NUTRITIONAL ECOLOGY OF ASSAMESE MACAQUE (*MACACA ASSAMENSIS*) AND CAPPED LANGUR (*TRACHYPITHECUS PILEATUS*) IN DAMPA TIGER RESERVE IN MIZORAM, INDIA

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I, **HT. DECEMSON**, hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form basis of the award of any previous degree to me or to do the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree in any other University/Institute.

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ABBREVIATIONS

%	Percentage
‘p’	Probability value between 0–1 of statistical significance
<	Less than
>	Greater than
=	Equal to/Equivalent
†	Denoted closest value compared to present with earlier works
~	Approximately/Roughly
°N or °E	Degree North or East
°C	Degree Celsius
T_a	Percent time spent on feeding activity
N_a	Number of records with feeding activity
N	Total number of records for the day
C	Climbers
H	Herbs
L	Leaves
FL	Flower
Fr	Fruit
T	Tree
Sd	Seed
Sh	Shoots
ADF	Acid Detergent Fiber
ADF*i*	Acid Detergent Fiber of *i* food item
AM	Assamese Monkey/Macaque
BMR	Basal Metabolic Rate
BSA	Bovine Serum Albumin

BWS	Barail Wildlife Sanctuary in Assam, India
C	Climbers
cm	Centimeter
Carbo %	Carbohydrate %
Prot %	Protein Percentage
Ash %	Ash Percentage
Fat %	Fat Percentage
Fiber %	Fiber Percentage
Prox %	Proximate Percentage
Digestibility %	Digestibility Percentage
Prot: fiber	Protein: Fiber
CITES	Convention on International Trade in Endangered Species
CL	Capped Langur
i	Food item
CL*i*	Crude Lipid of *i* food item
CP*i*	Crude Protein of *i* food item
TNC*i*	Total Non-structural Carbohydrates of *i* food item
NDF*i*	Natural Detergent Fiber of *i* food item
DBH	Diameter at Breast Height
DB&H Lab'	Developmental Biology and Herpetology Laboratory, Dept. of Zoology, Mizoram University, Aizawl, India
DM	Dry Matter
DM %	Dry Matter Percentage
DTR	Dampa Tiger Reserve in Mamit, Mizoram, India
et al.	Latin: *et alii*/*alia* (and others)
e.g.	Latin: *exempli gratia* or for example
F&UFL	Fiber and Undigested Fragments of Leaves
Fig.	Figure
FS	Fecal Sample
g	Gram
GPS	Global Positioning System
GraphPad Prism	GraphPad Software, Inc. (Online ver.)
H Test	Kruskal–Wallis Test
hactare	Hactare
hr	Hour(s)
IUCN	International Union Conservation of Nature
IUSP, 1994	Indo–US Primate Project of 1994
IVI	Important Value Index
IWPA, 1972	Indian Wildlife Protection Act of 1972
i.e.	Latin: *id est* or that is
JoRF	Jokai Reserve Forest in Assam, India

K&BRB	Kaligandaki and Budhigandaki River Basin in Nepal
kcal	Kilocalorie
kcal/g	Kilocalorie Per Gram
kcal/day	Kilocalorie Per Day
kg	Kilogram
km	Kilometer
km^2	$Kilometer^2$
KNP	Kibale National Park in Uganda, Africa
L	Leaves
m	Meter(s)
m^2	Square meter
Mean ±SD	Mean ±Standard Deviation
min	Minute
ml	Milliliter
&	And
MNP	Madhupur National Park in north–central Bangladesh
MYA	Million Years Ago
n	Number of samples
nm	Nanometer
N	Nitrogen
NGOs	Non–Governmental Organizations
NLUP	New Land Use Policy (Scheme under the Govt. of Mizoram)
NNNR	Nonggang National Nature Reserve in Guangxi, Southwest China
NNP	Nyungwe National Park in Rwanda, Africa
NNR	Nonggang Nature Reserve in China
OD	Observational Data
PKWS	Phu Khieo Wildlife Sanctuary in Thailand
PNP	Phawngpui National Park in Mizoram, India
PSPP	Philadelphia Society for Psychoanalytic Psychology (Gnu's Not Unix–GNU Project 2015) (Ver. 1.6.2)
PWS	Pakhui Wildlife Sanctuary in Arunachal Pradesh, India
RBA	Relative Basal Area
RDen	Relative Density
RDom	Relative Dominance
RF	Relative Frequency
RKWS	Rema Kalenga Wildlife Sanctuary in Bangladesh
RM	Rhesus Macaque
r	Statistical Correlation
S	Shrubs
Sd	Seeds

Sig.	Significance (Pearson Correlation)
SFD	State Forest Department
Sh	Shoots
SNNP	Shivapuri Nagarjun National Park in Nepal
SNP	Satchari National Park in Bangladesh
SSP	Sri Surya Pahar, Goalpara in Assam, India
spp.	Latin: *species pluralis* in biological taxonomy
T	Tree
TEE	Total Energy Expenditure
TPT	Tham Pla Temple, Chiang Rai Province in northern Thailand
*	Denotes species consumed for AM
#	Represents species consumed for CL
*#	Consumed both for AM and CL
U Test	Mann–Whitney Test
R^2 Linear	Coefficient of Determinant
WG&SPG	Wild and Semi–Provisioned Groups
ver.	Version
viz.	Namely

GENERAL INTRODUCTION

The order primates originated some 65 million years ago, there has been ample time for change **(Szalay et al. 1987)**. The order Primates, constituting one of about 20 orders of placental mammals, is most closely related to the orders Scandentia (treeshrews) and Dermoptera (colugos). This order consists of lemurs, lorises, bushbabies, tarsiers, New World monkeys and Old World monkeys, apes and humans **(Groves, 2005)**. Lemurs, monkeys, and apes are a diverse order of mammals known as the primates **(Rowe and Myers, 2016)**.

1.1: Origin of Primates

It is hard to diagnose the order primates, because evolution is an ongoing process, and those features which characterized the ancestors of any group of organisms may well have changed in their descendants **(Rowe and Myers, 2016)**. The absence of long bone, dental and cranial specializations are the reasons primates are often described as retaining primitive mammalian characteristics and it partly explains why it has been difficult to arrive at a consensus in diagnosing the order **(Rosenberger and Hartwig, 2013)**. However, **Dos Reis et al. (2012)** suggested that they may be one of the oldest modern orders to appear, at approximately 68–82 mya. The New World monkey fossil record has accumulated in three or four distinct temporal and geographic zones **(Rosenberger et al. 2009)**. The fossil record of Old World monkeys mirrors the recent and robustness of the modern radiation. The earliest specimens are rare and date to the Miocene epoch in Africa, at which time hominoids dominated Old World primate biodiversity. Few other Old World monkeys have been found in the rest of the Miocene anywhere in Africa or Eurasia until an explosion of taxa appears in Pliocene deposits ranging from the tip of South Africa to Europe and insular Southeast Asia. The fossil history of the modern euprimate radiations dates to the Eocene epoch, approximately 55 million years ago (mya). The order primates as a monophyletic group reveals the morphological continuity that primates share with other mammalian orders, thus their more remote origins. This primate includes six major groups: lemurs, lorises, tarsiers, monkeys, apes and humans **(Fleagle, 1999)**. Primates are organized taxonomically into two broadly distinct, monophyletic groups, the Strepsirhini and Haplorhini. Living strepsirhines, the lemurs (lemuri forms) and lorises (lorisiforms), are in a sense lip–less. They have a dog–like snout tipped with a bulbous, moist, textured, glandular patch of vertically grooved skin that is continuous with the inner nostrils and also tethered to the gum and palate inside the mouth via a strip that runs through a wide gap situated between the upper incisors.

1.2: Modern Primates

Living haplorhines are the tarsier, New and Old World monkeys, apes and humans. They all have a more human like configuration of the nose and mouth, although nowhere among them are the lips off-colored, puffy and everted in the typical *Homo sapiens* fashion, a feature that perhaps evolved as a component of courtship behaviour. Living primates are concentrated in tropical and subtropical habitats of South America, Africa and Asia and dryer, more open country particularly in Sub-Saharan Africa. In tropical rainforests, primates rank high among the mammalian groups in terms of taxonomic diversity. In the trees, they are the most agile and acrobatic of all nonflying mammals, walking, running, leaping, hanging and swinging through the canopy aided by feet that grasp and mobile shoulders **(Rosenberger and Hartwig, 2013)**.

