Nepalese Journal of Zoology

ISSN: 2705-4403 (Print); 2705-4411 (Online)
www.cdztu.edu.np/njz

Volume 9 | Issue 2 | December 2025

https://doi.org/10.3126/njz.v9i2.88087

Research article

Urban forests as refuges for terrestrial vertebrates: persistence and temporal activity in suburban Chennai, Southern India

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Suggested citation: Christudhas A., Narasimmarajan K., Jeswin S., Harikrishna, P. and Mathai M.T. 2025. Urban forests as refuges for terrestrial vertebrates: persistence and temporal activity in suburban Chennai, Southern India. Nepalese Journal of Zoology, 9(2):1–6. https://doi.org/10.3126/njz.v9i2.88087

Article history:
Received: 11 November 2024
Revised: 20 November 2025
Accepted: 21 November 2025

Publisher's note: The statements, opinions and data contained in the publication are solely those of the individual author(s) and do not necessarily reflect those of the editorial board and the publisher of the NJZ.

Abstract

Urban environments harbour many terrestrial vertebrate species. Apparently, urban forests are providing habitat for many terrestrial vertebrates without changing their spatial movement patterns, particularly without decreasing their home ranges in response to habitat limitation. Several species-specific studies suggest that urban vertebrates decrease their home ranges compared with non-urban counterparts; however, it remains unclear whether this pattern is widespread across taxa or restricted to specific taxonomic groups. Consequently, we conducted a camera trap survey in Madras Christian College Campus, Chennai, spanning approximately 317.45 acres (1.48 km^2) of Southern Tropical Dry Evergreen Forests with high human pressure to study the persistence and temporal activity patterns of terrestrial vertebrates. Camera traps were deployed at 11 locations within the campus and detected nine species of terrestrial vertebrates between September 2021 and April 2022. The temporal activity pattern of the golden jackal and Indian crested porcupine was found to be nocturnal, the Indian Peafowl is crepuscular, and the Indian grey mongoose was found to be diurnal. The human movement pattern also appeared during midnight and midday. The golden jackal and jungle cat had >60% temporal activity overlap, the golden jackal and Indian crested porcupine had >40% overlap, the golden jackal and chital had >25%, and the Indian crested porcupine and Indian grey mongoose had <20% temporal activity overlap, suggesting that these species may be tolerant to low levels of anthropogenic disturbance without changing their movement patterns. Our study thus indicates that urban forests still serve as a refuge for many terrestrial faunas. Further ecological research and conservation attention are needed to ensure the persistence of the last remaining populations of fauna through establishing a long-term ecological observatory to educate students and the urban public and to investigate the impact of urbanization on urban wildlife.

Keywords: Urban forests; Camera trapping; Activity pattern; Terrestrial vertebrates; Conservation

1 | Introduction

The persistence and temporal activity of terrestrial vertebrates in Indian urban areas are poorly documented, even though parts of the country fall within a global core area for terrestrial vertebrate conservation (Prater 1990). In particular, urban ecology and the spatial movement patterns of urban wild vertebrates are poorly studied, with a few exceptions (Rabinowitz 1989, 1991; Grassman et al. 2005; Rajaratnam et al. 2007; Baker et al. 2011). Camera-trapping has improved our ability to study the activity and terrestrial movements of vertebrates in forests that are difficult to observe or are rare (van Schaik & Griffiths 1996), species diversity, associations among species (Ngoprasert et al. 2007), and their habitats (Gray & Phan 2011). The time stamps recorded in photographs provide a detailed account of species activity patterns (Laidlaw & Shaharuddin 1998; Kawanishi & Sunquist 2004). Such data can be used to study the processes that shape ecological communities, especially whether potentially competing species overlap or avoid each other temporally, and how larger species might influence the activity of their smaller cohorts in the same habitat.

Numerous studies have been conducted on coexistence and resource niche partitioning between vertebrates in tropical forests (Karanth & Sunquist 1995; Ray & Sunquist 2001; Scognamillo et al. 2003); however, few studies have focused on the temporal activity patterns and habitat use of terrestrial vertebrates. Our study also aimed to investigate the temporal activity patterns of terrestrial vertebrates using a broad-scale dataset from eleven sites within the Madras Christian College campus (hereafter MCC campus) to quantify the temporal activity and overlap in habitat use among existing vertebrates and their principal predators (i.e., golden jackal- *Canis aureus indicus* and jungle cat - *Felis chaus*). We highlight the observed activity patterns and spatial overlap in the context of what is known about the movement ecology and habitat preference of individual species.

