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Research Article

Eco-ethological attributes of the Indian Giant Squirrel *Ratufa indica* in Kuldiha Wildlife Sanctuary, Odisha, India

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ABSTRACT

Present three year-long (2016 to 2019) study deals with the spatio-temporal distribution pattern of *Ratufa indica*, the endemic giant squirrel of India inhabiting Kuldiha Wildlife Sanctuary. The dietary preferences, behavioural attributes including different reproductive aspects and effect of forest phenology on breeding cycle of the species were documented. Results depicted that sighting frequency (23±0.7 per hour) of this canopy dweller was highest during pre-monsoon morning near forest personnel's residence (Site I). In monsoon and post-monsoon, they preferred to inhabit the denser parts of the forest (Sites II and III). Maximum occurrence and activities were observed at upper canopy layer (56%) during pre-monsoon, whereas, during late monsoon and early post-monsoon, they were observed to come down more frequently to the ground level (27% and 17% respectively). Forest phenology was noted to synchronize with the breeding cycle of this frugivorous rodent. Reproductive cycle was observed to be biannual via two breeding phases: the pre-monsoon and the post-monsoon; with the attainment of maximum litter size (3) during the former. Being an effective functional operator of forest ecology, maintenance of canopy contiguity coupled with the presence of juicy fruit-bearing plants turned out to be essential for this flagship animal's conservation strategy against the prevailing threat factors.

Key words: Giant Squirrel, Habitat preference, Breeding, Feeding, Canopy contiguity, Conservation

INTRODUCTION

Distinct ecological setup is noticed in the tropical deciduous forests which remain restricted to their distribution along the narrow equatorial belt extending up to 15° north and south of the equator. Mixed deciduous tropical forests, constituting only a smaller fraction (6%) of earth's land surface, represent one of the unique terrestrial habitats with respect to rich natural resource pool, diversity and density of wildlife, both flora and fauna of the world. The open canopy spaces of the dense forests permit the solar radiation to penetrate and reach the forest floor promoting profuse undergrowth, including various herbs, shrubs and climbers. It ultimately contributes to the maintenance of forest health by playing effective roles as nutrient reservoir of the ecosystem alongside nurturing the growth and propagation of faunal members. Such tropical ecosystems possessing multitier vegetation assemblages ensure ecological stability to the various associated faunal components. Arboreal animals of tropical forests are wonderful faunal assets, some of which truly spend their whole life span on the upper canopy layers, without venturing the ground. The different canopy strata of tropical forests provide unique microhabitats and niches to an array of specialized fauna resulting in a mosaic of compartmental profiles for particular canopy dwelling species with specific vertical and horizontal distribution patterns. Functional uniqueness of the canopy layer, an exclusively species with specific vertical and horizontal distribution patterns. Functional uniqueness of the canopy layer, an exclusively plant based dynamic and multifaceted food web unit, is maintained by geophysical processes like meteorological conditions, periodicity of biogeochemical cycles, as well as the ecological processes like environmental filtering, resource dispersal and productivity. All these factors effectively play their roles in tune with forest phenology and faunal resurgences (Nakamura *et al*., 2017). Whitworth *et al*. (2019) proposed arboreal mammals (mostly of larger body size) to be more influenced by forest disturbance and deterioration than the terrestrial ones.

The Indian Giant Squirrel, *Ratufa indica* (Erxleben, 1777) is an endemic species to India having distribution range across the evergreen to moist and dry deciduous forests of India (Gurjar *et al*., 2013). This mammalian rodent prefers top most canopy layer (strata A) and occasionally comes down to the substratum (Baskaran *et al*., 2011). The survival, population characteristics and distribution pattern of *R. indica* are significantly influenced by the types, vegetational composition, mode of occurrences of the tree species and the overall quality of canopy coverage of the forest (Ramachandran, 1992). They are known to be adapted to both evergreen and moist deciduous forests characterized by closed canopy density. The solitary animal displays diurnal activities (Joshua, 1992), but often live in pairs as observed during mating season.

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Food plant preference shown by this species was reported at Odisha by Palei *et al*. (2017). Their behavioural features were documented by Ramachandran (1992) and Rout & Swain (2005). Information on their nest building were provided by Srinivas, Benugopal & Ram (2008); Pradhan *et al.* (2017); and Rathod, Bharucha & Yardi (2022). However, no literature exists focussing on the underlying ecological basis of their heterogenous habitat distribution and management.

The present study has emphasized various autecological information *viz*. the spatio-temporal distribution, dietary and habitat preferences, ethological arrays including reproductive behavioural manifestation and parental care, mode of resource utilization and synchronizing effects of forest phenology on the life cycle of *R. indica* inhabiting in Kuldiha Wildlife Sanctuary (KWS), Odisha, India through different seasons of three consecutive years (2016 – 2019).