1.3: Research in Primates

Primates are valuable subjects for such studies for several reasons **(Marsh and Mittermeier, 1987)**. They are highly valued model animals, advancing our understanding of the evolutionary history of our species and providing insight into human behavior, cognition, parenting, cooperation, adult social bonds, forms of social conflict and resolution, learning and memory, and the evolution of tool use and language **(Fernandez–Duque et al. 2009; Hare, 2011; Thompson, 2013; Pontzer, 2015)**. Other than sharing a close evolutionary history with humans, primates contribute importantly to the biological and cultural richness and the natural heritage of the countries in which they occur, play key roles in ecosystem dynamics and sustainability and are central figures in local and regional traditional knowledge, folklore, history, and even economies **(Fuentes, 2012)**. It is our closest biological relatives; make a vital contribution to our planet. Not only do they provide a unique insight into human evolution, biology, behavior, or the emergence and transmission of infectious diseases **(Estrada et al. 2020)**, but they also perform key ecological functions, from pollinators and seed dispersers to maintaining community structures across multiple trophic levels **(Andresen et al. 2018; McConkey, 2018)**.

1.4: Global Primates

Across the globe, the most recent taxonomic compilation (as on April 2016) lists 701 extant taxa belonging to 504 species from 79 genera and 16 families. Primates occur in four regions—the Neotropics (171 species), mainland Africa (111 species), Madagascar (103 species) and Asia (119 species) and are present naturally in 90 countries **(Estrada et al. 2017)**. In the Indian subcontinent, there are three biodiversity hotspots *viz*; the Western Ghats, the Himalayas and the Indo–Burma regions, are hotspots of nonhuman primates **(Erinjery et al. 2015)**. 14 species of nonhuman primates occur in India–six species of macaques, five of langurs, two of lorises, and one species of gibbon **(Southwick and Lindburg, 1986)**. However, **Molur et al. (2003)** reported at least 24 species of primates that include; two species of lorises, 10 species of langurs, 10 species of macaques, and two species of small apes, with several of them being threatened or vulnerable. The Northeast India has the highest mammalian diversity in general and primates in particular **(Talukdar et al. 2021)**. The area falls under the Indo–Burma and the Himalayan global biodiversity hotspot **(Myers et al. 2000; Mittermeier et al. 2004; Talukdar et al. 2018)**. It is an extremely rich region for primate diversity with 13 of the 24 species including loris, macaques, langurs and small apes are found in the northeast **(Singh et al. 2020)**. All the eight primate species recorded in Mizoram state are also reported to occur from Dampa Tiger Reserve (DTR) which includes *viz*; Rhesus Macaque (*Macaca mulatta*), Assamese Macaque (*Macaca assamensis*), Stump–tailed Macaque (*Macaca arctoides*), Pig–tailed Macaque (*Macaca leonina*), Capped Langur (*Trachypithecus pileatus*), Phayre’s Leaf Monkey (*Trachypithecus phayrei*), Slow Loris (*Nycticebus benghalensis*) and Western Hoolock Gibbon (*Hoolock hoolock*) **(Sawmliana, 2013; Pachuau et al. 2013; Solanki, 2016; Parida, 2019)**.

1.5: Tropical distribution and feeding ecology of primates

Primates are confined in their distribution to the tropical and sub–tropical regions (23°N and 23°S) of Africa, Asia and Madagascar, Central and South America **(Gupta, 2000)**. Primates are first and foremost arboreal animals. Their success in the tropics is a function of the global distribution of wet dense forests and the multiple vertical levels of exploitation they provide. No living primate species except for humans is so exclusively adapted to a terrestrial lifestyle that its arboreal ancestry has been almost erased from the locomotor system **(Rosenberg and Hartwig, 2013)**. Primates are prey, predator, and mutualist species in food webs and thereby influence ecosystem structure, function, and resilience. Their evolution, feeding ecology, and geographic distribution are closely linked to the diversification of angiosperms, a principal source of food (pollen, nectar, fruits, and seeds) **(Sussman et al. 2013)** for many animals and humans **(Lambert, 1998; Koné et al. 2008; Heymann, 2011)**. Like all animals, primates required a full complement of carbohydrates, protein and lipids for growth, development, survival and reproduction. Primates acquisition of food resources is one of the most significant selective pressures affecting their biology and to meet nutritional requirements must be balanced with avoiding predation and securing mates, and thereby influences primate physiology, ecology, activity, movement, and social relationships. The universal adaptive zone of primates involves tropical arboreality based on a core, frugivorous diet, that is, a body plan that allows manoeuvrability in the trees in order to acquire its most prodigious, easily edible products and fruits **(Rosenberg and Hartwig, 2013)**.

Food resources influence the ecology and distribution of primates has been a central question of primate research since the first field studies began, and a critical problem involves temporal and spatial changes in food availability **(Chapman et al. 2012)**. Animal allocates their active time for various activities which provides a useful foundation to its overall ecological approach. Study on the activities of animals help the researchers to identify how they interact with the environment and also frame strategies for maximizing the energetic and reproductive success **(Defier,**

1995). The optimum utilization of resources by an animal in the habitat is paramount for their survival and reproduction **(Janson, 1992)**.

In terms of foraging, primates may decrease day range and/or time spent traveling during food shortages **(Boinski, 1987)**. Or, primates may increase day range length **(Barton et al. 1992; Overdorff, 1993)**, traveling and/or foraging time **(Milton, 1980; Garber, 1993; Gursky, 2000)**, and home range size **(Clutton–Brock, 1977)** during times of scarcity. Primates also change locations by moving among habitats and out of their regular home range in search of more resource–rich areas. The Old World monkeys have filled semi–terrestrial and marginal habitat niches as well as island and temperate latitude biomes, also managed to adapt to the fringes of human habitats, as in the case of baboons along safari trails and langurs living among temple ruins in India. They occupy tropical forest habitats and segregate themselves across genera according to preferences for different vertical zones in the canopy, different food parts and different ‘fallback’ foods to tide them over the lean seasons. This is facilitated largely by having evolved body size and locomotor variety. Of all the primate groups, Old World monkeys show the most flexibility for habitat preference and considered the most abundant and ‘successful’ of the modern primate groups, given their history of opportunistic colonization, geographic migration and climatic tolerance **(Rosenberg and Hartwig, 2013)**.

1.6: Plant feeding strategies and type of classifications

Feeding time may be reported as a percentage of all daily activities or as a percentage of feeding time and based on the classification of primates on the basis of feeding strategies, such as folivory or frugivory, appears straightforward and rational. Food and foraging for food are clearly involved in the psychological well–being of captive nonhuman primates. Young and mature leaves, petioles, shoots and other plant parts are eaten with various degrees of preference. Fruit–eaters sometimes consume only the pulp and spit out the seed, or they might consume the whole fruit and digest the pulp and seeds or pass the seeds intact in the feces. Some fruit is consumed only for the seeds, and the pulp and pod or husks are discarded. Gummivores (gum eaters and sap–eaters) tend to feed heavily on one or a few species of trees. Most primates are frugivores, but none consume diets entirely of fruit. Fruit intake is augmented with variable proportions of invertebrates, vertebrates and other plant parts, including leaves, flowers and exudates **(NRC, 2003)**. The gastrointestinal tracts of primates in this broad group exhibit little structural specialization, but variations among species have been described **(Chivers and Hladik, 1980)**. Reproduction of gummivore diets is facilitated by information on the chemistry of the preferred exudates **(NRC, 2003)**. It has been shown that food and nonfood items can be used in ways that stimulate natural feeding behaviors, extend feeding activity and inhibit stereotype **(Fajzi et al. 1989; Knapka et al. 1995)**. Acquisition of nutrient needs required in wild primates spends 25%–90% of their wake hours in foraging for and consuming food **(Clutton–Brock and Harvey, 1977)**.

Foraging enrichment can be used to disperse animals, occupy their time and reduce tension and aggressive interactions **(Boccia, 1989)**. **Kurihara and Hanya (2015)** defined food unit as each feeding item (one fruit, one leaf, one cluster of fruits, etc.) in which recording is repeated as many times as possible when focal animal feeding is observed where the food patch is counted as one individual tree or liana in which the focal animal fed. In the wild, primate diets are diverse and include leaves, stems, flowers, fruits, seeds, gums, insects, spiders, lizards, eggs, and other animal matter. The items selected vary with the species, and the proportions selected can vary from month to month without a clear association of the selections with seasonality of the habitat **(Chapman and Chapman, 1990)**. Precisely gathered information on natural dietary habits is scarce and field studies that include quantitative nutrient–intake data are exceedingly rare. Data gathered at different sites over time to account for location and seasonal differences and in which food use has been quantified and food composition determined can provide guidance for the development of rational captive dietary systems **(Clutton–Brock and Harvey, 1977)**.

