

## Distribution and ecology of the Indian giant squirrel (*Ratufa indica* Erxleben) in the Valparai Plateau, Southern India

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### Abstract

The Indian giant squirrel *Ratufa indica* (Erxleben) is considered Least Concern (LC) in the IUCN Red List of Threatened Species. Populations of Indian Giant Squirrel are distributed across the Anamalai Tiger Reserve (ATR), Tamil Nadu, India, situated within the Western Ghats, which is recognized as one of the world's 25 biodiversity hotspots due to its unique flora and fauna. The species is crucial to seed dispersal in this ecosystem. We studied *R. indica* in the ATR, using line transects to estimate numbers of *R. indica* and point quadrats to analyze vegetation. We describe the population density, habitat preferences, and tree species use of *R. indica* on the Valparai Plateau within the Anamalai Tiger Reserve between January 2021 and March 2021. A survey of 14 transects covering 220 km<sup>2</sup> revealed a group density of 10.7 groups/km<sup>2</sup> and an individual density of 17.9 individuals/km<sup>2</sup>, with a detection probability of 0.32. Habitat analysis showed significant differences in tree characteristics between areas with and without squirrels, with inhabited areas featuring larger trees, denser canopy, and greater species richness. Regression analysis identified positive correlations between *R. indica* abundance and canopy cover and tree height, whereas crown width and tree species diversity negatively impacted *R. indica* presence. Additionally, *R. indica* showed a preference for the lower and upper canopy levels of trees, with minimal sightings at lower elevations. Tree species analysis indicated that *Spathodea campanulata* and *Mesua ferrea* trees were most commonly used by *R. indica*, contributing significantly to the species composition. These findings provide insights into the factors influencing this species' distribution and habitat selection, which are essential for developing conservation strategies in the region.

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### Introduction

India hosts the richest mammalian diversity and is the one of the 17 megadiverse countries in the world due to its varied climatic conditions and diverse ecosystems. India is home to approximately 429 species of mammals, across 206 genera, 50 families, and 15 orders (Menon, 2014). This includes many

endangered species such as the Bengal tiger (*Panthera tigris tigris*), Asian elephant (*Elephas maximus*), and Indian one-horned rhinoceros (*Rhinoceros unicornis*) as well as smaller yet ecologically significant species like the Indian pangolin (*Manis crassicaudata*) and many species of bats and rodents. Mammalian diversity in India comprises species adapted to a wide range of habitats, including the Himalayan mountains, the

Western Ghats rainforests, the arid Thar Desert, and the huge Sundarbans mangrove swamps. This richness is shaped by India's complicated biogeography, which has enabled species endemism and unique evolutionary adaptations (Molur et al., 2005). Among these species, the Indian giant squirrel (*Ratufa indica*, Erxleben) is the focus of this study, as it plays a crucial role in forest ecology through seed dispersal and habitat connectivity.

The Indian Giant Squirrel *Ratufa indica* (Erxleben) (Rodentia: Sciuridae) is a tropical, solitary, and diurnal canopy-dwelling species endemic to India (Prater, 1980; Corbet and Hill, 1992; Hayssen, 2008; Baskaran et al., 2011). It is distributed across India at elevations from 180 to 2300 meters above sea level (Pradhan et al., 2017). Despite its wide range, there is limited scientific documentation on this species. *R. indica* is an essential component of tropical rainforests, particularly in lush, moist deciduous forests, the Eastern Ghats, and central India (Eisenberg, 1980; Das et al., 1993; Baskaran et al., 2011; Mehta et al., 2012; Gurjar et al., 2013).

All four species of *Ratufa* are listed as Least Concern (LC) by the IUCN Red List of Threatened Species and are under Schedule I in Wildlife Protection Act (WPA) of 1972 (Borges, 2007; Thorington et al., 2012). These squirrels play a crucial role in seed dispersal within their environment (Smythe, 1989). In India, squirrels consume a varied diet of fruits, flowers, nuts, bark, bird eggs, and insects and build nests using leaves and branches within their territory (Borges, 1989; Ramachandran, 1992).

However, the population and distribution of these squirrels are in decline due to anthropogenic pressures such as habitat destruction, fragmentation, and isolation (Ceballos and Ehrlich, 2002; Rajamani et al., 2010). Human activities have triggered significant habitat loss and species decline (Linderman, 2006). The habitat of *R. indica* suffers from canopy destruction and fragmentation, primarily due to deforestation, which has severely impacted the tropical forest ecosystem (Nandini and Parthasarathy, 2008). Consequently, *R. indica* is now approaching a state of vulnerability.

The study species exhibits unique nesting behavior, building nests high in trees with dense foliage. They can leap up to 6 meters (20 feet) between trees. As one of the largest squirrel species, their head-and-body length ranges from 25–50 cm, with tails of similar length and body weights from 1.5–2 kg, occasionally reaching up to 3 kg. The average head-and-body length is around 36 cm, with a tail length of approximately 45 cm and a weight range of 1.7–1.8 kg (Borges, 2007).

This study aimed to discover the population dynamics, distribution, and habitat characteristics of the Indian Giant Squirrel (*Ratufa indica*) within the Valparai Plateau of the Anamalai Tiger Reserve, Southern India (Appendix: Photo plate 1 and 2). Given their short lifespan and high reproductive rate, the species' population is closely linked to fluctuating food availability. Additionally, understanding habitat structure, nesting behavior, and population trends is essential for effective conservation efforts.

