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continued on the back inside cover

Cover: Fish species recorded in the Gowthami-Godavari Estuary, Andhra Pradesh: *Lutjanus johnii* (top left), *Triacanthus biaculeatus* (top right), *Acentrogobius cyanomos*, *Elops machnata*, *Trypauchen vagina*, *Oxyurichthys microlepis*. © Paromita Ray.

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ARTICLE

Dietary preference of Assamese Macaque *Macaca assamensis* McClelland, 1840 (Mammalia: Primates: Cercopithecidae) in Dampa Tiger Reserve, India

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Abstract: Dietary composition and selection of food items are important approaches for the flexibility and adaptability of macaques in different natural habitats. With a wide distribution range, Assamese Macaques feed on various food types. This study reports the consumption of 57 plant species from 30 families. A total of 2,233 scans resulted in 16,381 feeding behavioral records during the study period from 2018 to 2020. Macaques appear to be primarily folivorous in Dampa as leaves (young & mature) constitute 44.74% of their daily dietary intake while the fruit consumption was found to be 25.31% of the total dietary intake. Plant species like *Artocarpus lakoocha* (15.65%), *Albizia procera* (12.03%), *Glochidion hyneanum* (10.53%), *Diospyros glandulosa* (9.49%), and *Albizia lebbeck* (7.28%) contributed significantly to macaque's diet compare to other plants. No significant variation was observed on time spent for feeding on leaves, fruits, flowers, and seeds in both different months and seasons of the year. The highest percentage of the diurnal time invested on feeding activity was (59.04%) in the month of January (winter season), which may be due to the cold climate and scarcity of proper feeding items and the least was (35.19%) in June where food resources are more readily available. The richness of fruiting plants in Dampa Tiger Reserve appears to fulfill the dietary requirement of Assamese Macaque and therefore intactness of forest resources is necessary for their development and conservation.

Keywords: Conservation, diet, feeding behaviour, food selection, primate, richness.

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Competing interests: The authors declare no competing interests.

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INTRODUCTION

Diet or food selection is an important trade in an animal's life. Adaptation and alteration in dietary patterns account for the major ecological and behavioral differences among primate species especially in wild (Koirala et al. 2017; Ghimire et al. 2021). Dietary preference provides useful information on individual food species necessary for survival, insight into its level of dietary specialization, resource partitioning and also on monitoring strategies for threatened and elusive primates (Koirala & Chalise 2014; Koirala et al. 2017; Khatiwada et al. 2020). Assamese Macaque *Macaca assamensis* is one of the most widely distributed non-human primate species in southeastern Asia. They have a wide distribution range across the region inhabiting different forms of forest habitat such as evergreen broadleaf forests, deciduous broadleaf forests, mixed broadleaf, and conifer forests (Boonratana et al. 2008; Timmins & Duckworth 2013; Boonratana et al. 2020). It is categorized as a 'Near Threatened' species by the IUCN Red List of Threatened Species and listed as an Appendix II species of the Convention on International Trade in Endangered Species (CITES) (Boonratana et al. 2020; Ghimire et al. 2021) and also as Scheduled II species by the Indian Wildlife Protection Act, 1972.

Assamese Macaques (AM) are known to invest more than two-fifths (>40%) of the diurnal time on feeding (Ghimire et al. 2021) and are adaptable foragers able to modify their diet seasonally, being more folivorous in the dry season and more frugivorous in the wet season. Understanding the temporal availability of food to a particular species is crucial when examining the drivers of their feeding strategies (Bessa et al. 2015). Macaques in the tropics tend to consume more fruit and fewer leaves than temperate-living macaques (Hanya 2004; Tsuji et al. 2013; Hung et al. 2015; Li et al. 2019, 2020). Their natural feeding items in the wild include fruits, leaves, seeds, flowers, buds, young shoots, twigs, barks, roots, and resin of gymnosperms (Chalise 1999; Koirala & Chalise 2014; Koirala et al. 2017; Boonratana et al. 2020; Khatiwada et al. 2020; Ghimire et al. 2021). They may also feed on faunal resources such as grasshoppers, earthworms and other mammals, birds, reptiles, amphibians, mollusks, and spiders (Schulke et al. 2011; Hambali et al. 2014; Nila et al. 2014). Dietary selection among AM tend to be affected by factors like habitat quality, available foraging options, food resources, digestive capabilities, and the food nutrients it require (Chalise 1999; Poulsen et al. 2001; Jaman & Huffman 2012; Ghimire et al. 2021).

In recent years, the landscapes of northeastern India have witnessed swift alteration in the form of reduction of primary forest, shifting cultivation, mono-plantations, forests fire, habitat fragmentation due to constructions, threatening the primate diversity of the region (Choudhury 2001; Srivastava 2006; Choudhury 2011; Mazumder et al. 2014). Dampa Tiger Reserve (DTR), harbors several species of primates that inhabit the forest very close to the buffer areas and thereby have high chances of encroaching on the agricultural crop fields that are adjacent to the core. Such encroachment may lead to human-primate negative interactions due to crop loss suffered by local farmers. Hence understanding the feeding ecology of this species and developing suitable measures to mitigate them is necessary in the area. Till date, the macaque's response to such variations in the accessibility of food resources during seasonal changes is not yet reported in this region. As there is a scarcity of information on the feeding ecology and pattern of food selection, we intend to provide new insight to the food habits and dietary preferences of AM in the tropical forest of DTR in Mizoram, India, and possibly contribute for better management and conservation of the species and its habitat in the region.

Image 1. Assamese Macaque *Macaca assamensis* feeding on a grasshopper at Damparengpui in Teirei range, Dampa Tiger Reserve.

