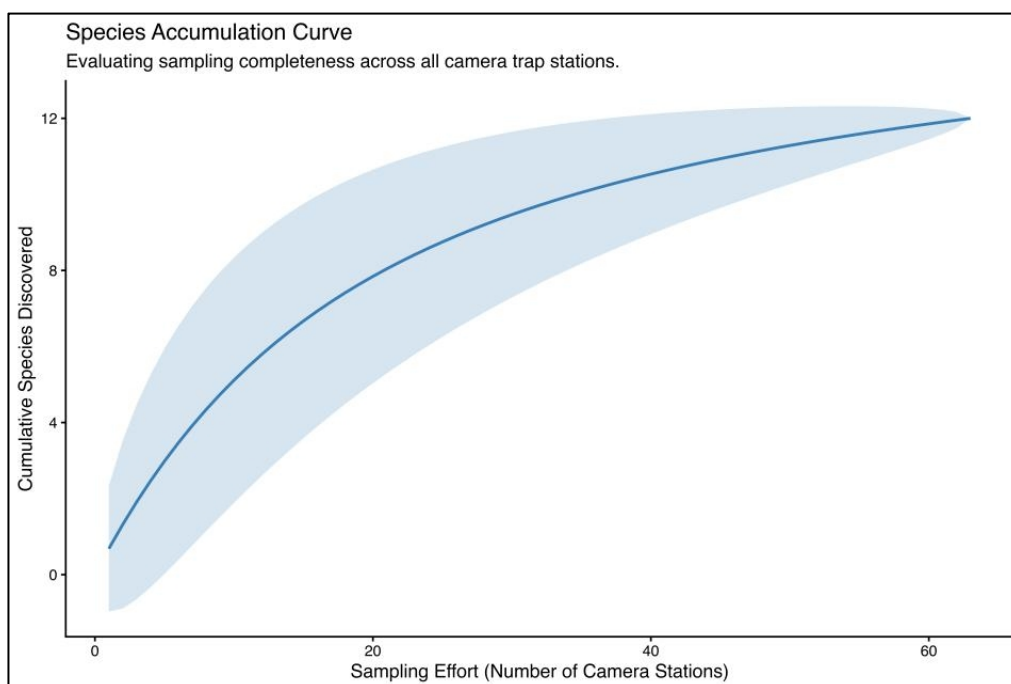


Figure 1: Species Accumulation Curve showing completeness of sampling across camera trap stations.

Common name	Count
Jungle Cat	1
Sloth bear	1
Dhole	2
Golden jackal	2
Tiger	3
Nilgiri marten	5
Small Indian civet	6
Brown palm civet	7
Brown mongoose	8
Leopard	13
Stripe necked mongoose	15
Leopard cat	21
Grand Total	84

Table 2: List of carnivore photo-captures

Carnivores were only detected in three forest types - Exotic tree patches, Shola Forests, and Shola Grasslands. Camera trap stations in Tea plantations, and agriculture land did not yield any carnivore detections during the sampling period (Figure 2).

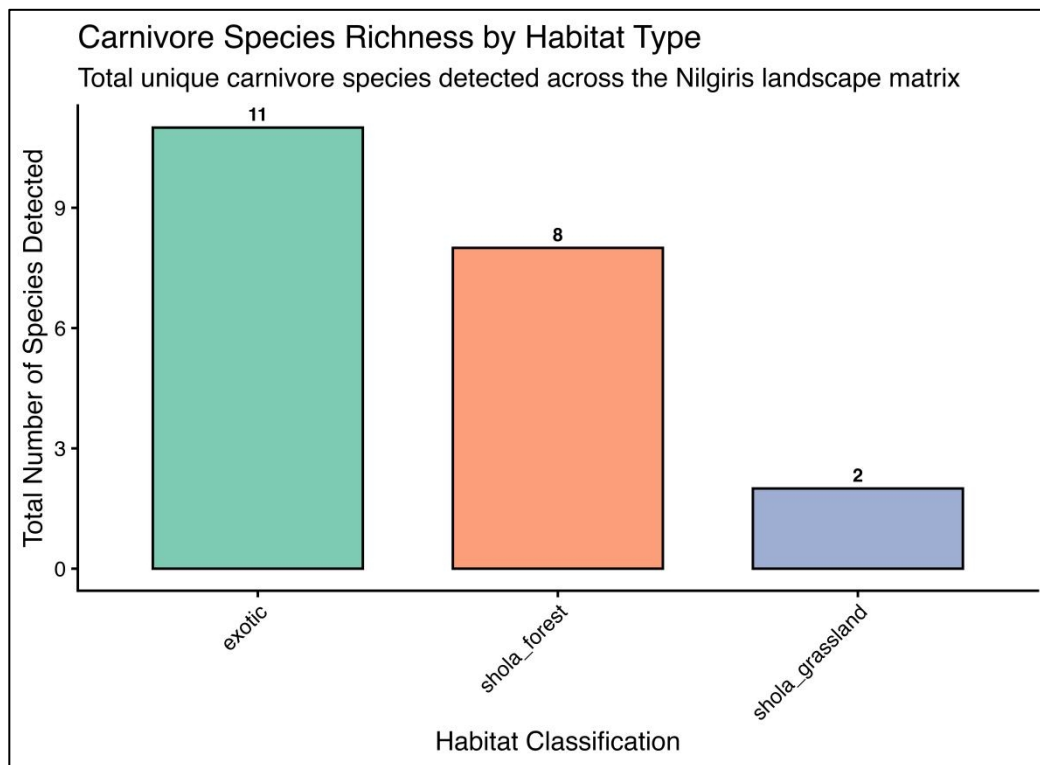


Figure 2: Species Richness across different forest types

4.3. Environmental Gradients

Principal component analysis showed that just two components - PC1 & PC2 - explained 61.7% of variance in the dataset. PC1 was driven by distance to settlement, distance to night light, and altitude, representing a gradient of remoteness. Higher PC1 values indicate high altitude, remote, undisturbed forests, while low PC1 values indicate lower altitude, human disturbed regions. PC2 was driven by canopy height, canopy cover, understory density, representing a gradient of habitat complexity. Higher PC2 values

indicate dense understory, high canopy height, and dense canopy cover, suggesting old-growth forests, while low PC2 values suggest open understory, with low or no canopy height and cover. (Figure 3)

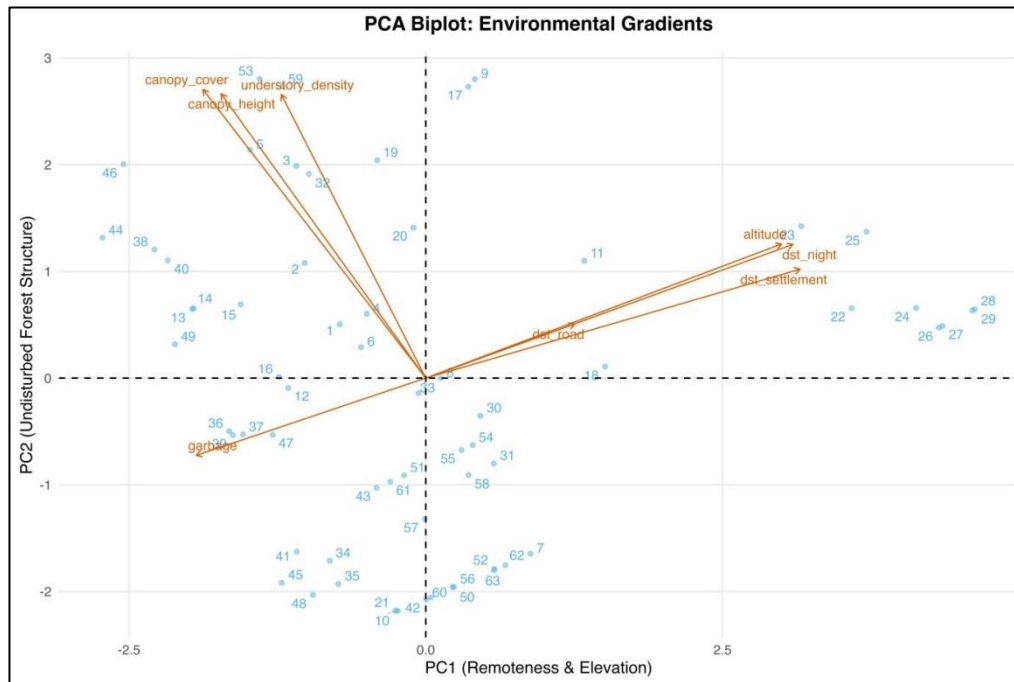


Figure 3: Biplot of PC1 & PC2 components from PCA

4.4. Habitat Drivers of Small Carnivores (GLM Outputs)

4.4.1. Leopard Cat

The generalized linear model evaluating leopard cat habitat use performed significantly better than intercept-only null model ($p=3.353 \times 10^{-11}$). The inclusion of categorical landscape variables and continuous environmental gradients substantially improved overall model fit, reducing residual deviance from 97.829 to 39.963 on 57 degrees of freedom, indicating that the parameterized model fitted the observed data better than the intercept-only model. The model summary identified Shola Forests, PC1 and PC2 as significant drivers of habitat use for leopard cats. PC2 showed the highest coefficient, indicating that PC2 is the significant driver of habitat use for leopard cats.

Plots developed from the predictive framework shows clear preference for the “Goldilocks” zone. Rather than scaling linearly, the predicted intensity of use by leopard cats peaked at intermediate to moderately-high values along both the PC1 and PC2 gradients. Intermediate to moderately-high PC1 and PC2 values show highest predicted intensity of use by leopard cats, indicating that leopard cats could be using areas of mid to high elevation and remoteness with moderately complex habitat structure characterised by moderate canopy height, canopy cover and understory density more intensely than other areas. Consequently, the optimal habitat profile for this species avoids both extreme barrenness and impenetrable density, favoring intermediate canopy height and moderate canopy cover over a dense understory matrix (Figures 4, 8 & 12)

4.4.2. Mongoose Group

Stripe necked mongoose and brown mongoose were pooled together into Mongoose Group for analysis, to account for low capture rates.

The generalized linear model evaluating Mongoose Group habitat use performed significantly better than intercept-only null model ($p=1.356 \times 10^{-8}$). The inclusion of categorical landscape variables and continuous environmental gradients substantially improved overall model fit, reducing residual deviance from 108.082 to 62.937 on 57 degrees of freedom, indicating that the parameterized model was reliable in explaining the drivers' role in habitat use.

The model summary identified PC1 and PC2 as significant drivers of habitat use for the Mongoose Group. Significance value for PC2 was the highest ($p=0.000763$) with a positive coefficient (6.51853), indicating that PC2 is the significant driver of habitat use for Mongoose Group.