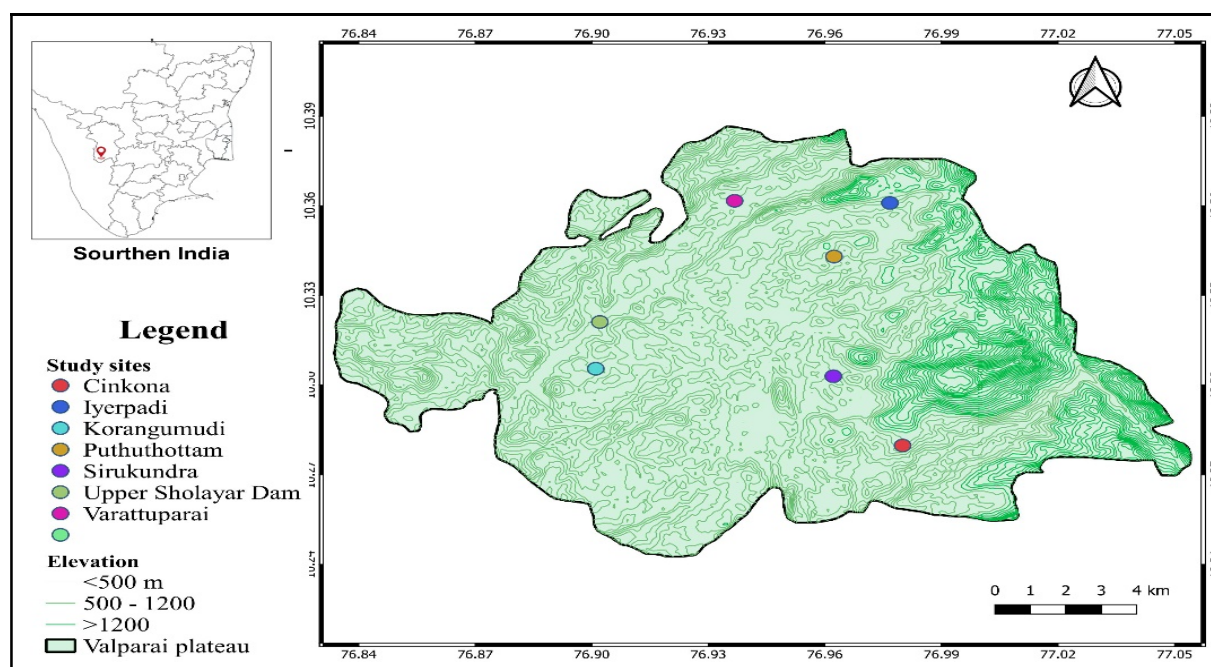
## Material and Methods

### Study area

The Anamalai Tiger Reserve, one of the largest protected areas in the Western Ghats—a global biodiversity hotspot—is located in Coimbatore District, Tamil Nadu (10°12' to 10°54' N and 76°44' to 77°48' E) (Fig. 1). This survey covered both unprotected and reserved forest areas, including Cinkona, Iyerpadi, Korangumudi, Puthuthottam, Sirukundra, Upper Sholayar Dam, and Varattuparai. The region's elevation ranges from 1650 to 2100 meters above mean sea level, with annual rainfall between 500 mm and 5000 mm and relative humidity from 64% to 82%. Temperature varies, with winter lows below 5 °C at elevations above 2000 meters, and summer highs approaching 40 °C in the eastern plains. The lower elevations of Anamalai support Southern tropical thorn forests, while mid-altitude zones are characterized by deciduous forests. Higher elevations, above 1000 meters, are home to wet evergreen forests. Slopes above 1800 meters harbor characteristic shola forests, and mountain summits feature extensive grasslands, forming a typical montane habitat (<https://power.larc.nasa.gov/data-access-viewer>). Shola forests are an endemic, distinctive type of stunted evergreen forest found in valleys and depressions at high elevations, typically interspersed with montane grasslands in Southern Western Ghats (Nalina, 2023, Thomas and Sankar, 2001), characterized by dwarf trees reaching about 25–30 feet in height (Nair, 2001). According to Champion and Seth's (1968) classification, the forest types in the Anamalai Reserve include Evergreen, Tropical Semi-Evergreen, Tropical Moist Mixed Deciduous, Tropical Dry Mixed Deciduous, Savannah-Woodland, and Grasslands.

### Distribution and population density

Surveys were conducted by systematically searching for the species across various sites using the line-transect method as outlined by Burnham et al. (1980). Transect locations were randomly selected within a grid system. A total of 14 transects, each spanning 2–3 km, were placed across different locations. Twenty grids were assessed, covering a total distance of 162 km, with 14 individual transects observed. Data collection occurred between January and March 2021. Each transect was walked twice daily - once in the morning (6:00 am - 9:00 am) and once in the evening (4:00 pm - 7:00 pm) - covering 2–3 km each day. Distribution was assessed following the line-transect method as described by Buckland et al. (2001). During each survey, we recorded the number of individuals and noted nest distribution (presence/absence) to determine species distribution and abundance. Distribution patterns of the population were examined based on the guidelines for assessing spatial patterns established by Clark and Evans (1954). The following formula calculated the density.



**Figure 1:** Map showing the study area at Valparai Plateau, Anamalai Tiger Reserve, Southern India.

$D = \frac{n}{2L \times ESW}$  Where, n- the number of detections; L- total transect length, and ESW - effective strip width (The distance within which animals could be detected). The density was computed using the DISTANCE software (Version 7.3), which models detection probability and converts observed counts into density (individuals/km<sup>2</sup>), forming the basis for estimating total population size.

#### Habitat structure analysis (nesting tree characteristics and habitat selection)

Habitat structure and vegetation assessment were carried out in designated transects. Each habitat-sampling point was linked to sightings of *R. indica*. A line transect was established across the grid system, and data were collected at each sample point using the point-centered quarter method (Newton, 2007) for trees with a DBH greater than 10 cm. In this method, the four closest trees, one from each 90° quadrant around each sample point, were sampled. The following parameters were recorded to determine habitat structure at each point of encounter: Tree density (per hectare), Tree girth at breast height (GBH), Tree diversity (Shannon index), Species richness, Canopy cover (%), Canopy disruption by human activity (%), Mainstem cutting by human activity (%), Tree height (m), Total branches per tree, Canopy height (m), Canopy lower height (m), Canopy width (m), Canopy shape characteristics (e.g., regularity %, oval shape %), Canopy continuity (%) (Ramos-Lara and Cervantes 2007).

#### Data analyses

Initially, data on species presence and absence were collected, followed by the organization of visual and habitat data into a Microsoft Excel file version 2019.

This file was then used to analyse the distribution by incorporating environmental covariates, which helped detect their influence on the presence of the giant squirrel. Analyses were conducted using DISTANCE 7.3 software (Buckland et al., 2005). Roosting site diversity was determined using the Simpson index ( $D = \sum ni (ni-1) / N(N-1)$ , for which D = Simpson's index, ni = the number of individuals in species I and N = the total number of individuals in the sample).

