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Impact of Provision Food on the Foraging Ecology of Rhesus Macaque (*Macaca mulatta*) Inhabiting Margalla Hills National Park, Islamabad

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ABSTRACT

This study explores the behavioral and dietary impacts of food provisioning on Rhesus macaques in Margalla Hills National Park, Islamabad, focusing on variations across high-provisioning (HP) and low-provisioning (LP) areas, visitor densities, and age-sex groups. Over 720 hours of observation, including 2,329 scans, revealed that HP rhesus macaques spent significantly more time foraging (67.53%) compared to LP rhesus macaques (46.21%), with lower levels of resting (11.36% vs. 22.49%) and grooming (9.85% vs. 13.49%). HP rhesus macaques also exhibited reduced locomotion (6.17% vs. 29.62%) and a higher reliance on human-provided food. Behavior analysis across visitor densities indicated that moderate visitor levels (51-80) promoted active behaviors like foraging and locomotion, whereas very high visitor levels (> 80) led to increased resting and grooming. Foraging peaked at 51-80 visitors and declined at extreme visitor counts, while grooming and resting behaviors showed opposite trends. Post hoc analyses revealed distinct behavioral patterns based on visitor density, with significant variations in grooming, locomotion, and food consumption. Age and sex differences indicated that adult females with infants foraged less frequently than adult males, and juveniles exhibited the highest foraging activity. Dietary analysis confirmed significant differences, with HP macaques primarily consuming human food, while LP macaques relied more on natural sources. Locomotion patterns differed markedly between provisioning areas, with HP macaques showing concentrated movement and increased social interactions. These findings underscore the influence of provisioning and visitor density on macaque behavior, highlighting the need to carefully manage the human-wildlife interactions.

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Authors' Contribution
SB conceived and designed the study, conducted the fieldwork, performed data analysis, and wrote the first draft of the manuscript. SA contributed to field visits and data collection. KZ assisted in data collection and manuscript preparation. MK prepared all maps used in the study, including distribution maps. ARK supervised the research.

Key words
Rhesus macaques, Food provisioning, Visitor density, Behavioral patterns, Dietary differences

INTRODUCTION

Food provisioning to the free-ranging primate population is a ubiquitous phenomenon that occurs in a wide range of sociocultural situations. Provisioning refers to the supplemental feeding provided by humans. Food provisioning may have cultural and spiritual reasons that facilitate interaction between people and primates in different habitat settings such as temples, towns, or tourist sites (Medhi *et al*., 2007). Provisioning has both positive and negative outcomes. On the positive side, it can significantly boost tourism, providing economic benefits to local communities and fostering a greater appreciation and willingness to protect wildlife (Knight, 2009). On the other side, provisioning can have detrimental effects on primates. It often leads to changes in their natural behaviors, health issues, and altered social dynamics (Maréchal *et al*., 2016). Moreover, it can result in higher population densities, leading to increased competition and stress among individuals (Becker and Hall, 2014).

Globally, human provisioning has been shown to alter primate behavior and ecology in multiple ways. The primates showed a diversity of specialized foraging adaptations and preferences. Spatial variation in primate population abundance is influenced by the interplay of food quality and quantity, with fallback food availability modulating population size under differing nutritional needs and environmental conditions (Hanya and Chapman, 2013). Fruit availability significantly influenced their feeding behavior, challenging previous assumptions about their dietary habits and highlighting the importance of fruit in their ecology and behavior (Matsuda *et al*., 2009). A study conducted in Ghana, West Africa, found that Lowe's Rhesus macaque (*Cercopithecus lowei*) spent less time foraging on natural foods, increased rest, and showed higher aggression compared to groups relying solely on wild foods (Badiella-Giménez *et al*., 2021). Provisioning

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has influenced population dynamics and disease risk by altering contact rates and immunity (Grossberg *et al*., 2003). A study in Ouzoud, Morocco, demonstrated that Barbary rhesus macaques displayed habitat diversity, with a notable presence in various environments where they show habituation to humans and partial reliance on provisioned food (El-Alami *et al*., 2013).

The rhesus macaque is the non-human primate with the most diverse geographical and ecological range. Rhesus macaques are distributed throughout South Asian countries like Pakistan, Afghanistan, Bhutan, Bangladesh, Burma, and Nepal, as well as China, Vietnam, and Thailand. The rhesus macaque is widely distributed in the Margalla Hills National Park, Islamabad (Aslam *et al*., 2024).

In Asia, Studies found that Provisioning has a profound impact on the ecology of Rhesus macaques. Rhesus macaques in India at pilgrimage and tourist sites spent more time on anthropogenic food, thereby decreasing natural foraging and increasing aggressive behavior (Sengupta and Radhakrishna, 2018). A study in Bangladesh showed that activity patterns of different Rhesus macaque groups are influenced by habitat, season, and food availability. These urban-rural disparities are primarily driven by distinct food resource availability, showcasing behavioral flexibility crucial for managing commensal populations (Jaman and Huffman, 2013). Unregulated roadside provisioning of long-tailed monkeys in West Sumatra, Indonesia, has led to a rise in road traffic accidents (RTAs), causing fatalities and injuries to both animals and humans (Ilham *et al*., 2023; Zhoa *et al*., 2023).