Similar to leopard cats, intensity of use plots developed from the predictive framework for Mongoose Group also shows clear preference for the intermediate zones. Rather than scaling linearly, the predicted intensity of use by Mongoose Group peaked sharply at intermediate to moderately-high values along both the PC1 and PC2 gradients. Intermediate to moderately-high PC1 and PC2 values show highest predicted intensity of use by Mongoose Group, indicating that they could be using areas of mid to high elevation and remoteness with moderately complex habitat structure characterised by

moderate canopy height, canopy cover and understory density more intensely. Consequently, the optimal habitat profile for this species shows high similarity to the habitat profile of leopard cats, avoiding both extreme barrenness and impenetrable density, and favoring intermediate canopy height and moderate canopy cover over a dense understory matrix. (Figures 5, 9 & 13)

4.4.3. Civet Group

Small Indian civet and brown palm civet were pooled together into Civet Group for analysis, to account for low capture rates.

The generalized linear model evaluating Civet Group habitat use performed significantly better than intercept-only null model ($p=1.402 \times 10^{-06}$). The inclusion of categorical landscape variables and continuous environmental gradients substantially improved overall model fit, reducing residual deviance from 66.491 to 31.337 on 57 degrees of freedom, indicating that the parameterized model fitted the observed data better than the intercept-only model.

Although the dataset showed higher number of civet captures in exotic tree patches, the model summary identified native forest types, PC1 and PC2 as significant drivers of habitat use for the Civet Group. Significance value for PC2 was the highest ($p = 0.002968$) with a positive coefficient (5.6099), indicating that PC2 is the significant driver of habitat use for Civet Group.

Similar to leopard cats and Mongoose Group, the fitted relationship was unimodal, with highest predicted intensity of use at intermediate PC1 values. Along the PC2 spectrum, Civet Group shows more affinity for moderately-high to high values. This could be indicating that they are intensely using areas of mid to high elevation and remoteness, with moderately-high to highly complex habitat structure. The optimal habitat profile for this group again shows high similarity to both leopard cats, and Mongoose Group. Civet Group also prefers any native forest type over exotic forests. (Figures 6, 10 & 14)

4.4.4. Small Carnivore Group

All small carnivores (leopard cat, jungle cat, small Indian civet, brown palm civet, brown mongoose, stripe necked mongoose, Nilgiri marten) were pooled together to form the Small Carnivore Group

The generalized linear model evaluating Small Carnivore Group habitat use performed significantly better than the intercept-only null model ($p=2.2 \times 10^{-16}$). The inclusion of categorical landscape variables and continuous environmental gradients substantially improved overall model fit, reducing residual deviance from 260.61 to 125.26 on 57 degrees of freedom, indicating that the parameterized model was reliable in explaining the drivers' role in habitat use.

Although the dataset showed higher number of small carnivore captures in exotic tree patches, the model summary again identified native shola forests, PC1 and PC2 as significant drivers of habitat use for the Small Carnivore

Group. Significance value for PC2 was the highest ($p=8.67 \times 10^{-9}$) with a positive coefficient (5.96035), indicating that PC2 is the significant driver of habitat use for Small Carnivore Group.

Plots developed from the predictive framework for Small Carnivore Group also shows clear preference for the “Goldilocks” zone. Rather than scaling linearly, the predicted intensity of use by Small Carnivore Group peaked sharply at values along PC1. Along the PC2 spectrum, Small Carnivore Group shows more affinity for intermediate to moderately-high to high values. This indicates that they might be intensely using areas of mid to high elevation and remoteness, with intermediate to moderately-high complex habitat structure. Optimal habitat profile for small carnivores shows high similarity to the optimal habitat profiles of previously mentioned groups. Small Carnivore Group prefers native shola forests over exotic forests. (Figures 7, 11 & 15)

Prediction Plots

PC1 - Remoteness Gradient

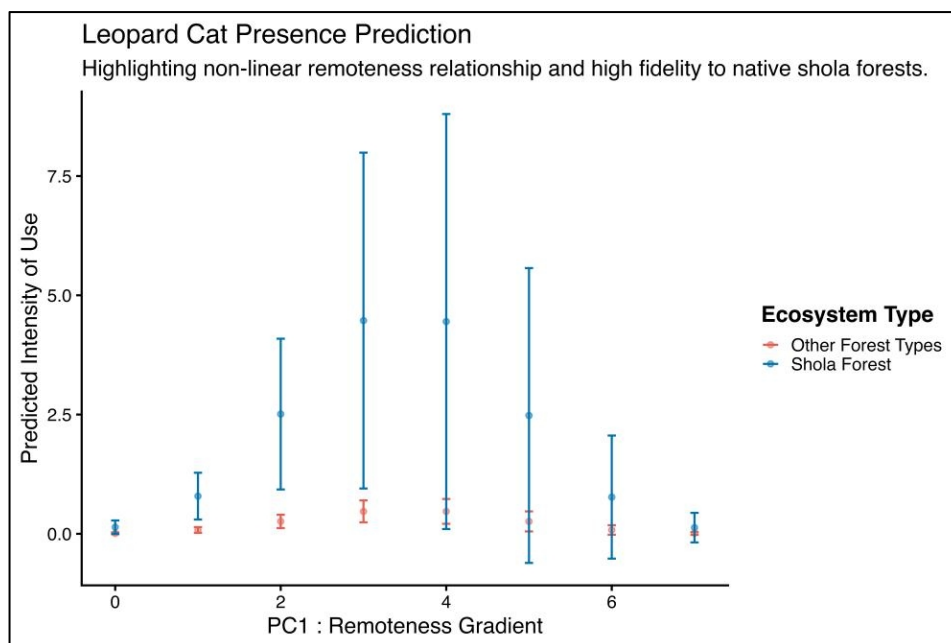


Figure 4: Prediction plot for Leopard Cats over PC1 (remoteness) gradient

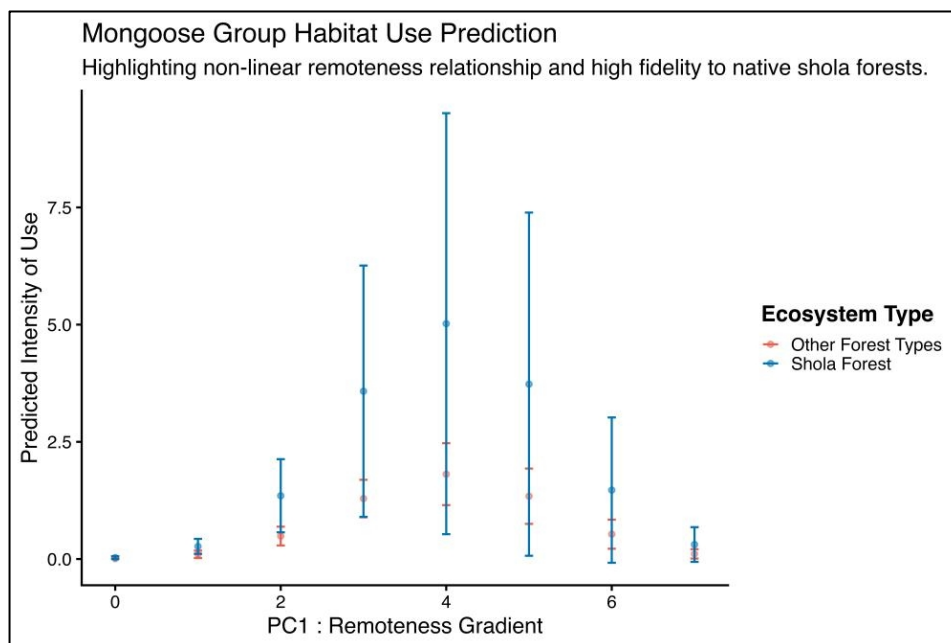


Figure 5: Prediction plot for Mongoose Group over PC1 (remoteness) gradient

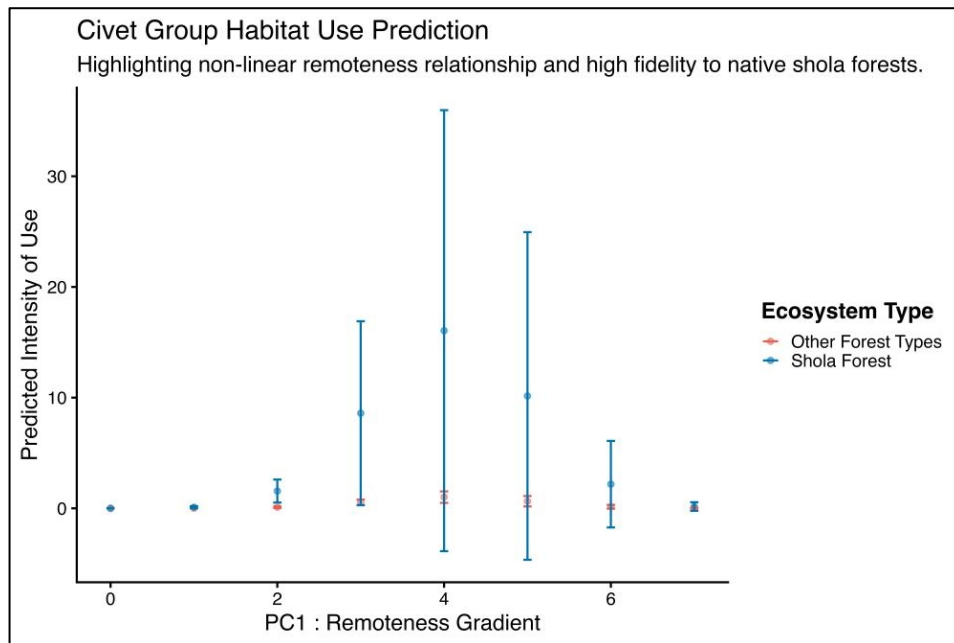


Figure 6: Prediction plot for Civet Group over PC1 (Remoteness) gradient

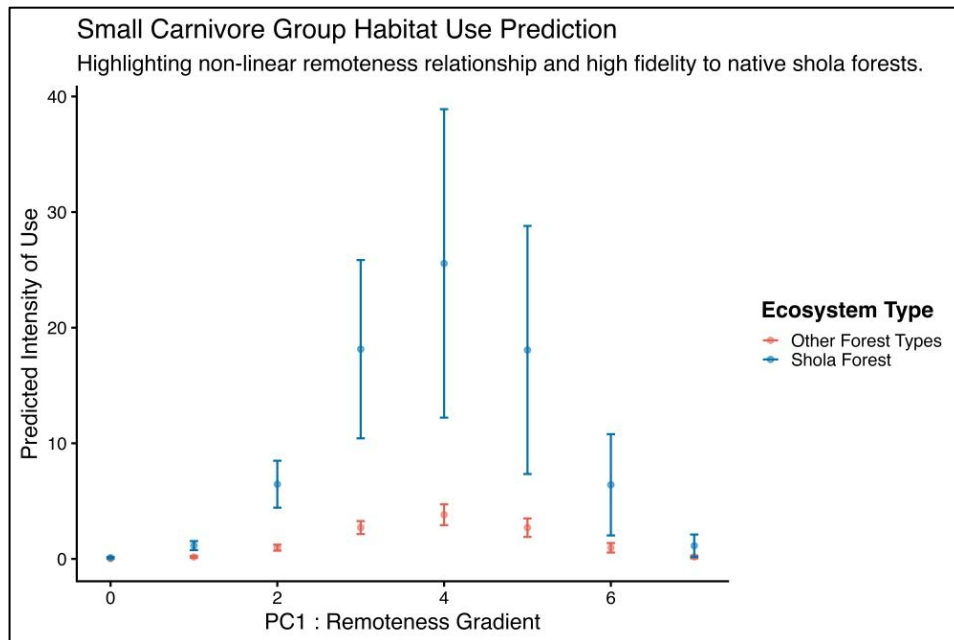


Figure 7: Prediction plot for Small Carnivore Group over PC1 (Remoteness) gradient