MATERIALS AND METHODS

Study area

The study was conducted from September 2018 to August 2020 at DTR (23.38–23.70 N & 92.27–92.43 E) located in the western part of Mizoram in Mamit district along the international border to Bangladesh. The reserve comprises a core area of 500 km^2 and a buffer 488 km^2, covering mountainous terrains, and elevation ranging 250–1,100 (Figure 1) (Johnson et al. 2021). The natural vegetation is distinct by the tropical evergreen to semi-evergreen of undulating, rugged in nature consisting of alternating ridges, medium hills, and slopes of mostly bamboo forest classified under the Cachar tropical evergreen and semi-evergreen: 1B/C3 and 2B/C2 forest, tropical moist deciduous forests: 3C/C3b and 3C2S1, sub-montane type: 2B1b (Champion & Seth 1968). The moist valley is lofty and evergreen, runs parallel along the rivers, steeper slopes have more deciduous elements, often with sympodial bamboos in the understory (Vanlalsiammawii et al. 2020). Weather pattern is characterized by a tropical humid climate with distinct cold (November–February), summer (March–June), and rainy (May–October) seasons. The temperature ranges from 4°C in winter (January) to 36°C in summer (May–June). The average annual rainfall is 2,200 mm. Forest canopy at lower elevation is 30–35 m, with evergreen and some deciduous trees

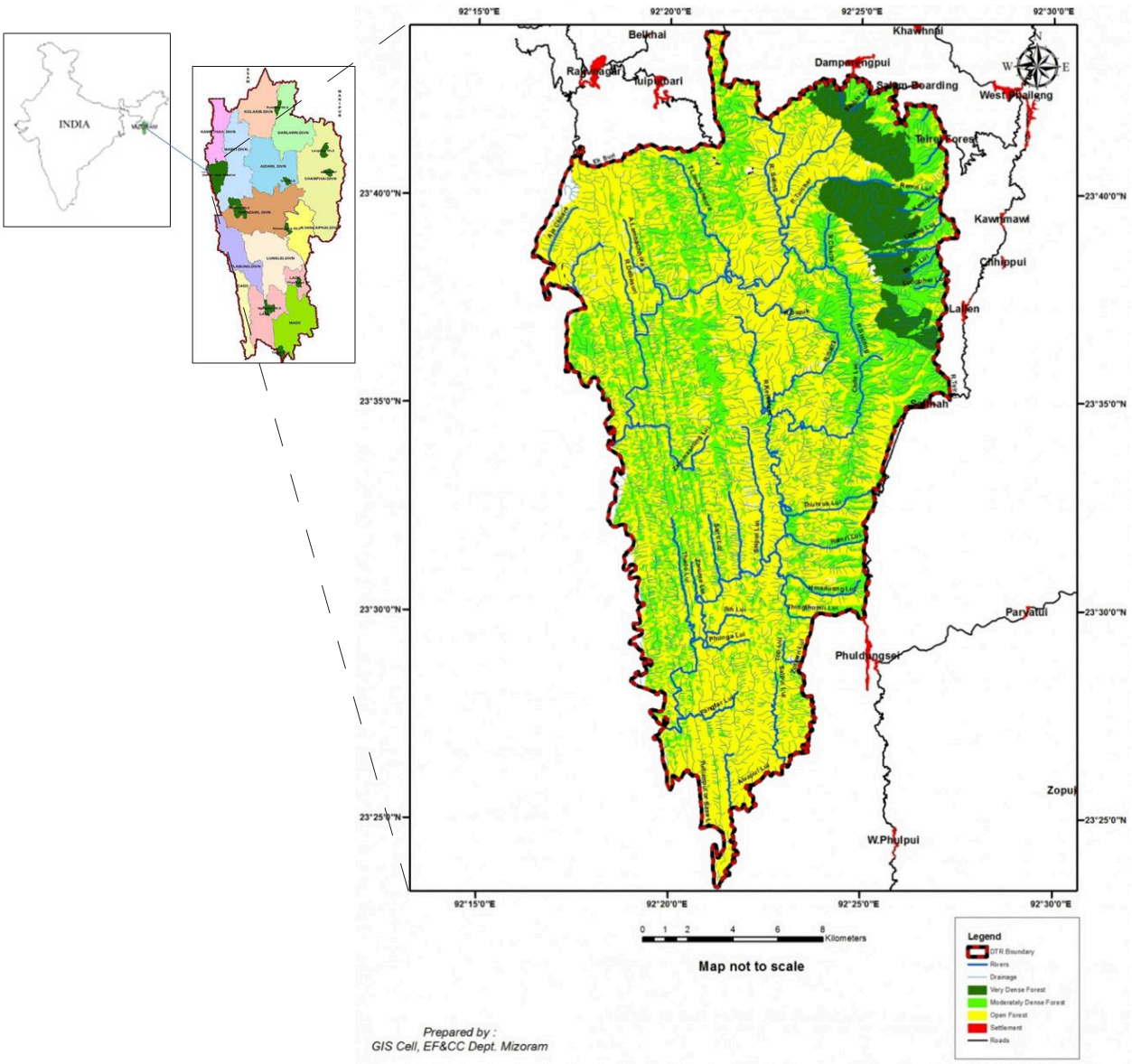

Figure 1. Dampa Tiger Reserve, the study area.

interspersed with tall (~40 m) emergent trees such as *Dipterocarpus turbinatus*, *Tetrameles nudiflora*, *Michelia champaca*, and *Arctocarpus chaplasha*, while from the elevation above 700 m, the forest forms a canopy at 25–35 m characterized by trees such as *Schima wallichii*, *Castanopsis indica*, and *Mesua ferrea* (Mandal & Raman 2016).

Other primate species in the DTR are Rhesus Macaque *M. mulatta*, Northern Pig-tailed Macaque *M. leonina*, Stump-tailed Macaque *M. arctoides*, Capped Langur *Trachypithecus pileatus*, Phayre's Leaf Monkey *T. phayrei*, Western Hoolock Gibbon *Hoolock hoolock*, and Bengal Slow Loris *Nycticebus bengalensis* (Pachuau et al. 2013).

Study subjects

The feeding ecology and dietary pattern of AM in DTR was determined by marking and following a particular troop. We observed for their daily activities and feeding plants from September 2018 to August 2020. The observation of AM in the field was conducted continuously during the study period along the adjacent buffer fringe. The time spent for monitoring AM was maximum, i.e., 10–12 h during dry seasons (winter and spring) and Minimal in monsoon (i.e., 6–7 h). Constraints faced during the survey period include inaccessible terrains, leeches, and bad weather conditions. Days lost to bad weather condition was compensated by the addition of observation hours and days during the dry and spring season. The individuals of the focal troop were identified with the help of different external characters and appearances such as body structure, facial features, fur color, cut marks, skin colour, and tail carriage. The troop consisted of two adult males, three adult females, five sub-adult females, three sub-adult males, two juveniles, and four infants that were classified by sex and age based on coloration, body size, and development of sexual characteristics following earlier established physical descriptions (Ulibarri & Gartland 2021).

Habitat and Vegetation sampling

Habitat and vegetation types in the study sites were determined by a stratified sampling method. We employed nine plots randomly in square subplots measured (20 x 20) m^2 in the Teirei range (23.68° N, 92.4° E and 23.66 N, 92.41° E) within an elevation range of 687–836 m. All sampling was made on foot on a transect line that were previously marked. The observation was made using a binocular, GPS, and digital camera. All the trees within the quadrats were identified to the species level (Sawmliana 2013; Hegde & Manpoong 2017), counted and their diameter at breast height was measured at approximately 1.37 m above the ground. The dominance of each species within a plot was calculated as the relative density (RD) and relative frequency (RF), following Irmayanti et al. (2022) and ultimately determined the Important Value Index IVI value for each plant species in a plot by summing the relative density (RD), relative basal area (RBA), and relative frequency (RF) following Deori et al. (2016).