Recent years have seen a rise in literature about Rhesus macaques in Pakistan. Aslam *et al*. (2024) documented the diet and food preferences of rhesus macaques in the highly biodiverse Margalla Hills National Park. Moreover, Ehtisham *et al*. (2021) examined the impact of tourism on the distribution of the rhesus macaques in the Galiyat area of Khyber Pakhtunkhwa. More recently, Hussain *et al*. (2025) studied the complex status of the rhesus macaques and the multifaceted challenges to their conservation in Machiara National Park, Azad Jammu and Kashmir. However, there is a notable lack of understanding of how explicitly tourist provisioning affects the feeding behavior and food choice of rhesus macaques in MHNP. This study addressed this significant gap

This study was conducted to assess the effect of tourist provisioning on the foraging ecology of the rhesus macaques in MHNP. More specifically, it assessed how the presence of visitors affects activity patterns and foraging strategies of rhesus macaques. In addition, the study investigated the effect of provisioning on the ranging behavior of rhesus macaques using distribution maps of group locations in high and low-provisioned areas to indicate differences in mobility. To address these objectives, behavioral and spatial data were collected.

MATERIALS AND METHODS

Study area

The current study was conducted in the Margalla Hills National Park (MHNP), located between (33.6° to 36.55° N and 72.8333° to 73.4333° E) situated in the Federal Capital city Islamabad, Pakistan (Fig. 1). It covers an area of 17,386 hectares, with elevation ranging from 456 to 1580 meters (m), and the landscape is rugged mountains. The climate of the study area is humid subtropical (Koppen climate classification). The region experiences two wet seasons because it lies in the monsoon zone; summer rains last from July to September, while winter rains last from January to March each year. The vegetation of the Margalla Hills range is classified as tropical dry mixed deciduous forest, dry subtropical semi-evergreen scrub, and subtropical pine forest (Khalid *et al*., 2019). The reported mammalian fauna of the park mainly includes the common leopard, Asiatic jackal, red fox, Asian palm civet, small Indian civet, yellow-throated marten, Indian pangolin, and rhesus macaque etc. (Anwar and Chapman, 2000).

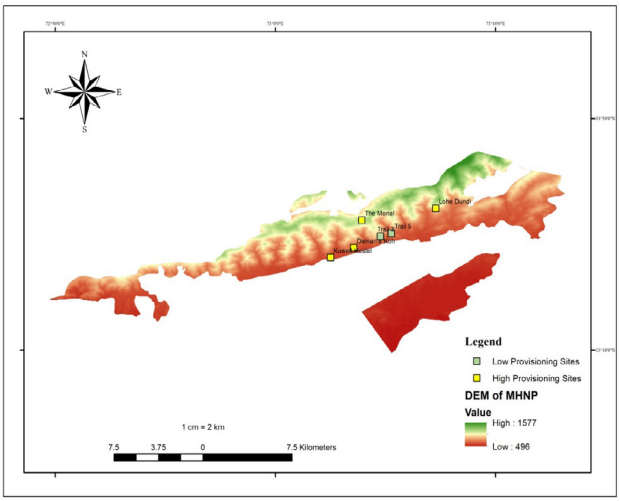

Fig. 1. Map of the study area (Margalla Hills National Park, Islamabad) showing different provisioning sites. Yellow colour boxes indicate four high provisioning sites, Damne koh, Monaal, Loh-e-dandi, and Faisal masjid (Kuwait hostel E 11). Green boxes show low provisioning sites (Trail 3 and Trail 5).

We divided our study area in the Margalla Hills National Park (MHNP) into high and low provisioning areas. The high provisioning area (HPA) included four

sites with substantial human-provided food: Damne Koh, Loh-e-Dundi, the Monal restaurant area, and the Faisal Masjid. While the low provisioning area (LPG) consisted of trails three and five, where rhesus macaques primarily rely on natural food sources due to lower tourist presence and less supplemental feeding.

Data collection

The current study was conducted from September 2022 till July 2023. The field data were collected from December 2022 to February 2023, and then from May to July 2023. At the onset of the study, we conducted are naissance survey of the study area in the month of November 2022 to assess the population size and distribution of rhesus macaques, as well as the patterns of visitor activity across various locations within the Margalla Hills National Park (MHNP). The composition of focal animal groups and identification of key individuals at each site is given, guided by Porter (2005) age-sex classification (Table I).

The field visits were structured as 10 days each month, with five days at high-provisioning sites and five days at low-provisioning sites. An ethogram of rhesus macaques' behaviors was developed following Porter (2005) (Table II). We recorded the behavior of all visible individuals of the focal group, categorizing their activities into predefined behavioral categories: Grooming (GR), Locomotion (LC), Resting (RS), Provisioning by People (PBP), Snatching (SN), Scavenging (SC), and Natural Food (NF).

