ABS ACTA BIOLOGICA SIBIRICA
A journal on the biodiversity of Siberia and the adjacent lands

Acta Biologica Sibirica 11: 745–762 (2025)
doi: 10.5281/zenodo.15651040
http://journal.asu.ru

RESEARCH ARTICLE

Dining in the wild: Unraveling wild Asian elephant (*Elephas maximus*) feeding behaviour and dietary dynamics in Jaldapara National Park, West Bengal, India

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Academic editor: R. Yakovlev | Received 22 January 2025 | Accepted 28 May 2025 | Published 16 June 2025

http://zoobank.org/CAA3899D-1368-4FAD-BB66-FE396CC79E5D

Citation: Saha S, Gupta M, Saha R, Roy S, Kirpotin SN, Babenko AS, Volkova II, Khovalyg AO, Kar PK (2025) Dining in the wild: Unraveling wild Asian elephant (*Elephas maximus*) feeding behavior and dietary dynamics in Jaldapara National Park, West Bengal, India. Acta Biologica Sibirica 11: 745–762. https://doi.org/10.5281/zenodo.15651040

Abstract

Megaherbivores like the Wild Asian elephant (*Elephas maximus*) are keystone species, playing a pivotal role in ecosystem dynamics. However, their survival is increasingly threatened by habitat loss and resource constraints due to their extensive spatial and nutritional needs. This study investigates the dietary preferences and feeding behaviours of elephants inhabiting the riverine floodplains of North Bengal, particularly Jaldapara National Park. Using a combination of direct observations, feeding sign analysis along elephant routes, and microhistological faecal analysis, we identified 41 plant species in their diet. Dietary composition revealed a preference for tree species (34.16%), followed by grasses (21.95%), mosses (17.07%), herbs (17.07%), shrubs (4.87%), and climbers (4.87%). The prominence of trees highlights their importance as a critical food resource, while the high diversity of Poaceae emphasizes the significance of grasslands in elephant habitats. A diurnal feeding pattern was observed, with heightened activity during the latter times of the day. These findings underscore the importance of conserving heterogeneous landscapes comprising forests and grasslands to support the dietary requirements of elephants. Additionally, the study provides insights into the ecological adaptations of Asian elephants and highlights the necessity of effective habitat management to ensure the availability of critical food resources throughout the year. The results offer valuable guidance for mitigating human-elephant conflicts and advancing conservation strategies for this ecologically vital yet endangered species.

Keywords

Asian elephant (*Elephas maximus*), dietary preferences, faecal microhistology, National Park, seasonal feeding behaviour

Introduction

The South Asian elephant (*Elephas maximus*), an iconic and keystone species, plays a crucial role in maintaining ecosystem health and biodiversity (Puri et al. 2019). As a large herbivorous mammal, it contributes to seed dispersal, nutrient cycling, and vegetation management within its habitat. In the riverine flood plains of the Dooars, West Bengal, these elephants thrive, adapted to the unique environmental conditions. Covering an extensive area of 99.51 square kilometers, the elephant reserves in West Bengal's Alipurduar district are vital for their conservation. Notable protected areas, including Buxa National Park, Jaldapara National Park, Buxa Wildlife Sanctuary, and the Chilapata forest, fall within this district. The Eastern Himalayan region, recognized as a biodiversity hotspot, owes much of its ecological diversity to the presence of these majestic creatures (Huang et al. 2019). Their preservation remains critical for the overall health of the environment and the sustainability of the region's rich natural heritage.

The dietary preferences and nutritional needs of Asian elephants have been the focus of various research endeavors, with significant attention given to identifying the species of plants consumed, quantifying the elephants' rate of consumption, and examining the dietary overlap between sympatric populations of elephants and rhinoceroses (Sukumar 1990; Steinheim et al. 2005; Chen et al. 2006; Joshi and Singh 2007; Pradhan et al. 2008; Baskaran et al. 2010). Despite these studies, there remains a notable gap in our understanding concerning the specific food choices and the seasonal variations in the diet composition of Asian elephants, particularly in North Bengal. This gap in knowledge is critical not only from a biological and ecological perspective but also for the practical implications it holds for conservation strategies. Detailed insights into the dietary habits of Asian elephants are pivotal for effective habitat management and for devising strategies to mitigate human-elephant conflicts. By understanding the elephants' food preferences and how these change with seasons, conservationists can better manage natural habitats to ensure the availability of key food resources throughout the year, thereby reducing the likeihood of elephants venturing into human-dominated landscapes in search of food, which is a primary cause of conflict.

Elephants exhibit distinct diurnal and seasonal variations in feeding behaviour. Peak feeding activity is typically observed during the early morning and late evening hours, just before dusk. However, seasonal changes significantly influence these patterns. In winter, elephants adjust their feeding peaks to midday, likely to minimize exposure to the coldest temperatures. Conversely, during summer, the midday heat prompts them to rest in shaded areas, resulting in reduced feeding activity. Notably, some elephants display nocturnal foraging behaviour during the summer months, aligning with their spatial movements. They tend to forage in open areas at night and retreat to denser forests during the day to mitigate heat stress. As temperatures decrease in the evening, they return to open areas to resume feeding. These observations highlight the adaptability of elephants to environmental conditions. They strategically adjust their feeding times for thermoregulation and resource utilization, demonstrating a remarkable seasonal flexibility (Joshi and Singh 2008).

