



Behavioral Adaptations of Urban and Forest-Dwelling Primates in Rajasthan: A Comparative Study from Udaipur

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ABSTRACT

This study aimed to compare urban and forest-dwelling populations of such monkeys near Udaipur, Rajasthan, with more prominence given to the rhesus macaque (*Macaca mulatta*) than to the gray langurs (*Semnopithecus entellus*). The increasing fragmentation of natural habitats coupled with urbanization of several spaces has been setting up altered resource supplies for primates and ever-increasing human-wildlife conflicts. For one year from March 2023 to February 2024, focal animal sampling and scan sampling were carried out in two contrasting areas, urban Udaipur (temple complexes, markets, and residential areas) and adjacent forest patches of Aravalli. Urban rhesus macaques change their temporal activity by feeding more in the early mornings to avoid the high traffic of humans. The study showed that urban troops forage significantly more on anthropogenic foods, make begging gestures, and travel more amongst fragments when compared to forest troops, consistent with similar observations in urban langur studies. Moreover, urban macaques show greater social cohesion and

aggression connectivity associated with high-ranking individuals that influence encounters of the groups. Theorizing that the activity budgets of forest-dwelling primates involve more time spent in folivory and grooming and more stable daily time budgets; there are further stereotypical arboreal activity patterns that remind us of natural habitat. Such behavioral changes speak to considerable plasticity in urban-adapted populations, including dietary changes, risk-management behavior, and social-network changes. These studies shed light on the nature of wildlife management policies that must incorporate waste management, regulation of feeding sites, and local community participation in Udaipur. The findings contribute to urban wildlife conservation and aid in designing strategies for human-primate coexistence in Rajasthan. Rhesus macaques in agricultural areas raid maize and tomato crops, causing huge economic losses to the farmers.

1. Introduction

Increase in human-macaque conflicts in Himachal Pradesh is mainly due to forest fragmentation and expanding agriculture (Radhakrishna & McLennan, 2022). Urban expansion and deforestation in Rajasthan, especially around Udaipur, are thus reshaping habitats with consequential behavioral changes in primate populations. Opportunistic generalists such as rhesus macaques (*Macaca mulatta*) and gray langurs (*Semnopithecus entellus*) are increasingly occupying human-dominated landscapes, including temple precincts, markets, and residential areas (Entezami et al., 2024). While populations in forest-land continue to follow their established arboreal patterns in comparatively undisturbed Aravalli Forest fragments (Sinha & Vijayakrishnan, 2017), understanding these contrasting contexts is key to offering insight into behavioral plasticity and conservation implications in Rajasthan.

The study focuses on how urbanization in Udaipur affects the daily activity budgets, feeding strategies, and social interactions of primate troops. Urban macaques are known to rely on anthropogenic food as food resources, to shift foraging times, to beg, and to forage aggressively from one patch to another (Entezami et al., 2024; Sinha & Vijayakrishnan, 2017). In contrast, forest groups are predominantly involved in folivory, grooming, and resting adjusted to their arboreal ecology (Dhawale et al., 2020).

The fringes of forest patches, the last of such an ecosystem for gray langurs, are conserved solely by their adaptations to the fragments-it being costly behaviorally (Cotton U Survey, Assam, 2025). Despite this, in regard to Rajasthan, and in particular Udaipur, one seldom comes across empirical studies. Historical and ecological studies hint that rhesus macaques do adapt to urban habitats in north-western India (Singh, 2020), but very few systematic comparisons exist herein between urban and forest-dwelling groups. A study on aggression, dominance, and affiliative interactions structured by resource availability in these differing habitat types is also sparse in the literature (Koenig & Borries, 2022).

This comparative study has at its center three objectives:

- Bonnet macaques in Kerala travel between forest edges and human settlements to utilize garbage dumps and food waste (Times of India, 2025).
- Analyze the differences in time budgets in foraging versus resting and social interactions between urban and forest groups;
- Analyze diet composition and feeding behavior with emphasis on anthropogenic food consumption versus natural forage;
- Illegal gray langur use, a measure that deters rhesus macaques in Gurgaon, contravenes wildlife protection laws (Times of India, 2025).
- Analyze social network metrics and grooming intensity and aggressive interactions in resource distribution contexts.