Observations were conducted from 06:00 to 18:00, encompassing the entire daylight period. We employed a two-tiered observational approach comprising scan sampling and focal animal sampling techniques to study the behavior and dietary habits of rhesus macaques (*Macaca mulatta*) in their natural habitat. Scan sampling, conducted at regular 15-min intervals following the methodology outlined by Altmann (1974), served as the primary method for recording specific behavioral activities. When an individual rhesus macaque was observed engaging in feeding behavior during a scan, we immediately initiated focal animal sampling on that individual. The focal observation lasted for a 15-min session, during which we closely monitored and recorded the specific food items being consumed and the duration of feeding.

Table I. Composition of rhesus macaque groups observed at high-provisioning areas (HPA) and low-provisioning areas (LPA) in Margalla Hills National Park. The table includes group ID, sampling site, total number of individuals, age-class distribution (infants, juveniles, sub-adults, adults), and notable/key individual characteristics.

Provisioning level	Sampling site	Total	Infants	Juveniles	Sub-adults	Adults	Notable Individual's characteristics
HPA	Daman-e-Koh	32	5	9	11	7	Adult female: Baby clung to the belly, short tail
	Loh-Dandi	17	3	3	6	5	Adult male: Head bigger than usual; Adult female: short tail, black scar, and injured leg
	Monal	15	4	3	5	3	Juvenile: Tail wrapped in rope; Adult female: spot near right eye
	Faisal Masjid	18	4	7	3	4	Sub-adult: Tail hook-shaped
LPA	Trail 3	22	5	2	6	9	Sub-adult: Coiled tail
	Trail 5	22	5	2	6	9	Adult female: Black saggy nipples

Table II. An ethogram of rhesus macaque (*Macaca mulatta*) behaviors used in the present study.

Ethogram behavior	Mode of foraging	Description
Foraging	Natural food	It included only feeding on natural resources in the locality
	Provisioned by people	Included all the food directly given by people
	Snatching	Included attacking people for food items
	Scavenging	Included scavenging through the dustbins and the ground for food residues
Resting		the animal remained stationary, adopting various postures such as standing, sitting, or lying down.
Locomotion		Included all animal movements, such as strolling, sprinting, swinging, jumping, etc.
Grooming		It included all individuals cleaning themselves or other troop members on the road.

Visitor numbers were recorded to assess the impact of human presence on the foraging behavior of Rhesus macaques. Visitor counts were conducted daily, with observations lasting two hours each in both the morning and afternoon. This approach ensured that visitor numbers were recorded during peak times when food provisioning typically occurred. The count of visitors was limited to those present within a 20-meter radius of the center of the focal rhesus macaque group. Based on the observed numbers, we have designed four categories: <20 visitors, 21-50 visitors, 51-80 visitors, and >80 visitors. The geographical coordinates for each sampled location were recorded using a handheld GPS device (Garmin eTrax Vista).

The collection of GPS coordinates was integral to our study design as it served the purpose of mapping the spatial distribution of rhesus macaques behaviors. By utilizing GPS locations, we gained insights into how the rhesus macaques behaviors varied across different areas within their habitat, allowing us to assess the impact of human-provided food on their movement patterns. The behaviors of rhesus macaques were digitally recorded using a mobile phone.

Data analysis

The collected data about the behaviors of rhesus macaques were analyzed using SPSS software (Version 23) by applying a t-test to check the activity pattern of the rhesus macaque population. A one-way ANOVA was applied to compare rhesus macaques' behaviors across areas, age-sex categories, and visitor numbers, followed by a post hoc test to identify specific group differences. A Chi-square test followed by post hoc (Holm) correction was applied to analyze the relationship in food items consumed by rhesus macaques in the Margalla Hills National Park. Finally, we mapped the daily locations of the rhesus macaques with the help of GPS coordinates by using Arc GIS software to show the difference in movement patterns at both high and low provisioning sites.

RESULTS

A total of 2329 scans were recorded in the current study, with 720 h, including 1335 observations for the high provisioning group (HPG), and 994 for the low provisioning group (LPG). The overall activity budgets of rhesus macaques differed between HPG and LPG groups and were further influenced by visitor levels (Table III). The HPG spent, on average, 67.53% of their time in foraging activities, which include all types of feeding, significantly higher than the LPG, which allocated 46.21% of their time to foraging ($p < 0.001$) (N=60, d.f= 58). The HPG showed significantly lower resting behavior (11.36%) compared to the LPG (22.49%) ($p < 0.001$) (N=60, d.f= 58). Grooming behavior was significantly lower in the HPG (9.85%) compared to the LPG (13.49%) ($p < 0.001$) (N=60, d.f= 58). The HPG exhibited a significantly lower moving behavior (6.17%) compared to the LPG (29.62%) ($p < 0.001$) (N=60, d.f= 58). Scavenging, feeding on natural food, feeding on human food, and snatching behaviors were also significantly different between the HPG and LPG ($p <0.001$) (N=60, d.f= 58) (Fig. 2).