PC2 - Habitat Complexity Gradient

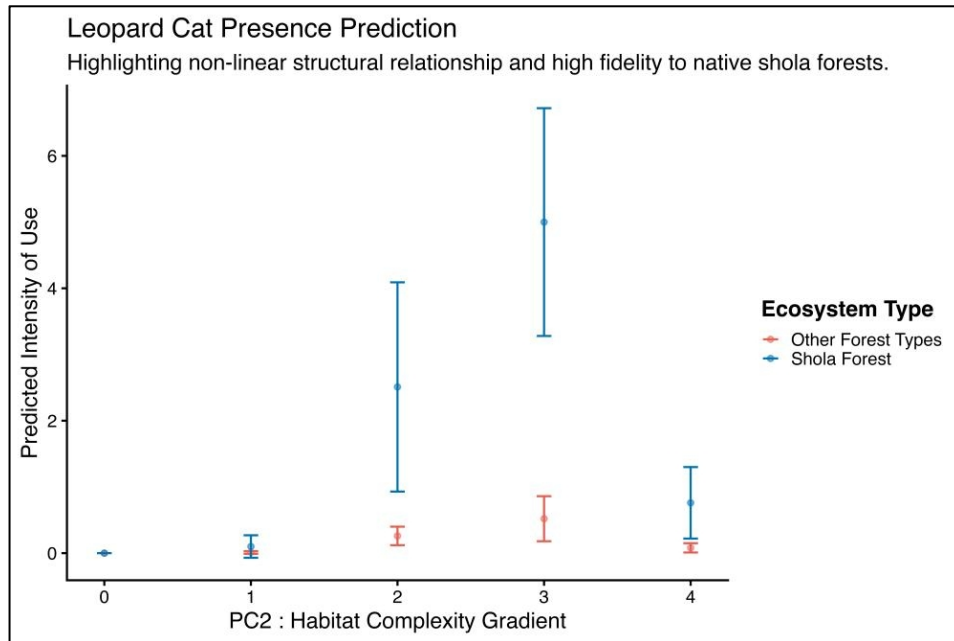


Figure 8: Prediction plot for Leopard Cats over PC2 (Structural Complexity) gradient

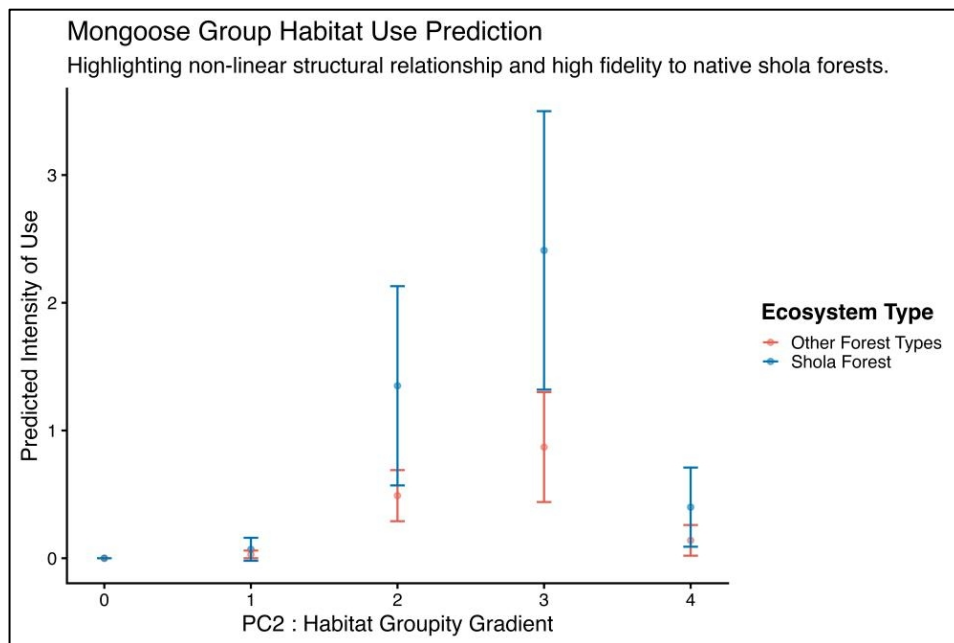


Figure 9: Prediction plot for Mongoose Group over PC2 (Habitat Complexity) gradient

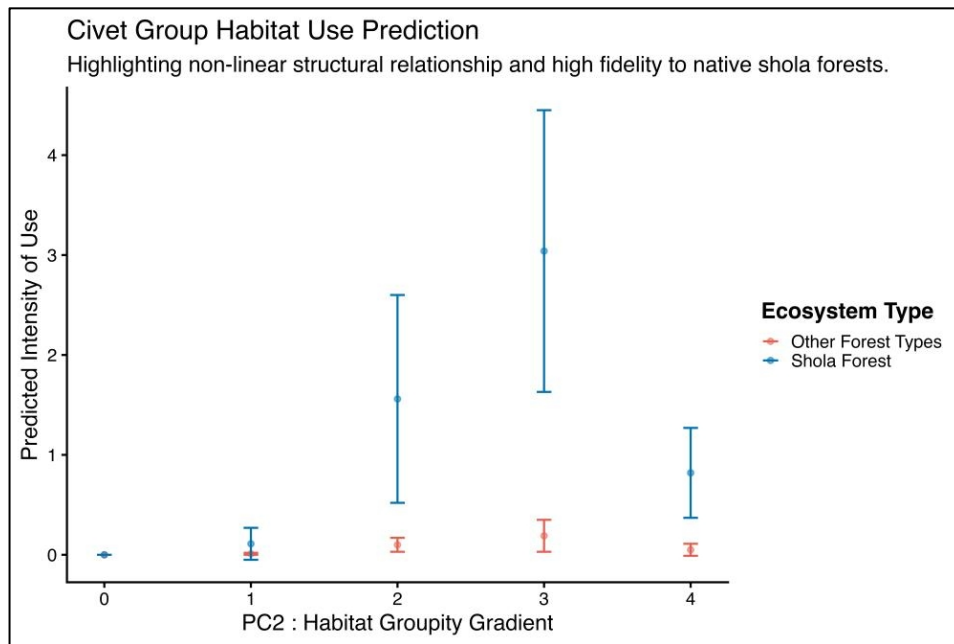


Figure 10: Prediction plot for Civet Group over PC2 (Habitat Complexity) gradient

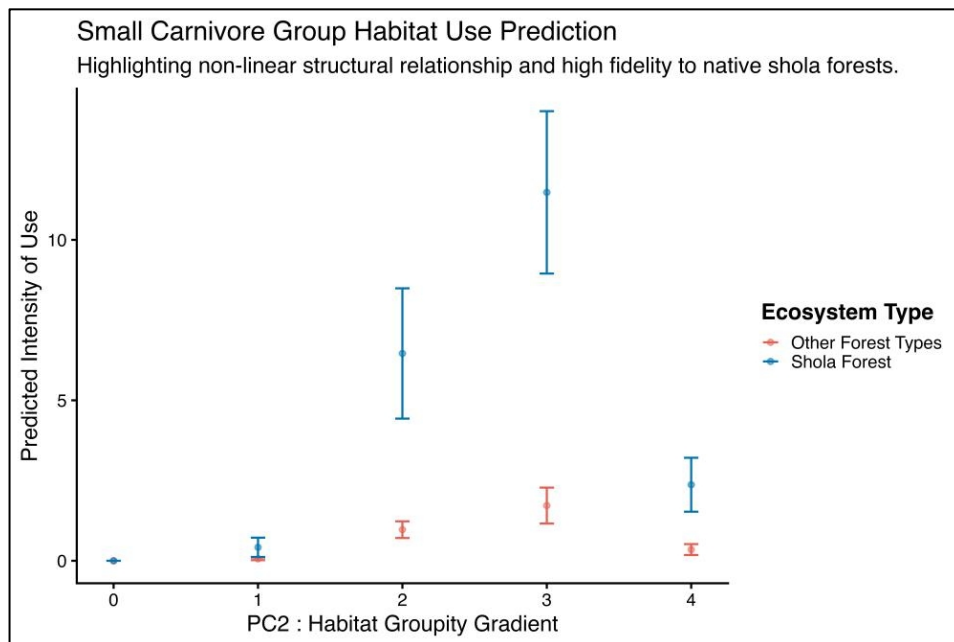


Figure 11: Prediction plot for Small Carnivore Group over PC2 (Habitat Complexity) gradient