The proboscis, or trunk, of modern elephants is a distinctive evolutionary adaptation that exemplifies the remarkable versatility and functional multiplicity of this organ, far beyond its sizeable appearance (Yang et al. 2006). The elephant's trunk, an extension of the nose and upper lip, represents a highly specialized and multifunctional muscular structure essential for various physiological and behavioural functions. Its roles encompass respiration and olfaction, as well as serving as a sophisticated tactile organ with remarkable strength and dexterity. The trunk facilitates diverse activities, including object manipulation, tool use for self-care (e.g., scratching and insect swatting), and critical feeding behaviours. These include grasping food items, drawing water for drinking, and performing hygienic practices such as dust bathing and water spraying, underscoring its indispensability for survival and well-being (Olson et al. 2023).

This study aims to advance the understanding of elephant feeding ecology by examining their dietary preferences with a focus on informing evidence-based habitat management strategies. Elephants exhibit a highly adaptable diet, incorporating both graminoids (grasses) and browse (leafy and woody vegetation), with marked seasonal and habitat-driven variations in forage selection. These dietary shifts significantly influence the nutritional quality and digestibility of consumed resources, with direct implications for habitat suitability and conservation planning. By investigating these dynamics, the study seeks to provide critical insights into the adaptability of elephant foraging behaviour in response to environmental fluctuations and resource availability, thereby supporting the development of effective conservation and habitat management practices.

Materials and methods

Study area

North Bengal boasts a vast ecological zone within the Eastern Himalayas, encompassing roughly 12,800 km^2. Forests blanket over a quarter of this area (around 3,306 km^2), with a significant portion (2,000 km^2) serving as a crucial habitat for elephants (Manoj et al. 2013). This region plays a vital role in biodiversity conservation, especially for these magnificent megafaunas. The dominant forest types here are moist tropical and subtropical, essential for maintaining ecological balance and supporting a rich variety of plant and animal life (Ghosh et al. 2021). Jaldapara National Park, a key component of this landscape, covers an area of 216.51 km^2. Located at 26°37'48.6508"N; 89°18'14.9825"E, the park is characterized by a unique mosaic of vast grasslands interspersed with riverine forests, providing a haven for diverse species (Fig. 1). The nearby Chilapata Forests act as a vital elephant corridor, connecting Jaldapara National Park with the Buxa Tiger Reserve. This corridor facilitates the movement of elephants between these protected areas (Veselovská et al. 2021). The prevalence of savannah and tall elephant grasses in these forests exemplifies the ecosystem's remarkable adaptation to support large elephant populations (Government of West Bengal Directorate of Forests Wildfire wing 2024). Jaldapara National Park and its surrounding areas thus play a critical role in conserving the Eastern Himalayas' rich biological diversity.

Elephant feeding data collection

Sampling sites were selected taking help from Forest Department staff who provided us with ideas about the commonly used routes of the elephants. Opportunistic direct feeding observations and the observations of elephant feeding signs on food trails (elephant feeding routes) were the methods used in the present study to determine the diet selection of elephants residing in different areas and travelling on different migration routes. The feeding routes observed to be taken by elephants were followed by field survey during sample collection, and all plant species showing signs of being eaten by elephants were recorded. Evidence of feeding signs included elephant footprints, fresh dung piles nearby to browsed foliage, and the identifying characteristics of plant damage caused by elephant browse, such as debarkation, branch breaking, and uprooting. The following data were recorded to determine the feeding preferences of Asian elephants: (1) plant species browsed, (2) parts of the plant eaten (leaves, branches, andor bark), (3) habitat type, and (4) global positioning system (GPS) coordinates of sample sites (Fig. 1). The relative frequency (percentage) of feeding sign was calculated to yield a feeding sign score. Feeding sign was ranked according to the intensity of browsing, the proportion of bark, stem, and foliage removed, andor the area of grass eaten.