Dietary composition and feeding activity

Data on the dietary composition and feeding behavior of AM were collected by direct observations in the field following the methods of Chalise et al. (2013). The feeding data was collected for 24 months from September 2018 to August 2020. Observations were noted down every 10 minutes per hour using direct observation of both adult male and female individuals from the time they were encountered to until out of sight via focal individual sampling, starting from 0600 h to 1700 h. Sampling was carried out for 5–10 consecutive days of every month (Solanki et al. 2008) until the focal individual under observation disappeared from view sight or retired to sleeping site (Altmann 1974; Bartlett 1999). The focal individual was randomly determined among adults prior to the observation and we focused mainly on adult male and female individuals and made 6 to 12 entries per day on information such as consumed food plants, food items, and feeding time based on the season. The feeding items or plant parts consumed were categorized as leaves (both young and mature leaves), flowers, fruits, seeds, and shoots. The time spent feeding on different food items was calculated as per Gupta & Kumar (1994):

$$T_a = \frac{N_a \text{ X } 100}{N}$$

where,

T_a = Percent time spent on feeding activity

N_a = Number of records with feeding activity, and

N = Total number of records for the day

Data Analysis

Kruskal-Wallis test was performed to determine the monthly and seasonal variation in time devoted to each plant part and the number of plant species consumed. A 'P' Value of <0.05 was considered statistically significant. SPSS version 16.0 software (SPSS Inc Chicago, Illinois, USA) and GraphPad Prism ver. 8.2 were used for statistical and graphical analysis.

RESULTS

Habitat types and vegetation

Vegetation in the study sites was determined through vegetative sampling and collection of ecological based data in various quadrats. The surveyed sites mainly consist of tropical deciduous forests and bamboo forests with ≥70% canopy cover. Tree species such as *Acer laevigatum*, *Canarium bengalense*, *Trema orientalis*, *Schima wallichi*, *Albizia chinensis*, *Derris robusta*, *Albizia rumphii*, *Ficus racemosa*, and *F. hirta* of basal width 40–80 cm were dominant in the surveyed sites. Bamboo species like *Dendrocalamus asper*, *D. longispatus*, *Cephalotachyum latifolium*, *Bambusa mizorameana*, *B. tulda*, and *Melocalamus compactiflorus* were also prevalent in the region. AM was observed to forage on 57 plant species belonging to 30 families (Table 1). Of the 57 feeding plants known to be consumed by AM, the highest relative density was recorded for *Melocana baccifera* (3.78%), followed by *Dendrocalamus longispathus* (3.36%), and *Artocarpus lakoocha* (2.94%) (Table 2). The highest relative frequency of the feeding plants was calculated for *Melocana baccifera* (4.87%), *Dendrocalamus longispathus* (4.38%), and *Musa ornata* (2.99%); while the least encountered plant species were the *Ficus* spp., i.e., *F. auriculata*, *F. elastica*, and *F. racemosa* with values of 0.49%, 0.73%, and 0.73%, respectively. The important value index (IVI) was contributed most by *Ficus auriculata* (15.2), *Bombax ceiba* (13.3), & *Albizia procera* (8.66) and the least was recorded for *Dysoxylum gotadhora* (2.80), *Gnetum gnemon* (2.81), & *Protium serratum* (2.96) (Table 2).

Dietary composition and feeding activity

In the study, 203 days of the survey resulted in 2,233 scans and 16,381 behavioural records. AM was observed to forage on 57 plant species from 30 families (Table 1). The number of food plant species consumed in each observation month ranges from 20 to 43 (32.42 ± 6.56) (Table 3). While plant species namely *A. lakoocha*, *C. graffithii* and all species of *Albizia* were fed throughout the year; species like *V. quinata, P. timoriana*, and *H. kurzii* were consumed in the least number (Table 3). Members of the family Moraceae (9), Meliaceae (5), Mimosaceae (4), and Euphorbiaceae (4) contributed to the most number of feeding plants in AM's diet, while the other listed plant families represent two or one plant species at most (Figure 2). Among the feeding plant species, trees accounted for 91%, herbs for 7%, and climbers/ vines for 2%. AM was found to munch on different plant parts such as fruits, leaves (young & matured), flowers, shoots, and seeds. Leaves formed the highest proportion of AM diet with 44.74% followed by fruits (25.31%), flowers (15.66%) seeds (12.14%), and shoots (2.14%) (Figure 3). Among the feeding plant species 13 species contributed for >1% feeding times. The major feeding plants of AM were identified to be *Artocarpus lakoocha* (15.65%), *Albizia procera* (12.03%), *G. hyneanum* (10.53%), *D. glandulosa* (9.49%), *Albizia lebbeck* (7.28%), *Cephalotaxus graffithii* (4.53%), and *F. auriculata* (4.20%) as it was observed to spend more time on this plants species. While plants such as *Walsura robusta* (0.31%), *Phyllanthus emblica* (0.30%), *Terminalia myriocarpa* (0.21%), *Vitex quinata* (0.12%) were found to be consumed in the least quantity (Table 1). Plants such as *A. lakoocha*, *Albizia procera*, *Diospyros glandulosa*, *P. serratum*, *Dendrocalamus longispathus*, and *Duabanga grandiflora* were identified to contribute with most number of consumable parts. Soft or tender shoots of *D. longispathus* and *M. baccifera* were the plants whose shoots were fed by AM. Distribution of feeding plant species indicates that *Melocana baccifera* (20), *Dendrocalamus longispathus* (18), *Caesalpinia cucullata* (16), *Musa ornata* (14), and *Walsura robusta* (13) were present in the highest number in the sampled quadrats although it does not represent the feeding utility by AM in its diet.

Monthly and seasonal effect on feeding phenology

In the present observation, leaves (young and mature) and fruits constituted the major food items of AM and they invested more time for feeding on these food items. Leaves, both young and mature leaves formed the highest bulk of AM's diet, as they were available throughout the years and no significant variation was observed on time spent on feeding leaves in different months of the year (X^2 = 19.46, df =11, p >0.05) (Figure 4). Similarly, there was no significant variation in the time spent on feeding of leaves in different seasons (X^2 = 3.429, df = 2, p >0.05). Fruits were most abundant during monsoon/summer and constituted the major food item during the month of June to August. They were observed to feed maximum fruits in the month of August (44.62% of the total food items), and the least consumption of fruits was recorded in the month of February (3.48% of the total food items). Time spent on feeding of fruits did not show significant variation in different months (X^2 = 15.87, df = 11, p >0.05) and seasons (X^2 = 4.571, df = 2, p >0.05). The highest consumption of flowers was observed in the month of February (28.05%), however, no significant variation in the time spent on feeding of flowers was observed monthly and seasonally

Table 1. Plants recorded that are consumed by Assamese Macaque *Macaca assamensis* in the study site.