Foraging (FG) varied significantly across visitor levels ($F = 33.92$, $p < 0.001$), being highest at 51–80 and 20–50 visitors, intermediate at >80 visitors, and lowest at <20 visitors. Among the foraging sub-categories, Natural food (NF) decreased as visitor numbers increased ($F = 31.99$, $p < 0.001$), whereas Provisioning by people

Table III. Activity patterns (%) of rhesus macaques in high-provisioning group (HPG) and low-provisioning group (LPG), under varying visitor levels (mean ± SD).

Behavior	HPG (%)	LPG (%)	<20 visitors	20–50 visitors	51–80 visitors	>80 visitors	F	p
Foraging (FG)	67.53 ± 11.85	46.20 ± 8.48	45.20 ± 7.37^{b}	69.97 ± 5.86^{a}	61.51 ± 1.39^{a}	35.64 ± 1.29^{c}	33.92	<0.001
└ Natural food (NF)	10.95 ± 3.73	33.62 ± 7.48	34.34 ± 6.96^{d}	12.35 ± 5.24^{b}	20.53 ± 1.26^{a}	7.30 ± 4.49^{c}	31.99	<0.001
└ Provisioning by people (PBP)	38.41 ± 10.89	4.60 ± 6.12	3.43 ± 2.33^{c}	38.53 ± 1.04^{a}	26.52 ± 2.10^{ab}	19.59 ± 7.94^{b}	34.21	<0.001
└ Snatching (SN)	12.65 ± 5.66	3.68 ± 3.31	3.16 ± 2.92^{c}	13.79 ± 4.39^{a}	9.17 ± 6.77^{b}	3.32 ± 0.57^{c}	22.05	<0.001
└ Scavenging (SC)	5.36 ± 3.70	3.70 ± 2.21	3.87 ± 2.42^{a}	5.15 ± 2.17^{a}	4.45 ± 2.87^{a}	5.42 ± 3.05^{a}	1.12	0.351
Grooming (GR)	9.85 ± 3.08	13.40 ± 3.20	13.58 ± 3.03^{ab}	9.38 ± 3.30^{c}	11.16 ± 3.25^{bc}	15.05 ± 0.12^{a}	7.85	<0.001
Locomotion (LC)	6.17 ± 3.37	12.41 ± 5.22	13.30 ± 4.99^{a}	6.49 ± 3.78^{bc}	8.04 ± 4.08^{b}	3.28 ± 0.43^{c}	11.97	<0.001
Resting (RS)	11.36 ± 10.68	22.49 ± 11.48	23.07 ± 1.10^{b}	8.08 ± 2.95^{c}	14.93 ± 1.15^{bc}	39.04 ± 1.54^{a}	14.81	<0.001

FG, Foraging (overall); Sub-categories: NF, Natural food; PBP, Provisioning by people; SN, Snatching; SC, Scavenging. Values within each row sharing the same superscript letter are not significantly different at $p < 0.05$ (Duncan post-hoc test).

Table IV. Activity patterns (%) of rhesus macaques across age–sex classes (mean ± SD).

Behavior	Adult male	Adult female	Adult female w/ baby	Sub-adult male	Sub-adult female	Juvenile	F	p
Foraging (FG)	58.10 ± 13.83^{b}	58.87 ± 12.36^{b}	40.90 ± 8.97^{a}	70.37 ± 1.91^{c}	61.73 ± 13.84^{c}	72.62 ± 3.68^{c}	8.31	<0.001
└ Natural food (NF)	24.06 ± 14.39^{b}	22.00 ± 12.03^{b}	27.39 ± 12.40^{b}	12.47 ± 2.86^{a}	23.00 ± 13.21^{b}	12.25 ± 4.56^{a}	1.67	0.157
└ Provisioning (PBP)	21.48 ± 21.10^{b}	24.65 ± 20.21^{b}	6.68 ± 7.94^{a}	33.15 ± 8.86^{c}	26.23 ± 23.03^{b}	37.53 ± 10.48^{c}	3.15	0.015
└ Snatching (SN)	7.73 ± 5.61^{b}	7.22 ± 4.41^{b}	2.63 ± 1.93^{a}	18.79 ± 6.78^{d}	8.67 ± 4.03^{b}	14.79 ± 1.59^{c}	11.42	<0.001
└ Scavenging (SC)	4.45 ± 2.24^{b}	4.23 ± 1.92^{b}	3.52 ± 2.33^{a}	6.83 ± 3.57^{c}	3.83 ± 2.06^{a}	7.08 ± 1.37^{c}	2.55	0.039
Grooming (GR)	12.66 ± 3.81^{b}	10.94 ± 1.92^{b}	12.79 ± 3.27^{b}	10.58 ± 1.41^{b}	10.77 ± 5.46^{b}	6.60 ± 2.13^{a}	2.23	0.064
Locomotion (LC)	10.15 ± 4.68^{a}	10.04 ± 6.98^{a}	10.03 ± 6.59^{a}	6.52 ± 4.44^{a}	8.84 ± 4.17^{a}	5.79 ± 1.74^{a}	0.76	0.586
Resting (RS)	14.01 ± 10.69^{b}	13.92 ± 5.87^{b}	31.12 ± 12.95^{c}	8.32 ± 2.40^{a}	14.53 ± 7.05^{b}	6.88 ± 1.64^{a}	8.12	<0.001

FG, Foraging (overall); Sub categories: NF, Natural food; PBP, Provisioning by people; SN, Snatching; SC, Scavenging. Values within each row sharing the same superscript letter are not significantly different at $p < 0.05$ (Duncan post-hoc test).