## Results

### Population density

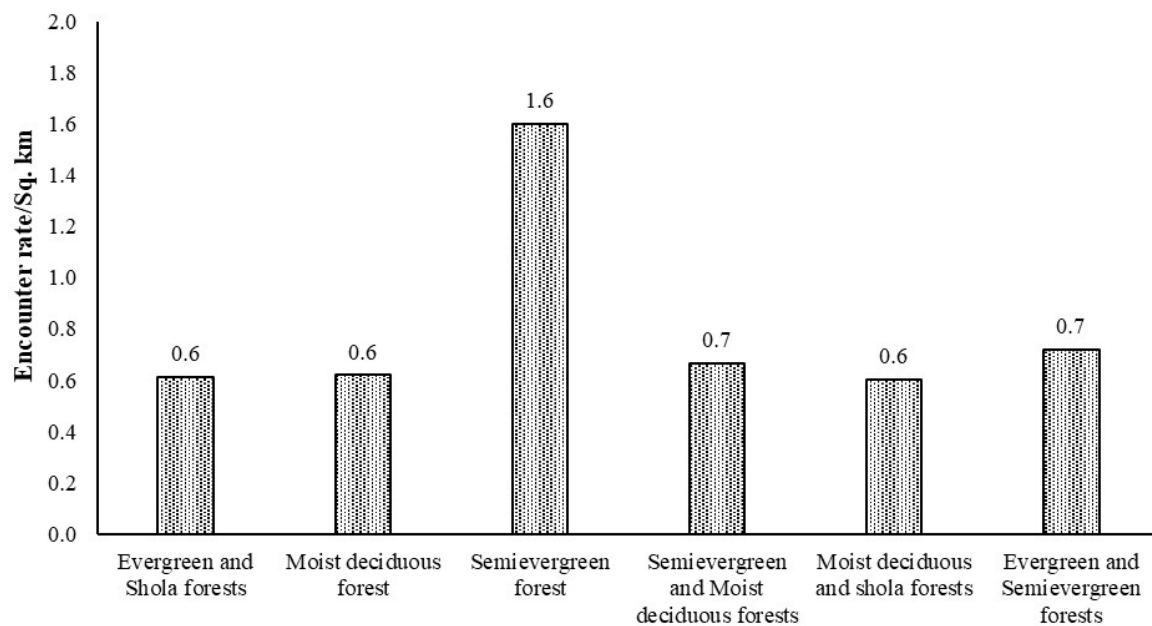
The study estimated the population density of *R. indica* using distance sampling across 14 transects with a total survey effort of 162 km walked, sixty-five groups were observed; the analysis employing the Hazard key function model with a simple polynomial adjustment reached an AIC value of 745. with the upper Solaiyar Dam areas occasionally having higher population densities than other forests (Table 1). The encounter rate of *R. indica* was 3.8 individuals/km CV 14.8%. The Mean group size was 1.6±0.10, and estimated group density/km<sup>2</sup> 10.7±2.00, The estimated density showed 17.9±3.51 individuals/km<sup>2</sup> (3.51 SE). The 95% confidence interval for individual density ranged from 11.95 to 26.83 individuals per km<sup>2</sup> (Table 1).

The highest encounter rate was observed in semi-evergreen forests (1.6 groups/km<sup>2</sup>), which indicates a strong preference for this habitat (Fig. 2), followed by evergreen, moist deciduous (0.6 group/km<sup>2</sup>, each), semi-evergreen and moist deciduous forests (0.7 groups/km<sup>2</sup>) suitable habitat for Indian Giant Squirrels, likely due to factors such as food availability and canopy connectivity, which support their arboreal lifestyle.

**Table 1:** Population density of *Ratufa indica* in Valparai Plateau, Anamalai Tiger Reserve, India.

Parameters	Details
No. of transects	14
Effort (l/km)	162
Number of groups detected (n)	65
Key function model	Hazard
Key adjustment	Simple polynomial
AIC	745.02
Detection probability	0.32±0.03
Effective strip width (m)	177.5±21.45
Encounter rate of group/km (n/l)	3.82
Encounter rate %CV	14.18
Mean group size	1.6±0.10
Group density/km <sup>2</sup>	10.7±2.00
Group density %CV	18.63
Group density 95% CI	7.26 – 15.90
Individual density/km <sup>2</sup>	17.9±3.51
Individual density %CV	19.61
Individual density 95% CI	11.95 – 26.83

\*AIC- Akaike's information criteria, CV- Coefficient of variation, CI- Confidence interval.



**Figure 2:** Encounter rate of *Ratufa indica* in different habitat types at Valparai Plateau, Anamalai Tiger Reserve, Southern India.

### Tree characteristics in inhabited versus uninhabited areas

The attributes of nesting trees in the inhabited and uninhabited areas highlight statistically significant differences between these areas (Table 2). The inhabited areas have a significantly higher girth at breast height ( $142.5 \pm 30.22$  cm) compared to uninhabited areas ( $72.1 \pm 2.23$  cm), with a significant Mann-Whitney U value of 5795.5 ( $p < 0.001$ ). The average tree height was similar between the two areas (28.9 m in inhabited vs. 28.3 m in uninhabited), showing no significant difference ( $U = 8112$ ,  $p = 0.829$ ). The crown height (m) is also similar (12.4 m in inhabited vs. 12.7 m in uninhabited) and do not differ

significantly ( $U = 7000.5$ ,  $p = 0.058$ ). The crown width (m) is significantly wider in inhabited areas ( $9.0 \pm 0.52$  m) than in uninhabited areas ( $7.5 \pm 0.18$  m) with a U value of 6795 ( $p = 0.027$ ). The crown length (m) is greater in inhabited areas ( $11.3 \pm 0.63$  m) compared to uninhabited areas ( $9.2 \pm 0.20$  m), with a significant difference ( $U = 6626.5$ ,  $p = 0.014$ ). The inhabited areas have denser canopy cover ( $89.19 \pm 5.61\%$ ) than uninhabited areas ( $71.31 \pm 3.11\%$ ), significantly different ( $U = 6665.5$ ,  $p = 0.017$ ). The pole height (m) does not differ significantly between areas (16.1 m in inhabited vs. 15.7 m in uninhabited;  $U = 7708.5$ ,  $p = 0.410$ ). Both inhabited and uninhabited areas have

similar ambient temperatures, with no significant difference ( $U= 8148.5, p= 0.862$ ). The relative humidity levels were similar (72.5% vs. 72.7%), showing no significant difference ( $U= 7995.5, p= 0.672$ ). The inhabited areas have significantly higher species richness (10.0) than uninhabited areas (5.0), with a significant U value of 8255 ( $p < 0.001$ ). The tree density was comparable between areas (72.4 in inhabited vs. 71.7 in uninhabited) with no significant difference ( $U= 8037.5, p= 0.723$ ). A significant difference is observed in the Simpson Index, with 0.8 in inhabited areas versus 1.8 in uninhabited areas ( $U= 8255, p < 0.001$ ). The Shannon index also differs significantly, with 1.6 in inhabited areas compared to 5.6 in uninhabited areas ( $U= 8255, p < 0.001$ ). The inhabited areas generally have larger trees, denser canopy, and greater species richness whereas uninhabited areas showed greater diversity (as indicated by the Simpson and Shannon indices), all statistically significant compared to uninhabited areas (Table 2, and Fig. 3).