2D Niche Space Plot

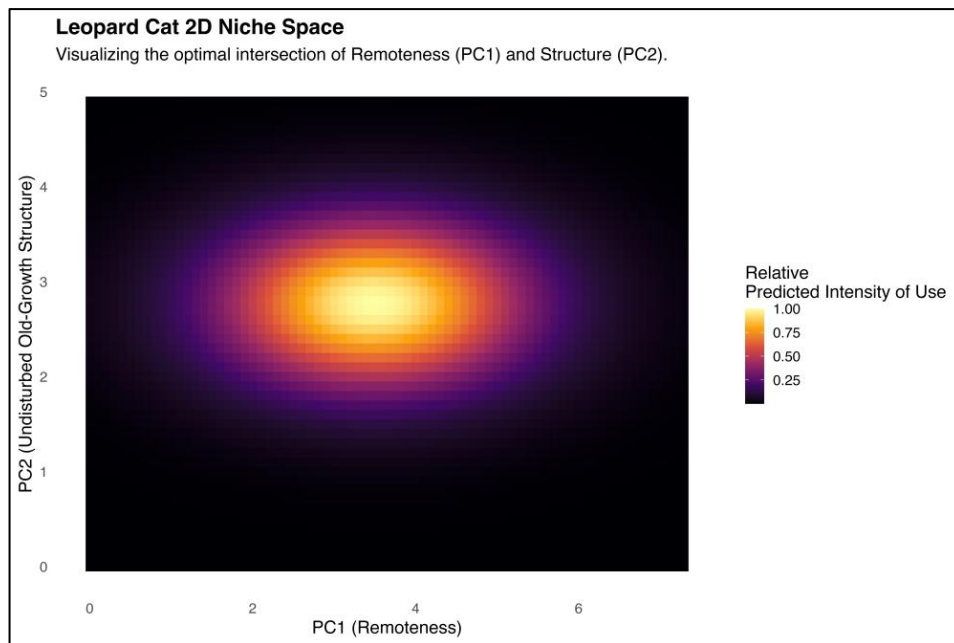


Figure 12: 2D Niche space plot for Leopard Cats

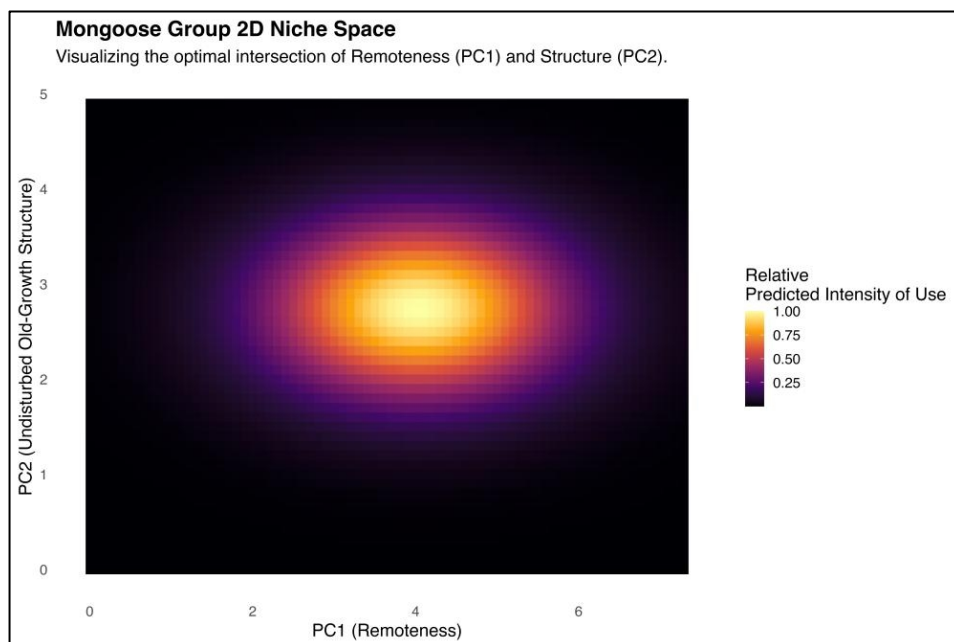


Figure 13: 2D Niche space plot for Mongoose Group

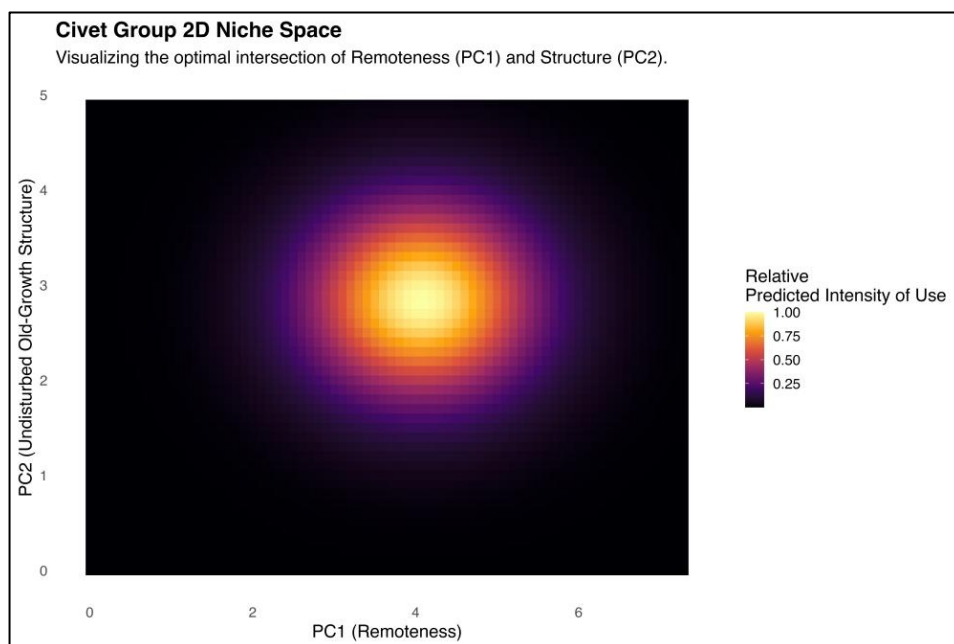


Figure 14: 2D Niche space plot for Civet Group

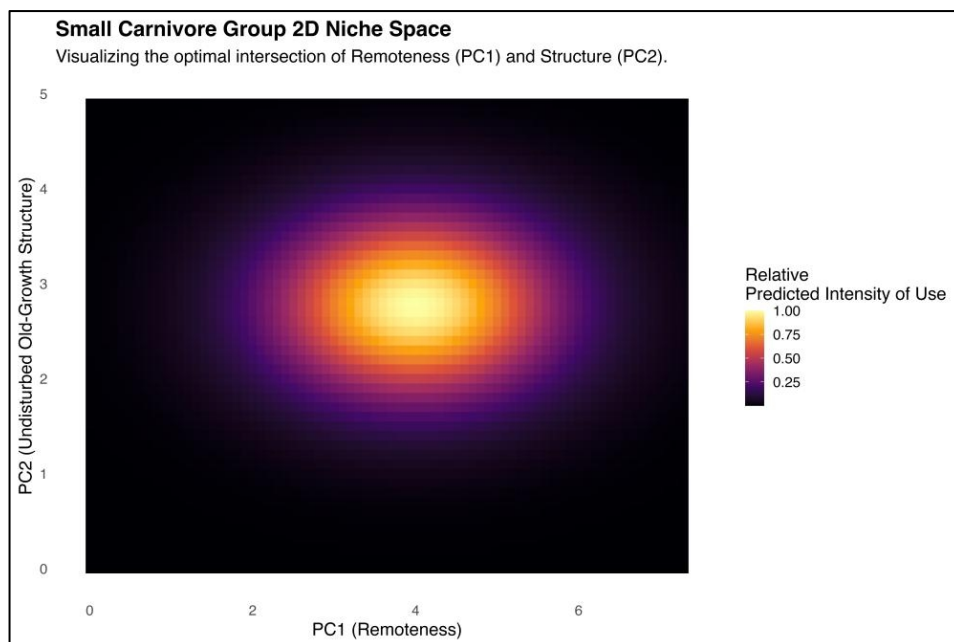


Figure 15: 2D Niche space plot for Small Carnivore Group

4.5. Spatio-Temporal Partitioning

4.5.1. Temporal Partitioning

The carnivore community exhibited distinct temporal stratification, with species demonstrating clear partitioning across the diel cycle. Activity density models revealed three primary functional guilds operating within the landscape: a diurnal assemblage, a nocturnal assemblage, and crepuscular assemblage. (Figure 16)

Diurnal Guild

Within the diurnal guild, the Nilgiri marten exhibited the most specialized temporal restriction, with activity rising sharply after sunrise and reaching a singular peak between 10:00 and 12:00, before ceasing entirely by late evening.

Brown mongoose and stripe necked mongoose also exhibit specialized temporal restriction. The brown mongoose's activity rises gradually after sunrise before plateauing out and later ceasing entirely by late evening. The stripe necked mongoose's activity slowly rises throughout the morning, reaching peak during early evening 14:00 and 17:00, then sharply dropping off.

Nocturnal Guild

The brown palm civet was highly nocturnal, with activity restricted between sunset and sunrise, with a sharp peak during late night around 22:00

to 23:00. Heightened activity just before sunrise, which drops off sharply with sunrise is also observed. No daytime brown palm civet detections were recorded in this dataset

Crepuscular Guild

Leopard cats and small Indian civets both exhibited crepuscular patterns, with almost uniform activity throughout the day and heightened activity during dusk and dawn. Small Indian civets showed a slight affinity towards late nights, with a very small peak of activity around 20:00. Leopard cats exhibited two peaks of activity, one before sunset and one after sunset, with lowered, but not absent, activity during the day.

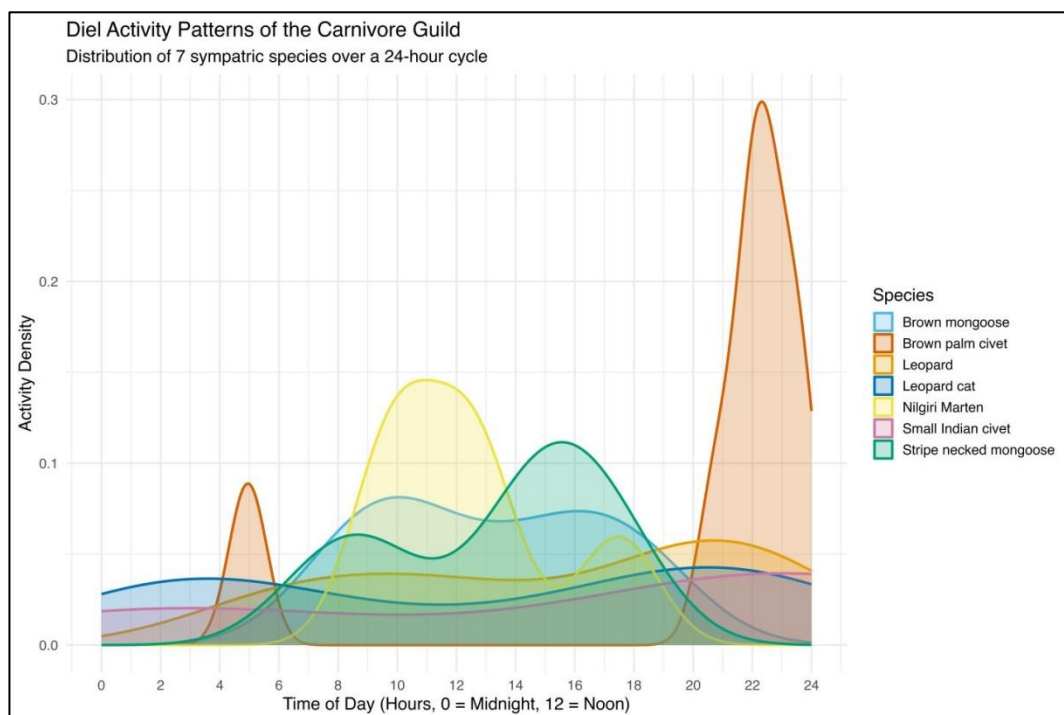


Figure 16: Diel Activity Patterns of Small Carnivores

Pairwise temporal overlap matrix shows considerable levels of overlap between species of same diel activity guild. (Table 3)

Nilgiri marten, brown mongoose and stripe necked mongoose were the only diurnal small carnivores. Both mongooses exhibited low temporal overlap with both civets, but high temporal overlap with Nilgiri marten (Table 3). Both civets also showed very low overlap with Nilgiri marten (Table 3). Leopard cats and small Indian civets showed intermediate temporal overlap (Table 3). Leopard cat showed low temporal overlap with Nilgiri marten (Table 3). Both civets showed intermediate temporal overlap with each other (Table 3).