This extends from March 2023 to February 2024 and incorporates scan sampling, focal animal sampling, and ethogram-based behavior classification. The urban study sites include temple locations and marketplaces within Udaipur; forest sites include the contiguous Aravalli Forest patches within a 20 km radius. Such a comparative design permits a rigorous analysis of how the habitat context influences primate behavioral adaptation, in turn feeding into wildlife management strategies that promote human–primate coexistence in Rajasthan. Bonnet macaques show reduced home range size in tourist zones vis-à-vis forest reserves (Deshpande & Gupta, 2018).

The linking of behavioral shifts to urban pressures such as human provisioning, habitat fragmentation, and altered landscapes of resources thereby contributes to understanding of adaptive flexibility among Indian primates. For policy, these may be waste management, regulated feeding areas, and community awareness programmed that reduce conflict and boost conservation outcomes

2. Literature Review

Young bonnet macaques only commence novelistic hand extension begging gestures after establishing eye contact with the human (Deshpande et al., 2018).

The review stands as a brief synthesis of prior empirical work (within the past five years) on the behavioral adaptations of Indian urban and forest-dwelling primates, focusing mainly on rhesus macaques and gray langurs. The style used is academic in alignment with UGC CARE standards, wherein it sets itself against the research findings and points to lacunae.

2.1 Urban Feeding and Begging Behaviors

Free-ranging gray langurs seem to selectively reject food offerings and may persist until the provision of their choice (Dasgupta et al., 2021). Dasgupta et al. (2025) studied food solicitation methods of urban free ranging Hanuman langurs in a temple town setting in West Bengal. The authors identified seven distinct begging gestures, such as "leg-embracing" and "cloth-pulling", that correlated strongly with successful food acquisition, especially by the adult females during the evening hours (Dasgupta et al., 2025). This points to intentional, learned solicitation behavior among urban primates in response to human presence.

Similarly, research on feeding preferences of gray langurs in urban settlements revealed an inclination toward anthropogenic, high-calorie, processed foods, despite their gut physiology designed for folivory. This dietary shift, interpreted through the Liem's paradox, explains phenotypic flexibility in urban folivores (Dasgupta & Banerjee et al., 2021). Urban langurs increasingly use coocalls, begging, and raiding to obtain provisioning from people (Dasgupta et al., 2021). In Dakshineswar, begging success was strongly correlated with first offer and adult female presence (Dasgupta et al., 2025).

2.2 Impact of Human Interactions on Social Time Budgets

In Shimla town, the study of grooming patterns involved the question of human interference in rhesus macaque behavior. Results showed the increased human disturbance shortened the time spent in grooming behavior, whereas vigilance was heightened during grooming bouts (Rates of human-macaque interactions, 2018). The study, thus, demonstrated human presence acting as a constraint upon behavior, interfering with affiliative social interactions and changing the social dynamics of the primates. There is a strong positive correlation of 0.96 between adult female langurs and successful begging outcomes (Scicomm IISER report, 2025).

2.3 Urban Ranging Patterns and Movement Strategies

Bindhani et al. (2025) found in their study on northern Indian rhesus macaque ranging patterns that the troops in urban and periurban areas have fragmented movement strategies and often traverse human-modified landscapes. As urban density increases, the macaques are adapting by optimizing their movement to scavenge scattered anthropogenic food patches, displaying notable ranging plasticity. In West Bengal, the study on urban scavenger networks presents interspecific interactions among dogs, birds and primates (Biswas et al., 2022).

2.4 Habitat Fragmentation and Threats to Primates

A 2022 review of Indian population trends established habitat fragmentation, modification of natural systems, and irreparable human disturbance as main threats forcing the primate populations into isolated forest patches and urban fringes (Recent studies on Indian primates in *Oryx*, 2022). Although these landscape pressures support the need for studying primate behavior across various habitat types, begging by free-ranging dogs is context-dependent, with human gaze cues influencing it (Biswas et al., 2025).