**Effects of tree characteristics on *R. indica* populations**

Four tree-species attributes were associated with *R. indica* habitation in the study area (Table 3 and Fig. 4). The constant and intercept were significant ( $p= 0.000$ ) with a coefficient of  $8.4 \pm 0.68$ , explaining 52% of the variation ( $R^2= 0.52$ ). Canopy cover percentage showed a positive effect, with a coefficient of  $3.2 \pm 0.26$  ( $p= 0.000$ ). Crown width (m) had a negative effect, with a coefficient of  $-2.5 \pm 0.21$  ( $p= 0.001$ ). Tree species diversity negatively affects *R. indica*, with a coefficient of  $-0.8 \pm 0.29$  ( $p= 0.002$ ). Tree height (m) shows a positive influence, with a coefficient of  $2.5 \pm 0.21$  ( $p= 0.000$ ). As a result, canopy cover and tree height positively

correlate with *R. indica*, whereas crown width and species diversity showed negative correlations.

***Ratufa indica* habitat characteristics**

GBH alone showed a statistically significant difference among the sites ( $P= 0.049$ ), suggesting that tree girth varies more than other measured characteristics in these habitats (Table 4). Other parameters (tree height, crown height, crown width, crown length, and pole height) did not show statistically significant differences (Fig. 5).

***Ratufa indica* preference for tree position**

Sightings of *R. indica* suggests a clear preference for specific levels within the tree structure. The lower canopy of trees, accounting for 35% of the sightings, and the upper canopy, with 20% of the sightings, were identified as the primary areas where the *R. indica* was most common (Fig. 6). Only 1% of sightings occurred near the lowest tree poles, suggesting that the *R. indica* does not frequent areas that are closer to the tree base or ground level.

**Tree species used by *R. indica***

The tree species, *Spathodea campanulata*, was most commonly used by *Ratufa indica* (19.67% of total frequency), with other species used at lesser frequencies (Table 5). Overall, species with significant sightings include *Mesua ferrea* (15.79%) and *Spathodea campanulata* (18.42%), reflective of their prominent role in the species composition of the study area, whereas many other species contribute modestly in terms of both frequency and individual count. (Table 5 and Fig. 7).

**Table 2:** *Ratufa indica* habitat selection nesting tree characters between inhabited and uninhabited areas.

Sl. No.	Attributes	Inhabited area	Uninhabited area	Mann-Whitney U	P value 0.05
1	GBH (cm)	142.5 ± 30.22	72.1 ± 2.23	5795.5	<b>0.000</b>
2	Tree height (m)	28.9 ± 1.57	28.3 ± 0.76	8112	0.829
3	Crown height (m)	12.4 ± 0.97	12.7 ± 0.34	7000.5	0.058
4	Crown width (m)	9.0 ± 0.52	7.5 ± 0.18	6795	<b>0.027</b>
5	Crown length (m)	11.3 ± 0.63	9.2 ± 0.20	6626.5	<b>0.014</b>
6	Canopy cover (%)	89.19 ± 5.61	71.31 ± 3.11	6665.5	<b>0.017</b>
7	Pole height (m)	16.1 ± 1.10	15.7 ± 0.64	7708.5	0.410
8	Ambient temperature	28.5 ± 0.04	22.0 ± 0.03	8148.5	0.862
9	Relative humidity	72.5 ± 0.45	72.7 ± 0.22	7995.5	0.672
10	Species richness	10.0 ± 0.00	5.0 ± 0.00	8255	<b>0.000</b>
11	Tree density	72.4 ± 2.19	71.7 ± 1.08	8037.5	0.723
12	Simpson index	0.8 ± 0.00	1.8 ± 0.00	8255	<b>0.000</b>
13	Shannon index	1.6 ± 0.00	5.6 ± 0.00	8255	<b>0.000</b>

**Table 3:** Regression tested for tree attributes and characteristics on *Ratufa indica* population in study area.

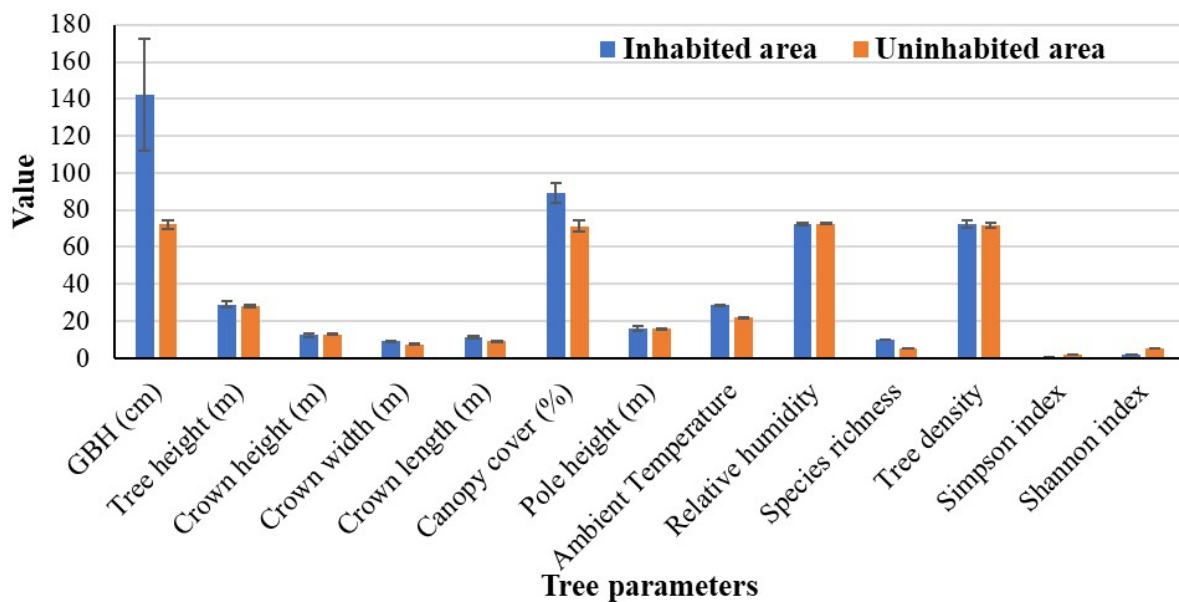
Sl. No.	Parameters	B±SE	t	Sig.	R2
1	Constant	8.4±0.68	12.45	0.000	
2	Canopy cover (%)	3.2±0.26	12.35	0.000	
3	Crown width (m)	-2.5±0.21	11.25	0.001	0.52
4	Tree species (diversity)	-0.8±0.29	3.17	0.002	
5	Tree height (m)	2.5±0.21	12.16	0.000	