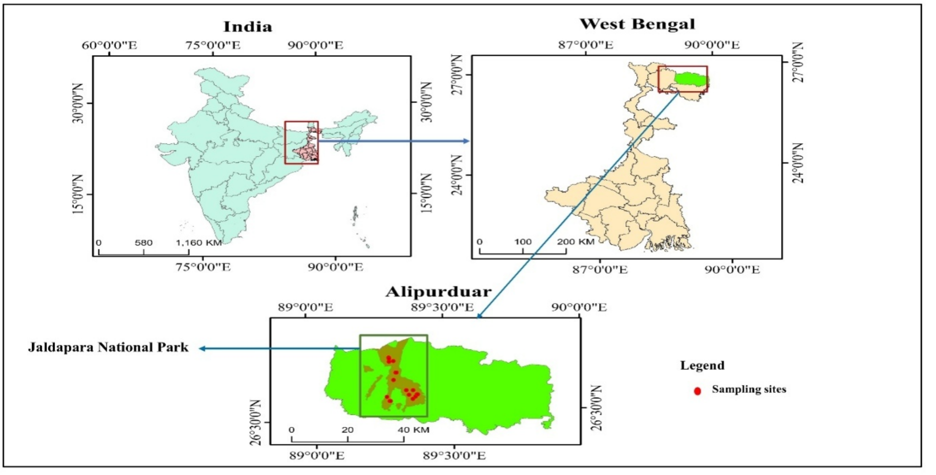

Figure 1. Map of Jaldapara National Park showing locations of plots for faecal sample collection and feeding behaviour study of Wild Asian Elephant.

Faecal sample collection

We collected approximately 100 grams of elephant dung, which was then securely placed in a screw-cap container. To preserve the faecal matter for further laboratory analysis, 70% ethanol was added to each sample. The samples were subsequently stored at ambient temperature conditions. This methodological approach to sample collection and preservation is critical for ensuring the integrity of faecal samples for nutritional analysis, gut microbiota studies, and for monitoring the health and dietary patterns of elephant populations, thereby contributing valuable data for conservation and management strategies (Fernando et al. 2016).

Elephant dietary analysis from dung samples

Elephant dung samples were collected by field survey during daytime from August 2022 to July 2023. Visual examination of deposited elephant dung piles was performed to identify the presence of macro plant fragments. Microplant fragments were identified through micro-histological analysis. This dual methodology is widely used for estimating the diet composition of herbivores (Mohapatra et al. 2013). Fragments of probable food species were collected for the preparation of reference slides. A total of 20, non-overlapping random fragments were isolated on each dung slide and compared with a reference slide for epidermal derivatives. Microphotographs were taken using a 100X, 40X, 10X, and 5X lens with a phase contrast microscope (Zeiss Axiolab 5).Two distinct methods were employed for sample preparation:

1. For the microscopic analysis of elephant faecal samples, a systematic protocol was developed to ensure consistency and accuracy. The process began with homogenizing the faecal matter using a mortar to achieve uniformity. A 0.5 g aliquot of the homogenized material was then transferred to a test tube and subjected to digestion with 3 ml of 65% concentrated nitric acid at 80 °C for 2 minutes. This digestion step aimed to degrade organic components, enabling the analysis of inorganic and indigestible elements. The digested sample was subsequently diluted with 250 ml of distilled water and processed through a sequential sieving system with mesh sizes of 1 mm and 0.125 mm to separate particles by size. The residue retained on the 0.125 mm sieve was evenly spread across three microscope slides, mixed with 50% glycerine, and sealed with DPX resin to ensure long-term preservation for detailed microscopic examination (Pareja et al. 2021).

2. A 20 g sample was extracted from each faecal specimen and placed in a 50 ml plastic tube. Boiling water (40 ml) was added to facilitate dung breakdown, followed by vigorous shaking and agitation for 30 minutes. The mixture was then filtered through a 2.5 mm sieve to remove macroscopic components, addressing documented bias (Chamrad and Box 1964). Subsequently, the filtrate was washed through a 0.2 mm sieve to refine the sample size range (0.2–2.5 mm), effectively eliminating fragments smaller than 0.1 mm (Martin 1955). The resulting plant fragments were re-suspended in water (3 ml), to which household bleach solution (sodium hypochlorite) was added to eliminate pigments potentially obscuring microscopic identification. This comprehensive preparation method significantly contributes to the reliability and validity of dietary analysis in elephants by ensuring a representative and bias-minimized sample for the subsequent identification process. Both samples were examined through microhistology analysis (Holechek 1982).

Behaviour observations

Elephant trunk actions during feeding were documented meticulously in real-time and categorized as distinct events. Feeding behavior included all actions related to finding, handling, and ingesting food and water. The scan animal sampling method was employed for the study. Direct observations were conducted whenever feasible, allowing for real-time analysis of dietary habits. A repertoire of 18 distinct behaviours, categorized under feeding was used following (Lefeuvre et al. 2020) with minor modifications (Table 1). The time of observation ranged from 10 am to 5 pm.