1.7: Plants phenology and effects of seasonality

Phenological monitoring has revealed spatial and temporal variation in the availability of ripe fruits and young leaves in practically all forests studied **(Van Schaik et al. 1993; Fenner, 1998; Jordano, 2000; Van Schaik and Pfannes, 2009)**. Availability of young leaves and flowers appears to be determined in large measure by climatic variables and often concentrated in the months following maximum insolation **(Van Schaik et al. 1993)**. The timing of peaks in fruit availability across sites is not as strongly correlated with climatic variables. However, with increasing seasonality, the interval between flushing and fruiting peaks decreases and this may have implications for consumers. Fruit availability can vary markedly between adjacent sites in similar forests **(Chapman et al. 1999)** and between years. A variable food supply is the norm for consumers in tropical as well as temperate regions, and primate face often marked spatiotemporal changes in the availability of their major food types **(Hemingway and Bynum, 2009)**.

In a seminal review of phenological patterns and their implications to vertebrate consumers, **Van Schaik et al. (1993)** identified six responses to food scarcity: occasional famine and mass mortality, dietary switching, seasonal breeding, seasonal movements, altitudinal migration, and hibernation. The range of behavior and physiological responses exhibited by primates is impressive, encompassing all those described for vertebrates **(Hemingway and Bynum, 2009)**. Dietary switching, *i.e.* feeding on alternative resources, can take several forms: (i) switching between food categories (*e.g.*, Japanese macaques consume primarily fruit, seeds, leaves, or animal matter, each food type at a different time of year **(Hill, 1997)**; (ii) switching to a different item within a food category (*e.g.*, gibbons select a different set of fruit species when fruit availability is low in central Borneo **(McConkey et al. 2002)**; and (iii) relying on keystone species as defined by authors (*e.g.*, capuchins rely on palm seeds to see them through fruit scarcity periods in Manu, Peru **(Terborgh, 1983)**. A change in diet composition is usually accompanied by a change in dietary breadth: the number of species consumed by primates may increase **(Oates, 1977)** or decrease **(Struhsaker, 1975)** during food scarcity. Overall, primate species that are 'frugivores' or fruit–preferring occur in ecosystems that support fruit bearing trees, 'folivores' or leaf–preferring occur in ecosystems with high abundance of trees with edible leaves and ‘insectivores’ or insect-preferring occur in ecosystems that sustain insects **(Erinjery et al. 2015)**. Fruits became larger and more colorful, more appetizing to primates and highly stimulating to the food chain of a diversifying arboreal fauna that included massive arrays of insects and arthropods **(Rosenberg and Hartwig, 2013)**. Frugivorous primates would have probably established a firm role as angiosperm seed dispersers instead of consumers, as the trees themselves began to produce large, attractive pulpy fruits as food in order to have their seeds swallowed (not chewed) and carried away whole to the next feeding site and beyond **(Rosenberger, 2010)**. Primates have evolved specializations to consume fruit, seeds, leaves, insects, gums, or most often a mixture of these dietary items. Each food source exhibits significant structural and chemical differences which influence primate foraging strategies and feeding adaptations.

1.8: Adaptability by body size, locomotion and habitat

Body size has a fundamental influence on all physical and physiological properties of an organism **(Gould, 1966; Peters, 1986; Schmidt–Nielsen, 1975)**. Primate diet is affected by body size and different primate species have developed a variety of strategies to ensure that they ingest sufficient calories and nutrients. For this reason, primates can be folivorous, frugivorous, insectivorous, faunivorous, gramnivorous or omnivorous **(Serio–Silva et al. 2008)**. Primate breakthrough as a shift in diet is followed by a euprimate innovation in locomotion **(Szalay et al. 1987)**. Depending on body size, primates have developed a suite of strategies to cope with the particular challenges of arboreal locomotion. Primates have never become highly adapted to specific functions but have always maintained great flexibility and adaptability in their behavioral responses to the changing conditions of their environment **(Schmidt, 2010)**. Evidence suggests that environmental conditions can influence the frequency in occurrence of some of these compounds, or the amount present in particular food items **(Chapman et al. 2012)**. The angiosperm coevolution hypothesis, elaborated by **Sussman (1991)**, sees the order as an ecological partner involved in contributing to the rise of woody, fruit–bearing trees that began their own success contemporaneously, aided by primates who would eventually serve as major seed dispersers of these plants.

1.9: Locomotor behavior of primates

Behavioral diversity in primates seems to be to differentiate between the five main types of locomotor behaviour. These are quadrupedalism, climbing, leaping, suspension and bipedalism. Primates are very active animals and members of the subfamily Cercopithecinae descend from a primarily terrestrially adapted precursor, but many living species have returned to an arboreal lifestyle. The locomotion of macaques (*Macaca*) is almost totally quadrupedal walking and running, with very little leaping and no suspensory behaviour. Limb mobility is also higher in these mostly arboreal primates such as; African guerezas (*Colobus guerezas*) and the Asian langurs, leaf monkeys and proboscis monkeys (*Semnopithecus, Presbytis, Pygathrix, Trachypithecus* and *Nasalis*) all are good leapers **(Schmidt, 2010)**.

1.10: Nutritional composition of food plants

Information on the nutrient composition of foods and feed ingredients is essential for formulating feeds and diets to meet the nutrient requirements of nonhuman primates **(NRC, 1998)**. Variability of nutrient composition of a specific feed ingredient is a function of several factors, including growing and harvest conditions, processing and storage influences and nutritional status of the organism. Investigating the chemical basis of dietary selection in primates has provided a unique understanding of their foraging strategies **(Whiten et al. 1991)**, facilitated evaluations of socioecological explanations of social organization **(Byrne et al. 1993)** and provided means to explore determinants of abundance **(Oates et al. 1990; Chapman et al. 2002)**. The requirement estimates apply to primates fed purified or semi–purified diets and assume a high nutrient bioavailability, little to no adverse interaction of nutrients and an apparent metabolizable energy of dietary in dry matter. Energy requirements, as estimated by a variety of techniques. Quantitative data on liquid–water consumption are available for few species of nonhuman primates **(NRC, 2003)**. Primate folivore have a variety of physical adaptations that promote, through symbiotic microbial fermentation and mechanical action, the degradation of the structural and chemical defenses of plants. The two principal adaptations involve enlargements of the stomach or the hindgut to accommodate microbial fermentation **(Parra, 1978; Langer, 1991)**. The extent of gastrointestinal tract modification is related to the proportions of plant parts (leaves, seeds and fruits) consumed **(NRC, 2003)**. Starchy and fatty fruit alone, either the pulp or rinds, cannot provide all the nutrients required, so the first primates must also have supplemented their diet with specific additives to provide protein, such as insects or seeds **(Rosenberg and Hartwig, 2013)**. Most foods contain some water, and water in the edible portions of cultivated fruits and vegetables generally makes up 80–95% of their mass **(NRC, 1989; Holland et al. 1991)**. Preformed water in the foods of free–ranging non–human primates can be as little as about 2–3% of air–dried seeds in hot deserts or over 70% of the fresh weight of succulent plant parts in a tropical rainforest **(Baranga, 1982; Calvert, 1985; Rogers et al. 1990; Barton et al. 1993; Robbins, 1993; Edwards, 1995)**. Small species of nonhuman primates might have higher water requirements; according to **Lunn (1989)** observations on 161 adult common marmosets (*Callithrix jacchus*) that it consumes water per day (mean of 11.7 ml). Few studies of carbohydrates in wild food plants have identified or measured the specific carbohydrates found in plant parts consumed by free–ranging primates. In some instances, analytic procedures were used to measure concentrations of moisture, crude protein, ether extract, ash, NDF, ADF, and ADL in consumed plant parts on fresh basis **(NRC, 2003)**.

Nitrogen (N), in the form of amino acids, is the fundamental building block of protein and plays a central role in metabolic processes, cellular structure, and genetic coding. For this reason, nitrogen has been proposed as a limiting factor for the growth, health, reproduction, and survival in many organisms **(Mattson, 1980)**. Although some researchers have suggested that primates aim to maximize protein intake by careful selection of food items (various colobine species, **McKey et al. 1981; Waterman et al. 1988; Barton and Whiten, 1994)**, rarely there is a conclusive pattern suggestive of protein maximization **(Felton et al. *in press*)**. **Milton (1979)** suggested that to understand the food preferences of herbivorous primates, the relative amount of plant cell wall material in diets should be considered. Plant cell wall material is often referred to as 'dietary fiber' and is composed primarily of cellulose, hemicellulose and lignin **(Cork and Foley, 1991)**. Because most animals lack the appropriate enzymes to digest cell walls, they must rely on gut micro–organisms to hydrolyze components of dietary fiber for the production of short–chain fatty acids and microbial protein **(Cork and Foley, 1991; Clements et al. 2009)**.