Objectives of the present study include detailed research activities pertaining to the seasonal variation of sighting frequency of *R. indica* populations, their mode of appearance during three specific diurnal phases at three different study sites having contrasting habitat characteristics and variable anthropogenic interaction levels. Nesting preference for host trees in three seasons was recorded and their foraging items were listed. Moreover, various eco-ethological aspects of life strategies of this characteristic rodent of KWS have been analysed with an aim to support sustainable conservation programme for this potential flagship species.

MATERIALS AND METHODS

Study area

The KWS located at Nilgiri civil subdivision of Balasore (Wildlife) division, Baleshwar district, Odisha between 21°20′ to 21°30′N and 86°30′ to 86°45′E, merging with Similipal Biosphere Reserve, covers an area of about 272.75 km^2 (Figure 1). The ranges of different meteorological parameters are: temperature (8°C- 42°C); relative humidity (62% - 88%); annual average precipitation (1600 mm - 1800 mm). The heterogeneous vegetation of this mixed tropical deciduous forest is known to harbour mammals like Leopard, Striped Hyena, Golden Jackal, Jungle Cat, Mongoose, Civet, (Saxena and Braham 1989); Elephant, Chital, Wild pig, Barking Deer, Langur, porcupine), etc. observed by the research team.

Duration of Study

Extensive field works were conducted during three seasons viz. pre-monsoon (PrM) (March- June), monsoon (Mn) (July- October) and post-monsoon (PoM) (November- February) through three consecutive years (March 2016- February 2019). Monthly visits were made during the study period with the continuous recording of ground truth data throughout the day in three shifts, each of three hours duration - morning session (MOR: 5:30- 8.30 hours), afternoon (AFTN: 10:30- 13:30 hours) and crepuscular (CRPS: 14:30- 17:30 hours). Such samplings were carried out consecutively for 6 days in order to cover

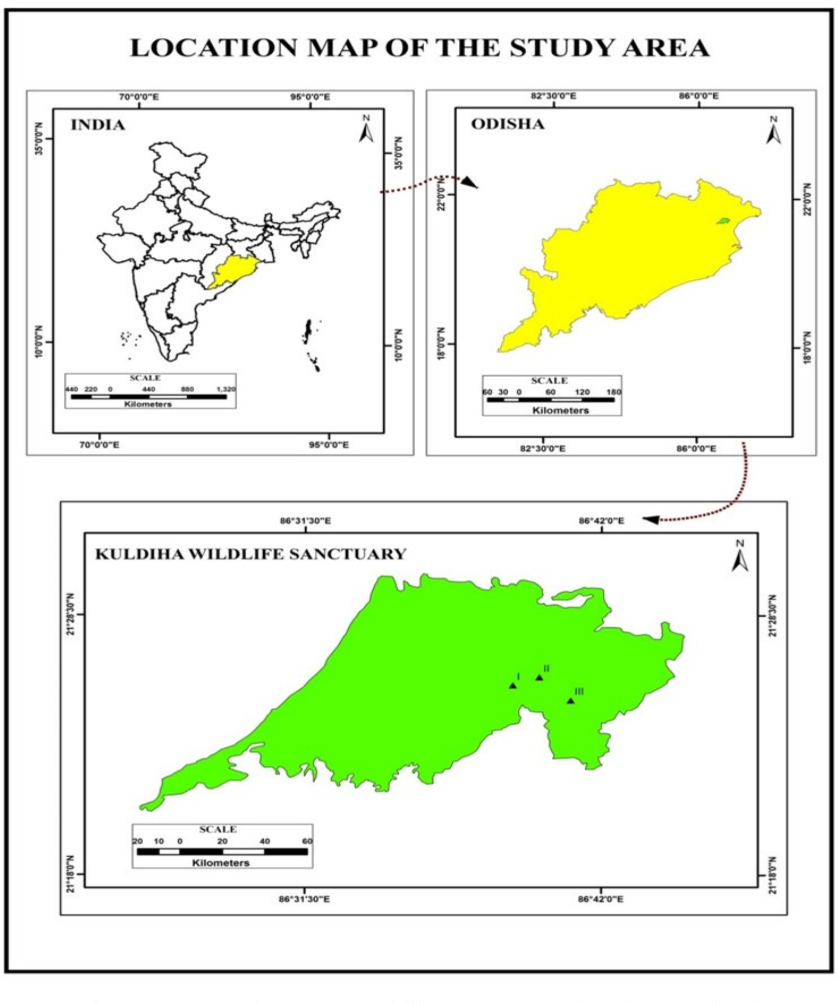


Figure 1. Location map of study area at Kuldiha WLS, showing three study sites- SI, SII and SIII.

Table 1. Details of sampling sites and sub-sites

Site	Abbreviation	Coordinates	Land Use pattern
S-I	FPR	21°25′40′′ N; 86°38′51′′N	Mixed forest patch having large trees, both natural and planted fruit trees near **Forest personnel's residence**
S-II	SLT	21°25′39′′ N; 86°38′52′′N	open canopy forest patch near **salt-lick**
S-III	CNP	21°25′39′′ N; 86°38′50′′N	**closed canopy** forest patch composed mainly of naturally dense trees with profuse undergrowth

three different study sites (Table 1) and research information have been expressed seasonally. Surveys were conducted on alternate days (first day for S-I, next day for S-II and the third day for S-III and then the same sequence was repeated). For estimating sighting frequency as well as behavioral patterns, observation of 15 minutes duration with 10 minutes interval was maintained continuously and uniformly during each session.