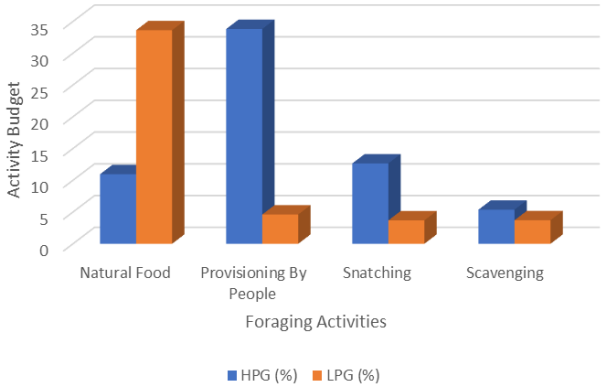

Fig. 2. Comparison between foraging activities of Rhesus Monkey between two groups: HPG, high provisioned group; LPG, low provisioned group.

(PBP) and snatching (SN) increased significantly ($F = 34.21$, $p < 0.001$; $F = 22.05$, $p < 0.001$). Scavenging (SC) did not differ with visitor level ($F = 1.12$, $p = 0.351$). Other behaviors were also affected: Grooming (GR) declined with increasing visitor numbers ($F = 7.85$, $p < 0.001$), Locomotion (LC) increased ($F = 11.97$, $p < 0.001$), and Resting (RS) was lowest at intermediate visitor levels and highest in the absence of visitors ($F = 14.81$, $p < 0.001$).

Age–sex classes also showed significant variation in activity patterns (Table IV). Foraging (FG) differed among groups ($F = 8.31$, $p < 0.001$), with juveniles and sub-adult males devoting the most time to foraging, while adult females with infants foraged the least. Within the sub-categories, Provisioning (PBP) and Snatching (SN) were significantly higher in juveniles and sub-adult males, and lowest in adult females with infants ($F = 3.15$, $p = 0.015$; $F = 11.42$, $p < 0.001$). Scavenging (SC) also varied significantly ($F = 2.55$, $p = 0.039$), being more common in juveniles and sub-adult males. Natural food (NF) did not differ significantly across groups ($F = 1.67$, $p = 0.157$).

Table V. Food item consumption of rhesus macaques at high-provisioning (HP) and low-provisioning (LP) sites. Percentages indicate the proportion of feeding scans in which each food type was consumed. Chi-square tests (χ^2) were performed using the total feeding scans (N = 2,329) to examine differences in diet composition between HP and LP sites. Post-hoc comparisons were conducted using Holm correction to identify which food categories differed significantly.

Food item	HP (%)	LP (%)	Chi-square (χ^2)	p value	Post-hoc (Holm)
Fruit	9.19	32.46	143.0	<0.001	***
Flower	12.28	28.77	99.0	<0.001	***
Leaves	6.95	24.27	70.7	<0.001	***
Human food	64.94	8.82	688.6	<0.001	***
Water	6.61	7.77	1.2	0.27	ns

Significant differences are indicated as *** ($p < 0.001$); ns, non-significant.

Overall, dietary composition differed significantly between high and low provisioned rhesus macaque groups ($\chi^2 = 794.79$, $df = 4$, $p < 0.001$) (Table V and Fig. 2). Post-hoc pairwise chi-square tests with Holm correction revealed that LPG of rhesus macaques consumed a significantly higher proportion of natural food items: fruits (32.46%), flowers (28.77%), and leaves (24.27%), compared to HPG rhesus macaques (9.19%, 12.28%, and 6.95%), respectively ($p < 0.001$). In contrast, HPG relied predominantly on human-provisioned foods (64.94%), whereas LPG consumed only 8.82% of these items ($p < 0.001$). No significant difference was observed in the consumption of water between the two groups.