Diet quality is thus defined as the ratio between protein and dietary fiber. This ratio has been found to be a useful indicator of whether or not certain folivorous primate species choose to consume a particular leaf. Although these studies indicate that leaf choice by some primates is positively related to a high ratio of protein to fiber, many exceptions occur. Leaf types with low protein: fiber ratios may be preferred under some circumstances **(Oates et al. 1990; Mowry et al. 1996)**, and rejected leaf types can have high protein: fiber ratios **(McKey et al. 1981)**. Although correlations have been found between the protein: fiber ratio and the types of foods selected or preferred, the value of the approach needs careful evaluation in conjunction with complementary analytical procedures **(Felton et al. 2009)**. Crude fiber (CF), as measured in the 19th century Weende procedure, is the insoluble organic residue remaining after sequential treatment of samples with acid and alkali to mimic digestion in the human stomach and intestine. Crude fiber was intended to represent the fibrous fraction of the plant cell that was indigestible **(NRC, 2003)**.

1.11: Energy dynamics and digestibility of primates

Notably, few studies quantify digestible or metabolizable energy, that is, the fraction of the ingested energy that is available for the animal to use **(Conklin–Brittain et al. 2006)**. Instead, researchers normally multiply each macronutrient fraction with a standard caloric factor and thus obtain gross energy content of the food **(NRC, 2003)**. Because gross energy does not represent the energy available to an animal **(Robbins, 1983)**, it is preferable to estimate the digestible and/or metabolizable energy concentrations of different foods **(Felton et al. 2009)**. The ingestion of one diet item can affect the digestion of another item **(Bjorndal, 1991; Villalba and Provenza, 2005)**; the value of one food type cannot be assessed in isolation of other food items eaten. In the concept of nutrient balancing, both digestible foliage and fruits rich in ready energy constitute high–quality food items when eaten in combination **(Milton, 1982)**. Several studies indicate that nutrient balancing may be a fundamental aim of wild primates. For example, **Davies et al.**

(1988) found that two colobine species selected leaves if they had high protein: fiber ratios, but selected seeds on the basis of high lipid concentrations and high digestibility **(Felton et al. 2009)**.

The daily energy intake was estimated by multiplying the monthly energy intake rate (energy intake/observation time) by the monthly mean day length **(Kurihara et al. 2020)**. The available energy content was calculated following the formula used by **Nakagawa (1989, 1997; Tsuji and Takatsuki 2012**, **Heesen et al. (2013)**.

$\text{Available energy content}i = (9 \times \%\text{CL}i + 4\times \%\text{CP}i + 4 \times \%\text{TNC}i + 3 \times \%\text{NDF}i) \times (\text{Digestibility}i - \text{Energy lost in urine})/100$.

Where, CLi = crude lipid of i food item, CPi = crude protein of i food item, TNCi = total non-structural carbohydrates of i food item and NDFi = natural detergent fiber of i food item.

Physiological fuel values of CL, CP, TNC and NDF were 9 kcal/g, 4 kcal/g, 4 kcal/g and 3 kcal/g, respectively **(NRC, 2003)** and the energy lost in urine was 4% **(Nagy and Milton, 1979)**. Then, the $\text{digestibility}i = - 1.10 \times \%\text{ADF}i + 98.15$ equation derived from data in **Sawada et al. (2011)**.

Total energy expenditure (TEE) as the daily energy expenditure. Body size is the main proximate determinant of TEE, both within and between species; physical activity, genetic variation, and endocrine regulation explain substantially less of the variation in TEE. Basal metabolism is the single largest component of TEE, far exceeding the cost of physical activity, digestion, growth and reproduction, and thermoregulation in most instances. TEE is the total amount of energy used for function of the body's organ at rest (BMR), physical activity, growth, reproduction, immune function, digestion, and thermoregulation **(Pontzer, 2015)** wherein, $\text{TEE} = 121.13 \times (\text{Body Mass})^{0.77}$. The use of TEE values provided by **Sha et al. (2018)** was considered feasible in their study (TEE was 533.6 kcal/day) by **Kurihara et al. (2020)**, thereon they assumed that TEE was maintained within a narrow physiological range (constrained energy model, **Pontzer et al. 2016**). Mass–adjusted TEE didn't differ between captive and wild populations **(Pontzer et al. 2014)** or among seasons **(Nagy et al. 1999; Sha et al. 2018)**.

1.12: Habitat evaluation for nutritional status of food

Global primates are threatened; therefore, it is important to know the determinants of primate population dynamics. It is widely reported that food plant diversity and nutrients are key determinants of many primate population dynamics **(Wang et al. 2022)**. The availability of food resources is a main indicator for habitat quality. Changes in food availability are a driving force of changes in primate populations **(Rode et al. 2006; Worman and Chapman, 2006; Mammides et al. 2009)**. The density of frugivorous primates is related to the presence of preferred food trees **(Worman and Chapman, 2006)** and influenced by food availability measured as the richness **(Mammides et al. 2009)** or the density **(Mbora and Meikle, 2004)** of food trees. Other studies of arboreal frugivorous primate species showed that food abundance and distribution also influenced ranging patterns as well as frequency of habitat use **(Olupot et al. 1997; Moscovice et al. 2010)**. Overall, understanding the distribution patterns of food resources and maintaining viable food trees for primates are crucial factors in primate conservation **(Mwavu and Witkowski, 2009)**. Food consumption in the wild is largely influenced by seasonality, habitat quality**,** food abundance and distribution **(Jaman and Huffman, 2013)**. Food abundance and distribution can directly determine primate ranging patterns and home range area **(Simmen et al. 2014; Ning et al. 2019)**. Primate nutritional ecology involves the interactions between the environment and a primate’s nutrient intake, and the individual’s resultant physiological state. It is a diverse field that includes physiology **(Ross, 1992)**, morphology **(Vinyard et al. 2003)**, ontogeny, growth, development **(Leigh, 1994)**, and ecology (*e.g.*, **Oates et al. 1990**). Underpinning all aspects of nutritional ecology is the need for individuals to procure appropriate quantities of certain macro- and micro-nutrients from their habitat. This requirement is not uniform among different species or individuals but may vary depending on factors such as body size, metabolic requirements, lifestyle, and digestive system **(Parra, 1978; Milton, 1993)**. Thus, different species may prioritize different nutritional parameters when choosing the types and quantities of foods they consume **(Felton et al. 2009)**.

Understanding determinants of primate abundance is becoming increasingly important as ecologists are asked to apply their knowledge to assist conservation biologists to construct informed management plans for endangered species. The importance of these theoretical issues has become critical because most primates live in tropical forests which are increasingly being impacted by human modification **(NRC, 1992)**. Cumulatively, countries with primate populations are losing 125140 km^2 of forest annually, resulting in the annual loss of 32 million primates **(Chapman and Peres, 2001)**. These populations are also being seriously harmed by forest degradation, particularly logging and fire, and hunting. Understanding the nutritional requirements of an endangered species can assist in the development of sound conservation and management policies. For example, if important tree species could be left standing in selective logging operations, population declines following logging might be lower and/or the speed of recovery might be more rapid for those species negatively affected by logging. Often authors do not report details about sample collection, making it impossible to assess whether samples were collected from the tree in which the animals fed or in different trees in the same area, or if they were collected at the same general time the animals fed on the item or at a different time **(Chapman et al. 2002)**. Quantifying food diversity and nutrients is the essential to explore the interaction mechanism between animals and habitats **(Deng and Zhou, 2018)**. An adequate nutrition in the habitat is necessary for survival and reproduction of individual non–human primates, influencing the growth of populations **(Rothman and Bryer, 2019)**.

Thus, to conduct primate nutritional studies efficiently and to provide new tools for primate conservation, it is necessary to assess the diversity and richness of nutrient–rich food plant species in the natural habitat utilized by primate groups. Thus, the nutritional status of food in the habitat requires coping with dietary needs, as a result this work intend to provide new insight to detail assessment of nutritional food plants for studied animals. Therefore, neither the feeding behaviors/ecology nor potential relationship of nutritional ecology for AM and CL is investigated in detail. The present works dedicate to provide such ecological based research works of these study animals from DTR, Mizoram, India for the first time.

1.13: Plausible threats of primates globally, including DTR

According to the recent assessment report using information from the IUCN by **Estrada et al. (2017)**, it was estimated that ~60% of primate species from all 16 extant families are threatened with extinction because of unsustainable human activities. Threats to primates are widespread: 87% of species in Madagascar are threatened, as are 73% in Asia, 37% in mainland Africa, and 36% in the Neotropics. The populations of 75% of primate species are decreasing globally. The IUCN Red List showed that the two main threats to primates worldwide are Biological Resource Use (including Hunting and Logging) and Agriculture. In particular, the loss of tropical forests, home to most primate species, is one of the main factors contributing to their decline **(Hanski et al. 2013; Estrada et al. 2017)**.