Behavioural study

The occurrence of this arboreal species was ascertained by field observation, occasional recording and photographic capture methods, direct sightings, hearing calls, through signs of immediate leaving of the animal from the presence of broken plant parts (twigs, branches, scattered foliage) and faecal pellets (Figure 2a). Data about foraging attributes and feeding preferences were collected through field observations upon searching the left-over fruit droppings after consumption (Figure 2b). Secondary information on the behaviour of the species was collected by interviewing forest staff and native villagers. Out of the total diurnal study period, time allocated for categories of behaviours were segregated to prepare an ethogram.

Data analysis

Data analysis and graphical representation was done using MS excel (Microsoft office version 10). GIS map was created using ArcGIS (10.6.1).

RESULTS AND DISCUSSION

The average sighting frequencies of *Ratufa indica* have been depicted in Figure 3 highlighting its diurnal and seasonal periodicity (number of sightings/hour) which reached its peak during the MOR phase in PrM period (23±0.7), followed by that in AFTN of PrM (18±1.3), CRPS of Mn (18±0.3) and MOR of PoM (17±0.9) respectively. Those peak frequencies of sightings were found in FPR and CNP, in late hours of MOR. At SLT (S-II), highest sighting frequency was reported (14±0.9) during MOR phase of PrM followed by the MOR of Pom (9±0.9). Least visit to SLT (S-II) was seen to occur during Mn (MOR 2±0.2, late hours 2±0.84). Inside the CNP (S-III), maximum frequency was found at CRPS phase of Mn (18±0.3) followed by that during MOR phase (12±0.8). Least sighting frequency was noted during PrM at CRPS phase and at AFTN and CRPS phase of PoM (2±0.3, 2±0.3, 2±0.4 respectively) at CNP (Site-III). These diurnal activities corroborated findings of Palei, Sahu & Nayak (2015). The topmost canopy layer was mostly occupied by them during late Mn and early PoM phases where they usually got shelter from heavy rains and were able to carry out their regular activities smoothly. Rathod et al. (2022) noted a higher encounter rate of *R. indica* at Bhimasankar Wildlife Sanctuary, Odisha.

a. b.

Figure 2. Signs of giant squirrel activity recorded for behavioural study – a. faecal pellets, b. semi-consumed fruits and torn leaves.

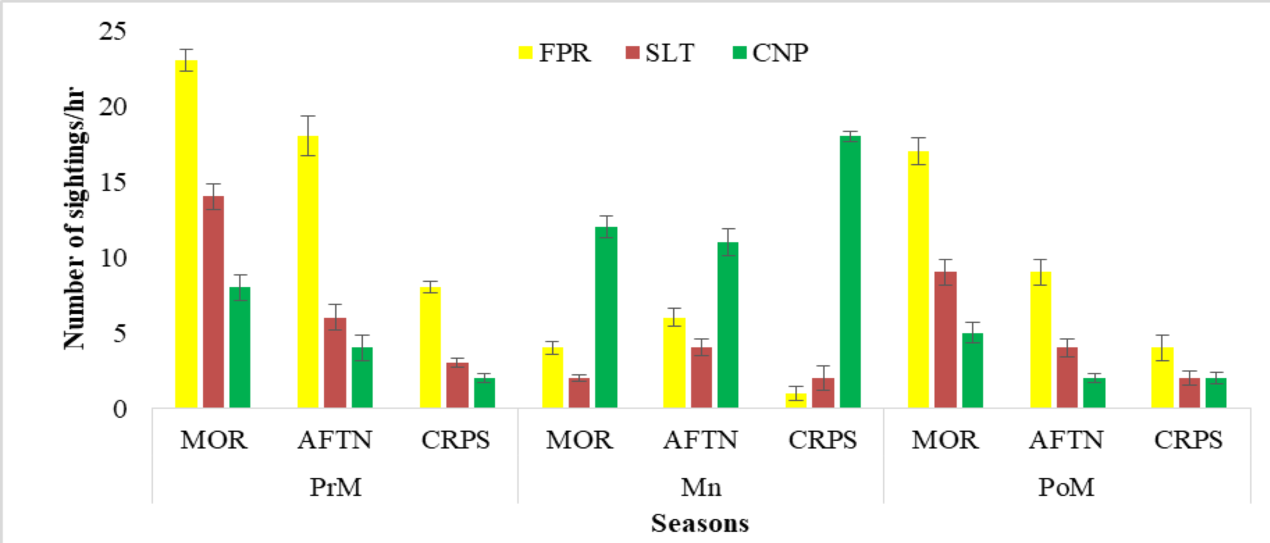


Figure 3. Average sighting frequency (number of sightings/hour) of *R. indica*: diurnal periodicity during PrM, Mn and PoM at different study sites

Figure 4 shows their distribution pattern throughout the vertical strata of the forest at selected habitats. Maximum occurrence was observed at upper canopy layer (56%), followed by that in the mid-canopy layer (30%) and least at lower canopy level (14%).