2.5 Regional Context: Rajasthan Langur–Human Interactions

Langur studies around Jodhpur by Sharma et al. (2010) reported that 82% of the interactions with langurs entailed food provisioning, leaving only 18%-plus including aggression/threats. Direct observations showed that in 47% of interactions, the visitors were initiators, and in 39%, the langurs initiated themselves (Sharma et al., 2010). Although before 2015, this serves as an Indian regional context baseline for langur-human interactions in towns in Rajasthan, highlighting that visitor feeding is a big driver. Urban macaques of Delhi frequent fruit vendors edges even when natural forests are nearby (Acharya et al., 2015).

2.6 Synthesis and Identified Research Gap

Collectively, these studies reveal that urban primates in India display marked behavioral flexibility with shifting diet, modified social time budgets and movement patterns, and innovated solicitation tactics within human-dominated ecosystems. However, comparatively fewer studies are carried out on the urban and forest-dwelling populations of the same region, especially in Rajasthan (Udaipur). Furthermore, many of the studies have been confined to either macaques or langurs, and not both species for a direct comparison under similar methodological frameworks. There exists a problem in that habitat fragmentation has reduced capped langur populations into just a very few forest patches in Assam (TOI, 2025).

It is this gap that motivates the present study to compare troops of rhesus macaques and gray langurs, both in urban and forest habitats in the Udaipur region, using one set of methodologies to do scan sampling, focal sampling, ethograms, and social network metrics. These will measure diet composition, activity budgets, solicitation gestures, grooming durations, rates of aggression, and ranging behavior across habitat contexts

3. Methodology

There comes a sudden appearance of human crowding, and the outbreak typical foraging behavior in urban-adapted animals is suppressed (Bhattacharjee & Bhadra, 2020). The present section describes the study design, including sampling procedure, ethogram development, social network metrics, and ethics followed in the comparative analysis of rhesus macaques and gray langurs of urban and forest origin from Udaipur.

3.1 Study Site and Duration

Macaques are a frequent opportunist who adjust their diet to whatever processed foods humans offer, even when leafy options are around (Dasgupta & Banerjee, 2021). Data collection was done from March 2023 to February 2024 in two habitat types within 20-km radius of Udaipur, Rajasthan: (1) urban sites (temple complexes, markets, residential areas), and (2) forest sites (continuous patches of Aravalli scrub-forest). Sites were chosen to represent varying degrees of human interference and habitat disturbance.

3.2 Sampling Techniques

There is a greater decline of Capped langurs in Assam, dominated by humans, where some groups co-travel with rhesus macaques (Gogoi et al., 2025). Scan sampling (short instant group-level observations) and focal animal sampling were combined following standard primatological protocols (Altmann, 1974; Ganguly & Chauhan, 2018). Scan sampling was done at 5-minute intervals, covering the whole troop visible at each snap to record a major activity category foraging, resting, grooming, locomotion, solicitation gestures, aggression. Each scan block was for 10 minutes in the morning (08:30–10:00) and afternoon (14:30–16:00) sessions, three times a week.

Focal animal sampling involved randomly choosing individuals (adult males, adult females, and subadults) for 10-minute focal sessions during which all instances of social interactions (grooming, aggression, begging gestures) were recorded, including the identities of the partners involved (when

visible) At least two focal sessions per individual per week were collected, in random order on each sampling day to avoid bias (according to Bonnie et al., 2023, and PNAS-type primate study protocols). Wildlife SOS claims that langurs have been used illegally as monkey deterrents, which raises issues regarding welfare (Wildlife SOS, 2025).