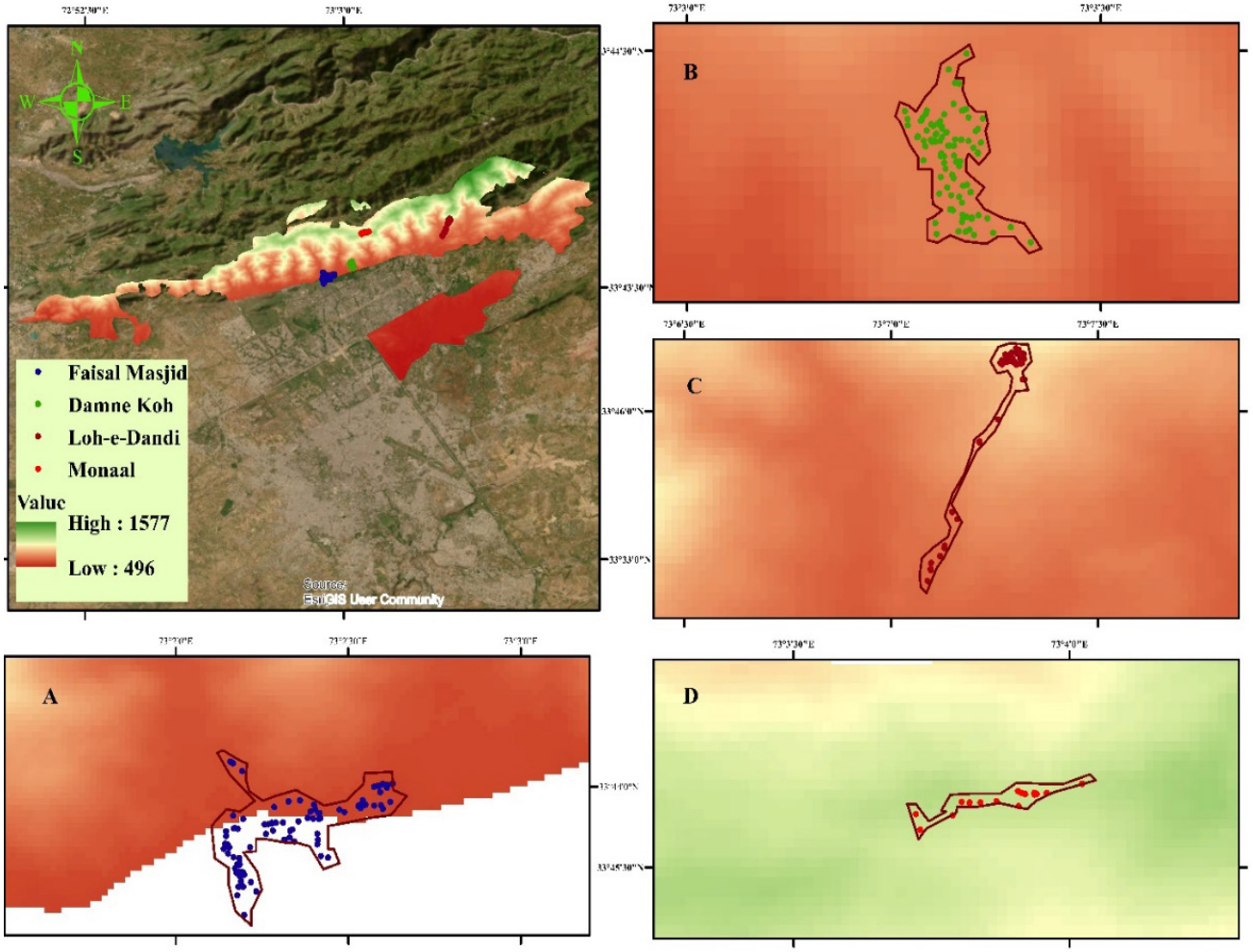

Fig. 3. Map of high provisioned sites; (A) Faisal masjid (Purple), (B) Damn-e-Koh (Green), (C) Loh-e-Dandi (Brown), (D) Monal (Red), and representing reduction in locomotion and movement pattern of rhesus macaques at Margalla Hills National Park, Islamabad.
*The delineated boundaries illustrate the locomotion patterns of macaques at the highly provisioned site.

Results of the current study showed that the rhesus macaques of the high-provisioned region limited their locomotion and became habituated to human food provided (Fig. 3). They spent most of their time around visitors at high-provisioned sites due to the availability of food without or with less expenditure of energy needed for foraging. In the high-provisioned areas, including Faisal Masjid, Damn-e-Koh, Loh-e-Dandi, and Monal, the rhesus macaques exhibit concentrated movement patterns, as indicated by the dense clustering of observation points. Conversely, in the low-provisioned areas represented by Trail 3 and Trail 5, the rhesus macaques demonstrate increased locomotion despite the scarcity of resources, with movement patterns appearing more dispersed as they search for food across a broader area (Fig. 4).

DISCUSSION

Overall analysis of the collected data indicated that the presence of visitors significantly influenced various behavioral types of the rhesus macaques in all sampling sites of the Margalla Hills National Park, Islamabad. The specific patterns of behavior varied depending on the number of visitors present, with different behaviors showing significant differences among the rhesus macaques groups. However, no significant differences were observed for scavenging behavior. Badiella-Giménez *et al*. (2021) reported that primates' routine foraging and social behaviors are highly impacted by the season and environment of their habitat.