Species	Leopard	Leopard cat	Stripe necked mongoose	Brown mongoose	Brown palm civet	Small Indian civet	Nilgiri marten
Leopard	1.000						
Leopard cat	0.616	1.000					
Stripe necked mongoose	0.294	0.272	1.000				
Brown mongoose	0.396	0.296	0.703	1.000			
Brown palm civet	0.445	0.466	0.019	0.021	1.000		
Small Indian civet	0.342	0.603	0.014	0.025	0.573	1.000	
Nilgiri marten	0.365	0.257	0.516	0.706	0.012	0.018	1.000

Table 3: Pairwise Temporal activity overlap estimates between target species

4.5.2. Spatial Partitioning

The small carnivore community displayed distinct spatial segregation among themselves. The three focal groups, leopard cats, Mongoose Group, and Civet Group, showed distinct segregation with certain degrees of overlap.

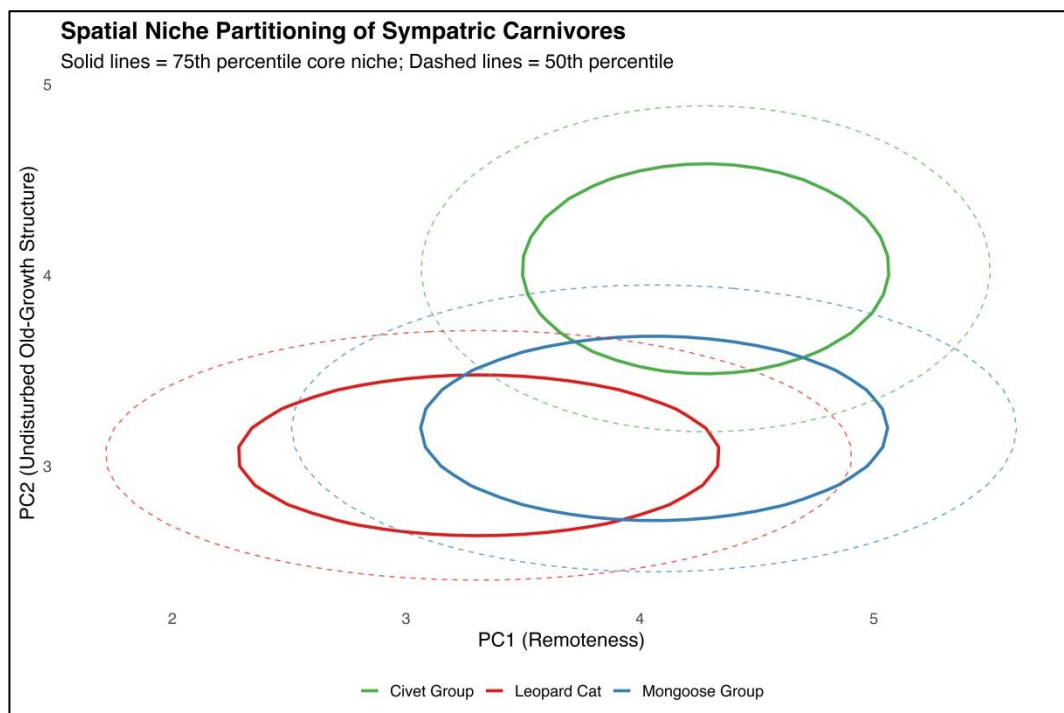


Figure 17 : Spatial overlap plot of Small Carnivores

Spatial overlap was highest between leopard cats and the Mongoose Group, with an overlap of 0.755. Overlap between leopard cats and Civet Group was 0.389, and overlap between Civet Group and Mongoose Group was 0.528. (Table 4)

The predicted habitat use of Civet Groups sits higher along the PC2 gradient, which translates to Civets using habitats of higher habitat structural complexity.

Species	Leopard Cat	Mongoose Group	Civet Group
Leopard Cat	1.000		
Mongoose Group	0.755	1.000	
Civet Group	0.389	0.528	1.000

Table 4: Spatial overlap estimates between focal groups

4.6. Nilgiri Marten

4.6.1. Empirical Field Observations (Camera Trapping)

Over the duration of the systematic camera trapping effort across the 32 designated grids, the target species exhibited an extremely low detection probability. A total of five independent photographic captures were recorded across two distinct camera trap stations situated far apart within the landscape. Interestingly, the captures showed a split in habitat utilization: one capture occurred in an intact Shola forest patch, while the remaining four captures were recorded by a single camera located within an exotic tree patch. This low empirical detection rate underscores the cryptic nature of the species and validates the necessity of integrating qualitative social data to form a comprehensive ecological baseline.

4.6.2. Social Survey Demographics

To supplement the limited photographic evidence, semi-structured interviews were conducted, resulting in 110 valid responses from local community members. The respondent demographic was diverse, with ages ranging from 18 to 74 (mean age = 43.6 years). Awareness of the species was remarkably high among established populations; of the 90 respondents who identified as long-term residents of the landscape, 77 (85.5%) confirmed they had personally seen the animal.

4.6.3. Synthesized Traditional Knowledge

The community-derived ecological data provided a high-resolution behavioral profile that expanded significantly upon the camera trap observations.

Habitat Associations: While the majority of empirical camera captures occurred in an exotic tree patch, local respondents overwhelmingly associated the species with native Shola forests and tree canopies. (Figure 18)

Dietary Profile: Respondents characterized the species as a highly opportunistic omnivore. When desegregating multiple-response answers, fruits were the most frequently reported dietary item (60 mentions), followed closely by eggs (51 mentions), birds (34 mentions), and small mammals and reptiles (23 mentions each). (Figure 19)

Activity and Social Structure: Community observations describe a primarily diurnal species, with 67 respondents noting daytime activity and 16 noting dawn activity. Furthermore, reports sighting the animal in pairs (42 mentions) were more common than solitary sightings (34 mentions). (Figure 20 & 21)

Population Trends: Despite the high sighting rate among long-term residents, the perceived population trend leans negative, with nearly half of the respondents (53 out of 110) indicating that the species has become "less common" over time. (Figure 22)