2 | Methods

2.1 | Study area

The Eastern Ghats mountains run parallel to the east coast region of India. Unlike the Western Ghats, these discontinuous mountain ranges are less understood and little studied. The Chennai Metropolitan area is part of the Eastern Ghats remnant, in which less than 1% of the Southern Tropical Dry Evergreen Forests (STDEF) exist. The MCC campus, measuring approximately 1.48 km^2, is located at 12.5520° N, 80.0720° E and 5 m above sea level (Meher-Homji 2007) and is classified as a primitive forest historically part of the Vandaloor and Selaiyur Reserve Forests, home to rich faunal and floral diversity (Narasimmarajan & Mathai 2015). Apparently, the MCC campus flora is well documented, whereas there is limited documentation on campus wildlife, particularly terrestrial vertebrates. Although urbanization has affected the surrounding areas, the MCC campus remains less disturbed, harbouring its pristine flora and fauna. Chennai is one of the metropolitan cities in India and is home to more than 10 million people. Chennai suburbs have more than 26 forest patches with areas varying from 23 acres to 6,500 acres (Champion and Seth 1968). The main forest types include deciduous forests (mixed and dry scrub) found in drier areas (<500 mm rainfall), with annual average temperatures between 25 °C and 40 °C (Narasimmarajan & Mathai 2015) (Fig. 1).

2.2 | Camera-trap data collection

The study's objective was to examine terrestrial vertebrate diversity and temporal activity patterns through the camera trap method (Kitamura et al. 2010). We deployed automated camera traps (Bushnell 119739 NatureView Camera Trap HD Max 12MP) at 11 locations with a total effort of about 760 camera-trap nights within the MCC campus (Fig. 1). Across the sites, camera traps were consistently placed along animal trails following ridges and water crossing points. At all sites, cameras were set to record activity 24 hours per day. Therefore, while detection probabilities for terrestrial vertebrates were not optimized at every site, there was no temporal bias in the probability of being detected. Photographs were independently verified before inclusion in the dataset (Gray & Phan 2011). Photographs with time/date stamps were obtained from camera trap pictures for golden jackal (*Canis aureus indicus*), Indian crested porcupine (*Hystrix indica*), small Indian civet (*Viverricula indica*), Asian palm civet (*Paradoxurus hermaphroditus*), Indian grey mongoose (*Herpestes edwardsii*), jungle cat (*Felis chaus*), chital (*Axis axis*), humans (*Homo sapiens*), and Indian peafowl (*Pavo cristatus*) across the study areas from September 2021 to April 2022 (Table 1).

2.3 | Data analysis

For each species, camera trap data were pooled, and activity patterns were defined. The day-night cycle remains constant throughout the year within the study site, as sunrise occurs at 06:00 hours and sunset at 18:00 hours local time (GMT+5:30). We defined activity as strongly nocturnal (≥85% of observations between 18:00–06:00 hours), strongly diurnal (≥85% of observations between 06:01–17:59 hours), and strongly crepuscular (≥85% of observations between 05:00–07:00 and 17:00–19:00 hours) (Azlan & Sharma 1996). These categories were established to refine previous, more simplistic classifications of activity patterns (van Schaik & Griffiths 1996).

2.4 | Vertebrate activity analysis

All captured vertebrate species are fully terrestrial, and since our camera traps only recorded activity at ground level, we were able to assess temporal activity. Capture times for each species were regarded as a random sample of photographs taken at any time of day. We estimated the daily activity pattern and overlap between sympatric vertebrate species by applying the statistical methodology developed by Ridout and Linkie (2009). We computed each species' temporal activity pattern separately using kernel density estimation or by fitting trigonometric sum distributions (Ridout & Linkie 2009). Then, a measure of overlap between two

Figure 1. The study area at MCC Campus, Chennai suburban forests (black square). The red points indicate the camera trap stations used from September 2021 to April 2022.

Table 1. List of terrestrial vertebrates recorded in the camera trap survey at the MCC Campus, Chennai Suburban Forests.