	Species name	Family	Vernacular (Mizo)	Habit	Parts eaten by *M. assamensis*	Time spent for feeding (%)
1	*Artocarpus lakoocha*	Moraceae	Theitat	T	L, Fl, Fr, Sd	15.65
2	*Albizia procera*	Mimosaceae	Kangteknu	T	L, Fr, Fl, Sd	12.03
3	*Glochidion hyneanum*	Euphorbiaceae	Thingpawnchhia	T	Fl, L, Fr	10.53
4	*Diospyros glandulosa*	Ebenaceaea	Theivawkmit	T	L, Fr, Fl, Sd	9.49
5	*Albizia lebbeck*	Mimosaceae	Kangtek	T	L, Fl, Fr, Sd	7.28
6	*Cephalotaxus graffithii*	Cephalotaxaceae	Thinglenbuang	T	Fr, L	4.53
7	*Ficus auriculata*	Moraceae	Theibal	T	L, Fr	4.20
8	*Protium serratum*	Burseraceae	Bil	T	L, Fr, Sd	3.04
9	*Albizia chinensis*	Mimosaceae	Vang	T	L, Fr, Sd	1.57
10	*Bombax insigne*	Bombacaceae	Pang	T	L, Sd	1.44
11	*Dendrocalamus longispathus*	Poaceae	Rawnal	H	Sh	1.37
12	*Prunus ceylanica*	Rosaceae	Ruphir	T	Fr, Sd	1.21
13	*Garcinia succifolia*	Clusiaceae	Tuaithleng	T	L, Fr, Sd	1.15
14	*Cassia javanica*	Caesalpiniaceae	Makpazangkang	T	L, Fl, Sd	0.99
15	*Ficus semicordata*	Moraceae	Theipui	T	L, Fl, Fr	0.98
16	*Melocana baccifera*	Poaceae	Mautak	H	Sh	0.97
17	*Gmelia arborea*	Magnoliaceae	Ngiau	T	L	0.94
18	*Antidesma bunius*	Fabaceae	Thingkha	T	L, Fr	0.94
19	*Aporosa octandra*	Euphorbiaceae	Chhawntual	T	L, Sd	0.93
20	*Albizia odoratissima*	Moraceae	Kangtekpa	T	L, Sd	0.91
21	*Ficus elastica*	Moraceae	Thialret	T	Fl, L	0.87
22	*Parkia timoriana*	Mimosaceae	Zawngtah	T	Sd, L	0.87
23	*Dioscorea pentaphylla*	Verbenaceae	Thlanvawng	C	L, Sd	0.81
24	*Musa ornata*	Musaceae	Changvandawt	T	Fl, Fr	0.76
25	*Aglaia edulis*	Meliaceae	Raithei	T	L, Fl, Fr	0.76
26	*Bischofia javanica*	Euphorbiaceae	Khuangthli	T	L, Fr	0.75
27	*Magnolia oblonga*	Magnoliaceae	Ngiau	T	L, Fr	0.74
28	*Derris robusta*	Fabaceae	Thingkha	T	L, Fl, Sd	0.72
29	*Gnetum gnemon*	Gnetaceae	Pelh	T	L, Fl, Fr	0.70
30	*Bombax ceiba*	Bombacaceae	Phunchawng	T	Fl, L	0.66
31	*Artocarpus nitidus*	Moraceae	Tatte	T	L, Fl, Fr	0.65
32	*Mallotus macrostachyus*	Euphorbiaceae	Kharpa	T	L, Fl, Fr	0.64
33	*Chukrasia tabularis*	Meliaceae	Zawngtei	T	L, Fl, Fr	0.61
34	*Toona ciliata*	Meliaceae	Teipui	T	L, Fl, Fr	0.57
35	*Mangifera indica*	Anacardiaceae	Ramtheihai	T	Fl, Fr	0.56
36	*Syzygium cumini*	Myrtaceae	Lenhmui	T	L, Fl, Sd	0.55
37	*Ficus rumphii*	Moraceae	Hmawng	T	L, Fl, Fr	0.55
38	*Ficus racemosa*	Moraceae	Theichek	T	L, Fl, Fr	0.54
39	*Ficus retusa*	Moraceae	Rihnim	T	L, Fr	0.54
40	*Dillenia indica*	Dilleniaceae	Kawrthindeng	T	L, Fr, Fl	0.51
41	*Spondius pinnata*	Anacardiaceae	Tawitaw	T	L, Fr	0.49
42	*Dysoxylum gotadhora*	Meliaceae	Sahatah	T	L, Fl, Fr	0.48
43	*Hibiscus macrophyllus*	Malvaceae	Vaiza	T	L, Fl	0.48
44	*Caesalpinia cucullata*	Caesalpiniaceae	Hlingkhang	C	L, Fl, Sd	0.47

	Species name	Family	Vernacular (Mizo)	Habit	Parts eaten by *M. assamensis*	Time spent for feeding (%)
45.	*Anogeisus acuminata*	Combretaceae	Zairum	T	L, Fl, Fr	0.46
46	*Litsea monopetala*	Lauraceae	Nauthak	T	Fr	0.45
47	*Hydnocarpus kurzii*	Flacourtiaceae	Khawitur	T	L, Fl	0.44
48	*Heliconia rostrata*	Heliconiaceae	Changelpar	H	Fl	0.43
49	*Duabanga grandiflora*	Sonneratiaceae	Zuang	T	L, Fl, Fr, Sd	0.41
50	*Schima wallichii*	Theaceae	Khiang	T	L, Fr, Fl	0.37
51	*Xantolis tomentosa*	Sapotaceae	Maudo	T	L, Fr	0.37
52	*Terminalia crenulata*	Combrataceae	Tualram	T	L, Fl, Fr	0.36
53	*Castanopsis tribuloides*	Fagaceae	Thingsia	T	L, Sd	0.36
54	*Walsura robusta*	Meliaceae	Perte	T	L, Fl, Fr	0.31
55	*Phyllanthus emblica*	Phyllanthaceae	Sunhlu	T	Fr	0.30
56	*Terminalia myriocarpa*	Combretaceae	Char	T	L, Fl, Fr	0.21
57	*Vitex quinata*	Verbenaceae	Thlengreng	T	L, Fl, Sd	0.12

L—Leaves | FL—Flower | Fr—Fruits | Sh—Shoots | S—Seeds | T—Tree | H—Herb | C—Climber.