At KWS, *R. indica* populations were observed to opt for diverse trees as their potential source of nutrition and shelter (Table 2). Density and GBH (girth at breast height) were found to be significantly greater in their distribution area than those which could be considered as their non-distribution area (Baja *et al*., 2017). The dreys were found to occur on trees with more than average height, greater GBH and incessant closed canopies, which facilitated their swift escape to the next tree upon attack from predators (Rathod *et al*., 2022). A considerable number of fodder plants also offer suitable sites for nesting (Nayak & Patra, 2015). Figure 5 depicts the seasonal profiles of consumption ratio of different dietary components. During PrM, maximum preference was observed for fruits (28%) followed by that for seeds (21%), which is in tune with the observations of Palei *et al*. (2015). Flowers and petioles during PrM constituted a preferred proportion (13% and 11% respectively), which contrastingly declined during PoM (9% for each). During PoM, a remarkable shift in dietary preference was noted. The seasonal shifting in the squirrel's dietary preference may be correlated to the phenology of their fodder plants. Indian giant squirrels have been reported to show greater preference for evergreen trees for nest building than those for deciduous trees (Shukla & Mishra, 2017).

Blooming period of most of the host plants occurred during PrM, *viz*., *Shorea robusta* (March - April), *Emblica officinalis* (March – May), *Terminalia tomentosa* (April - May), *T. bellirica* (May), *Mangifera indica* (February – April), *T. arjuna* (April-May); some plants bloomed during PoM like *Dalbergia latifolia* (October - March). Few plants bloomed year-round *e.g.*, *Cassia fistula* (April- September), *Aegle marmelos* and *Pongamia pinnata*. Overlapping utilization profile of host plants was commonly noted (Table 2). The PrM breeding phase overlapped with the blooming phase of most of the host trees ascertaining the post-natal supply of nutritional resources. The PoM breeding phase, in contrast, followed the squeezing of nutritional resource availability (flowers, fruits) just immediately after the Mn downpour (Table 2, Figure 5).

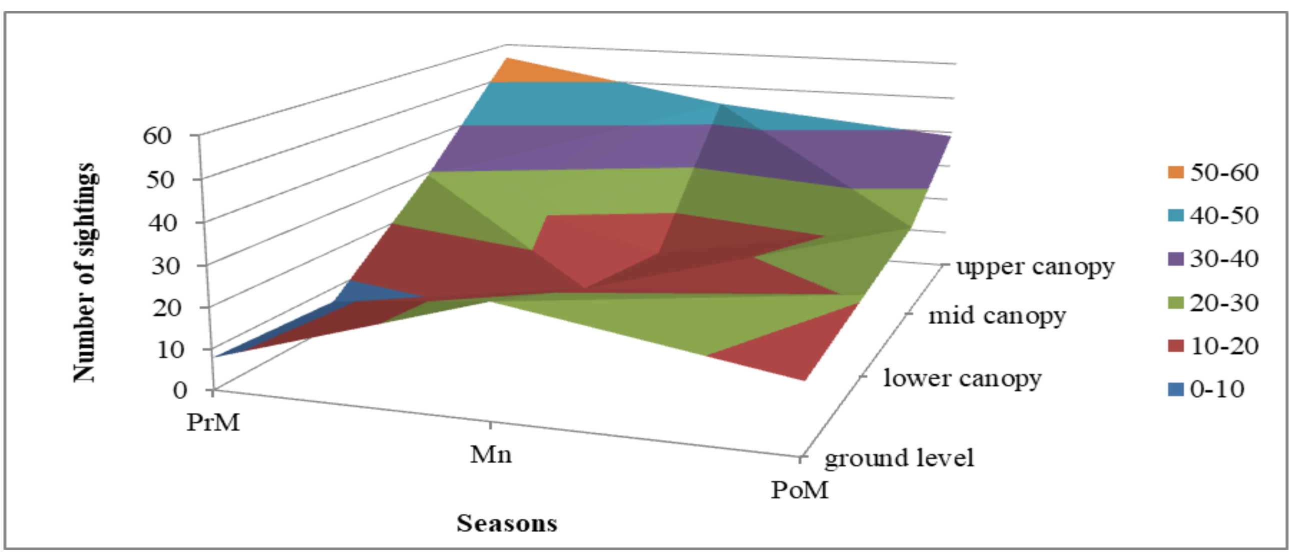


Figure 4. Distribution of *R. indica* through vertical strata: seasonal profile

Table 2. Overlapping blooming phase of host plants with life cycle phases of *R. indica*