Species	Order	Family	IUCN Red List status	Number of photos captured	Photo capture rate
Golden jackal	Carnivora	Canidae	Least Concern	11	4.6
Indian crested porcupine	Rodentia	Hystricidae	Least Concern	135	51.1
Indian grey mongoose	Carnivora	Viverridae	Least Concern	15	6.3
Asian palm civet	Carnivora	Viverridae	Least Concern	14	5.9
Jungle cat	Carnivora	Felidae	Least Concern	7	2.9
Chital	Artiodactyla	Cervidae	Least Concern	10	4.2
Indian peafowl	Galliformes	Phasianidae	Least Concern	28	11.8
Small Indian civet	Carnivora	Viverridae	Least Concern	16	6.7
Human being	Primates	Hominidae	-	14	6.1

focal species' distributions was calculated. Ridout and Linkie (2009) favored the coefficient of overlapping, Δ_1, which is defined as the area under the curve formed by taking the minimum of two density functions at each time point. The coefficient of overlap equals 1 if the activity densities are identical and equals 0 if they have no common active period.

All statistics were performed in R version 2.11.1 (R Development Core Team 2009). We used the estimator for the coefficient of overlap because it is recommended for small sample sizes (Ridout & Linkie 2009) and is defined by the following formula:

$$\Delta_1 = \int_0^t \min \{f(t), g(t)\}\, dt$$

The photo capture rate for each species was calculated using the Camera-trap photographs (/trap-days) N° individual species photo captured x individual encounters/100 camera-trap-days using non-parametric statistics.

3 | Results

3.1 | Temporal activity pattern of terrestrial vertebrates

In general, small mammals are nocturnal and very secretive in nature. Similarly, the terrestrial vertebrates observed in the MCC campus are predominantly nocturnal, followed by crepuscular and diurnal. Most species appeared to be more active during night hours, i.e., 18:00 to 06:00 hours, and during early morning and late evening hours between 05:00–07:00 and 17:00–19:00 hours. The Indian crested porcupine showed peak activity between 18:00–06:00 hours, followed by the golden jackal, small Indian civet, Asian palm civet, and jungle cat, which all appeared to be nocturnal (Fig. 2). The Indian peafowl and chital appeared to be crepuscular, and the Indian