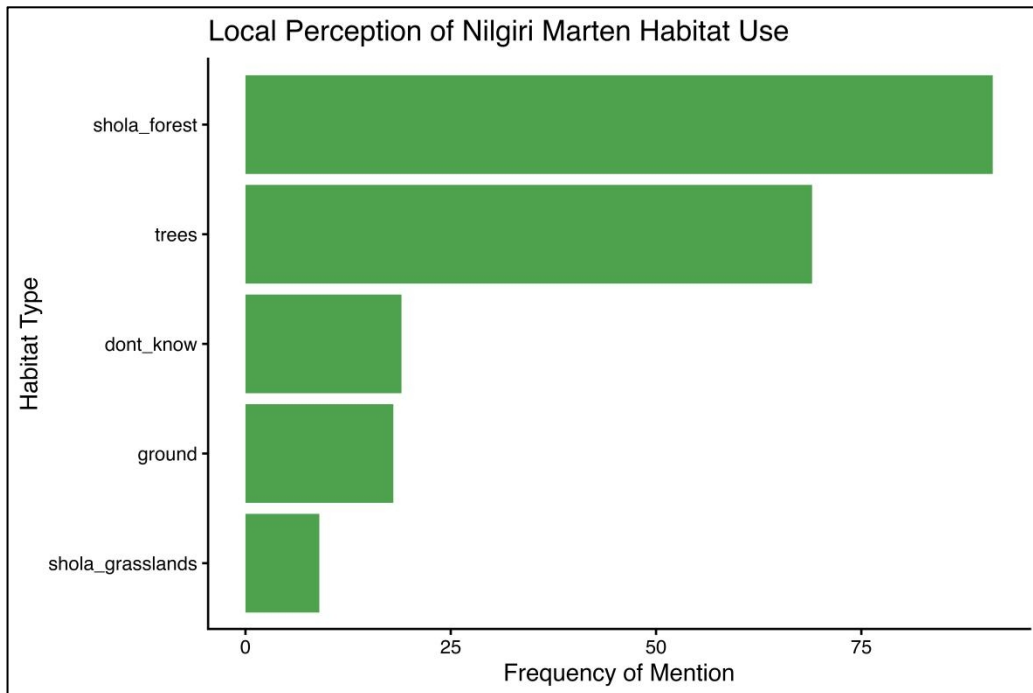


Figure 18: Local Perception of Nilgiri Marten Habitat Use

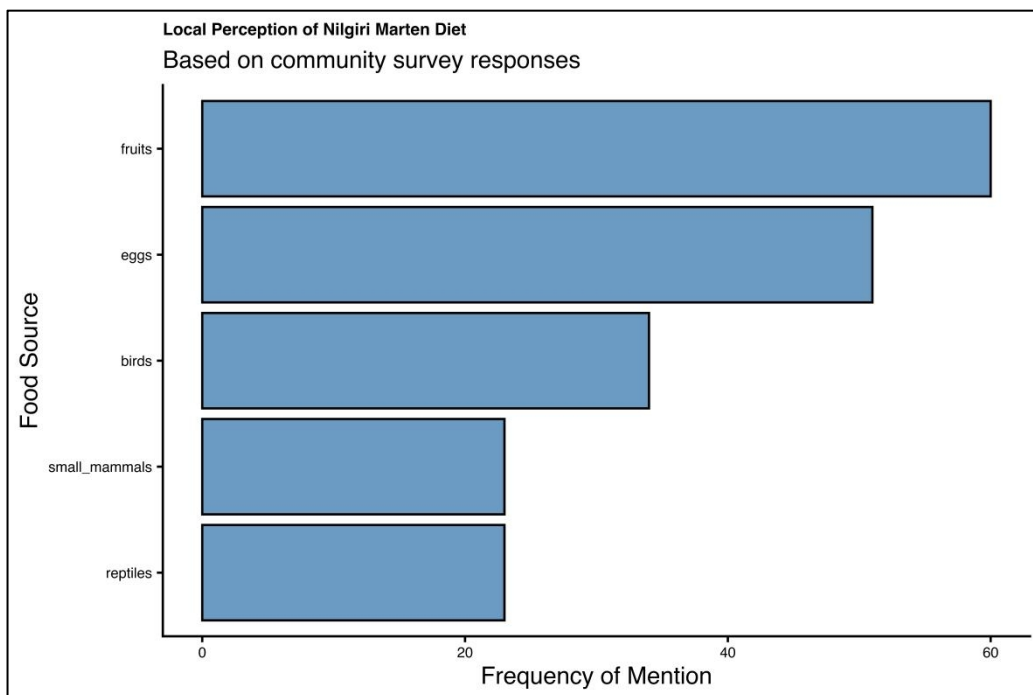


Figure 19: Local Perception of Nilgiri Marten Diet

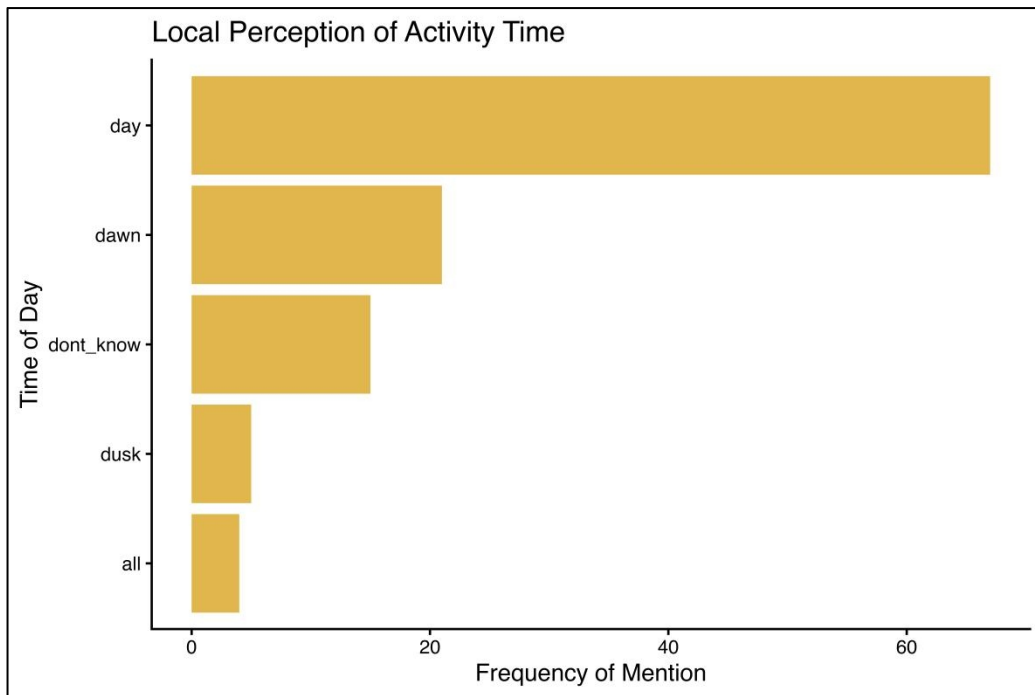


Figure 20: Local Perception of Nilgiri Marten Activity

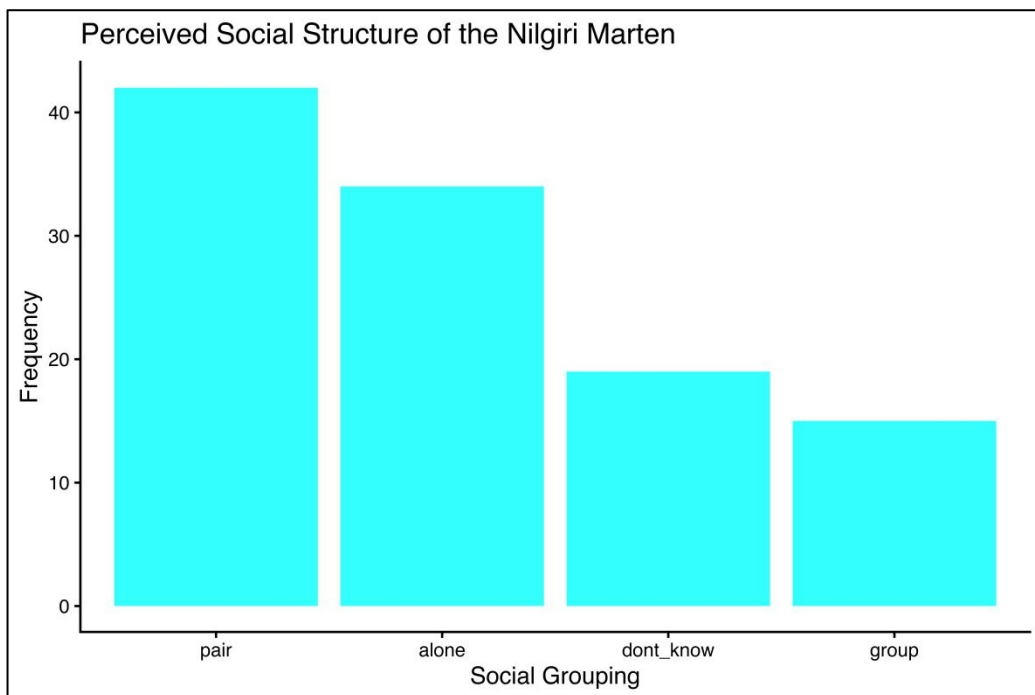


Figure 21: Local Perception of Nilgiri Marten Social Structure

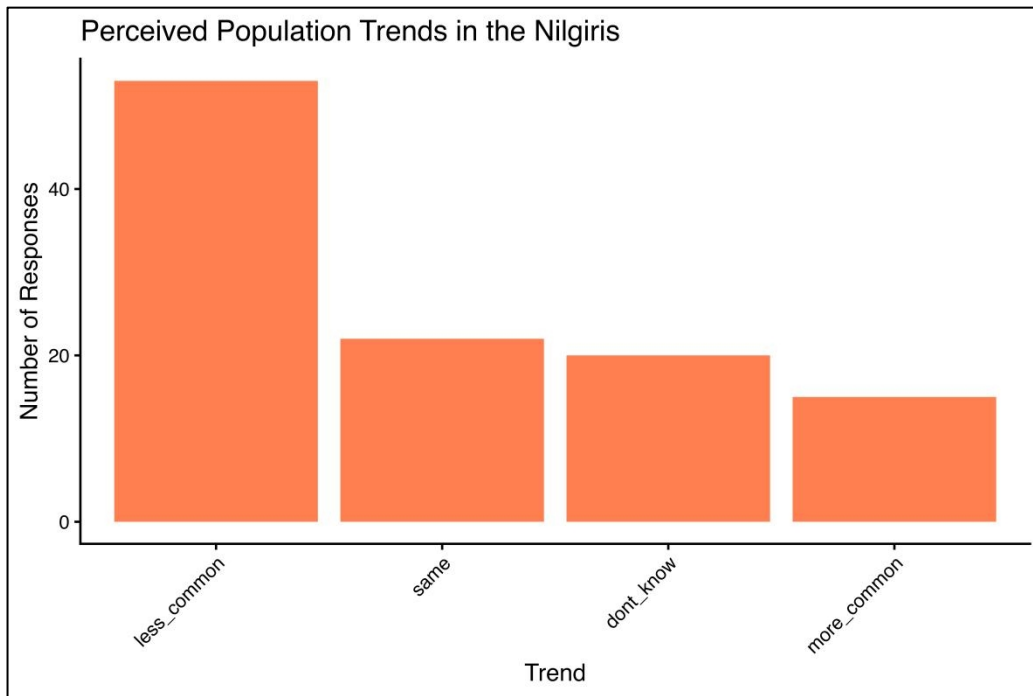


Figure 22: Local Perception of Nilgiri Marten Population Trend

Local names were also documented. Two previously undocumented names were found - “Karumverugu” from the Tamil language, and “Peshku” from the Toda language, a language spoken exclusively by the Toda community in the Nilgiris.

4.6.4. Perceptions of Human-Wildlife Interaction and Conservation

Analysis of the five-point Likert scale questions revealed an overwhelmingly positive community attitude toward the species, characterized by an absence of perceived human-wildlife conflict.

Risk and Depredation: The perceived risk to human safety is practically non-existent, with 104 respondents disagreeing or strongly disagreeing that the animal poses a danger to people. Similarly, 84 respondents disagreed that the species causes economic damage through the depredation of livestock or poultry. (Figure 23 & 24)

Conservation Support: Community support for conservation initiatives is nearly unanimous. One hundred respondents strongly agreed that the species holds ecological importance, and 104 strongly agreed that it requires formal protection. Furthermore, 85 respondents expressed a strong interest in learning more about the animal, indicating high potential for future community-led monitoring or educational outreach programs. (Figure 25)