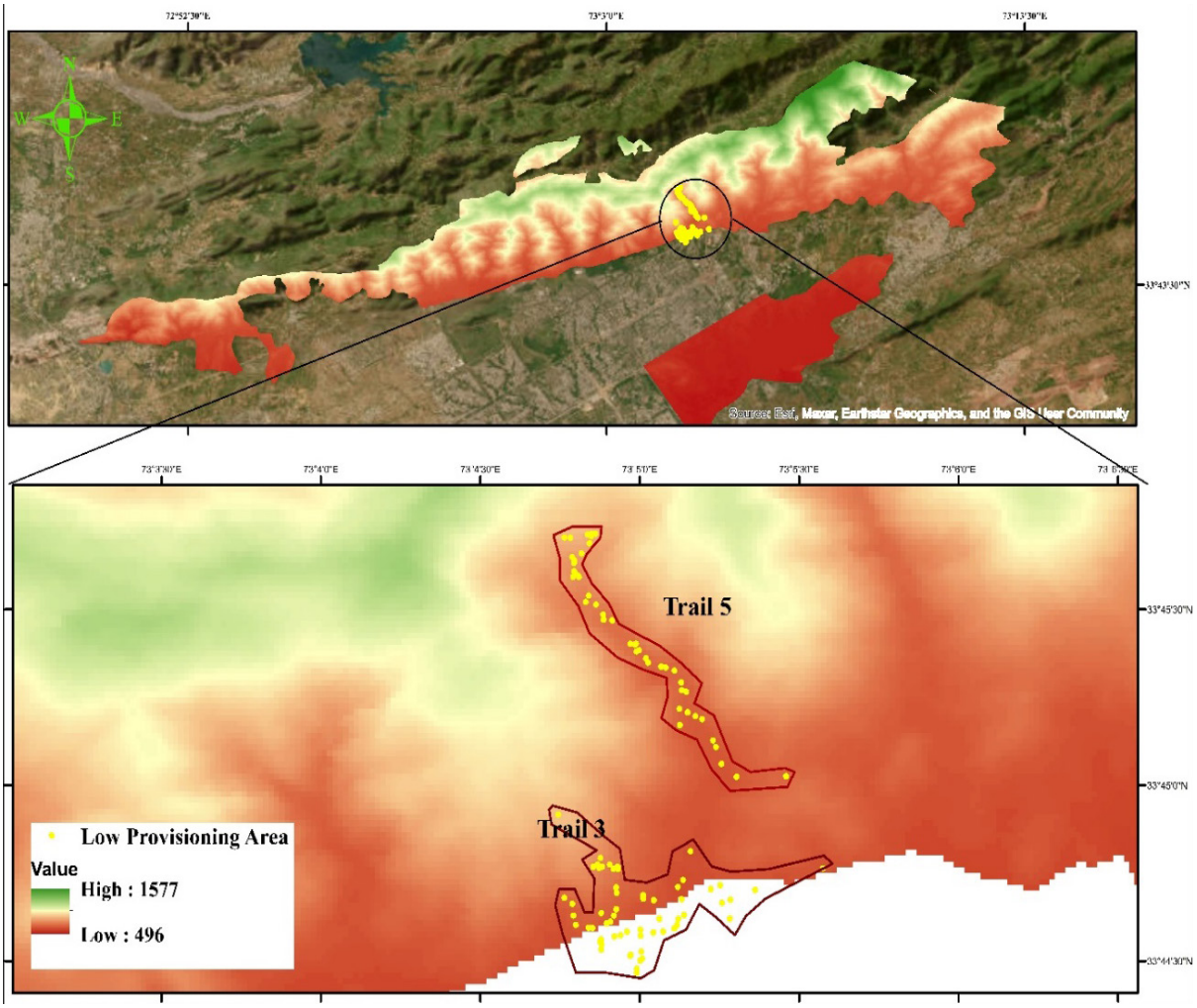

Fig. 4. Map of low-provisioned sites; Trail 3 and Trail 5 (yellow), representing an increase in locomotion and movement pattern of rhesus macaques at Margalla Hills National Park, Islamabad.
*The delineated boundaries illustrate the locomotion patterns of macaques at the low-provisioned site.

In the current study, we have investigated the impact of food provisioning to macaques by humans in the Margalla Hills National Park, Islamabad. Our results indicate that the foraging behavior of rhesus macaques has changed; the rhesus macaques spend more time at the sites around the visitors where they get food from them. Rhesus macaques in HPG have been found to spend 67% of their activity time in foraging activity around the visitors, as against the LPG rhesus macaques that spend 46% of their time in feeding behavior, which is significantly different. Our study observed that the LP group spent substantially less time grooming and more time actively foraging, a pattern consistent with findings reported by another researcher (Brennan *et al*., 1985). The findings of the current study highlight that LPG and HPG rely more heavily on fruits and provisioned food, respectively, and this fact was previously reported Boutourlini's blue macaques in forested areas, that ate more fruit than those in fragmented forests (Tesfaye *et al*., 2013).