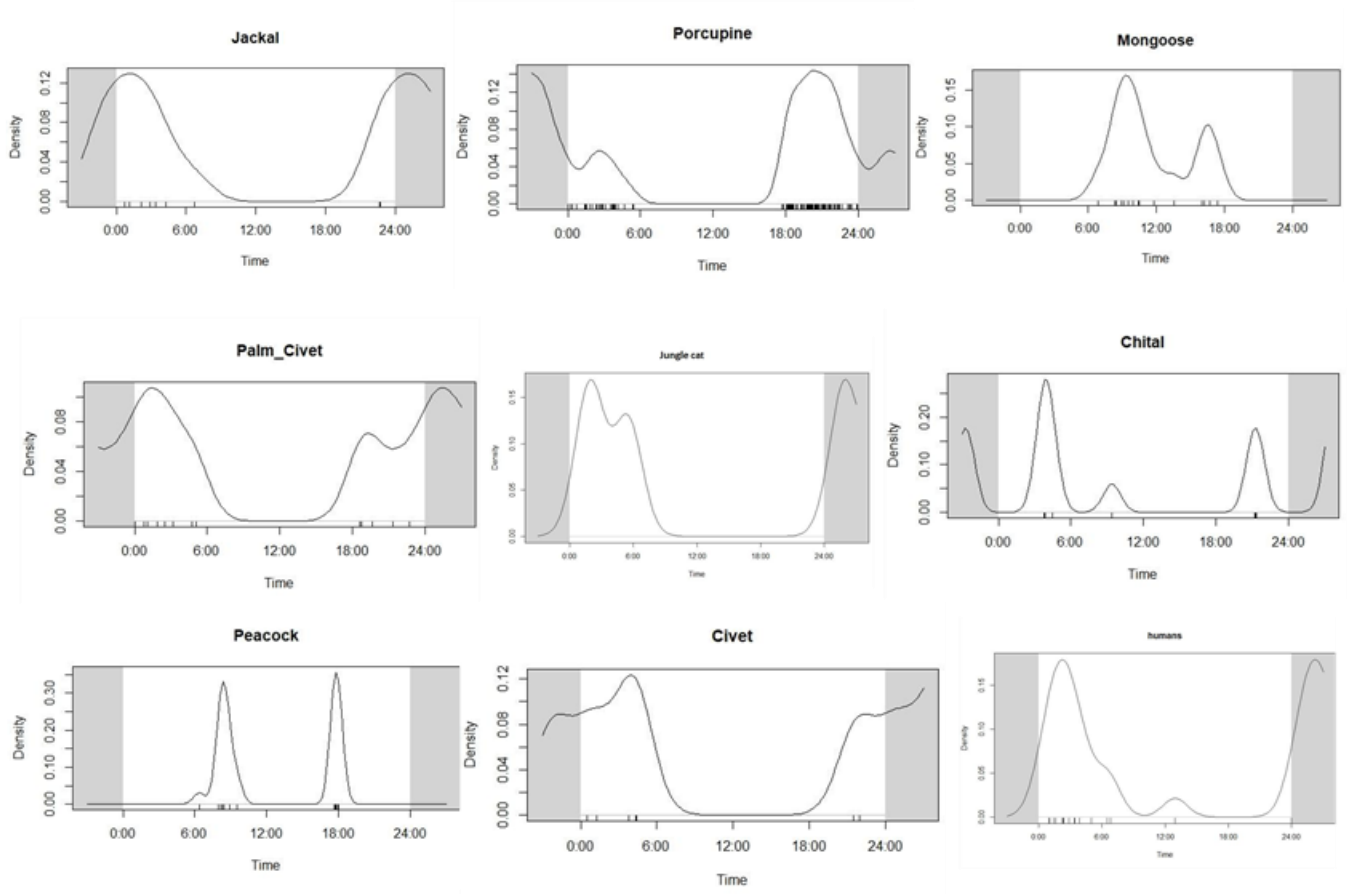

Figure 2. Density estimates of daily activity patterns of eight vertebrate species in MCC campus. Solid lines are kernel-density estimates; dashed lines are trigonometric sum distributions. The short vertical lines above the x-axis indicate the times of individual photographs.

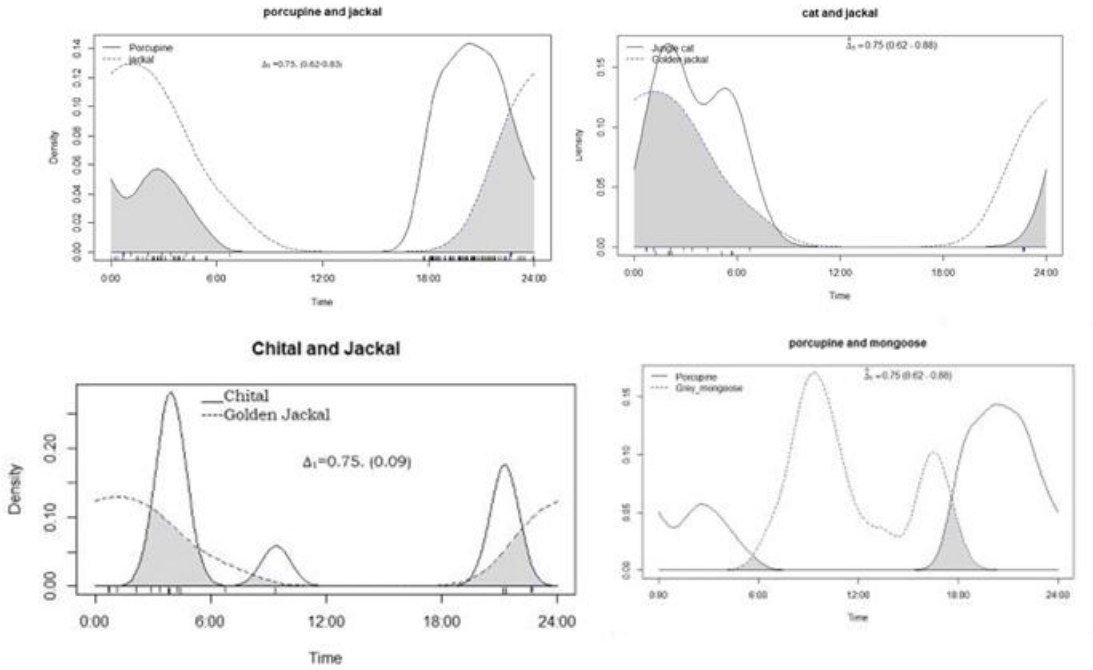

Figure 3. Daily activity patterns and overlap of golden jackal compared with jungle cat, golden jackal and porcupine and Indian crested porcupine and Indian grey mongoose in MCC campus, Southern India. Individual photograph times are indicated by the short vertical lines above the x-axis. The overlap coefficient is the grey shaded area under the two density estimates.