Table 1. The repertoire of feeding behaviour in elephants (following Lefeuvre et al. 2020 with minor modifications)

No	Code	Observed behaviour	Description
1	a1	Pinch	Catch little items between the fingers of the trunk. Can be helped by a breath

No	Code	Observed behaviour	Description
2	a2	Side pinch	Catch little items between the fingers of the trunk laying down on one side. Taking the item from the side. This can be helped by a Breath
3	a3	Blow	Exhalation around an item, usually to clear lightweight elements like hay or sand
4	a4	Gather	Gather or bring back items with the end of the trunk or just the fingers. Potential side preference
5	a5	Torsion	Wrap and torsion of the trunk by creating a pressure point, usually to break a branch
6	a6	Bundling	Compact an item on the ventral part of the trunk once or several times before pinching it and bringing it to the mouth
7	a7	Shake	Shake vigorously a pinch held in the trunk
8	a8	Sweep	Sweep with the side of the trunk to gather items before catching them. Potential side preference
9	a9	Grasp	Wrap the trunk around a big item, which would be difficult to maintain with one finger. Potential side preference
10	a10	Pull	Pull an item to break it or separate it from the others
11	a11	Drink	Water suction and release into the mouth, trunk high-positioned
12	a12	Adjust	Adapt the position of an item going out of the mouth, usually a branch
13	a13	Search on ground	Separate items in a pile with the end of the trunk in order to select and sample only a part
14	a14	Search in height	Separate items in a net in height with the end of the trunk in order to select and sample only a part
15	a15	Bring to mouth	Bring a bite to the mouth in order to eat it
16	a16	Grazing	Feed on grass
17	a17	Trunk to mouth	The trunk is brought to the mouth without providing or removing items
18	a18	Block	Wedge an item between the trunk and a tusk, to keep it from others or to manipulate it

Data analysis

As described in the literature, feeding constituted the primary activity of the elephants, encompassing a significant portion of their time. Feeding behaviours accounted for a substantial percentage of all observed behaviours. Our study identified a repertoire of 18 distinct feeding behaviours. However, nine of these behaviours were rarely observed (fewer than three occurrences) and were thus excluded from the analyses.

Initially, we aimed to establish a correlation between the different feeding behaviours and the types of food items handled. The six types of food items were herb (H), shrub (S), tree (T), grass (G), moss (M), and climber (C). Among these, feeding behaviours associated with moss were infrequently observed and therefore excluded from the analysis. We compiled a dataset recording the study date, time of behaviour occurrence, and food type. This dataset was then used to create a standardized graph depicting the relationship between feeding activity and time, incorporating standard deviations. The graph represents the modal behavioural activity at each time of day, along with the standard deviation from the mean frequency of the activity. Data from all days of observation were pooled for the average time intervals.

Further investigation into the multifaceted feeding behaviours of elephants focused on the dynamics of their interactions with various food types over time. Utilizing a three-dimensional scatter plot, we delineated the complex interplay between the elephants' feeding actions, including shaking, gathering, browsing, pinching, torsion, blowing, and blocking, and the nature of the food items they consumed.

Statistical analysis and graphs were done using GraphPad Prism (version 5.0; GraphPad Software Inc., La Jolla, CA) MS Excel 2010, and JMP (version 17.0; SAS Institute Inc., Cary, NC). The mean value and the standard deviation from the mean were used for analysis.

Results

A total of 243 elephant dung samples were collected during the study period. The food plants were identified by direct observations of feeding, indirect evidence of feeding as well as micro histological analysis of faecal samples. In our study, we identified a total of 41 plant species utilized by elephants for feeding. The distribution of these species across different plant types is as follows: 14 species (34.16%) were trees, 9 species (21.95%) were grasses, 7 species (17.07%) were mosses, 7 species (17.07%) were herbs, 2 species (4.87%) were shrubs, and 2 species (4.87%) were climbers (Table 2 and Fig. 2). The elephants were found to feed mainly on the leaves, twigs, and stems of the food plants. However, in some cases, flowers and buds were also consumed.

Fig. 3 illustrates the feeding behavioursof elephants, emphasizing the frequency of specific actions such as shaking, gathering, and browsing as they search for food. A total of 2452 occurrences from the repertoire of 18 behavioural patterns were recorded during the study. Notably, during the later parts of the day, there is a marked increase in gathering and browsing activities. This diurnal variation in feeding strategies suggests a behavioural adaptation to environmental and possibly energetic demands. The propensity for elephants to engage in gathering and browsing in the later parts of the day. The evening shift towards these behaviours could also be influenced by temperature fluctuations which are lower at dusk. This behaviour underscores the complexity of elephant feeding strategies and their ability to modify behaviours in response to temporal changes within their ecosystem. The data presented in Fig. 3 provide valuable insights into the adaptive foraging strategies of elephants, contributing to our understanding of their ecological role and the factors that influence their feeding habits.