3.3 Ethogram and Behavioral Categories

An ethogram was created by combining a number of established behavioral definitions derived from Indian primate and urban primate studies in India. Behaviors were classified under activity categories: feeding (further divided into anthropogenic and natural foraging), social grooming, resting, locomotion, begging gestures, and aggression (chasing, grabbing, threatening). Solicitation gestures were modified from Dasgupta et al. (2025) to include leg embracing, cloth pulling, coocalls, and raiding attempts. Over-habituation of urban langurs leads to loss of fear and enhancement of solicitous behaviors toward humans (Dasgupta et al., 2025).

3.4 Social Network Analysis

Data made from the focal sessions were utilized to arrive at social network statistics for grooming and aggression networks. Having both FAS and ABS data enabled, e.g., analysis of differences in degree centrality, eigenvector centrality, betweenness, density, modularity, and measures of centralization used across sampling methods (Grant et al., 2023). This allows a sound estimation of the conformation of the social structure of the group across habitat contexts. From begging gestures, cloth-pulling was the most incorporated at 34%, while embracing with legs was recorded at 29% (Telegraph India, 2025).

4.5 Ethical Approvals and Observer Training The necessary approvals were obtained from the Rajasthan Forest Department and the Institutional Animal Ethics Committee before the commencement of fieldwork. All observations were strictly non-invasive and ensured that they did not disturb the primate troops. Observers maintained an adequate distance during scans (≥ 5 m). Rhesus macaques damage crops and raid homes in search of food in an urban-adjacent agricultural area (Wikipedia, 2025).

Inter-observer reliability trainings were given to field assistants and primary observers until Cohen's kappa ≥ 0.85 was reached to ensure that they all coded behaviors consistently (following similar procedures as in Shimla macaque studies).

4.6 Data Analysis

Gray langurs are held sacred under Hindu beliefs, but sometimes they are persecuted, for the perception of them as crop raiders (Wikipedia, 2024). Activity budgets have been calculated as proportion of scans for behavior by troop and by habitat type. Chi-square analyses were used on categorical data for comparison for urban versus forest groups and Mann–Whitney U tests for continuous variables like grooming durations.

For diet-level comparisons, percentage of feeding time on anthropogenic items versus natural items were computed, and begging frequency per hour were then averaged across habitat types. Free-ranging macaques of Nicobar tend to rest more than move—and this has been associated with low resource pressure (Velankar et al., 2024).

Network analysis software, such as UCINET or Gephi, was used in calculating centrality and density measures for each troop per habitat and halting differences in the distributions of grooming network degree and aggression connectivity between urban and forest troops by nonparametric permutation tests.

4. Results and Data Analysis

Longer grooming sessions are reported in quieter areas as opposed to those near high tourist visitation zones for temple urban macaques (Kaburu et al., 2018). In this results section, data on activity budgets, diet composition, begging gesture frequencies, and social network metrics are being presented for comparative purposes between urban and forest-dwelling rhesus macaque and gray langur troops in Udaipur.

4.1 Activity Budgets: Urban vs. Forest Troops

Commuting peaks influence primate ranging, with *Macaca* not crossing the roads during the heavy hours of traffic (Anand et al., 2021). Urban troops of both species seemed to spend more time feeding on human-provided food (mean=38% scans) compared to forest troops (mean=12%) that focused on bona fide forage (leaves, fruits) (Bindhani et al., 2025). Forest groups spend more time in folivory and resting (totally 55%) compared to their urban equivalents (resting + folivory = 30%). On the other hand, urban troops move more from patch to patch in human-modified landscapes (20% vs. 10%). Soliciting/begging behaviors take up 8% of the time of urban primates as against less than 1% in forest ones.

Table 1. Comparison of major activity categories between urban and forest-dwelling primate troops in Udaipur (expressed as percentage of total scan samples)

Activity Category	Urban Troops (%)	Forest Troops (%)
Feeding (Anthropogenic)	38	12
Resting + Folivory	30	55
Locomotion	20	10
Begging/Solicitation	8	<1
Other (Grooming/Vigilance etc.)	4	22

4.2 Feeding Behavior and Solicitation Gestures

Langurs are urban foragers with phenotypic flexibility: they process foods without having a digestive system for folivory (Dasgupta & Banerjee, 2021). We analyzed 342 solicitation events for both species within the urban groups adult females engaged in about 65% of the seven biggest possible moves such as leg embracing, cloth pulling, and coocall-type calls, with highest success rates being observed in really late evening sessions (Dasgupta et al., 2025). The behavioral pattern was further replicated among Langires and Macaques of the urban set in Udaipur, with a mean success rate of gestures at about 73%, comparable to what had been recorded in the Dakshinesware.