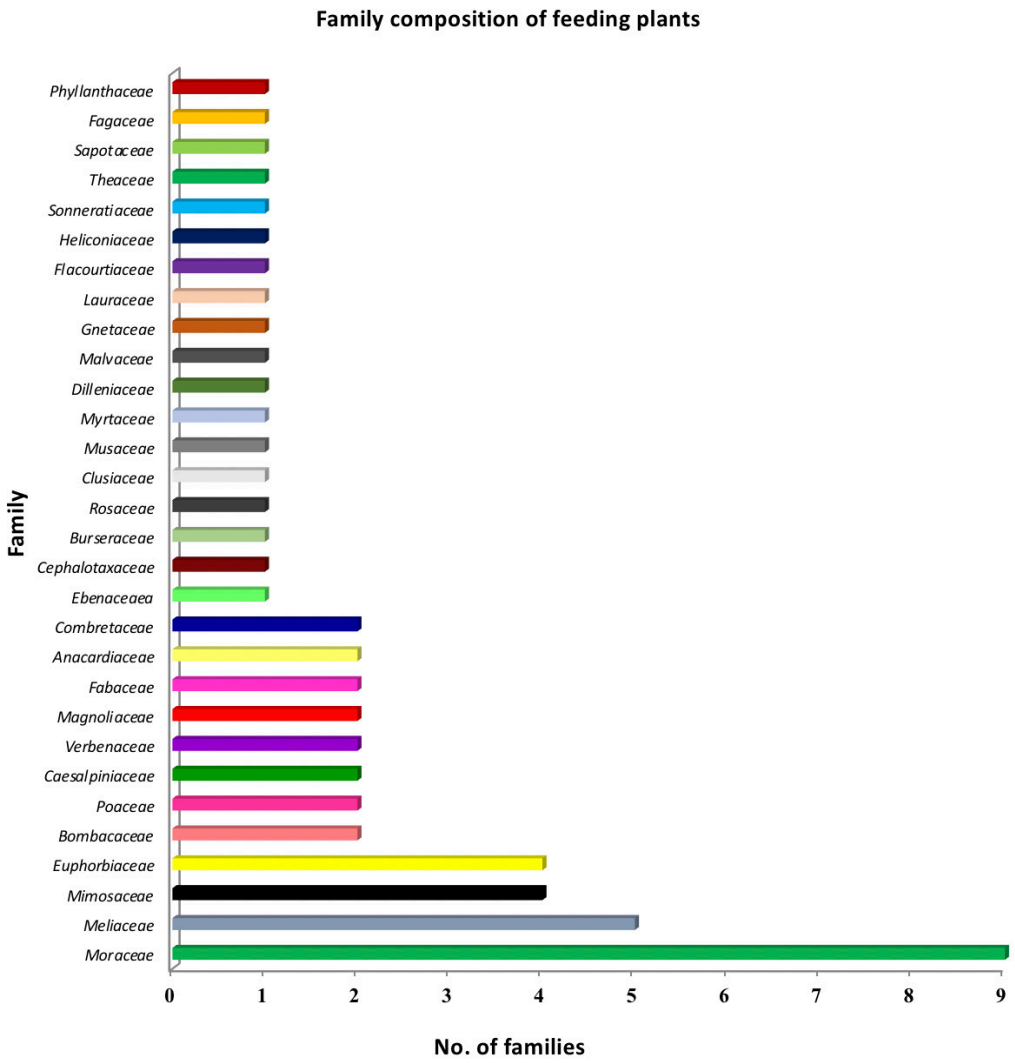

Figure 2. Diversity of feeding plant species.

Table 2. Distribution of feeding plant species in the study site in order of food preference.

Species name	Frequency of Occurrence	RF	R Den	R Dom	IVI
Artocarpus lakoocha	12.00	2.92	2.94	1.10	6.96
Albizia procera	7.00	1.70	2.52	4.44	8.00
Glochidion hyneanum	4.00	0.97	1.26	1.61	3.85
Diospyros glandulosa	5.00	1.22	0.84	1.21	3.27
Albizia lebbeck	7.00	1.70	2.56	2.42	6.69
Cephalotaxus graffithii	7.00	1.70	1.68	0.61	3.99
Ficus auriculata	2.00	0.49	0.85	13.86	**15.20**
Protium serratum	6.00	1.46	1.28	0.22	2.96
Albizia chinensis	5.00	1.22	1.28	1.69	4.19
Bombax insigne	4.00	0.97	1.28	4.84	7.10
Dendrocalamus longispathus	18.00	4.38	3.36	0.10	7.84
Prunus ceylanica	8.00	1.95	1.71	1.03	4.68
Garcinia succifolia	5.00	1.22	1.71	0.68	3.60
Cassia javanica	8.00	1.95	2.10	0.91	4.96
Ficus semicordata	5.00	1.22	1.28	0.62	3.12
Melocana baccifera	20.00	4.87	3.78	0.05	8.70
Gmelia arborea	4.00	0.97	1.28	4.05	6.31
Antides mabunius	5.00	1.22	1.71	0.81	3.73
Aporosa octandra	11.00	2.68	1.71	0.46	4.85
Albizia richardiana	8.00	1.95	2.56	1.88	6.39
Ficus elastica	3.00	0.73	0.85	5.24	6.83
Parkia timoriana	8.00	1.95	2.14	0.72	4.81
Dioscorea pentaphylla	9.00	2.19	2.56	0.97	5.72
Musa ornata	14.00	3.41	2.99	0.27	6.67
Aglaia edulis	11.00	2.68	2.56	0.81	6.05
Bischofia javanica	7.00	1.70	2.14	0.71	4.55
Magnolia oblonga	3.00	0.97	1.28	3.23	5.48
Derris robusta	12.00	2.92	2.56	0.54	6.03
Gnetum gnemon	6.00	1.46	1.28	0.07	2.81
Bombax ceiba	5.00	1.22	1.28	10.89	**13.39**
Artocarpus nitidus	9.00	2.19	1.71	1.21	5.11
Mallotus macrostachyus	6.00	1.46	2.14	1.29	4.88
Chukrasia tabularis	8.00	1.95	2.14	0.56	4.65
Toona ciliata	4.00	0.97	1.71	4.84	7.52
Mangifera indica	8.00	1.95	2.56	0.50	5.01
Syzygium cumini	5.00	1.22	1.28	2.42	4.92
Ficus rumphii	3.00	0.73	1.28	3.32	5.33
Ficus racemosa	3.00	0.73	1.28	3.23	5.24
Ficus retusa	3.00	0.73	1.28	2.39	4.40
Dillenia indica	4.00	0.97	0.85	1.21	3.04
Spondius pinnata	6.00	1.46	1.71	1.41	4.58
Dysoxylum gotadhora	4.00	0.97	1.28	0.54	2.80
Hibiscus macrophyllus	5.00	1.22	1.28	1.05	3.55
Caesalpinia cucullata	16.00	3.89	1.71	0.12	5.73