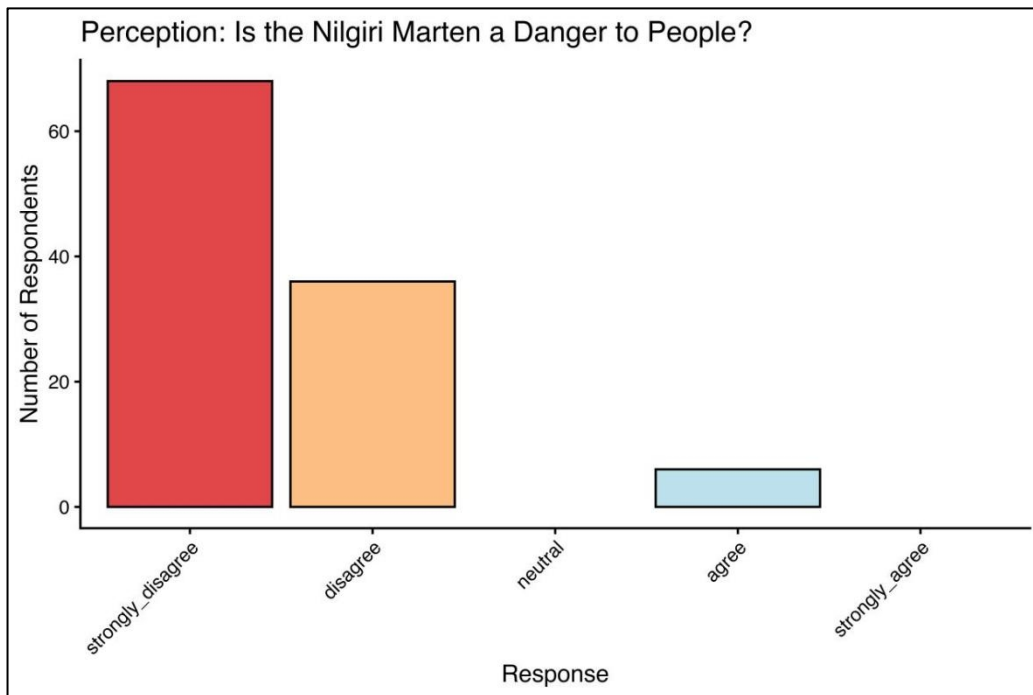


Figure 23: Local Perception on Danger to Human

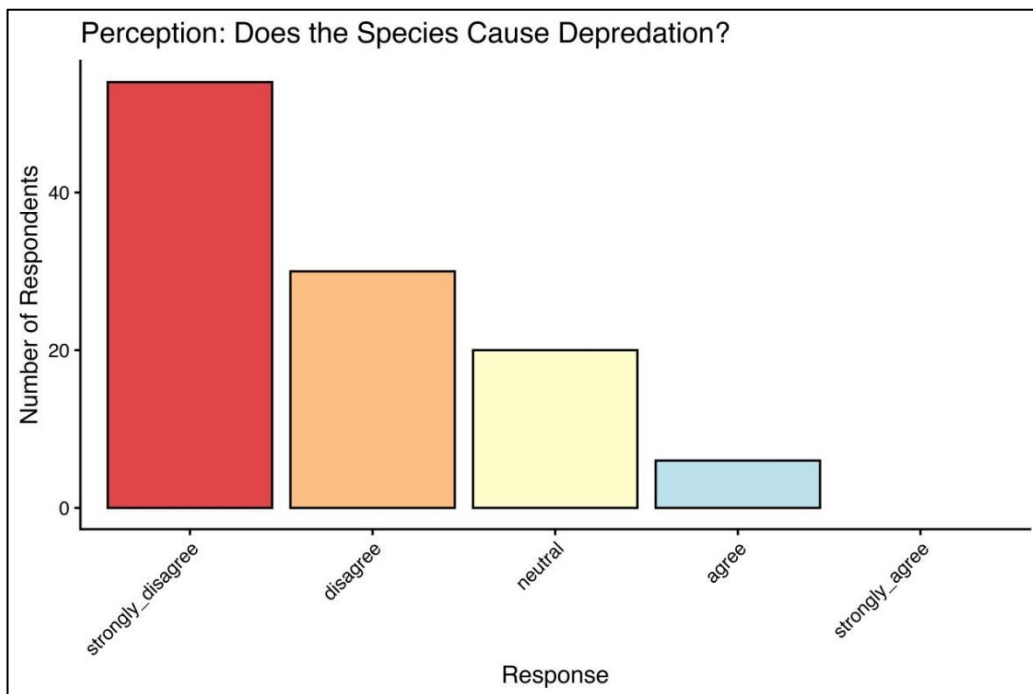


Figure 24: Local Perception of Depredation by Nilgiri Marten

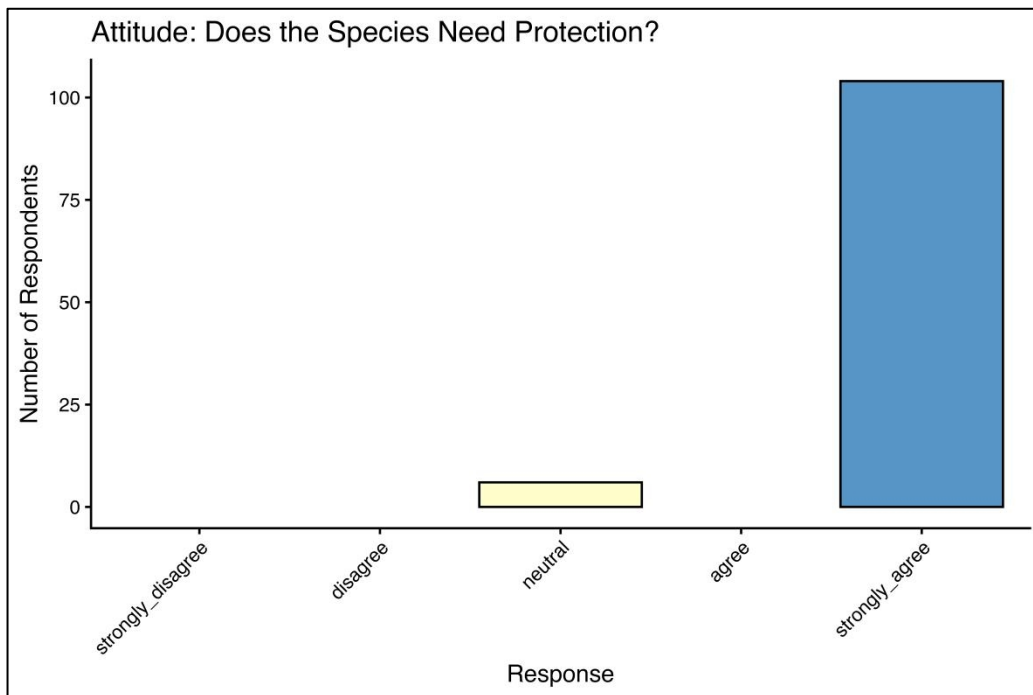


Figure 25: Local Perception of Nilgiri Marten Conservation Importance

5. Discussion

The results of this study broadly suggest that habitat use of small carnivores does not vary drastically for different species groups in the Nilgiris. Difference in habitat use for the different species groups vary slightly from each other in accordance to the species' ecological needs. Factors such as distance to settlements, altitude, canopy cover percentage, canopy height were found to influence habitat use of all focal groups. This could correlate with other factors such as prey availability, which was not accounted for in this study. An analysis of activity patterns also reveals interesting patterns. Species morphologically, and ecologically similar were found to be temporally overlapping with each other, while species not similar were found to be temporally avoiding each other.

A synthesis of traditional knowledge on Nilgiri martens, recorded through semi-structured social surveys, reveal interesting perspectives. Two previously undocumented local names were also documented through the surveys. Despite a large number of respondents saying that they are unfamiliar with the species, an overwhelming majority of them expressed interest in learning more about the species and also in conserving the species.

5.1. Habitat use and its drivers

Leopard cats are the most frequently captures species with 21 captures, whereas specialized species such as Nilgiri martens had very few captures (5 captures). The higher number of Leopard cat detections may be consistent with its broader habitat tolerance, although differences in abundance, movement, and detectability could also contribute. Their behavioral and morphological plasticity allows them to exploit varied ecological niches, unlike obligate species that require intact primary forests (Roemer et al., 2009). There was a complete absence of carnivore detections in tea plantations and agricultural lands during the sampling period. This could be due to the sampling bias caused by uneven sampling across tea plantations and agriculture lands. This absence could also be explained by heavy anthropogenic pressures - such as seasonal clearing, and pesticide use - which may act as strict deterrents to habitat use. At this point, it is difficult to conclusively say what caused lack of detections in agriculture lands and tea plantations

Principal component analysis resulted in two axes, PC1 and PC2, which together explained 61.7% of variance. While PC1 comprises distance to settlement, distance to night light, altitude, PC2 comprises canopy height, canopy cover, understory density. PC1, positively influenced by distance to settlement, night light and altitude, represent a gradient of remoteness. As you move across PC1, remoteness increases, as altitude and distance from settlements increase concurrently. Low PC1 values represent lower altitude

areas closer to human settlements, with presence of garbage. On the other hand, PC2 represents a gradient of habitat complexity. Being driven by factors such as canopy height, canopy cover, understory density, they represent a gradient of low canopy height, low canopy cover, open understory to high canopy height, dense canopy cover and thick understory. Although they did not arise as significant factors in the GLM, the presence of fallen and fruiting trees could also be influencing the habitat use of small carnivores. The presence of fallen and fruiting trees could be a direct result of habitat complexity, as high complexity often represent old growth forests in highly disturbed areas such as the Nilgiris.

Throughout all models, PC2 had the lowest p-value, denoting high significance in explaining the model. All focal groups (Leopard cat, Mongoose, Civet) displayed a non-linear preference for intermediate to moderately-high levels of structural complexity (PC2). For leopard cats, Shola forests was identified as a major driver of presence. This, when coupled with intermediate to moderately high understory density, could provide leopard cats with the micro-habitats it prefers. Intermediate PC2 values also indicate moderate to high canopy height and canopy cover, which could directly influence the presence of terrestrial deadwood. Such micro-habitats could offer safe refuges for leopard cats. More than that, the presence of terrestrial deadwood and fruiting trees could directly increase prey availability. As we noted in the Results earlier, species like the stripe necked mongoose, brown mongoose, and small Indian civets are also positively influenced by moderate PC2 values.

Higher presence of these species would act as a healthy prey base for leopard cats.

Similarly, for the Mongoose Group, PC2 was again a major driving factor. In the context of mongooses, intermediate to moderately-high understory density, canopy cover percentage, and canopy height are the major driving factors. Being ground dwelling, intermediate to moderately-high understory density would offer mongooses more refuges to hide from predators. Canopy cover and canopy height directly influences the presence of terrestrial deadwood and presence of fruiting trees, as discussed earlier. Terrestrial deadwood is an excellent habitat for termites, bugs and grubs. Presence of fruiting trees guarantees a steady stream of fallen fruits.

Another thing to be noted is, despite the majority of mongoose captures in this study being in exotic tree forests, a clear preference for native shola forests is visible in the predictive framework. This means that provided two habitats have similar remoteness and habitat complexity, one in a native forest and the other in an exotic forest, mongooses intensively use the native forest more. As for the observation in this study, mongooses might be choosing exotic forests which are older and unmanaged, which may often develop a dense secondary understory and accumulate fallen deadwood, providing an artificial physical architecture similar to ones found in native forests.

Similar patterns emerge when you look at the habitat use of civets. Although, one major difference between the predictive framework of civets and other focal groups is that for civets, the highest predicted capture count is slightly more skewed to the right side of the PC2 gradient. This denotes a preference for PC2 values higher than that preferred by other focal groups. When you look at the factors which make up PC2, this observation starts looking less like an anomaly. Higher PC2 value indicates more structural complexity, through taller canopies, higher canopy cover and denser understory. Civets being semi-aboreal, would naturally select for areas with taller canopies and higher canopy cover. This could enable them to forage for food, and hide from predators, more effectively.

5.2. Spatio-temporal partitioning

The camera trap data also revealed strict temporal segregation within the small carnivore community, dividing the guild into distinct assemblages:

Diurnal - Nilgiri marten, Brown Mongoose, Stripe Necked Mongoose

Nocturnal - Brown Palm Civet

Crepuscular - Leopard Cats, Small Indian Civets

These patterns, when viewed ecologically, helps us better understand temporal niche partitioning among small carnivores.

During the course of this study, Nilgiri martens were only captured during the day. Similarly, stripe necked mongooses and brown mongooses were also observed to be diurnal, temporally overlapping with each other. (Figure 16). As for nocturnal species, the brown palm civet was observed to be strictly nocturnal. The small Indian Civet also showed nocturnal tendencies, with increased activity post sunset. This clearly represents a scenario where morphologically, and ecologically similar sympatrics overlap temporally (Cusack et al., 2017, Davies et al., 2007, Robinson et al., 2014, Vanaket al., 2013).

Spatial overlap analysis using the predicted habitat use reveals moderate levels of overlap between the focal groups. The high degree of spatial overlap between leopard cats and mongooses can lead to increased competition between them. But the temporal overlap estimates show clear temporal partitioning between leopard cats and mongooses. This helps in keeping competition under control. Temporal segregation among spatially overlapping species is a well documented mechanism employed by species to reduce competition with sympatrics.