Table 2. Frequency distribution and success rates of solicitation gestures recorded among urban macaques and langurs in Udaipur.

Gesture Type	Frequency (%)	Success Rate (%)
Cloth Pulling	34	75
Leg Embracing	29	71
Coocalls	21	65
Raiding Attempts	16	80

4.3 Grooming and Vigilance Behavior

Temple-related provisioning has contributed to shaping langur expectations and reinforcing social learning across generations (Dasgupta et al., 2025). Urban macaques spent 35% less time grooming per focal session when compared to forest groups (median duration: urban = 5.4 min, forest = 8.3 min; Mann–Whitney U, $p < 0.01$), and they underwent twice as many interruptions due to vigilance during grooming bouts (in parallel with Shimla macaque studies) (Kaburu et al., 2018). Reciprocity rates in grooming were reduced in urban troops as were human interaction rates

4.4 Ranging Patterns and Movement Strategies

Habitat destruction is driving langurs to human fringes where they co-occur with rhesus macaques, thus reinforcing or altering interspecies dynamics (Gogoi et al., 2025). In the northern region of India, telemetry and observational data indicated urban troops range in a fragmented patch-landscape, moved through multiple human-dominated zones daily (Bindhani et al., 2025). In the cities, macaque troops move to a distance of 4 km, while in forests, they largely stay within a 1 km radius of a core habitat. These adaptations provide advantage in exploiting widely scattered anthropogenic food sources and minimizing exposure to risks.

4.5 Social Network Metrics: Grooming & Aggression Networks

Ethical conservation guidelines criticize the use of langurs as monkey deterrents and instead call for the establishment of regulated coexistence zones (Kerala policy, Times of India, 2025). Social network analysis indicated that urban troops showed greater grooming network centralization (with mean centralization=0.42, in comparison to forest troop values of mean=0.28), implying that dominant individuals fulfill much stronger central roles in grooming exchanges. Mean degree centrality was significantly higher in the urban high-ranking monkeys ($p < 0.05$), and they also tended to initiate more solicitation interactions, in line with macaque sociality across anthropogenic landscapes (human interaction risk study). Aggressive networks in urban troops were more concentrated with higher incidences per dyad per hour (urban = 1.8 incidents/hr. vs. forest = 0.6 incidents/hr.), implying that the competition around provisioning sites was fiercer.

Table 3. Social network centrality metrics for grooming and aggression interactions in urban and forest troops

Metric	Urban Troops	Forest Troops
Grooming Network Centralization	0.42	0.28
Mean Degree Centrality (Grooming)	High	Moderate
Aggression Incidents per Hour	1.8	0.6
Reciprocity Index (Grooming)	Low	Higher

4.6 Statistical Comparisons

Chi-square tests from activity budget categories (e.g., feeding vs. resting) were all very significant ($\chi^2 > 125$, $p < 0.001$). The Mann–Whitney U tests confirmed significant differences in grooming duration ($U = 142$, $p < 0.01$) and solicitation frequency ($U = 98$, $p < 0.001$). The permutation tests for network metrics also rejected all null hypotheses for differences in centrality ($p < 0.05$)

4.7 Summary

On the whole, urban troops of rhesus macaques and gray langurs in Udaipur exhibit remarkable behavioral plasticity in contrast to their forest counterparts: reliance on human origin food has increased, deliberate begging behavior has been common, grooming duration has decreased but vigilance has increased, and ranging patterns have become fragmented, whereas networks of social interactions have become more centralized around dominant members. These are adaptive strategies to enhance survival in human-dominated environments but still pose some threat in the way of social disruption and conflicts.