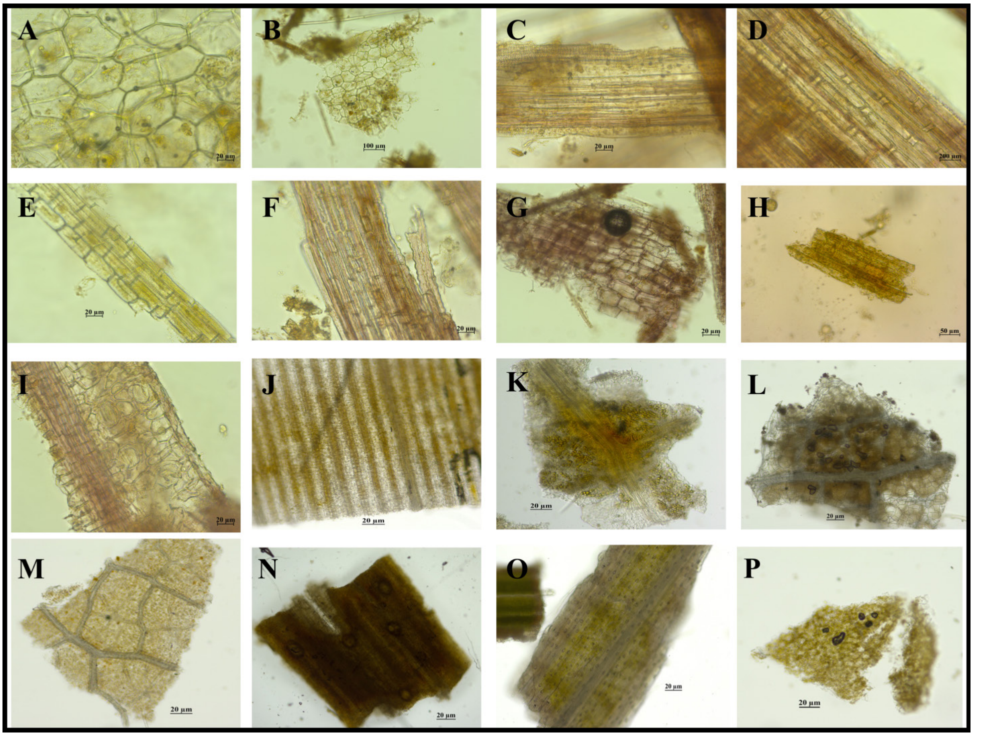

Figure 2. Microhistology of different plant parts extracted from the faecal samples of Wild Asian Elephants, observed under a phase contrast microscope. The images illustrate the diversity of plant species consumed by the elephants, showcasing the anatomical features that facilitated species identification: (**A**) *Apium* sp., (**B**) *Begonia* sp., (**C**) *Dichrocephala* sp., (**D**) *Funaria* sp., (**E**) *Grimmia* sp., (**F**) *Leptobryum* sp., (**G**) *Orthotricum* sp., (**H**) *Philonotis* sp., (**I**) *Schistidium* sp., (**J**) *Digitaria* sp., (**K**) *Ficus bengalensis*, (**L**) *Ficus religiosa*, (**M**) *Bauhinia* sp., (**N**) *Syzygium cumini*, (O) *Dendrocalamus* sp., (**P**) *Tinospora* sp.

Table 2. Plant species identified in the Wild Asian Elephant diet at Jaladapra National Park through direct observations and micro histological analyses

Sl No	Plant species	Family	Type	Plant parts eaten
1	*Apium* sp.	Apiaceae	H	Stem with branches and leaves with twigs
2	*Dichrocephala* sp.	Asteraceae	H	Flowers and leaves with branches
3	*Philonotis* sp.	Bartramiaceae	M	Stem, flower buds
4	*Begonia* sp.	Begoniaceae	S	Stem, leaves
5	*Scleropodium obtusifolium*	Brachytheciaceae	H	Leaves
6	*Leptobryum* sp.	Bryceae	M	Leaves, branches
7	*Bryoxiphium* sp.	Bryoxiphiaceae	M	Stem, branches

Sl No	Plant species	Family	Type	Plant parts eaten
8	*Carex melanostachya*	Cyperaceae	H	Leaves and twigs
9	*Shorea robusta*	Dipterocarpaceae	T	Leaves
10	*Cassia fistula*	Fabaceae	T	Leaves, flowers and flower buds
11	*Butea monospermia*	Fabaceae	T	Tree and leaves
12	*Bauhinia* sp.	Fabaceae	T	Twigs with leaves
13	*Pterocarpus marsupium*	Fabaceae	T	Root
14	*Pyramidula tetragona*	Funariaceae	H	Leaves
15	*Funaria* sp.	Funariaceae	M	Stem, branches
16	*Grimmia sessitana*	Grimmiaceae	H	Twigs with leaves
17	*Grimmia* sp.	Grimmiaceae	M	Leaves with twigs
18	*Schistidium* sp.	Grimmiaceae	M	Flower bud with stem and stem
19	*Lagerstroemia parviflora*	Lythraceae	T	Bark
20	*Bombax ceiba*	Malvaceae	T	Bark and branch
21	*Tinospora* sp.	Menispermacae	C	Stem
22	*Acacia catechu*	Mimosaceae	T	Twigs with leaves
23	*Acacia pennata*	Mimosaceae	C	Twigs with leaves
24	*Ficus benghalensis*	Moraceae	T	Twigs with leaves and branch and bark
25	*Ficus religiosa*	Moraceae	T	Twigs with leaves and branch and bark
26	*Musa* sp.	Musaceae	S	Stem pith and leaves
27	*Syzygium cumini*	Myrtaceae	T	Twigs with leaves
28	*Orthotrichum* sp.	Orthotrichaceae	M	Leaves with twigs and branches with leaves
29	*Pinus sylvestris*	Pinaceae	T	Leaves
30	*Arrhenatherum* sp.	Poaceae	G	Grasses
31	*Dendrocalamus* sp.	Poaceae	G	Twigs with leaves
32	*Digitaria* sp.	Poaceae	G	Leaves
33	*Phragmites* sp.	Poaceae	G	Stem with leaves
34	*Saccharum* sp.	Poaceae	G	Stem with leaves
35	*Setaria palmifolia*	Poaceae	G	Stem with leaves
36	*Thysanolaena maxima*	Poaceae	G	Stem with leaves
37	*Oryza sativa*	Poaceae	G	Leaves with root and fruits
38	*Zea mays*	Poaceae	G	Leaves with root and fruits
39	*Madhuca longifolia*	Sapotaceae	T	Leaves and twig
40	*Mimusops elengi*	Sapotaceae	T	Leaves
41	*Alpinia* sp.	Zingiberaceae	H	Stem without twigs and leaves