The IUCN indicates that the main threats to primate species are loss of habitat due to agriculture (76% of species), logging and wood harvesting (60%), and livestock farming and ranching (31%), as well as direct loss due to hunting and trapping (60%). Other threats, such as habitat loss due to road and rail construction, oil and gas drilling, and mining, affect 2 to 13% of primate species, and there are also emerging threats, such as pollution and climate change. Globally, agriculture is the principal threat, but secondary threats vary by region. Deforestation, hunting, illegal trade, and wood extraction are leading to a worldwide impoverishment of primate fauna. **(Estrada et al. 2017)**. Many primate species are increasingly threatened by legal and illegal unsustainable trade. Primates are traded for consumption, biomedical research, zoo and wildlife collections; as pets; for the sale of body parts (bodies, skins, hair and skulls) used in traditional medicine; as talismans and trophies; and for magical purposes **(Alves et al. 2010; Nijman et al. 2011)**.

Deforestation due to the establishment of rubber plantations in India is reported to have severely affected the Bengal slow loris (*Nycticebus bengalensis*), the western hoolock gibbon (*Hoolock hoolock*), and Phayre's langur (*Trachypithecus phayrei*) **(Fan et al. 2014; Mazumder, 2014)**. Moreover, human population growth and associated increases in human activities, such as urban expansion, hunting, trade, logging, climate change, diseases transmission, fossil fuel extraction, mining, infrastructure development, tourism, and threats to human–primate coexistence (including persecution killing) jeopardize primate existence, as many countries struggle to balance economic development with biodiversity protection **(Estrada et al. 2017, 2020; Li et al. 2018; Boonratana, 2020)**. Besides this, a recent global assessment suggests that numerous primates will experience changing climatic conditions during the 21st century, with the Amazon, the Atlantic Forest of Brazil, Central America, East and Southeast Asia considered hotspots of climate change–induced primate vulnerability **(Graham et al. 2016)**.

In the present work, DTR refers mainly to the core area, while the core area and surrounding buffer zone together are referred to as the Dampa landscape. The population is predominantly tribal, with people of Lushai, Riang (Bru), and Chakma communities **(Census of India, 2011** *http://www.censusindia.gov.in/2011census/population_enumeration.html***)**. Large parts of DTR's buffer zone have been converted to Forest Department plantations of teak (*Tectona grandis*), established since the 1980s or earlier, and oil palm (mainly *Elaeis guineensis*) monocultures, established from 2006–2007 onward **(Raman, 2014)**. The expansion of monoculture plantations, such as those of oil palm and rubber, at the expense of forests and multicrop agriculture is affecting the conservation of biological diversity over large parts of the world's tropics **(Fitzherbert et al. 2008; Harvey et al. 2008; Warren Thomas et al. 2015)**. Jhum is a better form of land use than monoculture plantations, and the denser and more diverse forest mosaic that it creates also helps to retain a significant fraction of forest birds in the landscape. As a form of land use, jhum therefore deserves to be supported as a better option for the buffer zone around Dampa, as noted by the reserve's management plan **(Zathang and Sharma, 2014)**. The Serhmun village which was located at the north of the Teirei Range relocated in 2017. Besides, jhuming and other monoculture plantations of oil palm, teak and rubber recently, a commercially benefitted and introduced by the native in the Dampa is monoculture plantation of the betel (*Areca catechu*).

To minimize the impact of monoculture plantations and enhance their conservation value, regulations and international best–practice guidelines need to be adopted in the region. This could include strictures to retain forest patches along ravines, riparian buffers, and ridgelines, integrate native shade trees and natural vegetation such as hedges between rows or fields of oil palm, and prohibit the establishment of plantations in areas of high conservation value, especially around conservation reserves **(Mandal and Raman, 2016)**.

1.14: Measure for mitigation and conservation

Primate conservation needs a greater focus on the creation of new protected areas and on improving enforcement of current protected areas to safeguard preferred habitats, reduce habitat fragmentation and prevent illegal hunting and collection of primates. There is evidence that that improving enforcement of protected areas is more effective than most other initiatives **(Junker et al. 2020a; 2020b)**. In order to prevent the extinction of a significant percentage of primates, empirical information about primates and their habitats was required. In 1994, Srivastava and his team set up an integrated, collaborative Indo–US Primate Project to conduct systematic status surveys, record fragmentation of primate habitats and develop eco–ethological profiles of individual species to provide a basis for the conservation and management of primate habitats and species living therein **(Srivastava, 2006)**. Conservation community and primate range states must put considerable effort into effectively supporting the sustainable use of natural resources for communities living alongside primate populations, as well as alternative livelihoods and co–developing strategies to improve human–primate coexistence in shared landscapes **(Fernández et al. 2022)**. Thus, conservationists working to reduce threats to primate populations must collaborate closely with local people to develop site–specific guidelines and facilitate their long–term adoption **(Chan et al. 2007)**.

The first being that primates have always retained a strong tie with the arboreal environment with some spend considerable time in trees (Macaques) when resting or searching and consuming food (**Schmidt, 2010)**. It is noteworthy to present a variety of features that have little or nothing to do with locomotion or feeding as it is reflected by anatomical specializations that enable unique access to a type of food acquired by travelling in a certain way through a particular habitat. Such conditions can make primates very successful predators, even on other primates **(Rosenberg and Hartwig, 2013)**. Based on the current study on account of nutritional ecology, it would be crucial to highlight and point out distinct dissimilarity and basic physical characters between the two study primate species of DTR, Mizoram, India.

1.15: Physical morphological description of study animals

(i) Assamese Monkey (AM)

Assamese monkey resembles the Rhesus monkey having a brownish–grey to yellowish–grey coat, which is uniform in pelage, lacks a pinkish face and absence of red loins/buttock. It has darker fur in exposed area while whitish-blonde haired to ashy-white in abdominal and inner parts. Male has dark purple (egg–plant color) snout particularly around the nose while female has crimsoned red to pinkish red around the eyes and cheeks. Local saying appropriately reflects the fur color variation within a group as this species is called 'Missal'- means mixed color. The palm, sole and nails are dirty brown/black in color. The ischial callosities in male are conspicuous from a distance and distinct in darker individuals. In higher elevation, the animals are with darker fur on back and whitish in abdominal parts resembling Tibetan monkey **(Chalise et al. 2013)**. The Assamese monkey is a large sized monkey weighing from 5–10 kilograms with a range of 51–73.5 cm with 15–30 cm long tail. It is a diurnal animal feeds on vegetables, cereals, twigs, and invertebrates with arboreal habit **(Chalise, 2000, 2003; Menon, 2003)**.

(ii) Capped Langur (CL)

Capped langur, *Trachypithecus pileatus* (Blyth 1843) belong to Cercopithecidae family and has four recognized sub–species (IUCN Red List) *viz*; *Trachypithecus brahma*, *Trachypithecus durga*, *Trachypithecus tenebricus* and *Trachypithecus pileatus*. These are diurnal, arboreal and folivorous animals, but fruit is also a major component of the diet, occurring in a wide range of habitat and behaves differently in order to maintain time–energy balances **(Watanuki and Nakayama, 1993; Menon and Poirier, 1996; Li and Rogers, 2004)**. Physical description was based on coloration, body size, and development of sexual characteristics following earlier established physical descriptions **(Ulibarri and Gartland, 2021)**. *Trachypithecus pileatus* is indigenous to the north eastern part of India **(Srivastava, 1999)**. Its global distribution is limited to Bangladesh, north–western Myanmar, Bhutan, southern China and north eastern states of India **(Stanford, 1991; Ahsan, 1994; Srivastava, 1999)**. The Capped langurs live in a diverse array of habitats, the biology and behaviour of this primate has not been studied except by Stanford **(Stanford, 1991)** in Bangladesh, **Solanki and Kumar (2010)** in Arunachal Pradesh and a short study by **Gupta (1994); Alfred et al. (1998)** in Tripura, **Decemson et al. (2018)** in Mizoram, **Borah et al. (2021) and Bharbhuiya et al. (2022)** in Assam, India. Degraded state of their habitat brings about survival challenges to them and this constraint exerts pressure on the animal for budgeting its available time in the most efficient manner **(Pyke et al. 1977; Altmann, 1980)**.

1.16: Statement of the problem

Until recently, the present study site DTR became the center of working field site for wildlife research. Nonetheless, minor work was done on aspects of the distribution, abundance and habitat ecology for DTR primates from previous workers like; **Pachuau et al. 2013** (Hoolock gibbon); **Solanki, 2016; Decemson et al. 2018** (Phayre's Leaf Monkey and Capped Langur) and **Parida, 2019** (Phayre's Leaf Monkey). However, no work on the nutritional ecology for AM and CL of DTR was carried aptly so, research on nutritional aspect for these two animals was carried out.