Species name	Frequency of Occurrence	RF	R Den	R Dom	IVI
Anogeissus acuminata	10.00	2.43	1.71	0.69	4.83
Litsea monopetala	5.00	1.22	1.71	1.41	4.34
Hydnocarpus kurzii	5.00	1.22	1.28	0.44	2.94
Heliconia rostrata	8.00	1.95	1.71	0.24	3.90
Duabanga grandiflora	9.00	2.19	1.71	0.20	4.10
Schima wallichii	11.00	2.68	1.71	0.38	4.77
Xantolis tomentosa	7.00	1.70	2.14	0.14	3.98
Terminalia crenulata	4.00	0.97	1.28	1.47	3.73
Castanopsis tribuloides	7.00	1.70	1.28	0.36	3.34
Walsurarobusta	13.00	3.16	2.14	0.36	5.66
Phyllanthus emblica	8.00	1.95	1.71	0.64	4.30
Terminalia myriocarpa	7.00	1.70	1.71	0.85	4.26
Vitex quinata	4.00	0.97	1.71	1.67	4.36

RF—Relative frequency | RDen—Relative density | R Dom—Relative dominance | IVI—Important value index.

(Table 4). Seeds were found to be consumed mainly in winters when there was a scarcity of fleshy fruits, and the highest seed consumption was recorded in January (12.4%). Shoots of bamboo sp. were fed only in monsoon (June–October) and the total time spent on feeding of shoots during the observation period was only 2.14%. Plant species such as *Cephalotaxus graffithii*, *Diospyros glandulosa, A. lakoocha*, *Albizia chinensis*, and *Bombax insigne* were observed to be eaten throughout the year and thus represent the primary sources of nutrients for AM. The highest percentage (59.03%) of the diurnal time invested on feeding was in the month of January and the least (35.19%) was in the month of June (Table 4).

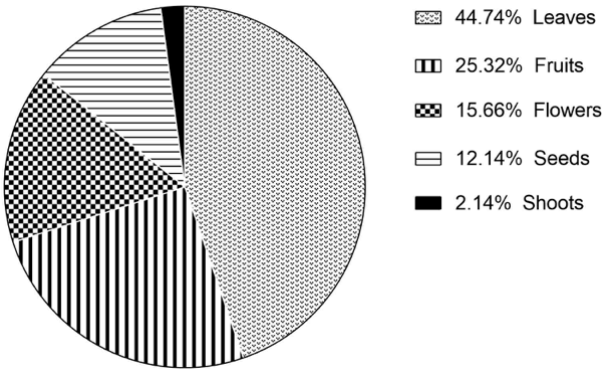

Figure 3. Dietary composition of Assamese Macaque *Macaca assamensis*.

DISCUSSION

Primates have a diverse feeding ecology and are highly adaptable in their dietary requirement. Dietary flexibility has permitted primates to live in a variety of habitats including tropical forests, semi-evergreen forests, montane forests, limestone bamboo forests, and secondary degraded forests (Timmins & Duckworth 2013; Mazumder et al. 2014; Huang et al. 2015; Koirala et al. 2017; Boonaratana et al. 2020). Similar to other findings across southeastern Asia, AM in DTR are also primary folivorous as leaves (young & mature) constitute 44.74% of their daily dietary intake compared to 25.32% of fruit (Srivastava 1999; Chalise et al. 2013; Zhou et al. 2011; Huang et al. 2015; Ghimire et al. 2021). Young leaves, when available were the major food items (spring and pre-monsoon). Contrastingly, mature leaves were the preferred food items during winter. Although the availability of young leaves decreased markedly from November to February, a high level of leaves was maintained in the diet of AM almost year-round as reported by Srivastava (1999) and Zhou et al. (2011). The scarcity of most young leaves during the dry winter season was compensated by some of the major food plants that thrived throughout the dry season in the study sites like *Albizia chinensis*, *A. lebbeck*, *A. procera*, *A. lakoocha*, *Bombax insigne*, and *Protium serratum* (Table 3). Apart from leaves, the amount of time invested among other food items such as, fruits, flowers, and seeds were high. We suggest that they like to avoid leaves (especially mature) and try to intake other more nutritive food whenever possible. Similar to this observation, AM in central Nepal switched between the young and mature leaves according to their availability, but the higher preference been the young leaves (Ghimire et al.

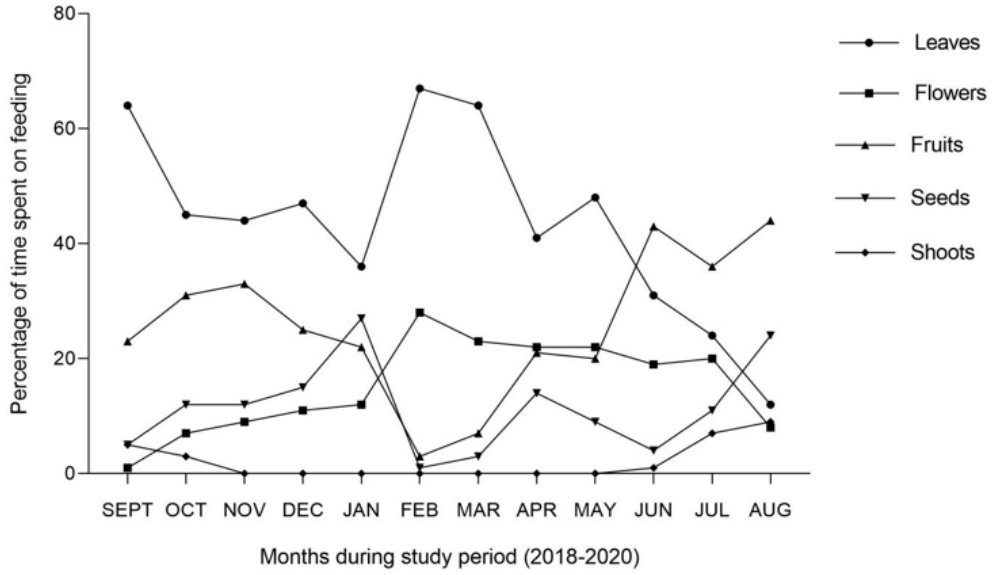

Figure 4. Monthly variation in feeding budget of Assamese Macaque *Macaca assamensis.*