Note: H – herb, S – shrub, T – tree, G – grass, M – moss, C – climber.

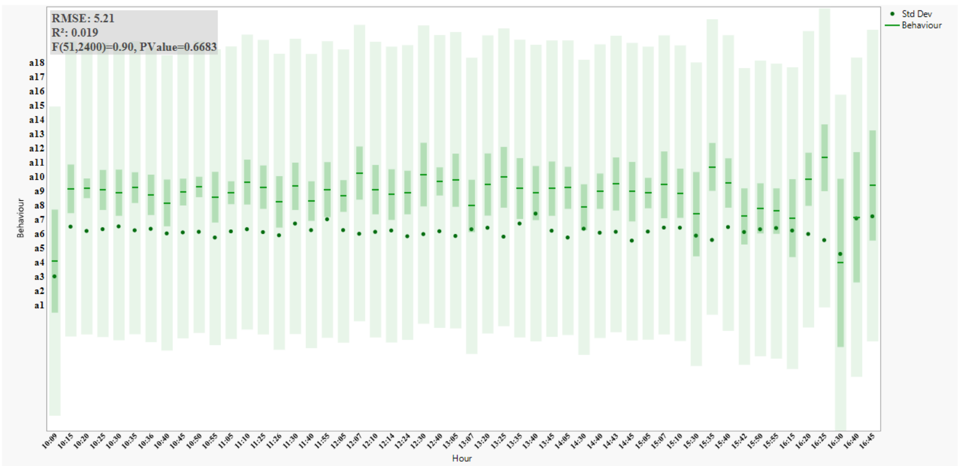

Figure 3. Behaviour activity vs time graph relationship with a standard deviation of Wild Asian Elephants at Jaldapara National Park, West Bengal, India. The modal behavioural activity at each time of the day is shown along with the standard deviation from the mean frequency of the activity. Data from all days of observation for the average time intervals were pooled.

Elephants exhibit a pattern in their feeding behaviours, as illustrated in Fig. 3. The frequency of shaking, gathering, and browsing activities varies throughout the day, with a notable increase in gathering and browsing observed during the latter parts of the day.

We further investigated the multifaceted feeding behaviours of elephants, focusing on the dynamics of their interactions with various food types over time. Utilizing a three-dimensional scatter plot (Fig. 4), we delineated the complex interplay between the elephants' feeding actionsincluding shaking, gathering, browsing, pinching, torsion, blowing, blocking, and the nature of the food items they consume. Our analysis reveals a nuanced pattern of behaviour, with elephants employing specific strategies like pinching and torsion for certain food types, indicative of a sophisticated adaptation to their dietary needs and the physical characteristics of their food sources. Additionally, it can also be seen that the elephants prefer to graze on grasses in the earlier part of the day and shift to browsing on shrubs and trees in the later part of the day.

Discussion

The present study recorded 41 plant species across 25 families foraged by Wild Asian elephants in Jaldapara National Park and its surrounding areas. In an extensive study, Roy documented 111 species of plants belonging to 52 families from the nearby Buxa Tiger Reserve (Roy 2010). Comparatively, Sukumar documented 112 plant species in southern India (Sukumar 1990). Joshi (2018) reported 50 plant species consumed by elephants in Rajaji National Park, India; Mohapatra et al. (2013) recorded 71 food species from Kulida Wildlife Sanctuary, Odisha. Huang et al. (2019) reported 106 species in Shangyong National Natural Reserve, China, while Koirala et al. (2016) reported 57 species of plants from Parsa Wildlife Reserve (PWR) and Chitwan National Park (CNP), Nepal. In our study, the comparatively lower number of plant species recorded might partly be due to the shorter period of study which is one year, and the duration time of the field visit which is 10 AM to 5 PM. Overall, elephants exhibited two main feeding periods, one in the morning and another in the evening. During midday, they spent nearly equal amounts of time feeding and resting. This behaviour mirrors patterns observed in both African elephants (Kalemera 1987; Wyatt and Eltrigham 1974) and Asian elephants (McKay 1973). Due to data collection occurring from 10 AM to 5 PM, we were unable to obtain information about the elephants' diet patterns before 10 AM. Consequently, this limitation results in a lack of data regarding the main feeding period in the morning.