OBJECTIVES

The following objectives were carried out the proposed work on nutritional ecology of selected primate species at the study site in DTR, Mamit district, Mizoram, India:

1. To study the food plants preference and the composition of the diet.
2. To analyze chemical compositions in food plants and fecal matter.
3. To study the energy dynamics and digestibility.
4. To evaluate the habitat for nutritional status of food.

CHAPTER 1: FOOD PLANT PREFERENCES AND DIETARY COMPOSITIONS

I. INTRODUCTION

A diet or selection of food is an important trade in an animal life. Primate food consumption in the wild is largely influenced by seasonality, habitat quality, food abundance and distribution **(Jaman and Huffman, 2013)**. An 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 and Chalise, 2014; Koirala et al. 2017; Khatiwada et al. 2020)**. Understanding the temporal availability of food to a particular species is crucial when examining the drivers of their feeding strategies. Foraging can be defined as the behavior activity in which monkey searches for food or wanders in search for food including eating any substance, licking stone, drinking water and slight movement in search of food **(Chalise, 2013).** Feeding is defined as the chewing, ingestion and swallowing of food. When visibility conditions allowed for the observation of feeding without interferences from surrounding vegetation for the focal animal sample and combined with continuous recording when a subject are observed feeding **(Altmann, 1974)**. Therefore, the underlying factor is to record primates food intake (*i.e.,* the amount of food consumed by an individual) in the wild which is a crucial measure for studying feeding behavior, however its measurement requires high visibility of individuals and long recording sessions, these are mostly tough accomplishment under field conditions **(Reynoso–Cruz et al. 2016)**.

Assamese macaque (*Macaca assamensis*) of the genus '*Macaca*' is one of the most widely distributed non-human primate species distributed in Bangladesh, Bhutan, China, northeastern India, Lao People's Democratic Republic, Myanmar, Nepal, Thailand and Vietnam. This species is diurnal and omnivorous, and at times both arboreal and terrestrial. **(Boonratana et al. 2020)**. They live in many different habitats in tropical and subtropical semi–evergreen forests, dry deciduous and montane forest including monsoon evergreen broadleaf forest, deciduous broadleaf forest, mixed broadleaf and conifer forest, and conifer forest between 200 m and 3100 m above sea level **(Zhang et al. 1997; Srivistava and Mohnot, 2001; Timmins and Duckworth, 2013; Boonratana et al. 2020)**. It prefers dense forest **(Choudhury, 2001)**, and does not usually occur in secondary forest. Some studies have been undertaken on the diet of Assamese macaques in the highlands of Nepal, Bhutan and India, and have concluded that they are primarily folivorous **(Ahsan, 1994; Chalise et al. 2003)**. 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 according to the Indian Wildlife Protection Act (IWPA), 1972. 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 and Chalise, 2014; Koirala et al. 2017; Boonratana et al. 2020; Khatiwada et al. 2020 and Ghimire et al. 2021)**. 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)**. 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 are 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. 2011; Jaman and Huffman, 2013; Ghimire et al. 2021)**.

Capped langur (*Trachypithecus pileatus*) has a global distribution including Bangladesh, Bhutan, India, Myanmar, Tibet, and China. **(Srivastava, 1999; Groves, 2001; Groves et al. 2013; Choudhury, 2014; Das et al. 2020; Khan et al. 2022)**. In India, the species is confined in the north-eastern states including the Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland and Tripura **(Choudhury, 1989, 2012, 2014; Das et al. 2020; Khan et al. 2022)** and it is the most common langur species in north–eastern India **(Choudhury, 2001)**. They are most commonly found in tropical and subtropical wet evergreen forest, broadleaf, moist deciduous, bamboo forests, teak plantations and sub-montane forest **(Srivastava and Mohnot, 2001; Choudhury, 2001, 2014; Das et al. 2020)**. It ranges from the low plains (10 m above sea level in Tripura, but as low as 5 m in Bangladesh) to 2800 m in Nagaland and the eastern Himalaya (there is an extreme record at 3000 m in temperate forest, near Thungri, West Kameng district in Arunachal Pradesh) **(Choudhury, 2012, 2014)**. Capped langur (CL) species is reported diurnal, predominantly arboreal and folivorous **(Molur et al. 2003)**. It is primarily folivorous, preferring fruiting trees and a variety of other food items, including flowers **(Choudhury, 1989; Stanford, 1991; Solanki et al. 2008a; Choudhury, 2012; Khan et al. 2022)**. Environmental factors influence their diet, including the condition of their habitat and the availability, quality, dispersion, and abundance of resources **(Ganguli et al. 1964; Tejwani, 1994)**, primates change their feeding strategy based on the availability of specific resources **(Chapman, 1988)**, and the dietary composition is largely influenced by seasonal abundance of resources **(Remis, 1997)**. According to the IUCN Red List of Threatened Species it is classified 'Vulnerable' species and listed as an Appendix I species under the CITES **(Das et al. 2020)** and according to the IWPA, 1972 classified Schedule I under Part I **(Srivastava and Mohnot, 2001; Das et al. 2020)**. Population declines have been attributed to habitat destruction such as tree felling, jhum cultivation, monoculture plantations, timber and firewood harvests, and other development **(Molur et al. 2003)**, encroachment, and hunting **(Choudhury, 2014)** as well as trade for meat and as pets **(Molur et al. 2003; Das et al. 2020)**. CL diet has been studied in Bangladesh **(Islam and Husain, 1982; Stanford, 1991; Kabir, 2002; Khan et al. 2022)** and India **(Solanki et al. 2008a, Solanki et al. 2008b; Choudhury, 2012)** with a focus on food items, plant species and habits in undisturbed forests.

In recent years, the landscapes of Northeast India have witnessed swift alteration in the form of reduction of primary forest, shifting cultivation, mono-plantations, forests fire, habitat fragmentation due to constructions, etc. threatening the primate diversity of the region **(Choudhury, 2001; Srivastava, 2006; Choudhury, 2011; Mazumder et al. 2014)**. Dampa Tiger Reserve harbors several species of primate that inhabits in the forest very close to the buffer areas and thereby has high chances of encroaching on the agricultural crop fields that are adjacent to the core. Such encroachment may lead to human–primate conflict due to crop loss suffered by local farmers. Hence understanding the feeding ecology of this two 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. The landscape around the reserve has seen an increase in the area of teak and oil palm plantations established on what was formerly shifting agriculture lands. While teak plantations have been mostly established under State Forest Department (SFD) programs, oil palm plantations have been established since 2007 under government horticulture promotion schemes and the state's New Land Use Policy (NLUP), the stated goal of which is the eradication of so–called ''wasteful'' shifting agriculture in Mizoram **(Singh, 2009)**. An earlier study **(Raman, 2001)** suggested that long-rotation (>10 yr) shifting cultivation in the buffer zone, coupled with protection of mature forests in the core area of DTR, could be better for conservation than monocultures **(Mandal and Raman, 2016)**. Moreover, shifting agriculture, or jhum (locally known as 'Lo' in Mizo and 'Hu' in Riang), is still extensively practiced in the buffer zone landscape of DTR **(Raman et al. 1998)**. 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 and CL in the tropical forest of DTR in Mizoram, India for the first time that may possibly contribute for better management and conservation of the species and its habitat in the region.

II. REVIEW OF LITERATURES

Over the last four decades, there have been an ever–increasing number of field studies on apes and other primates that have focused on food acquisition, food processing, habitat utilization, foraging strategies, the relationship between ecology and sociality, and related topics. Earlier workers like; **Srivastava (1999, 2006), Molur et al. (2003), Choudhury (2001, 2011, 2012), Mazumder (2014)**, reported on the brief account of status of northeastern Indian primates highlighting each species food preferences and their conservation status.

1.17: Earlier works on Assamese Monkey

Although, diets and feeding behavior of primates have been primary topics to study for many decades **(Maruhashi, 1980; Post, 1983; Agetsuma, 1995; Hanya, 2004)**, detail work on feeding behavior and food plants of AM in order to infer diet preference in their habitat has been done for at least 20 years by field primatologists.