**Table 4:** *Ratufa indica* habitat characteristics in various studied sites.

Sites	GBH (cm)	Tree height (m)	Crown height (m)	Crown width (m)	Crown length (m)	Pole height (m)
Cinkona (n= 12)	1986.0±602.50	29.3±4.73	14.8±3.47	10.2±1.11	13.8±1.31	14.3±2.240
Iyerpadi (n= 7)	1480.7±685.05	24.4±4.73	8.1±1.41	9.7±2.29	12.1±2.65	16.3±4.32
Korangumudi (n= 14)	3325.3±647.15	36.1±5.37	17.1±3.27	11.1±1.49	13.8±1.53	18.4±2.67
Puthuthottam (n= 6)	1564.8±745.42	26.0±4.24	8.3±1.05	9.7±2.16	11.8±2.36	17.7±3.69
Sirukundra (n= 8)	3345.1±808.46	37.3±5.72	17.8±3.91	14.0±1.44	16.3±1.42	19.5±3.14
Upper Sholayar Dam (n= 5)	12503.2±9587.79	22.0±4.01	9.6±2.27	10.2±2.50	15.2±3.50	12.4±2.36
Varattuparai (n= 13)	2358.3±720.70	30.2±5.20	11.6±2.51	10.2±1.65	13.5±1.95	18.6±2.95
F test	2.268	0.944	1.442	0.678	0.473	0.574
P Value	0.049	0.471	0.215	0.668	0.826	0.749

**Table 5:** Tree species used by *Ratufa indica* in the study area.

Sl. No.	Tree species	Frequency of the tree	% Contribution	No. of individuals	% Contribution
1	<i>Actinodaphne malabarica</i>	4	6.56	5	4.39
2	<i>Anacardium occidentale</i>	1	1.64	2	1.75
3	<i>Artocarpus heterophyllus</i>	6	9.84	13	11.40
4	<i>Bombax ceiba</i>	5	8.20	8	7.02
5	<i>Canarium strictum</i>	3	4.92	4	3.51
6	<i>Cinnamomum malabratrum</i>	1	1.64	2	1.75
7	<i>Cullenia exarillata</i>	3	4.92	4	3.51
8	<i>Elaeocarpus oblongus</i>	1	1.64	2	1.75
9	<i>Elaeocarpus tuberculatus</i>	2	3.28	4	3.51
10	<i>Erythrina variegata</i>	6	9.84	11	9.65
11	<i>Eucalyptus grandis</i>	3	4.92	6	5.26
12	<i>Ficus microcarpa</i>	2	3.28	3	2.63
13	<i>Ficus racemosa</i>	1	1.64	1	0.88
14	<i>Macaranga peltata</i>	4	6.56	5	4.39
15	<i>Mesua ferrea</i>	8	13.11	18	15.79
16	<i>Nageia wallichiana</i>	2	3.28	2	1.75
17	<i>Ormosia travancorica</i>	1	1.64	3	2.63
18	<i>Spathodea campanulata</i>	12	19.67	21	18.42

**Figure 3:** *Ratufa indica* habitat selection nesting tree characters between inhabited and uninhabited areas at Valparai Plateau, Anamalai Tiger Reserve, Southern India.