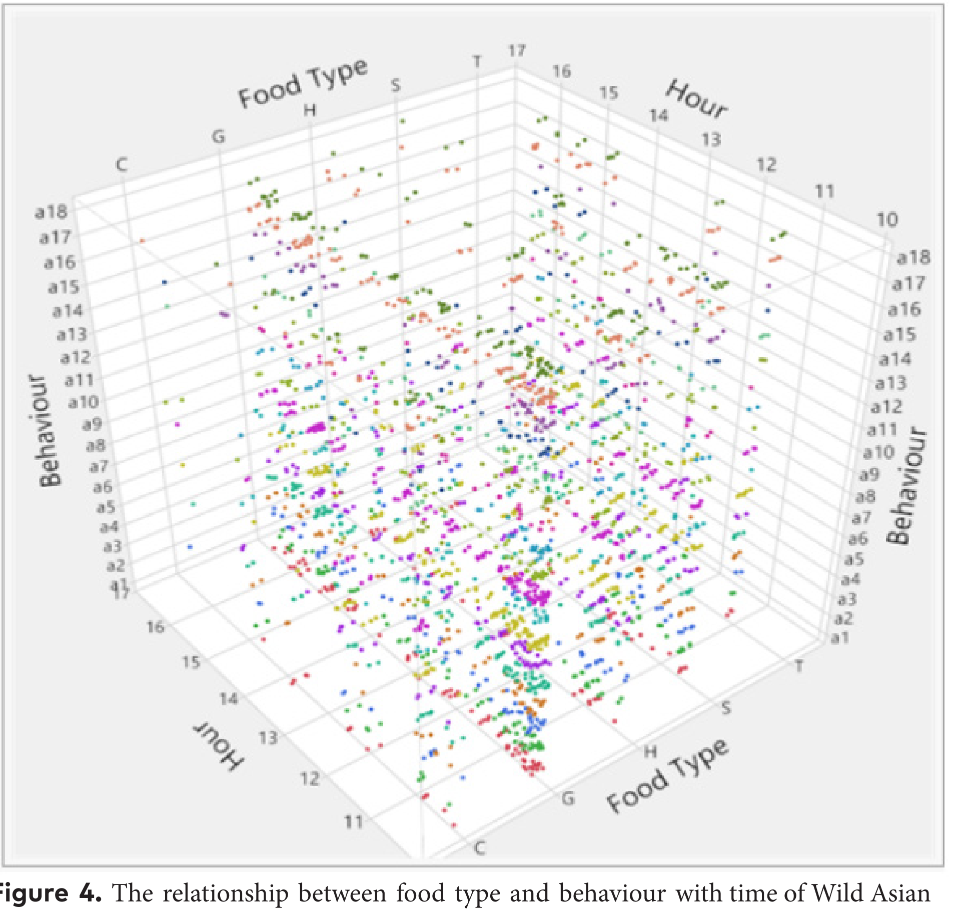

Figure 4. The relationship between food type and behaviour with time of Wild Asian Elephants at Jaldapara National Park, West Bengal, India.

Feeding by grazing or browsing in elephants varies significantly across different regions and seasons, reflecting the adaptability of their foraging behaviour to local ecological conditions. In southern India, elephants primarily consume graminoids during the wet season, transitioning to woody vegetation in the dry season (Sukumar 1990). Comparable seasonal shifts have been documented in Nepal's Bardia National Park and among African elephants in Uganda (Koirala et al. 2016). In the Nilgiri Biosphere Reserve, grasses dominate the diet throughout the year, with browse vegetation gaining prominence during the dry season (Baskaran et al. 2010). Conversely, in the Himalayan foothills, browse constitutes the primary diet during dry seasons, while in regions such as Malaysia, northeastern India, and Bihar, browse is a year-round dietary staple (Lahkar et al. 2006).

The findings from this study reveal a pronounced preference for tree species, which account for 34.16% of the total plant species consumed throughout the year. This preference is likely driven by the nutritional value and consistent availability of trees, which often provide a reliable source of both quantity and quality compared to other vegetation types. Grasses, comprising 21.95% of the diet, represent the second most consumed plant type, consistent with elephants' grazing behaviour in grassland and savanna habitats. Herbs and mosses contribute 17.07% each to the diet, suggesting their moderate importance in sustaining dietary diversity. In contrast, shrubs and climbers constitute only 4.87% of the diet, likely due to their limited availability, accessibility, or lower palatability.

Among the 25 plant families identified in the elephants' diet, the Poaceae family is the most represented, emphasizing the critical role of grasses in fulfilling their dietary requirements. Furthermore, tree species from 14 of the 25 identified families highlight the ecological significance of forested habitats in supporting elephants' feeding needs. The dominance of Poaceae aligns with elephants' general grazing tendencies.