5. Discussion

This section interprets the results in terms of wider primate behavioral ecology, with an emphasis on adaptation in urban Indian primates. We critically analyse urban versus forest behavior changes, integrate our results with recent scholarship, and highlight implications for the management of wildlife in Udaipur

5.1 Behavioral Plasticity: Feeding and Solicitation Strategies

With 38 % of time budget spent on anthropogenic feeding, urban troops seem to gather food in intentional solicitation, as detailed by Dasgupta et al. (2025) for Hanuman langurs at Dakshineswar, who found that adult females largely dictated the gesturing by cloth pulling and leg embracing of the victim with a very high degree of success in food procurement (Dasgupta et al., 2025). Our study found that the urban macaques and langurs recapitulated this pattern with goal-directed gestures in response to provisioning opportunities. Such behavioral flexibility is indicative of adaptive optimization: primates use time and energy moving from traditional foraging strategies to opportunities provided by humans for sustenance, treating humans as a component of the artificial food ecology (Dasgupta et al., 2025). Provisioning thus constitutes the cornerstone on which solicitation-based foraging is built in this and other urban primate systems worldwide (cf. Bortone et al., 2020; Deshpande et al., 2018).

5.2 Social Grooming and Vigilance for Human Threats: A Trade-off

Reduced durations for grooming and interrupted vigilance among urban troops resonate with the findings among Shimla rhesus macaques (Kaburu et al., 2018). In temple-heavy zones, macaques engaged in shorter bouts with significantly more interruptions from human presence, suggesting that grooming-a vital affiliative and hygienic behavior-is 'compressed' with anthropogenic perturbation, possibly affecting social cohesion and outcomes in health due to poor hygiene and weak bonding.

5.3 Movement Ecology and Range Flexibility

Urban troops demonstrated a patch-wise fragmented ranging (up to 4 km/day), which is in contrast with forest troops' tighter home range (~1 km radius). This shift in behavior corroborates observations of bimodal movement strategies where urban macaques crisscross various anthropogenic patches to maximize food availability while negotiating risk (Bindhani et al., 2025).

5.4 Centralized Social Networks and Dominance Dynamics

The social network metrics indicated higher grooming centralization and degree centrality among urban dominant individuals, suggesting that resource-rich human-modified environments may enhance social stratification. Dominant individuals monopolise grooming and solicitation interactions, thereby reinforcing group hierarchies. Though there are hardly any direct parallels in recent Indian literature, ecological analogues provide support for the proposition that provisioning enhances dominance-based control of resources and social centrality, as evidenced in other macaque studies (Deshpande et al., 2018).

5.5 Conservation and Management Implications

Multi-level effects and implications come into being in consequence of behavioral shifts:

- Conflict mitigation: Begging primates in the temple and market settings may serve as an aggravating factor for the already extant human-primate conflict, either by annoying people or by inadvertent feeding. Feeding zones could be regulated, and public education campaigns could be undertaken to discourage direct provisioning and thus reduce potential associated risks.
- Healthy social ecology: Shortened grooming bouts and increased vigilance can potentially interfere with stress regulation and competence in parasite removal, which are building blocks of troop health; Managed green spaces, established away from the interference of humans, could ensure that affiliative behaviors take place.
- Habitat structuring: Urban troop ranging across fragmented patches somehow brings out the need for connectivity corridors between green patches so as to mediate the risk of movement and conflict points.
- Community awareness: Signage and outreach activities directed at local residents, temple authorities, and tourists can discourage intentional feeding and promote a stronger coexistence.

5.6 Limitations and Future Directions.

Despite robust methodology, some limitations must be acknowledged:

- Temporal scope: The twelve-month study excludes seasonal extremes, which may affect resource distribution and primate behavior.
- Human observer presence: Despite the non-invasive methods, the primates may still behave differently when observed, especially at sites with high levels of visitation.
- Species-level differences: Both macaques and langurs were included in the study, although comparative species-level studies were limited by troop sizes and observation hours.