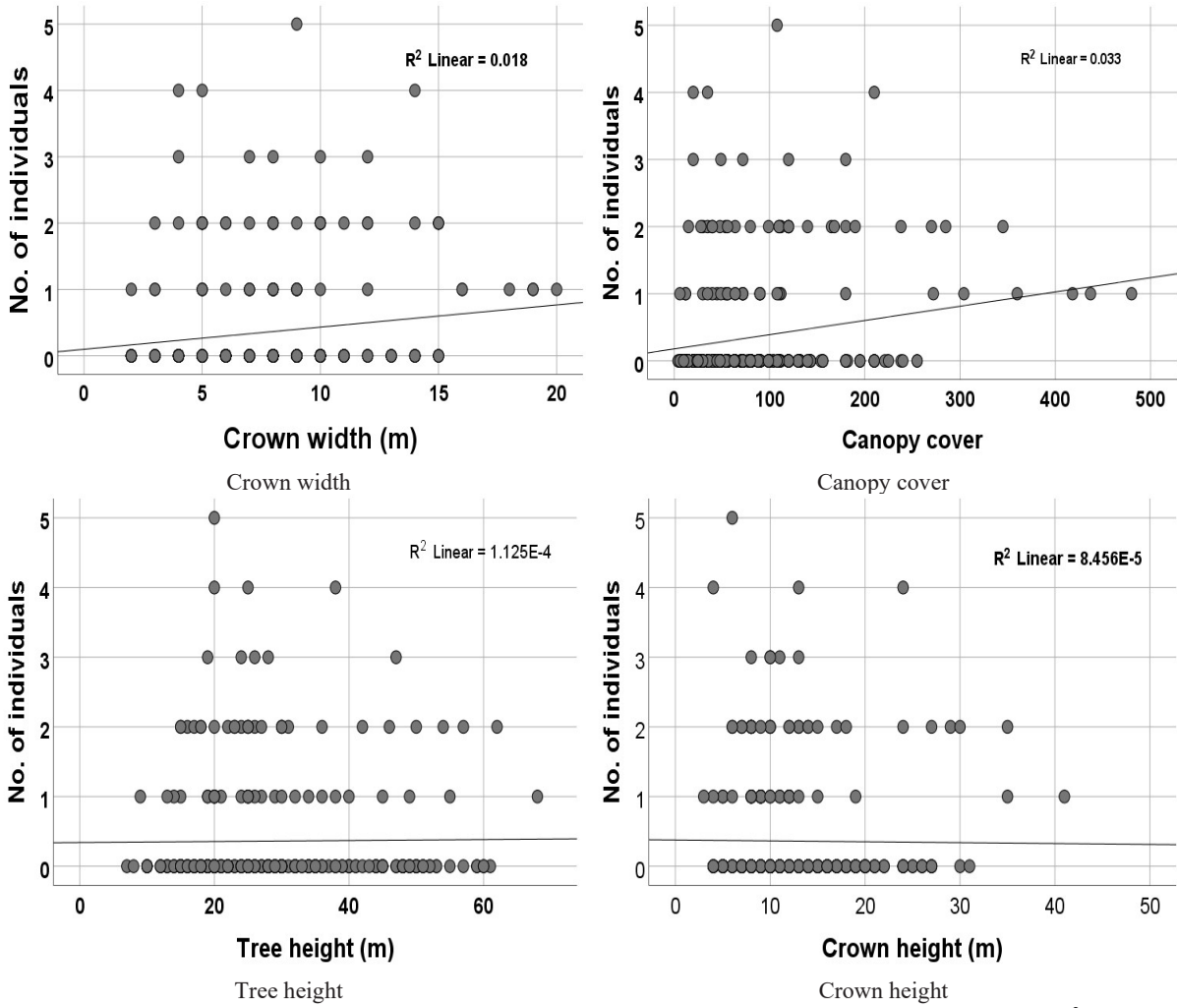


Figure 4: Regression tested for tree species attributes and characteristics on *Ratufa indica* population in study area ( $R^2=0.52$ ).

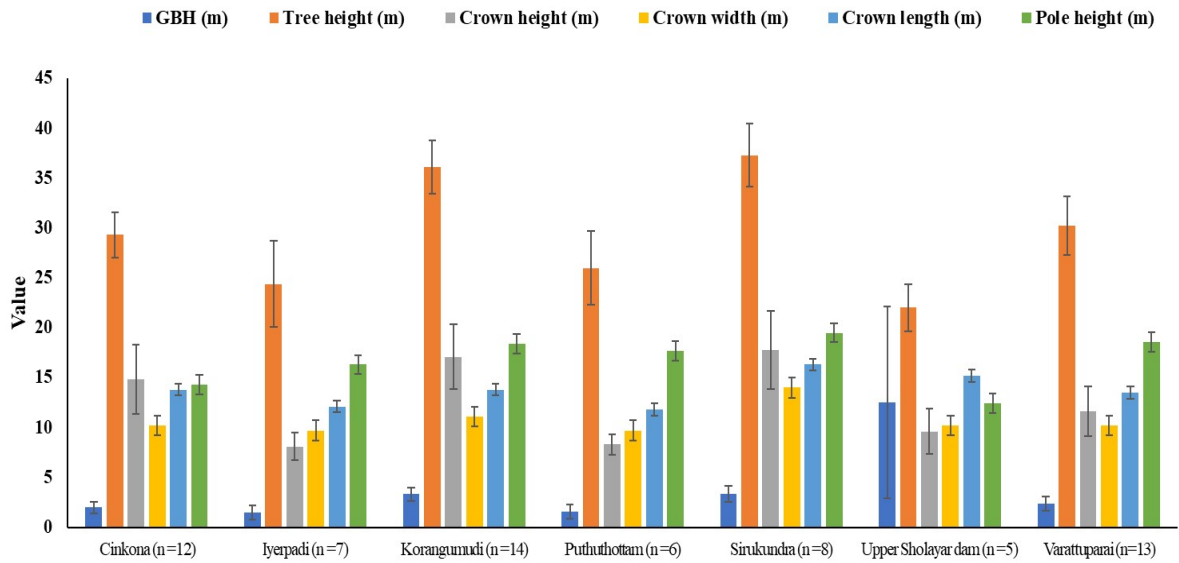


Figure 5: *Ratufa indica* habitat characteristics in various sites during the study period.

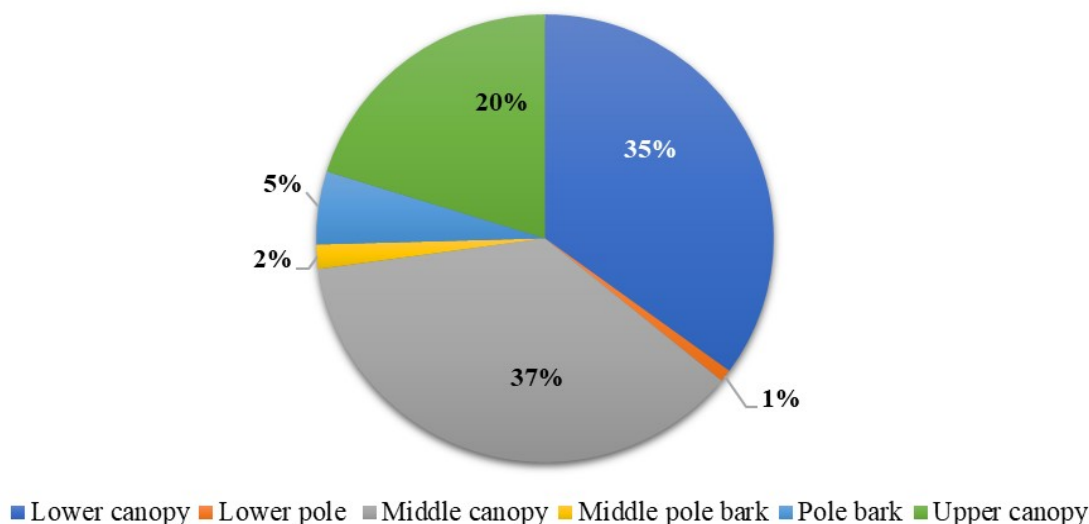


Figure 6: *Ratufa indica* abundance with respect to position on tree.