These findings underscore the necessity of conserving diverse habitats, including forests and grasslands, to meet the nutritional and ecological needs of elephants. The reliance on tree species highlights the importance of maintaining forested landscapes, while the diversity of grasses within the Poaceae family underscores the critical role of grassland ecosystems. Effective conservation strategies should therefore prioritize the preservation and restoration of heterogeneous landscapes to ensure the availability of diverse forage resources essential for the sustenance and well-being of elephant populations.

Most of the above cited works have used direct observation, feeding signs on food trails, examination of gut content of culled animals and investigation of dung piles for recording the food plants consumed by elephants. In addition to the above-mentioned methods, except for the examination of the gut content of culled animals, we have also used microhistological analysis of the dung samples for reconstructing the diet of the elephants. The microhistological analysis technique offers a noninvasive, efficient method for elucidating the dietary preferences of free-ranging herbivores through the microscopic identification of plant species from epidermal fragments preserved in faecal samples or stomach contents. This methodological approach, underscored by the seminal works of many authors (Alipayo et al. 1992; Shrestha and Wegge 2006; Veselovská et al. 2021), presents significant advantages over traditional dietary analysis techniques. Notably, its non-invasive nature ensures that the sampling process neither disrupts animal behaviour nor necessitates the sacrifice of the subjects under study, thus preserving the welfare of the animals and maintaining the integrity of their natural environments. The ease of sample collection further enhances the practicality and applicability of this method across diverse settings. Given these strengths, micro histology emerges as an exceptionally suitable technique for elucidating the dietary preferences and patterns of free-ranging herbivores, providing valuable insights into their feeding ecology without imposing undue stress or harm upon the animal populations being investigated (Kerley et al. 1995; Duffy et al. 2002; Kerley and Landman 2006; Guy 1981; Kerley and Landman 2006).

Elephants are mixed feeders, showing seasonal as well as diurnal variations in food selection (Burton-Roberts et al. 2022). Our study found that both browse flora and grasses were consumed during the day with grazing predominating the earlier hours of the day and browsing more prominent in the later hours. This suggests an adaptation to environmental and potentially energetic demands. As readily available food sources dwindle throughout the day, elephants may need to invest more time and effort in later hours to find sustenance, explaining the increased gathering and browsing behaviours. Additionally, cooler evening temperatures and potentially lower predator activity might create a safer environment for these time-consuming foraging activities. This behavioural plasticity underscores the complexity of elephant feeding strategies and their remarkable ability to adjust their approach based on temporal changes within their ecosystem.

The temporal patterns that emerge from our data suggest a temporal dimension to these feeding strategies that may be aligned with the availability of food types or the energy requirements of the elephants. This comprehensive exploration not only deepens our understanding of elephant feeding ecology but also highlights the intricate relationship between behaviour, diet, and environmental factors, offering insights into the adaptive strategies employed by elephants in response to their nutritional landscape.

Overall, our study highlights the intricate and adaptive feeding behaviours of wild Asian elephants, demonstrating their ability to modify their feeding strategies based on the type of food and time of day. This adaptive behaviour underscores the elephants' complex interaction with their environment and their ability to optimize feeding efficiency.

Conclusions

Wild Asian elephants have a diverse diet including monocot and dicot plants. However, further studies are needed to understand their feeding selectivity and its implications for the elephants. The current study provides baseline information about different types of natural food consumed by elephants in the Jaldapara National Park. This information is important for realizing successful outcomes for the conservation of Asian elephants and improved management for the long-term protection of this endangered species and its shrinking habitat. Additionally, elephant movements and conflicts with humans are primarily driven by the availability of diet and nutritional preferences, especially as their habitats shrink. Understanding elephants' foraging patterns and seasonal food availability is crucial for mitigating these conflicts.

Acknowledgements

We extend our sincerest thanks to The Principal Chief Conservator of Forests (Wildlife) & Chief Wildlife Warden, West Bengal for granting permission to conduct this research work. We thank the Divisional Forest Officer, Jaldapara Wildlife Division, for his valuable help and input in conducting the research work. Special thanks to the AWLW, Jaldapara Wildlife Division, for facilitating the work. The help extended by the Beat officer of Holong Beat is highly appreciable. Last but not least, we extend our gratitude to all other forest staff without whom the work would not have been possible. Sergey N. Kirpotin, Andrey Babenko, and Irina I. Volkova are grateful to the Tomsk State University Development Programme ("Priority-2030"). Aldynay O. Khovalyg is grateful to the Russian Science Foundation project 23-14-20015 "Studying the patterns of formation of carbon reserves in biological systems and landscapes in the transition space from North Asia to Central Asia".

Ethical note. Observations were made from a distance and under the supervision of forest officials and staff. No animals were disturbed during the course of the study. Collection of faecal samples is a non-invasive process and does not require any contact with the animals.

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