5.3. Status of Nilgiri Martens, Traditional Knowledge and Social Perception

The Nilgiri marten detections were extremely low during the course of this study. A total of 5 photo-captures over 2477 trap nights represent a capture rate of 0.201 captures per 100 trap nights. This could be due to naturally extremely low densities, or due to lack of arboreal camera trapping, which could not be done due to resource constraints.

Despite this setback, semi-structured social surveys helped gather much needed baseline data on the perception regarding Nilgiri martens in the Nilgiris.

The results of the social surveys also yielded two new, previously undocumented local names for the Nilgiri marten - “Karumverugu” from the Tamil language, and “Peshku” from the Toda language, a language spoken exclusively by people of the Toda community in the Nilgiris.

According to the social surveys, majority of people associate the Nilgiri marten with shola forests. This stands in contrast to the photo-captures from this study, where only 1 marten was captured in a shola forest, and the rest 4 captures were from an exotic tree forest.

People in the Nilgiris also extensively view Nilgiri martens as a diurnal species (Figure 20). This is reflected in the activity pattern we computed

(Figure 16). The local inhabitants of Nilgiris also largely associate Nilgiri martens with frugivory, with fruits are the most noted dietary item (60 mentions), followed closely by eggs (51 mentions), birds (34 mentions), and small mammals and reptiles (23 mentions each) (Figure 19).

Most of the respondents also expressed their interest in learning more about the species. An overwhelming majority also was in support of conserving this species, while maintaining that the species was ecologically important, and that their population has been declining. (Figure 22, 25 & 27)

5.4. Caveats and methodological issues

The biggest caveat of this study is the low capture rates of all focal species. This tends to make predictive modelling hard as the model could suffer from overfitting. Another major caveat arises due to the merging of captures from the randomly placed camera traps and the optimized camera traps. This was done due to the extremely low capture rates. The third major limitation is the unequal sampling effort across both blocks. Delays and difficulties in obtaining permission from the agriculture land owners to put up camera traps caused deployment to be delayed. To maintain minimum 30 days sampling period across all camera traps, the number of deployed camera traps had to be cut short. Another major caveat of this study is the complete lack of carnivore photo-captures from agricultural land and tea plantations. One reason for this could be that most of the agricultural land and tea plantations in the study area were fenced to prevent wild animal intrusions. This study could not account for this factor. Future studies should ensure fenced land is accounted for, or ensure alternate study sites are available.

5.5. Conclusion

Small-carnivore detections in the study area were concentrated in shola forest, shola grassland, and exotic-tree patches, while no detections were recorded in the sampled tea and agricultural sites. The fitted models suggested non-linear associations between capture counts and the PCA-derived gradients of remoteness and vegetation structure. However, low capture numbers, unequal sampling among habitats, pooled camera-placement strategies, and the absence of explicit detection-probability modelling limit the strength of these conclusions.

These species minimize competition by strictly dividing their time and habitat use. They could be utilizing highly specialized diurnal, nocturnal, and crepuscular rhythms to minimize direct competition, while ensuring spatial segregation minimized their chances of encountering sympatrics. Although this was not directly tested in this study, it lays ground for future work.

Beyond the camera trap, this study highlights the untapped scientific value of the people who share this landscape. Traditional Knowledge proved invaluable for establishing a baseline for the elusive Nilgiri marten, revealing a community that not only understands the animal's ecology but overwhelmingly supports its conservation, free from the friction of human-wildlife conflict. Moving forward, securing the future of the Nilgiris' mesocarnivore guild will require a dual approach: we must protect the structural integrity of native forest micro-habitats, and we must elevate local communities from passive observers to active partners in conservation.

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Appendix

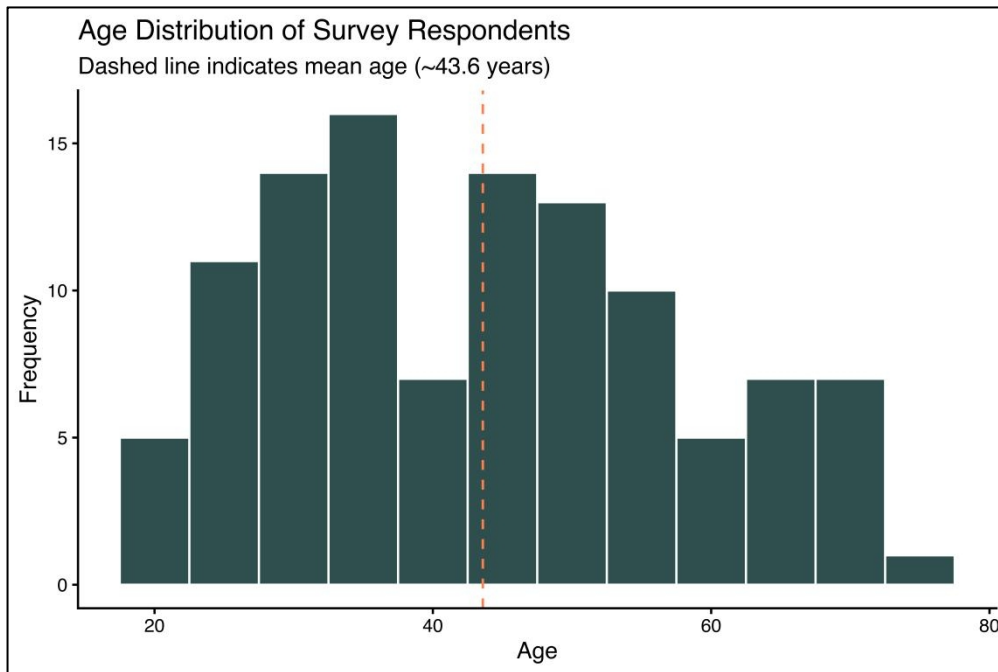


Figure 26: Age Demographic of Social Survey Respondents

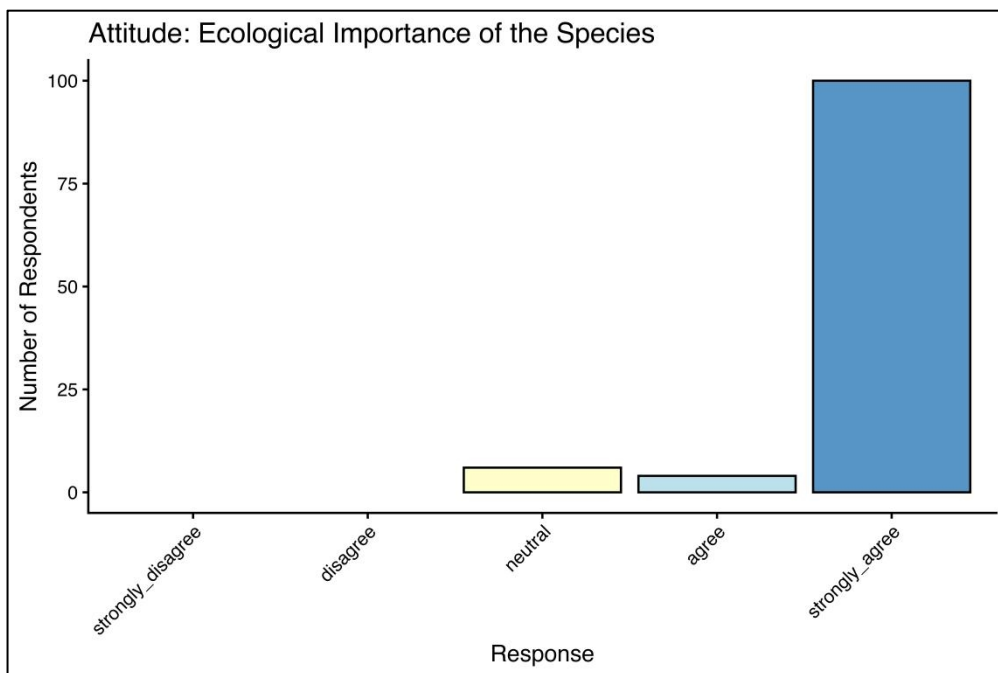


Figure 27: Social Perception- Attitude Towards Ecological Importance of Species

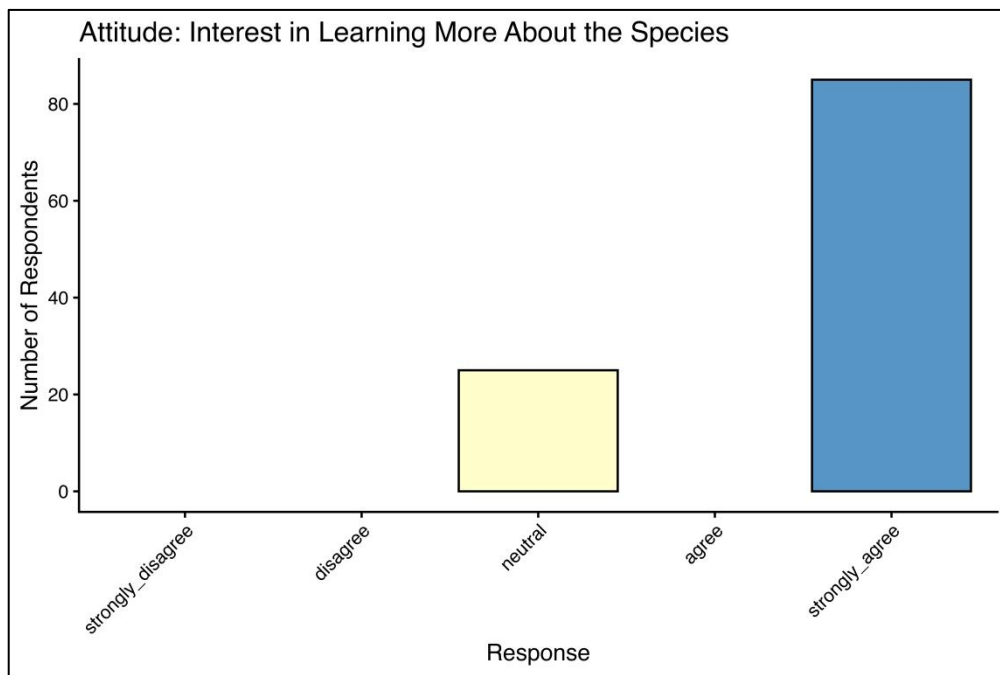


Figure 28: Social Perception - Interest in Learning More About the Species

Few Photographs from the camera traps



Nilgiri Marten (*Martes gwatkinsii*)



Leopard Cat (*Prionailurus bengalensis*)



Brown Palm Civet (*Paradoxurus jerdonii*)



Brown Palm Civet (*Paradoxurus jerdonii*)



Nilgiri Marten (*Martes gwatkinsii*)



Leopard Cat (*Prionailurus bengalensis*)



Bengal Tiger (*Panthera tigris*)



Bengal Tiger (*Panthera tigris*)