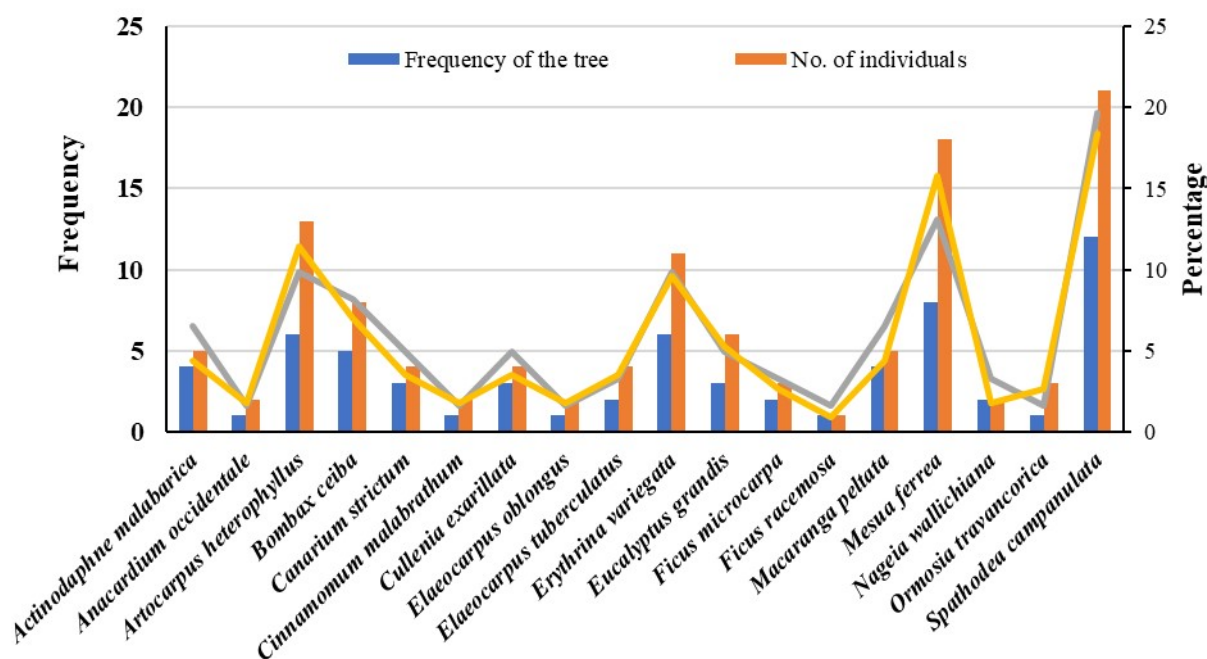


Figure 7: Tree species used by *Ratufa indica* in the study area.

**Discussion**

The distribution of *R. indica* across various habitat types at the Valparai Plateau in the Anamalai Tiger Reserve reflects notable trends in encounter rates that align with patterns observed in other regions of Southern India (Srinivas et al. 2008). Animal encounters were more frequent in habitats such as dry evergreen and wet deciduous forests, mirroring findings from studies in similar biogeographical zones (Orissa-Rout and Swain, 2005; Maharashtra - Mehta et al., 2012; Srivilliputhur - Baja et al., 2017). These results suggest that these forest types provide essential resources such as food, water, and cover,

which likely support higher wildlife densities and diversity. The population density of *R. indica* in the Valparai Plateau, based on the 65 groups identified across the 162 km line-transect survey, provides valuable insight into the distribution and habitat preferences of this species within the Anamalai Tiger Reserve. The density (Individuals- $17.9 \pm 3.51/\text{km}^2$ ) (Table 1) appears consistent with previous studies conducted in similar habitats, such as those by Baskaran et al. (2011) (Individuals  $-2.9 \pm 0.31/\text{km}^2$ ) in Tamil Nadu and Nayak and Patr (2015) in Odisha, which report comparable encounter rates and densities in other regions. Additionally, comparing these density estimates with those from other regions

(Gurjar et al., 2013; Naresh et al., 2014) provides a broader understanding of the ecological factors influencing the Indian Giant Squirrel populations across Southern India. The individual density of *R. indica* (0.12/km<sup>2</sup>) is influenced by the presence of dense forests, barren areas, open forests, and semi-open forest cover (Shukla and Mishra, 2017). The high density (42.7 *R. indica*/km) in the Kamlapur cluster compared to other clusters (Baskaran et al., 2011; Prakash et al., 2011; Mehta et al., 2012; Gurjar et al., 2013; Naresh et al., 2014) may be due to the more closed canopy and better habitat due to pruning that has not been carried out for the last several years. The large number of host plant species used by *R. indica* to build nests provide the flexibility to adapt to different species during stress (Prakash et al., 2011; Nayak and Patra, 2015).

The habitat selection and nesting-tree characteristics of Indian Giant Squirrels in the Valparai Plateau demonstrate a notable variety of tree species used for nesting (Table 5) compared to other regions, reflecting a rich diversity of host plants in distribution areas. The number of tree species used as host plants in Valparai is higher than in Bhimashankar Wildlife Sanctuary (31 species; Borges and Rao 2014), Kuldhia Wildlife Sanctuary (15 of 27 available species), Mudumalai Wildlife Sanctuary (15 species), and Sitanadi Wildlife Sanctuary (30 species; Nayak and Patra 2015; Kanoje 2008; Baskaran et al. 2011). This diversity suggests that Indian Giant Squirrels on the Valparai Plateau benefit from a greater range of suitable nesting sites, which may enhance their adaptability and resilience in this habitat. The high diversity of nesting-tree species could be attributed to the plateau's unique forest composition, which includes a mixture of primary and secondary forests as well as various microhabitats that support a range of flora.

The identification of 18 tree species across the seven study sites indicates a selective nesting preference among *R. indica* on the Valparai Plateau. The choice of certain tree species more frequently than others aligns with findings from Kanoje (2008) suggesting that *R. indica* populations exhibit strong preferences for specific types of nesting trees. Such selectivity highlights the importance of particular tree characteristics—such as canopy structure, branch density, height, and stability—that may better meet the species' nesting and protection requirements. Tree species chosen most often by the squirrels may offer benefits such as protection from predators, favourable microclimatic conditions within nests, and proximity to food sources. The selectivity in nesting trees is consistent with Prakash et al. (2011), who reported that *R. indica* populations are well adapted to specific habitats where suitable nesting trees are available. *Spathodea campanulata* was frequently used by *R. indica* in the study area, it is an invasive African species (Lim, 2013) known to affect native forest ecosystems negatively. Historically, *R. indica* depended on native canopy trees such as *Artocarpus heterophyllus*

and *Ficus* spp., (Mohan et al. 2023; Nayak and Patra, 2015). However, despite the availability of native species, *R. indica* was detected to prefer *S. campanulata* in the present study, possibly due to its dense canopy structure, branching pattern, and year-round flowering that may provide suitable nesting and feeding opportunities.

This adaptation is likely essential to their survival, as Indian Giant Squirrels depend on mature trees for both nesting and foraging. The findings from this study emphasize the need to protect and conserve these preferred tree species, as their availability directly impacts the population dynamics of *R. indica* in the Valparai Plateau. Loss or degradation of these key species could lead to a decrease in suitable nesting sites, which might negatively affect squirrel populations.