(i) International status

Reported on the status and ecological behavior of AM from Nepal was made by **Chalise (1999, 2003, 2010)**. The census and ecological niche modeling on AM in Nepal was conducted by **Khanal et al. (2019)** and the result congruently revealed that the mid–hills of eastern and central Nepal outside the protected areas as the major habitats of this nationally endangered and protected primate. **Boonratana et al. (2020)** provided the IUCN assessment status of AM and information on taxonomy, geographic range, map distribution, population, habitat and ecology, use and trade, threats and conservation actions. **Schulke et al. (2011)** studied about the ecology of AM at Phu Khieo Wildlife Sanctuary (PKWS), Thailand. Unlike **Zhou et al. (2011)** they recorded that AM spent large time feeding on fruits. They concluded that AM spent about 40% of their activity time on the ground and in the lowest stratum of the forest. The canopy was used rarely by focal troop and they spent a third of their activity time on feeding. **Zhou et al. (2011)** studied on diet of AM in limestone seasonal rain forests at Nonggang Nature Reserve (NNR), China. They found that AM are highly folivorous, where young leaves were staple food items (74.1% of the diet) and fruit accounted for only 17.4% of the diet. **Chalise et al.**

(2013a, 2013b) studied the ecology, behavior and population of AM in Shivapuri Nagarjun National Park (SNNP), Nepal. They concluded that AM spent most of their time in foraging while playing was the least favored activity and grooming was a regular behavior to strengthen social relationship within troop. **Huang et al. (2015)** carried out a research work on dietary adaptations of AM in limestone forests, Nonggang National Nature Reserve (NNNR), Guangxi, Southwest China and their results suggest that bamboo consumption represents a key factor in the AM dietary adaptation to limestone habitat.

Based on the investigation of diet and feeding behavior of AM at Tham Pla Temple (TPT), Chiang Rai Province, northern Thailand conducted by **Kaewpanus et al. (2015)**, they reported that despite provisioned food provides an essential food supply to macaques but an excess of food could deteriorated macaques' health and a balance of dietary composition between natural food and provisioned food is important for the macaques' survival and health. **Huang et al. (2016)** collected data using instantaneous scan sampling methods to investigate dietary composition and temporal variation across daytime hrs in a limestone forest at NNNR, Guangxi, Southwest China during rainy season. They observed that macaques consumed a total of 45 plant species, which included 30 tree, 3 shrub, 11 vine, and 1 herb species and on an average, macaques consumed 22.3 plant species per month. **Paudel and Chalise (2017)** focused on general behavior and vegetation associated with the habitats of AM along Kaligandaki River bank (KRB), Western Nepal and by applying quadrate sampling, 58 plant species with 716 number were recorded in which Sal (*Sorea robusta*) was the dominant plant species with relative density 31.42% and relative frequency 8.37% which was followed by Tiju (*Diospyros malabarica*) with relative density 10.93% and relative frequency 8.37%. Investigation on the diet and activity of AM in Wild and Semi–Provisioned Groups (WG and SPG) in SNNP, Nepal was conducted by **Koirala (2017)** from which they found that both groups spent most of their time in feeding activities and were quite arboreal, but there were significant differences in the activity budgets and diets between the groups and, human food was the main component of the diet for the SPG, whereas it was fruit for the WG, indicating a normally frugivorous diet.

Furthermore, they reported that the activity budget and diet composition varied in response to the season and these results indicated that provisioning alters the activity and feeding behavior of macaques, and could also increase human-macaque conflict and disease transmission. **Li et al. (2019, 2020)** reported that nutrient contents predict the bamboo–leaf–based diet of AM's living in limestone forests of southwest Guangxi, China and also implicated their findings that the monkeys not only adjusted their daily activity patterns and feedings to cope with the seasonal and micro-variations in temperature and dietary requirements, but also to adapt to their particular environment.

From the comparative ecological and behavioural study of *Macaca assamensis* and *Macaca mulatta* in SNNP, Nepal reported by **Khatiwada et al. (2020)**, it was reported that AM's were generally arboreal, with 94.0% of their activities in trees, whereas Rhesus macaques (RM) were largely terrestrial, with 58.5% of their activities on the ground. These differences in food selection, home-range size, ranging and activity patterns, and habitat use suggested that AM and RM reduced resource competition through resource partitioning to coexist in a landscape matrix. **Ghimire et al. (2021)** studied on the feeding ecology of AM troops in Kaligandaki and Budhigandaki River basins of central Nepal and concluded that food choice and time investment on the feeding of different plant parts differ depending on the availability of food in the area and AM living in comparable habitats with similar food plants have analogous food choices and time investments.

(ii) National status

Field studies on the status and ecology of AM were carried out earlier by **Southwick et al. (1964); Khajuria (1962); Fooden (1971); Tiwari and Mukherjee (1992). Mukherjee et al. (1995)** surveyed in some parts of Darjeeling. Recently the Indo–US Primate (IUSP) Project carried out the status and behavior study of this species in northeastern India **(Murmu et al. 2004).**

In Mizoram, **Mishra et al. (1994); Raman et al. (1995)** reported six troops and four troops from DTR and Phawngpui National Park (PNP), respectively. **Mitra (2002, 2003)** reported foods consumed and feeding behavior of AM from West Bengal, India where 63 plant species were recorded and stated that feeding behavior and selection of dietary items had direct relationship with human interaction, food availability, vegetation pattern, group interaction and ranging pattern. A study based on activities profile of free ranging forest group of AM in Jokai Reserve Forest (JoRF), Assam, India, **Sarkar (2000)** and **Sarkar et al. (2012)** stated that the studied groups spend more than one third (40%) of their total annual time for foraging purpose, followed by 25% on locomotion, 13% on resting, 10% on grooming, 9% on monitoring, 1% on playing and 2% in sexual and other activities. The activities of forest group have revealed that foraging was the crucial factor responsible for the variation in the activities profile. In forest, as the food was randomly distributed, the group arranged their total time cost effectively and spent more time on foraging, locomotion and resting and less time in grooming, monitoring and play activities. They suggested from their finding that nature of distribution of food resources is the guiding force for allocating time to various activities in various habitats. **Solanki and Parida (2022)** conducted a study on population status and distribution of AM across altitudinal gradients in DTR, Mizoram, India. They recorded nine groups of seven to 21 individuals comprising of 123 individuals mostly at an altitude between 250 m to 856 m. **Decemson et al. (2022)** studied on the dietary preference of AM in DTR, Mizoram and reported that the richness of fruiting plants in DTR appears to fulfill the dietary requirement of AM and therefore intactness of forest resources is necessary for their development and conservation.

1.18: Earlier works on Capped Langur

Until the mid–1980s, the scanty literature available for *Trachypithecus pileatus* was restricted to publications by **Hinton (1923); Pocock (1928); McCann (1933, 1942); Oboussier and Maydell (1959); Khajuria (1962)** with some information also provided by **Blanford (1888–1891); Finn (1929); Prater (1971); Ellerman and Morrison–Scott (1951); Napier and Napier (1967); Roonwal and Mohnot (1977)** and **Khan and Ahsan (1981). Hinton (1923)** and **Pocock (1928)** gave detailed accounts on taxonomic variation; the others provided general information, including characteristics, distribution, and aspects of their ecology and behavior.

(i) International status

From Bangladesh, various workers reported on preliminary information **(Islam and Husain, 1982)**, behavioral ecology and activity patterns of CL **(Stanford, 1987; Stanford, 1991a; Kabir, 1991, 2002, 2006; Mandal and Kabir, 2014; Alom, 2015; Monirujjaman and Khan, 2017)** reproductive tactic **(Stanford, 1991b)** population size and distribution **(Naher and Khan, 2018)**. **Choudhury (1990c, 1992a)** reported on primates in Bhutan and mentioned probable sympatric distribution of *Trachypithecus geei* and *Trachypithecus pileatus* in Bhutan. A study conducted in Madhupur National Park (MNP) north–central Bangladesh by **Standford (1991a)** showed that the data supported the hypothesis that the colobine feeding strategy is adapted to cope with seasonal food scarcity. He observed that an annual diet of CL was comprised largely of mature leaves (42% of 20,460 total feeding records), new leaves (11%) and fruit (24%), and seasonal breakdown of diet revealed that during the monsoon months of May through September (the period of maximum fruit availability), the CL diet is approximately 50% fruit. Thus, the data on diet and food availability, however, indicated that while capped langurs subsist on mature leaves during the dry season (80% of diet from November to March); they selected fruit and new leaves and switched to those foods whenever they were available. **Mandal and Kabir (2014)** conducted a study on the activity patterns of CL at Rasulpur in the MNP, Bangladesh from June 2006 to May 2007, they reported that CL spent 35.67% of their time in feeding, 36.38% in resting, 10.5% in movement and 17.45% time in other activities, and activity budgets of group varied significantly between hours of the day and months. Based on the work carried out by **Khan et al. (2022)** on the dietary composition, food choice and food plants of CL in the deciduous sal (*Shorea robusta*) forest and its adjacent area of human habitation in and around MNP, Bangladesh from April 2016 to March 2017, it was reported that CL preferred leaves (55.4%), followed by fruits (25%), flowers (7.6%), seeds (5.4%), flower buds (4.35%), bamboo shoots (1.1%) and tree bark (1.1%) derived from 77 food plant species under 38 families, which implicated that increasing the availability of preferred food plants in the natural forest could result in CL eschewing areas of human habitation. On the basis of a study on the comparative activity pattern and feeding behaviour of CL and RM (*Macaca mulatta*) in MNP, Bangladesh carried out by **Monirujjaman and Khan (2017)** reported that the CL spent 42% of the day time in feeding on a total of 51 species of plant under 28 families, 45% in resting, 6% in moving, 4% in playing, 2% in grooming and 1% in breeding.