2021). In the study, it was observed that the abundance of plant species has no correlation with the selection of feeding items. Plant species like *Ficus auriculata*, *Bombax ceiba*, and *Melocana baccifera* although were dominant and widely distributed, more preference was given to species like *Albizia* sp., *Ficus* sp., and *Artocarpus lakoocha,* which are in accordance with reports of Zhou et al. (2011) and Ghimire et al. (2021). AM are adaptable foragers able to modify their diet seasonally, being more folivorous in the dry season and more frugivorous in the wet season or post-monsoon (Li et al. 2019; Ghimire et al. 2021). Many studies have shown a strong correlation between rainfall and fruit availability in the dry season from November to March (Zhou et al. 2006, 2011).

AM in DTR spent majority (>44 % on average) of their diurnal time on feeding. They devoted more time in search of food items during the winter months (November–February) when resources were limited in cold and dry periods. Seasonal variation in the diet of AM was clearly linked to seasonal fluctuation in food availability which is a common observation across their home ranges. AM greatly altered their diet with a mixture of plant items including fruits, flowers, leaves, shoots and even seeds. While primate species such as Hoolock Gibbon *Hoolock hoolock*, Stump-tailed Macaque *Macaca arctoides*, and Rhesus Macaque *Macaca mulatta* are frequently encountered in crop fields (Mazumder et al. 2014), no such observation was made in DTR region, although they are reports available of crop raiding by AM in their home ranges (Regmi et al. 2013; Adhikari et al. 2018). The richness of fruiting plants in DTR appears to fulfill the dietary requirement of AM as no incidences of human-primate negative interactions are reported from the region and co-habitation was also observed between AM and other primate species. However, with the increase in settlement areas along the periphery of DTR, more dependency on forest resources, construction of road networks, and clearing of forests for cultivation, such conflict are inevitable in near future. Although in some cases, AM was found to survive in disturbed habitats, but the long-term consequences on reproduction and survival are unknown (Srivastava 2006). Hence understanding the feeding ecology of AM and adapting timely measures will be important for preventing human-AM negative interactions as well as conservation of primates in the region.

CONCLUSION

The macaques, changed their diets in accordance with the season and availability of food items as they appear to be folivorous in the dry and pre-monsoon season and more frugivorous in the monsoon and post-monsoon seasons. They consumed a wide range of trees, herbs, shrubs, and climbers. It is happening that the primates in northeastern India have been forced into crop raiding because of the loss of their natural habitat from various anthropogenic activities. However, it is evident that some species have clearly learned to co-exist with humans by raiding crops. Conflicts of this kind are likely to increase in the future as the human

Table 3. Monthly variation in feeding time (%) on each plant species during 2018–2020.

	Plant species	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	No. of food plants eaten in 12 months
1	*Aglaia edulis*	0.9	-	0.9	1.9	1.3	9.2	6.2	1.8	-	-	-	-	7
2	*Albizia procera*	11.8	7.3	11	11.3	11.4	9	10	-	4.3	19.3	3.5	12	11
3	*Albizia chinensis*	2.6	9.0	4	-	2.2	8.3	11	6.2	2.5	3.4	1.3	4.1	11
4	*Albizia lebbeck*	8.8	12.6	11.6	13.5	8.8	11.7	8.1	3.3	5.6	2.4	5.9	-	11
5	*Albizia richardiana*	0.3	0.6	-	1.1	1.2	5.2	5.4	2.3	-	-	-	3.1	8
6	*Anogeissus acuminata*	-	-	-	-	1.5	2.7	2.3	-	-	-	0.5	-	4
7	*Antidesma bunius*	-	0.8	-	0.5	1.2	1.4	1.7	0.8	0.9	0.9	0.8	-	9
8	*Aporosa octandra*	0.2	-	2.5	-	0.7	1.5	2.6	-	-	-	0.6	-	6
9	*Artocarpus chaplasha*	1.0	1.0	0.3	2.0	-	2.9	2.6	1.5	2.0	-	0.8	-	9
10	*Artocarpus lakoocha*	13.5	13.9	14.5	11.1	12.6	17.2	13.2	9.5	14.3	17.1	10.8	13.2	12
11	*Bischofia javanica*	-	-	1.2	1.9	2.6	2.3	2.3	0.9	0.4	-	2.3	-	8
12	*Bombax ceiba*	-	-	1.3	1.7	1.0	3.2	2.1	0.8	1.8	-	1.5	-	8
13	*Bombax insigne*	8.6	1.5	6.4	8.6	5.0	4.0	3.7	6.1	-	8.2	2.8	1.4	11
14	*Caesalpinia cucullata*	0.7	0.6	-	-	0.0	2.1	2	0.9	1.8	1.4	-	0.5	9
15	*Cassia javanica*	1.5	0.6	-	-	1.4	2.1	1.9	1.1	-	-	0.7	2.8	8
16	*Castanopsis tribuloides*	0.8	1.8	-	0.5	0.0	2.1	1.9	2.5	2.2	-	-	1.8	9
17	*Cephalotaxus graffithii*	3.2	2.3	3.8	4.5	3.9	3.1	3.9	5.6	6.4	1.8	3.2	5.5	12
18	*Chukrasia tabularis*	-	-	-	2.2	0.9	1.6	2.9	2.3	3.4	-	2.7	0.9	8
19	*Dendrocalamus longispathus*	4.5	2.4	-	-	-	-	-	-	-	1.6	3.8	2.5	5
20	*Derris robusta*	-	-	0.6	-	1.6	1.9	1.4	-	-	-	3.6	1.1	6
21	*Dillenia indica*	0.8	-	-	1.1	0.8	1.4	1.3	3	-	-	-	2.7	5
22	*Dioscorea pentaphylla*	-	1.7	1.2	1.6	0.9	1.3	1.9	0.4	2.3	-	-	-	8
23	*Diospyros glandulosa*	9.5	12.4	9.3	12.9	10.8	0.3	2.6	10	13	9.4	2.8	-	11
24	*Duabanga grandiflora*	-	-	0.9	-	2.3	1.2	1.1	-	-	-	1.4	-	5
25	*Dysoxylum gotadhora*	-	-	-	1.0	1.3	0.9	1.0	0.8	-	-	2.0	-	6
26	*Ficus auriculata*	2.7	2.5	-	-	0.0	-	0.4	6.7	7.9	7.9	7.3	11.2	9
27	*Ficus elastica*	-	0.9	0.6	-	1.2	0.6	0.6	-	2	-	0.6	-	7
28	*Ficus racemosa*	-	0.6	2.4	-	1.8	0.6	0.6	-	0.9	-	0.8	-	7