We found that the high provisioning group (HPG) spent significantly more time on provisioned food and spent less time on natural feeding, compared to the low provisioning group (LPG). This increased focus on human food in the HPG resulted in significantly less time spent on other activities, such as resting, grooming, and moving. Previous studies on activity budgets have demonstrated that Barbary macaques with high levels of provisioning spent less time in natural foraging (Unwin and Smith, 2010; Alami *et al*., 2012). Additionally, their frequent interactions with human visitors during feeding likely

contributed to reduced time for stress-relieving activities like grooming. Instead, the competition over provisioned food often led to conflicts, as members of the HPG frequently engaged in fights during feeding sessions. This shift in behavior highlights the complex impact of human provisioning on both the foraging patterns and social dynamics of rhesus macaque groups.

The findings suggest that rhesus macaques adjust their behavior based on visitor density, with moderate visitor levels (51-80 visitors) promoting active behaviors like foraging and locomotion, while very high visitor levels (> 80 visitors) lead to increased resting and grooming, likely due to stress or competition for resources. When examining the impact of visitors' presence on the HP group, we discovered that, in comparison to when visitors weren't present, their presence significantly increased the feeding time and decreased the resting time, particularly during visits where the rhesus macaques are long-term hand-fed by visitors, as reported by Asquith (1989).

It was observed in the MHNP that in the case of overcrowding of people at the tourist sites, rhesus macaques felt threatened, so they reduced their locomotion and got hidden in plantation patches or moved in the forest as Ruel and Ayres (1999) documented that increased or decreased locomotion and grooming may reflect changes in stress levels or attempts to adjust to the new environmental conditions created by human presence. Snatching may be an adaptive reaction to new food resources brought by visitors, but provisioning by visitors might result in opportunistic eating behaviors and rivalry among individuals, as reported by several researchers (Fuentes, 2002; Robbins and Hohmann, 2006).

Our study reveals that the presence of humans leads to an increase in resting behavior among these rhesus macaques. This observation aligns with findings from various studies across different species, suggesting that animals may choose to rest more when faced with unexpected or potentially threatening human interactions. This behavior likely serves to reduce stress or conserve energy during such encounters, as noted by Hashmi and Sullivan (2020).

Adult females with infants in our study were observed to avoid areas with high human presence, which is in line with Maréchal *et al*. (2016). Maréchal *et al*. (2016) reported that provisioning can induce stress responses in rhesus macaques, leading to changes in behavior such as increased reliance on natural food sources and avoidance of human activity. Our findings that juveniles and sub-adults have a notable preference for human-provided sustenance align with observations by De Waal (1984). The research highlighted how provisioning by humans can influence rhesus macaques foraging behavior, particularly by increasing the reliance on human-provided resources among younger individuals. The observed differences in foraging behavior among the age-sex categories of Rhesus macaques in our study align with and extend findings from previous research. Our results indicate that adult females with infants exhibit reduced foraging activity compared to adult males, consistent with findings by Jaman and Huffman (2013). They observed that female rhesus macaques with infants exhibit lower foraging rates, as they prioritize infant care over foraging, leading to increased dependence on available natural food sources.

The findings of our study show that the movement of rhesus macaques gets restricted due to provisioning by humans, and the same was reported by Sengupta *et al*. (2015). Rhesus macaque groups in HPA exhibited reduced movement through the forest during provisioning, indicating that provisioning may contribute to shorter travel distances, and same fact was reported by other studies, which shows that the abundance and ease of access to food from visitors influenced the ranging patterns of *C. lowei* in BFMS (Badiella-Giménez *et al*., 2021; EI-Alami *et al*., 2012). Visitors use food as an attractant to approach and feed the rhesus macaques with provisioned food, which in turn results in a decrease in the rhesus macaques' home range size and daily travel distances (Asquith 1989).

CONCLUSION

These results highlight the significant influence of resource distribution on the locomotion and habitat use of rhesus macaques, underscoring the importance of future research that incorporates detailed travel and dispersal data to better understand the impact of human interventions on the ecological role of rhesus macaques in seed dispersal. Therefore, educational programs should be implemented to raise awareness of the negative ecological impacts, such as increased conflict, disease transmission, and animal road-kills. These programs should also encourage proper waste disposal and discourage wildlife feeding. Enhanced patrolling and enforcement by local authorities, along with penalties for feeding, can further curb this behavior. Additionally, a nationwide literacy campaign is recommended to educate the public on the detrimental effects of feeding rhesus macaques, as a lack of understanding of ecosystem dynamics contributes to ongoing environmental issues.

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Ethical statement

We strictly followed the PMAS-Arid Agriculture University's Ethical Committee's protocol and guidelines (reviewed in the 26th meeting held on 06th January 2020) during the conduct of this research study. No animal, in any form, was harmed during this study.

Generative AI and AI-assisted technology statement

The authors declare that no generative AI or AI-assisted technologies were used in the design of the study, data collection, data analysis, or interpretation of results.

Statement of conflict of interest

The authors have declared no conflict of interest.

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