grey mongoose was diurnal in the MCC campus. The overlap between the principal predators, i.e., golden jackal and jungle cat, was 60%, whereas the predator-prey overlap between golden jackal and Indian crested porcupine was about 40%, the golden jackal and chital had >25%, and the overlap between prey species, Indian crested porcupine and Indian grey mongoose was about 20% (Fig. 3). The density plots of golden jackal and jungle cat activity times indicated a high overlap, and the Indian crested porcupine and golden jackal activity times indicated an overlap. The golden jackal and chital had a synchronized overlap of 50% in their activity patterns. The overlap between Indian grey mongoose and Indian crested porcupine was lower during the survey (Fig. 3).

3.2 | Temporal activity representation by the vertebrate species

A total of 720 trap-night efforts yielded 236 independent photo captures representing 8 different species, of which the Indian crested porcupine photo-capture rate was highest at 51.1/100 trap nights, followed by the Indian peafowl at 11.81/100 trap nights,

Figure 4. The camera trap pictures of terrestrial vertebrates captured at the MCC campus, Chennai.

small Indian civet at 6.79/100 trap nights, Indian grey mongoose at 6.38/100 trap nights, Asian palm civet at 5.90/100 trap nights, golden jackal at 4.65/100 trap nights, chital at 4.28/100 trap nights, and the lowest capture rate was that of the jungle cat at 0.84/100 trap nights; humans were captured at 6.1/100 trap nights. Our observations confirm that 90% of the terrestrial vertebrates on the MCC campus were nocturnal and partially crepuscular and diurnal in their activity patterns. The Indian crested porcupine was most active during night hours (96.1%) and progressively less active during day hours (3.9%). In contrast, the Indian grey mongoose was most active during day hours (98.2%), followed by the Indian peafowl (91.9%) and chital (90.4%), respectively (Fig. 4).

4 | Discussion

Our findings suggest that terrestrial vertebrate activity patterns throughout the survey were shaped directly by prey activity and, to a lesser extent, were largely uninfluenced by human presence, partly corroborating the hypothesis (O'Donnell & Delbanco-Trillo 2020). During periods of human disturbance under restricted area conditions, these species may display nocturnal activity synchronized with their prey. At night, when humans were active, golden jackal activity rhythms also tracked prey activity across lunar phases. Golden jackal and jungle cat spatial behavior may be shaped by humans during both day and night and by prey activity during the night (Herrero et al. 2020). As our cameras were placed at 11 sites along campus roads used by humans (guards, students), the effect of human disturbance on terrestrial vertebrate activity in the MCC campus could be less pronounced due to infrequent use of roads during the day (Herrero et al. 2020). This corroborates that the hypothesis that humans drive an increase in nocturnal activity among wildlife (Karanth & Sunquist 1995) did not apply to campus vertebrates. Our results also do not align with the general concept of the human role as a diurnal "super predator" who interferes with predator-prey relationships at multiple levels and in multiple contexts (Karanth & Sunquist 1995; Haswell et al. 2017). Shifts in activity patterns help terrestrial vertebrates coexist with or avoid encounters with humans and, as such, may facilitate their survival in human-dominated urban forests. However, the consequences of these behavioral observations for individual fitness and the long-term persistence of populations remain unknown. A similar study conducted at the Taiyur Reserve Forest by Narasimmarajan and Mathai (2015) suggested that urban wildlife needs to be thoroughly studied for a better understanding of their persistence and threats, which would help draw better management plans for urban wildlife.

5 | Conclusions

The MCC campus is home to many threatened vertebrates; further ecological studies from their perspective are recommended. The conservation of urban vertebrates requires research attention to sustain populations through establishing a Long-term Ecological Observatory (LTEO) to educate urban students and the public about the impact of urbanization on urban wildlife. Increasing levels of urbanization restrict the spatial movement of species across taxa; these findings are relevant for expanding ecological studies and drawing management strategies for urban wildlife populations.

Acknowledgements

The Authors wish to thank the Principal, Bursar, Dean of Research and Development and the Head, Department of Zoology of Madras Christian College, Tambaram, Chennai- 600 059 for providing/ sanctioning the seed money grant to Dr. Anulin Christudhas for undertaking this project.

Authors' contributions

KN assisted in designing, data analysis and drafting the manuscript; AC & MTM conceived the idea and helped draft the manuscript and performed the data collection with JS & HP.

Conflicts of interest

The authors declare no conflict of interest.

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