Blooming season												
Host plants	**PrM**				**Mn**				**PoM**			
Shorea robusta	■	■										
Emblica officinalis	■	■	■									
Terminalia tomentosa		■	■									
Terminalia bellirica			■									
Mangifera indica	■	■										■
Terminalia arjuna		■	■									
Dalbergia latifolia	■							■	■	■	■	■
Cassia fistula		■	■	■	■	■	■					
Aegle marmelos	■	■	■	■	■	■	■	■	■	■	■	■
Pongamia pinnata	■	■	■	■	■	■	■	■	■	■	■	■
Overlapping life phases of *R. indica*												
Seasons	**PrM**				**Mn**				**PoM**			
	MAR	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**JAN**	**FEB**
Breeding I	■											■
Post-breeding I		■	■	■	■							
Breeding II						■	■					
Post-breeding II							■	■	■	■	■	

The shifting in diet preference during PoM from fruits to seeds and lesser dependence on flowers during PoM may occur as an adaptive strategy against this resource limitation problem arisen immediately following the Mn (Figure 5). Such shifting of foraging preference was also supposed to occur in correlation to their breeding cycle. The nutritional requirement of the growing juveniles also becomes instrumental in shaping up the season-specific foraging spectrum of this arboreal species. During PoM, fruits were preferred by 18% level, much lesser than that of PrM and seeds turned out to be more dependable food sources with 32% preference level. Mn with heavy downpour was unfavorable season for *R. indica* in the mixed deciduous forest landscape of KWS. *R. indica* is primarily granivore or generalist herbivore (as they often opt for leaves upon the unavailability of fruits), mostly feeding in the upper and the middle canopy strata and rarely on the ground (Payne, 1979). Very rarely they were seen to feed on birds' eggs from arboreal nests or various insects. Nutrient and energy content ratio are the ultimate driving force behind the selection of food by them. They mostly depended on the high- nutrient-rich, energy yielding and easily digestible food sources (fruits), also substantiated by Gurnell (1987) and Alvarenga & Talmoni (2006). Mature leaves and bark significantly offer mineral nutrients, particularly during post-parturition (Borges, 1992). Dependence on seeds is naturally selected as these remain available throughout the year and possess high calorific value. The mixed deciduous vegetation of KWS consisting of petioles, leaves, flowers and fruits are only seasonally available and their consumption ratio is effectively correlated to the phenology of forest vegetation. Switching over to leaves, barks, pith, etc. is an occasional phenomenon that occurs in absence of seeds. Such foraging flexibility exhibited by *R. indica* via seasonal dietary shift actually turned up as an adaptation to scarcity of particular food items.

Table 3 depicts the squirrels' biphasic annual nesting cycle exhibiting an average litter size of 1-3, whereas Table 4 resolves few interesting findings of their nest building attributes. The strata-A canopy was found to be most preferred microhabitat for nest building, followed by strata-B and E, which are similar to findings of Pradhan *et al.* (2017) and Rathod *et al*. (2022). Considering the inter-nest distances, it became evident that a modest spacing between nests is generally maintained. They were found to be mostly solitary creatures, but living in pairs was encountered only during the onset of breeding cycle. Throughout the breeding phase, male members were found to play more effective roles in comparison to their female partners, be it the case of collecting the nesting raw materials, participating in the active nest building procedure or in providing protection to the nests, by maintaining territoriality and guarding from predators. Multiple nest inhabitancies were reported by the local informants. In the present study, instances of re -use of nests by few of the next phase breeders, particularly during the PoM breeding phase were noted and corroborated by the views of the expert forest personnel. Average time span required for building a single nest was 2.5 hours, as per forest guards; however, it was flexible during PoM taking almost 5 hours to get completed. The availability of nest building materials is comparatively less easily accessible during PoM phase