	Plant species	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	No. of food plants eaten in 12 months
29	*Ficus religiosa*	0.5	0.7	-	-	1.4	0.4	0.4	0.6	-	-	-	0.9	7
30	*Ficus retusa*	0.6	-	0.8	-	-	0.4	1.3	0.5	0.8	-	1.4	-	7
31	*Ficus variegata*	0.6	1.6	-	-	1.0	-	-	0.6	1.8	0.4	1.3	1.9	8
32	*Garcinia succifolia*	1.3	2.2	1.7	0.3	-	-	-	1.5	0.5	1.2	0.9	0.9	9
33	*Glochidion heyneanum*	5.9	10.7	9.5	10.3	7.4	-	3.0	8.3	14.2	15.7	7.0	12.4	11
34	*Gmelia arborea*	-	0.8	0.6	0.8	2.1	-	-	0.6	1.6	-	0.8	1.9	8
35	*Gnetum gnemon*	-	1.2	0.8	0.5	0.9	-	-	0.7	0.5	-	2.2	-	7
36	*Heliconia rostrata*	1.0	-	1.7	-	1.9	-	-	1.3	-	0.7	1.7	-	6
37	*Hibiscus macrophyllus*	-	-	1.0	-	1.4	-	-	-	-	-	1.9	-	3
38	*Hydnocarpus kurzii*	-	-	-	0.8	0.5	-	-	-	-	-	-	-	2
39	*Litsea monopetala*	1.0	0.4	-	-	0.0	-	-	0.9	-	1.7	-	1.9	8
40	*Magnolia oblonga*	1.5	2.9	1.6	-	1.3	-	-	1.6	1.9	-	2.8	0.8	8
41	*Mallotus macrostachyus*	-	0.8	0.4	0.5	1.1	-	-	0.8	-	0.8	-	0.6	7
42	*Mangifera indica*	1.3	0.4	1.3	-	-	-	-	1.8	-	-	1.3	2.0	6
43	*Melocana baccifera*	1.5	1.3	-	-	-	-	-	-	-	0.8	1.9	6.0	5
44	*Musa ornata*	-	-	1.3	-	0.5	-	-	0.5	-	-	3.2	-	4
45	*Parkia timoriana*	-	-	-	-	-	0.8	0.7	-	-	-	-	-	2
46	*Phyllanthus emblica*	4.2	0.9	-	1.1	-	-	-	1.7	-	-	0.9	-	5
47	*Protium serratum*	7.2	2.8	2.4	1.9	-	-	-	1.7	4.1	4.5	3.8	4.2	9
48	*Prunus ceylanica*	1.8	1.6	-	0.6	1.0	-	-	3.5	0.7	1.2	-	0.9	8
49	*Schima wallichii*	-	-	0.5	1.0	1.2	-	-	-	-	-	0.9	-	4
50	*Spondius pinnata*	-	-	-	0.4	-	-	-	1.1	-	-	-	2.8	3
51	*Syzygium cumini*	-	-	1.6	0.5	0.6	-	-	0.4	-	-	1.3	-	5
52	*Terminalia crenulata*	-	-	-	0.7	-	-	-	1.3	-	-	1.5	-	3
53	*Terminalia myriocarpa*	-	-	-	0.5	-	-	-	0.3	-	-	2.8	-	3
54	*Toona ciliata*	-	-	1.5	2.3	0.9	-	-	1.7	-	-	-	-	4
55	*Vitex quinata*	-	-	-	1	-	-	-	-	-	-	-	-	1
56	*Walsura robusta*	-	-	0.5	0.3	0.5	-	-	1.1	-	-	1.3	-	5
57	*Xantolis tomentosa*	0.9	-	1.3	-	-	0.8	-	0.7	2.3	-	1.1	-	6

Table 4. Diurnal time invested on feeding activity.

	Month	Leaves			Flowers			Fruits			Seeds			Shoots			Diurnal time spent (%)
		2018–2019	2019–2020	Total	2018–2019	2019–2020	Total	2018–2019	2019–2020	Total	2018–2019	2019–2020	Total	2018–2019	2019–2020	Total	
1	Sep	142.8	221.2	364	0	5.8	5.8	34.2	100.6	134.8	22.4	8.0	30.4	8.4	21.4	29.8	39.22
2	Oct	165.2	149.6	314.8	20.0	29.4	49.4	112.2	110.0	222.2	30.0	56.8	86.8	8.8	16.8	25.6	48.52
3	Nov	161.8	136.4	298.2	33.4	33.4	66.8	109.6	117.6	227.2	22.0	61.8	83.8	0	0	0	46.94
4	Dec	143.3	149.6	292.9	51.4	20.8	72.2	107.4	48.0	155.4	44.9	49.0	93.9	0	0	0	42.66
5	Jan	162.6	150.4	313.0	78.1	32.0	110.1	79.2	116.2	195.4	106.8	124.8	231.6	0	0	0	59.03
6	Feb	204.2	246.1	450.3	94.4	94.0	188.4	15.0	8.4	23.4	5.6	4.0	9.6	0	0	0	42.89
7	Mar	311.4	206.6	518.0	97.4	91.6	189.0	49.2	12.0	61.2	5.6	24.2	29.8	0	0	0	55.41
8	Apr	144.6	104.6	249.2	79.8	55.1	134.9	30.8	97.0	127.8	23.6	65.6	89.2	0	0	0	41.74
9	May	144.0	139.0	283.0	76.0	56.0	132.0	30.3	90.0	120.3	0	53.9	53.9	0	0	0	40.91
10	Jun	64.5	97.0	161.5	49.6	47.0	96.6	107.9	111.2	219.1	9.0	13.0	22.0	7.6	0	7.6	35.19
11	Jul	55.0	89.0	144.0	65.8	52.6	118.4	95.2	117.8	213.0	32.8	35.0	67.8	21.6	24.4	46	40.91
12	Aug	39.4	36.2	75.6	43.8	5.6	49.4	109.4	151.0	260.4	47.4	93.6	141	28.0	29.2	57.2	40.52

population continues to grow exponentially in this region and encroachment on primate habitats continues. With increasing trends of habitat destruction in all the home ranges and reports of crop raiding, understanding keys factors and feeding ecology of the species in the wild will be crucial for addressing proper management and conservation of the species and their remaining habitat.

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