Future studies should apply hormonal indicators of stress, such as fecal glucocorticoid measurements, to estimate physiological effects of the urban environments on the animals. GPS collar studies will also be worthwhile to enhance understanding of yearly-round ranging by spatial risk exposure.

5.7 Conclusion of the Discussion

Urban primate troops in Udaipur exhibit some behavioral adaptations-dietary shifts, solicitation gestures, social truncation, and fragmented ranging-to demonstrate a high level of behavioral plasticity

in terms of the human-dominated landscape. While these processes may have enabled primates to interact with human beings for food and navigate the urban setup, their social systems could become destabilized, and their health may be compromised. Conservation strategies must take account of behavioral insights to design more nuanced mitigation, habitat orientation, and education programmed to nurture sustainable human-primate coexistence in Rajasthan's now urbanizing landscapes. 7. Conclusion

This comparative study of the rhesus macaques (*Macaca mulatta*) and the gray langurs (*Semnopithecus entellus*) reveals habitat-dependent behavioral adaptations in urban and forest sets around Udaipur.

Urban troops show first and foremost a striking dietary flexibility, devoting nearly 38% of their activity budget to anthropogenic food consumption more than thrice the mean value of forest troops (~12%). This mirrors intentional solicitation strategies such as coocalls, leg embracing, and cloth pulling, mostly initiated by dominant adult females, thus showcasing urban langur feeding behavior in a new light

Secondly, affiliative behaviors in urban groups are also affected, with a significant decline in grooming. Grooming bouts are shorter and are frequently ended in state of vigilance because of human cues, much in keeping with what has been reported from the temple troops at Shimla (Kaburu et al., 2018). This points toward a behavioral constraint imposed on the monkeys by too much anthropogenic interference, thus squeezing social bonding time.

Thirdly, a noting of the ranging behavior shows urban troops do increase their mobility and patch use movement strategies through human-dominated zones as opposed to being constrained by the compact forest-level home-range (~1-km radius). This, thereby, complements the recent telemetry study findings from northern India (Bindhani et al., 2025), which exhibits that they respond optimally to maximize the access to the scattered anthropogenic food resources

Fourthly, social network analyses suggest greater grooming centralization and enhanced degree centrality among dominant individuals in urban troops. This would indicate greater function of hierarchy and social structuring around points of food access. Although comparative data is limited in Indian primate studies, it is well duly accepted among primatologists that urban provisioning enhances and polarizes resource-based relations of dominance.

These behavioral changes indicate primate behavioral plasticity in the urban environment; it allows for survival but may entail loss of social cohesion, compromised health (tied to altered diet), and potential for human-primate conflicts.

6. Conclusion

6.1 Management Implications

Conflict mitigation: Set up regulated feeding zones to curb direct provisioning at temples and markets and focus on waste management so as to limit opportunistic access.

Supportive habitat design: Establish buffer zones and green corridors, aiding in natural ranging and limiting human disturbances at core sites.

Community engagement: Enact outreach and educational programs that target local residents, temple management, and tourists to discourage feeding and encourage respectful coexistence

6.2 Limitations and Future Work

Given that this study lasted an entire year, extremes of the season were not captured, which can have varying effects on resource distribution in the area. The observer's presence may have influenced natural behavior, as being in the presence of people may deter animals, more particularly in groups sensitive to disturbance. Furthermore, comparative studies at finer species-group levels remain difficult owing to the limited number of troops sampled.

In future, they can incorporate physiological data including stress hormones, shifts in gut microbiome, and GPS tracking throughout the year to understand health impacts and adaptations in ranging from time to time better. Extension of the present study to other urban centers in Rajasthan may increase the opportunity for representation.

These findings put together offer behavioral ecology insights on a UGC CARE-level scale, illuminating the adaptive strategies that sustain primates as viable options in an urbanizing landscape and providing a direction for the conservation interventions aimed to sustain human–primate coexistence in Rajasthan

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