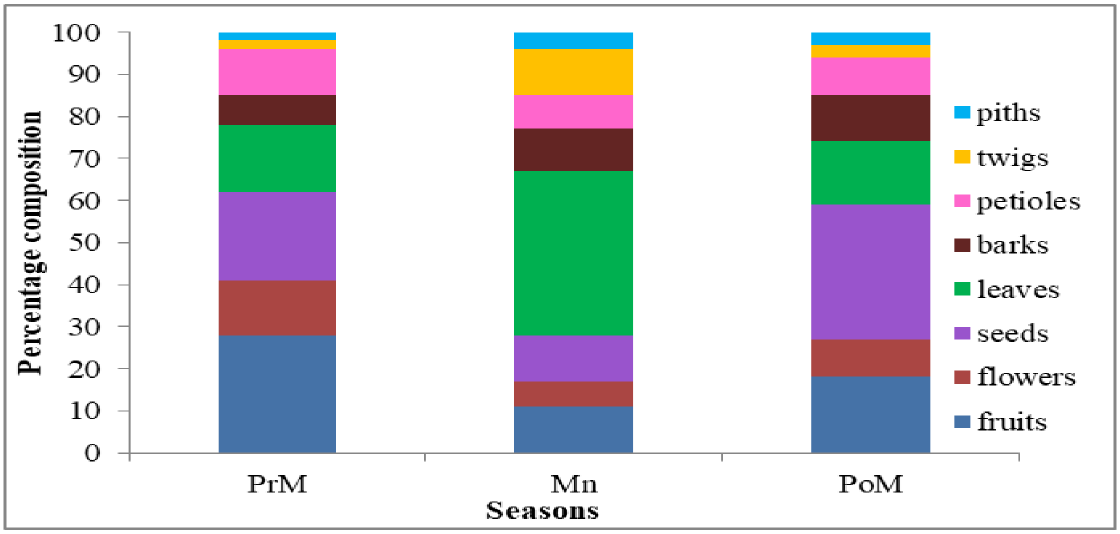


Figure 5. Dietary composition (% consumption ratio) of *R. indica*: seasonal profile

due to the prevalence of adverse climatic conditions during Mn. Most prominent nest-building trees at KWS were *Mangifera indica, Terminalia arjuna, Pongamia pinnata, Ziziphus mauritiana, Cassia fistula,* etc. A total of 57 nests were identified on 28 trees throughout the three different study sites covering both the seasons. Rathod *et al*. (2022) suggested that squirrels favored particular trees, often not most abundant ones in that forest and not always their host plants, to construct their nests. Except the breeding phase, they often reside inside tree cavities (Nowak, 1991). Males actively competed for mating with females. Breeding pairs may remain associated for longer period of time. Average litter size of this iteropaa maximum of 3. Their gestation period ranged for 25-30 days. Young ones are taken care until they become able to emerge from nests and move independently (Borges, 1992). Juveniles were often carried away by holding of their neck by their parents. An interesting ethological phenomenon was observed that in case of falling down of any juvenile from a nest, the individual was not taken back to the nest by its parents and was deserted. Besides raptors and snakes, some other carnivores have been documented as the natural predators of *R. indica*, which include *Felis chaus* (Jungle cat), *Viverricula indica* (Small Indian Civet), *Panthera pardus* (Leopard), *Hyaena hyaena* (Striped Hyena), Golden Jackal (*Canis aureus*) etc. (Mukherjee *et al*., 2004).

Table 5 represents the framework explaining gross ethological features resolved during the sampling and clusters specific manifestations that were witnessed under different behavioral categories. Figure 6 portrays their ethogram while Figure 7 documents the major behavioural attributes of *R. indica* which could be captured at KWS corresponding to Table 5. It could be inferred that maximum time budget was allocated for foraging (43%) followed by that for resting (23%) and locomotion (17%), as depicted by Figures - 7 b, c, a & e, similar to findings of Palei *et al*. (2015) and others. These squirrels are known to build multiple nests within single territory, devoting 3% of daily time for nest-building (Rathod *et al*., 2022). Their appearance and behaviour were exclusively diurnal. During heavy monsoon, they were found to take shelter under roof and built-up constructions near forest personnel's residence. Peak activity level was restricted to early morning, especially for foraging, communication and grooming (Figures 7 b, c, f & h) and rest of the time, they were mostly found in resting phase (Figure 7 g). Sometimes, they used to come down from their top canopy lodging, often with juveniles and took shelters in burrows of tree trunks. Gender specific ethological manifestation was observed where behaviour of males demonstrated striking differences from that of the females. Males are often noticed to exhibit aggressive behaviour for maintaining territoriality, whereas females were found to rely on scent marking strategy (Joshua, 1992).

Table 3. Annual nesting cycle of *R. indica* (biphasic)

Nesting phases		Months	Period of juvenile birth
1.	**PrM**	February- March	April-May
2.	**PoM**	August- September	September- October
3.	**Average litter size**	1-2	2-3

Table 4. Resolution of biparental nest building behaviour of *R. indica* throughout reproductive phases showing inference indicators

Preference of canopy level for nest building	Upper canopy level (≥ 20m)	Mid canopy level (10-20m)	Lower canopy level (10-20m)
	> 75%	50-75%	< 50%
Inter-nest distance (average) [within same or contiguous canopy]	Proximal- 20-50m	Intermediate-50 -80m	Distal- > 80m
	< 50%	< 50%	50-75%
Use of satellite nests	Pre-breeding state	Post-breeding state	
	< 25%	25-50 %	
Participation ratio in collection of nest or dry building material	Males	Females	
	> 80%	< 25%	
Participation ratio in nest building	Males	Females	
	> 80%	< 25%	
Participation ratio in nest guarding	Males	Females	
	> 80%	< 25%	
Re-use of nest by next breeders	Pre-monsoon	Post-monsoon	
	< 50%	> 75%	
Time spent for building single nest (average)	Pre-monsoon	Post-monsoon	
	2.5– 5 hrs	≤ 2.5 hrs	
Intra-specific nest parasitism	Seldom occurs		

Table 5. Overall ethological spectrum of *R. indica* at KWS throughout the study period