The analysis of factors influencing the distribution of *R. indica* in the Valparai Plateau highlights key environmental attributes that significantly impact their population density and spatial distribution. The factors showing higher values, as outlined in Table 5 and Figure 4, are strongly correlated with *R. indica* habitat preferences, particularly in relation to canopy cover and tree species composition. Regression testing further emphasizes the critical role that tree species attributes and canopy structure play in shaping *R. indica* distribution patterns, in line with previous studies (Ramachandran 1992; Rout and Swain 2005; Baskaran 2011). Canopy cover emerges as one of the most influential factors affecting *R. indica* distribution. This aligns with the species' arboreal nature, where dense canopy cover provides essential protection from predators and environmental stressors. Additionally, a closed canopy offers a continuous network of pathways for movement and foraging, reducing the need to descend to the ground where the squirrels are more vulnerable. A well-developed canopy also supports a variety of tree species, which is crucial for *R. indica*, given their selective nesting preferences and reliance on specific tree types for shelter and food.

The composition of tree species in the region also significantly impacts *R. indica* distribution. The availability of a diverse mix of tree species provides both food resources (such as fruits, nuts, and leaves) and suitable nesting sites. The regression analysis highlights the importance of tree species richness and the presence of particular tree types that the squirrels prefer for nesting. The negative correlation between *R. indica* populations and tree species diversity supports the idea that squirrels are more abundant in areas with a variety of tree species, which can cater to their needs for both food and shelter. As these conditions provide the resources necessary for the squirrels' survival. This highlights the need for conservation efforts that focus on maintaining and enhancing forest integrity.

The preference of *R. indica* for trees with greater girth at breast height (GBH), canopy height, and canopy contiguity provides important insights into the habitat selection and behavior of this species. These tree attributes are crucial for the squirrels' movement, safety, and foraging activities. As noted by Nayak and Patra (2015), trees with larger GBH and taller canopies provide a range of benefits that enhance the squirrels' ability to navigate their environment efficiently while minimizing risks. The preference for trees with greater GBH indicates that *R. indica* are selecting mature, robust trees that can support their large size and heavy weight. These trees likely provide more stable and secure nesting sites as well as better access to food resources. Canopy height and contiguity further improve squirrel mobility within their home ranges. A taller canopy allows *R. indica* to move freely across the treetops, offering a continuous network of branches that facilitate movement between trees. These findings reinforce the importance of preserving mature, contiguous forest habitats with well-developed canopy structures for the conservation of Indian Giant Squirrels. The availability of trees with greater GBH, canopy height, and canopy contiguity not only supports the squirrels' movement and safety but also provides the resources necessary for their reproductive success and overall well-being. Conservation efforts should focus on maintaining forest integrity, promoting the growth of large, mature trees, and preventing habitat fragmentation that could disrupt canopy continuity.

## Conclusion

This study provides valuable insights into the population density, habitat preferences, and tree species utilization of the *R. indica* in the Valparai Plateau. The results indicate a high population density with an estimated 17.9 individuals per km<sup>2</sup>, and the species is more likely to be found in areas with larger trees, denser canopies, and higher species richness. Notably, inhabited areas had significantly larger trees and greater canopy cover compared to uninhabited areas, suggesting that these features play a critical role in *R. indica* habitat preference. Canopy cover and tree height positively influence *R. indica* populations, while species diversity and crown width had negative effects. Additionally, *R. indica* shows a preference for higher tree canopies for shelter and foraging, with lower occurrences at the ground level. Tree species such as *Spathodea campanulata* and *Mesua ferrea* are key to the species' distribution, contributing the most to *R. indica* sightings. These findings underscore the importance of preserving suitable tree habitats with adequate canopy cover and structural complexity for the conservation of the Indian Giant Squirrel.

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## Author contributions

Aneena Lakshmanan: Data collection and analyses and draft preparation. Mahaly Moorthi: Supervising, data analyses and final draft preparation. Selvarasu Sathishkumar: Analyses, formatting and draft preparation.

## Conflict of interest

The authors declare that there are no conflicting issues related to this research article.

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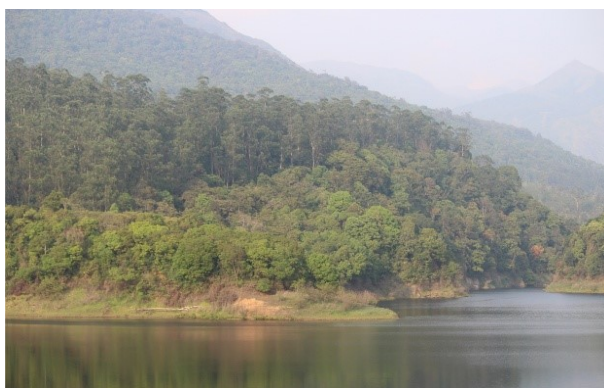
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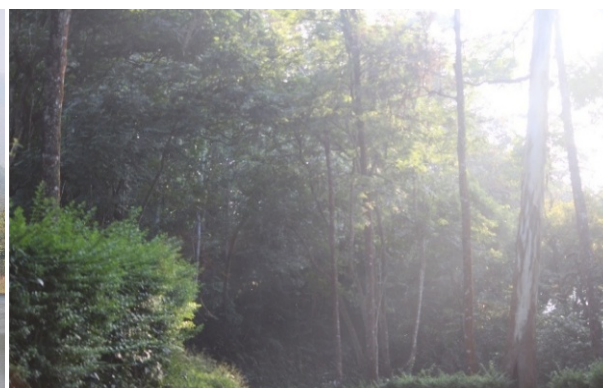
## Appendix



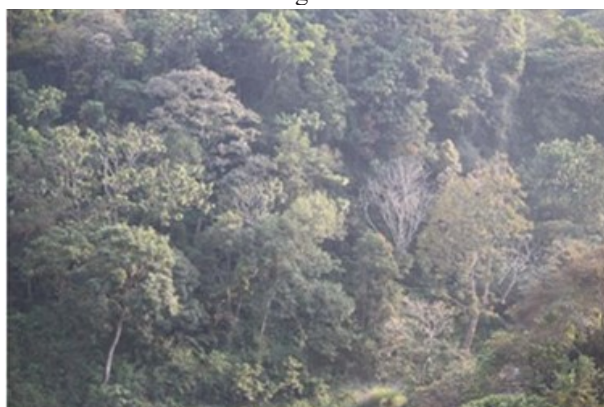
Photo plate 1: Photographs of *Ratufa indica* in Valparai Plateau, Anamalai Tiger Reserve, Southern India.



Semi-evergreen Forest



Evergreen Forest



Tropical Evergreen Forest



Moist Deciduous Forest

Photo plate 2: Photographs of various landscape patterns in Valparai Plateau, Anamalai Tiger Reserve, Southern India.