Ethological attributes	**Behavioural forms**	**Prominent behavioural forms**	**Specific behavioural manifestation**
Basic life maintaining behaviors	Foraging	• scanning • selection • consumption of food items	• scanning by movement of shoulder and head • grasping food item by hand • handling of food item by maintaining support on hind leg • tail and holding the food item by foreleg
	Locomotory	• movement along branches • climbing along tree trunk • seldom ground movement	• Walking on hind legs • grasping the branches by forelegs
	Reproductive	• mate finding • courtship, mating	• scanning for potential mates • repeated chasing along vertical tree length and across horizontal canopy level • settlement and mounting on suitable sites on tree trunk
	Protective/ sheltering	• throwing alarm call • exhibiting or advertising • hiding	• alarm call with certain pitch • exhibiting or advertising maintaining certain erected body form and postures maintaining balance on hind limbs and tail • sheltering behind tree branches with wider diameter and leaf bunches
	Resting	• inclined on tree branch or roof of any construction set up of forest personnel	• lying on tree branch or other suitable surface • gripping the branch with fore and hind limbs • balancing with tail

Table 5 continued in next page

Basic life maintaining behaviors	Brood caring	• nest building • lactating • nest guarding • training the juveniles	• collection of nest building materials like twigs, branches, leaves with forelimbs and mouth both by males and females • constructing the nest using both fore and hind limb and mouth, • lactating the pre-weaning juveniles by females • nest guarding and maintenance mostly by females • food collection for juveniles, mostly by females • training the juveniles for searching food by both the parents
Interactive behaviors	Aggressive	• at intraspecific level among reproductively potential males and among the male juveniles and the dominant male • at interspecific levels to secure nest building sites from associated nest builder species like birds, protecting the juveniles inside the nest from predatory birds, snakes etc.	• erected body posture • stunted movement • angular fixed position of tail • erected pinna • chasing other adult and juvenile males by dominant males • throwing alarm calls
	Neutral to cooperative	• keeping indifferent or communicating through vocal signals • body movements or contacts	**interspecific:** • behaviour towards other canopy dwellers like langurs, squirrels • occasional fighting observed with squirrels for procuring particular food items like seeds or fruits **intraspecific:** • biparental nest building • anti-predatory alarm call to warn canopy neighbors • participation in community calls in certain • climatic conditions like heavy rainfall, lightning etc.
	Communicatory	• exhibited both inter and intra specific levels	• calling • signalling by body part movement
Auxillary behaviors	Grooming	• intraspecific	• between mates • offered towards juveniles by female parents
	Calling	• both for intra (towards mates and juveniles and other conspecifics) and inter specific communication (towards canopy neighbours belonging to other species like squirrels, langurs) • executed during foraging, courtship, mating, nest guarding and as alert calls in presence of predators	• vocal signaling
	Urinating	• at canopy stratum	• holding tree branch with fore and hind limbs
	Defecating	• most of the times at canopy levels • seldom at ground levels	• maintaining certain body posture balanced by the grip of limbs over the surface or holding objects like tree branches etc.
	Drinking	• intake of water from tree cavity, rock hole or crevices over leaf surface	• licking the water • balance maintained by limbs

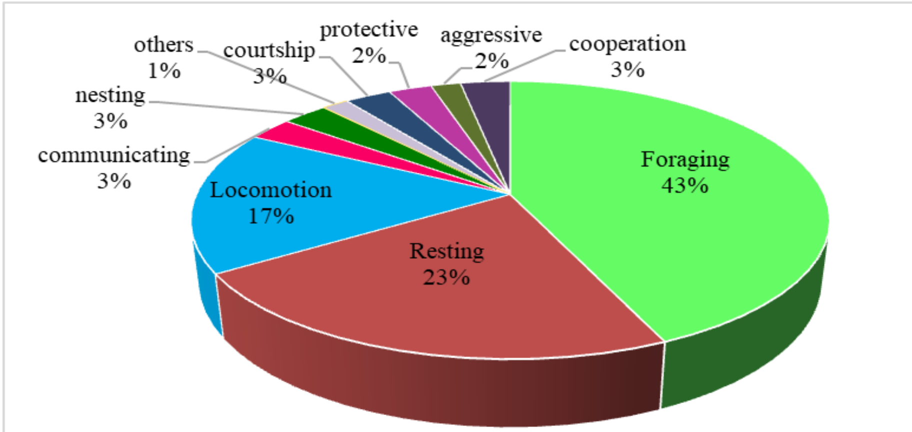


Figure 6. Time budget allocation for different ethological manifestations in *R. indica*

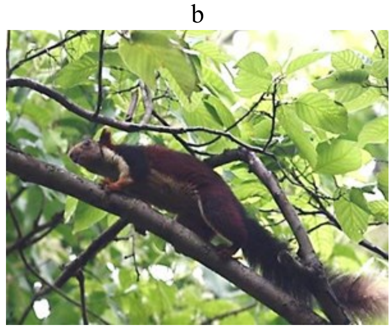
The arboreal rodent species plays many effective ecosystem functionalities such as natural pollination, seed dispersal and canopy food chain linking between producers (plants) and the higher-grade consumers (the carnivorous predators). Thus, besides playing significant role in maintenance of forest food web, they also act as potential bio-indicators (William & Lidickes, 1989). Sometimes they are reported to be treated as pests by the native villagers and tribal populations as they stand responsible for the economic losses to local cultivation by damaging the seeds of food crops, fruits and by competing with poultry birds, snatching their feed. There are also chances of these animals acting as vectors themselves for transmitting infectious diseases (Mukherjee *et al*., 2004).


a


b


c


d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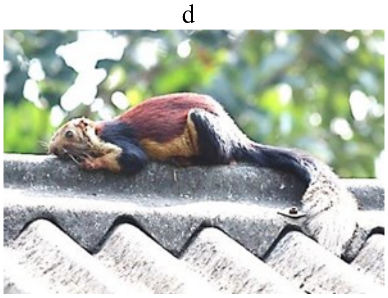
g


h


i

Figure 7. Photographic documentation of different behavioral attributes of *R. indica* at KWS. a. Locomotory (downward movement); b, c. Foraging (searching for food, grasping a fruit); d. Protective or Aggressive (alert gesture); e. Neutral (indifferent); f. Communicatory (mating call); g. Resting (utilizing human-made roof for basking); h. Grooming; i. Brood caring (nesting)

As long-term effect of loss and alteration of habitats and edge effect, habitat specialist species like *R. indica* have become threatened badly. The forest canopy of KWS is recently being threatened with the alterations of natural eco-geophysical attributes like gradual climatic warming and rapid increase in atmospheric CO_2 level. Soil erosion, forest fire and natural loss of mature trees have added to as the threat factors for forest communities. Deforestation created by selective logging of mature trees for setting up of establishments, forest fragmentation due to the construction of roads or dams, grazing inside forest settlement area, collection of firewood and removal of dry litter by the native villagers are some of the prominent anthropogenic risk factors worsening the scenario for the whole forest landscape. Effective management measures may include exact estimation of vegetation coverage as well as canopy dimension via remote sensing (Verma *et al*., 2016). Distribution of their natural populations often gets negatively influenced by habitat fragmentation (Rathod *et al*., 2022). Canopy contiguity plays effective role in assuring continuous distribution of *Ratufa* sp. by facilitating cryptic behaviour, escape from potential predators and thus ultimately enhancing survival (Molur & Singh, 2009; Sengupta *et al*., 2022). Riverine wetlands, streams or forest rivulets serve the role of "corridors" between suitable or favourable habitat patches with optimal resource facility. Interspersed grasslands distributed in patchy mosaic pattern act as potential corridors for wildlife (Liu *et al*., 2018). Threat factors lead to the gradually disappearing habitat connectivity, loss of canopy dynamics and disturbance to the microhabitat uniqueness by the lowering of the canopy height and spatial uniformity over the tree surfaces; ultimately faced with limited dispersal ability and increasing exposure to their natural predators.

Some of the documentations have shown patchy distribution profile and affinity for riverine habitats (Baskaran *et al.,* 2011), but in present study, their most utilized habitat site was found to be placed in vicinity of forest personnel's quarter, in and around the campus area. Choosing the habitats near the FPR at KWS are supposed to provide them safety against these potential threat factors because of the presence of forest security personnel where they enjoy selective advantage for survival at their native places and got flourished within a preferred habitat. This finding may be treated as an instance of successful wild faunal management effort.

CONCLUSION

Four hypotheses can be put forward based on such elaborate eco-ethological study of *R. indica*:-

Hypothesis 1: Habitat preference of this unique arboreal mammalian species is determined both by their inherent as well as acquired behavioural manifestations, as they select their shelters with double fold options to ensure their own protection as well as access of the food from the natural vegetation and from planted orchards around the residential zone of forest personnel (FPR).

Hypothesis 2: Although they seem to be comfortable undertaking reproductive activities in a protected site (FPR) with utmost safety rendered by personnel, they may shift to disturbance-free denser forest zone (CNP) to give birth to their young ones avoiding human confrontation.

Hypothesis 3: Out of their two breeding cycles per year, one of the phases tended to synchronize with the blooming period of trees (Mn) to ensure ample availability and supply of fruits for the juveniles. However, during second breeding phase (PoM), they may alter their foraging behaviour as a survival strategy by switching over their dietary preferences from fruits to leaves, soft bark, etc. especially for the juveniles because of the dearth of fruits. This reproduction-linked diet shifting may be treated as an instance of ethological plasticity paving the way of co-adaptation with the floral partners on which they depend.

Hypothesis 4: Their daily movements as well as nest-shifting activities often get disrupted by the fragmentation of their habitats coupled with the encroaching pressure from the local people usually entering the forest to harvest non-timber forest products. Here lays the vital role played by the forest personnel for securing the care and conservation of this flagship species.

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Conflict of interest

Authors declare no conflict of interest for the current research.

Ethics approval

No ethical approvals are required

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