(ii) National status

Subsequent studies on CL carried out in Northeast India are reported mainly in Assam **(Mukherjee, 1978; Choudhury, 1988, 1989a, 1989b, 1990a, 1990b, 1990c, 1992a, 1993, 1996a, 1996b, 1997a, 1997b)**, but also in other states such as Arunachal Pradesh **(Borang and Thapliyal, 1993; Kumar, 2006; Kumar and Solanki, 2004, 2008; Solanki et al. 2008a, 2008b; Solanki and Kumar, 2010)**, Manipur **(Choudhury, 1992b)**, Tripura **(Mukherjee and Chakraborty, 1992; Gupta, 1998)** and Mizoram **(Mishra et al. 1994)**. **Mishra et al. (1994) and Raman et al. (1995)** reported five troops and four troops from DTR giving an encounter rate of 0.13 troops per km (toward and return sightings along the trails). Though the species was reported by locals, they did not encountered in the PNP in Mizoram. **Kumar and Solanki (2004)** observed a rare case of the CL feeding on water lilies (*Nymphaea alba*) in the Pakhui Wildlife Sanctuary (PWS), Arunachal Pradesh, India and concluded that lactating mothers require more food and energy than non–lactating females and males; that may be why only the lactating mothers entered the water to feed on the water lilies which was a rich source of protein, minerals, energy and contain low fiber. **Murmu and Chaudhari (2006)** while surveying non–human primates of MNP, Mizoram, India, he sighted one group of CL consisting of 15–18 individuals from a distance and also reported that there were only 2–3 groups of CL inhabited the park as informed by the villagers. **Solanki and Kumar (2008a, 2008b)** conducted the first study to examine the feeding ecology of capped langurs for 12 months in the PWS, Arunachal Pradesh, India, which provided baseline data for the species. They reported that CL spent 44% of their feeding time in terminal canopies and their average feeding height was 30–35 m, they spent 68% of their feeding time on leaves, 16% on flowers, and 16% on fruits of 52 plant species throughout the year and 57% on leaves, 17% on fruits and 3% on seeds derived from 43 plant species during winter. **Choudhury (2014)** reported on the distribution and status of the CL in India, and reviewed geographic variation in its subspecies. **Decemson et al. (2018)**

conducted a study on feeding behavior of CL during summer season (March–May, 2014) in DTR, Mizoram, India. They reported that the CL selected 7 food plant species and spent 93% of its time on feeding (48%) and resting (45%) only. **Borah et al. (2021)** conducted feeding ecology of CL in Sri Surya Pahar (SSP), a disturbed habitat in Goalpara District, Assam which generated information that could be useful for evaluation and improving the quality of the habitat and formulating conservation and management action plan for CL. They observed a significant change in the diet composition of CL during different seasons altogether derived from 41 species of plants belonging to 24 families and spent maximum time feeding on leaves which is highest during pre-monsoon season (63.70%) and lowest in winter (7.82%). Recently, **Barbhuiya et al. (2022)** reported that CL spent maximum time in resting than other activities from their observation on time budget and activity pattern of the group in Barail Wildlife Sanctuary (BWS), Assam, India from January 2017 to December 2019. From the observation it has been found that langur spent maximum time for resting (45%) followed by feeding (34%), locomotion (11%), grooming (5%) and others activity (5%). The amount of time allocates for different activities throughout the months was significantly different. Time devoted to feeding was maximum in April (37%) and resting was 50% in August. In seasonal variation, it spent maximum (48%) time for resting in monsoon and lowest (41%) in winter. Highest (35%) feeding activity was in winter and summer followed by lowest (32%) in monsoon and the seasonal variation of all the activities was significantly varied.

II. MATERIALS AND METHODS

1.19: Study area

The study was conducted from September 2018 to August 2020 at DTR (23.38°–23.70°N and 92.27°–92.43°E) located in the western part of Mizoram in Mamit district, northeastern India along the international border to Bangladesh. The reserve comprises 500 km^2 for core area and buffer 488 km^2, covering mountainous terrains, and elevation ranging from 250–1100 m at Fig. 1 (A & B). **(Johnson et al. 2021)**, making it Mizoram's largest wildlife protected area. 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 and Seth, 1968; Devi et al. 2011)**. 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 2200 mm **(Mandal and Raman, 2016)**. Forest canopy at lower elevation is 30–35 m, with evergreen and some deciduous trees 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 and Raman, 2016)**.

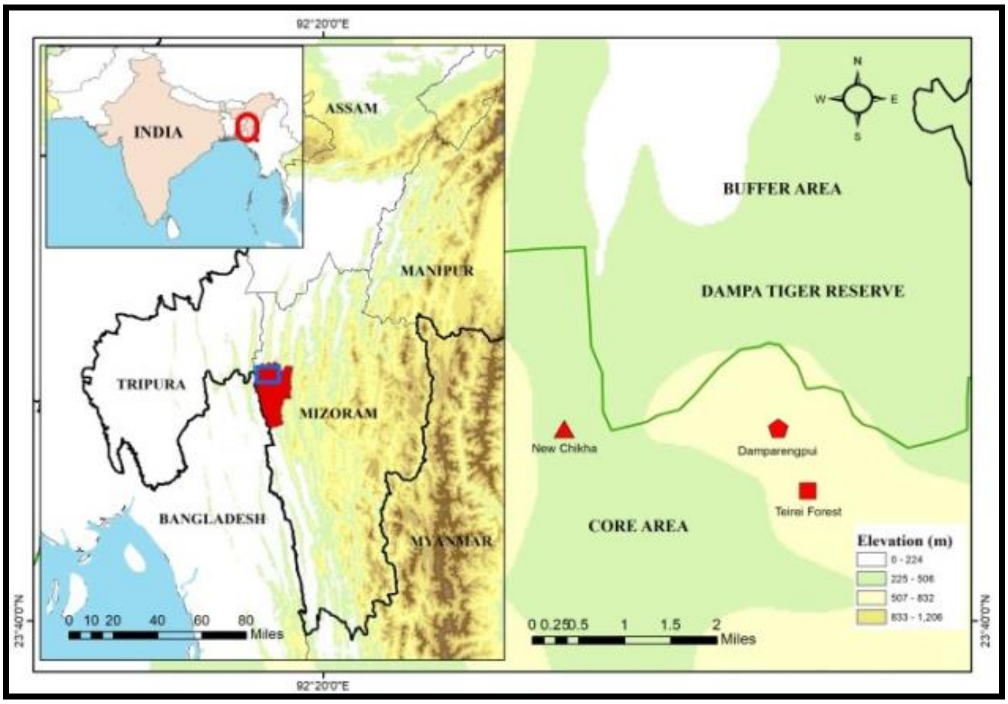

Figure 1 (A): The study site DTR and selected three sites namely: (i). Dampa watch tower (red square), (ii). Sesih hnar (red polygon) and (iii). New Chikha, now abandoned village (red triangle) during the study period from 2018–2020.

Nine random quadrats were laid measuring 20x20 m^2 at the areas covered of three sites selected to study AM and CL; Dampa watch tower (GPS location 23.4117°N–92.2641°E; elev. 521 m and 11.8 km^2 area) near Teirei Forest, Sesih hnar (GPS location 23.4155°N–92.2405°E; elev. 770 m and area covered 7 km^2) near Damparengpui and at New Chikha (now abandoned village) (GPS location 23.4016°N–92.2121°E; area covered 2 km^2; elev. 507 m) located at the Teirei range at Fig. 1 (A). Constraints faced during the survey period included were inaccessible undulating terrains, steep slopes, leeches and hostile weather conditions (Fig. 2.1). Days lost due to unfavorable weather condition were compensated by the addition of observation hours and days during the dry and spring season. Other primate species reported from the DTR includes namely; Rhesus macaque (*Macaca mulatta*), Northern pig–tailed macaque (*Macaca leonina*), Stump–tailed macaque (*Macaca arctoides*), Phayre's leaf monkey (*Trachypithecus phayrei*), Western hoolock gibbon (*Hoolock hoolock*) and Bengal slow loris (*Nycticebus bengalensis*) **(Pachuau et al. 2013)**.

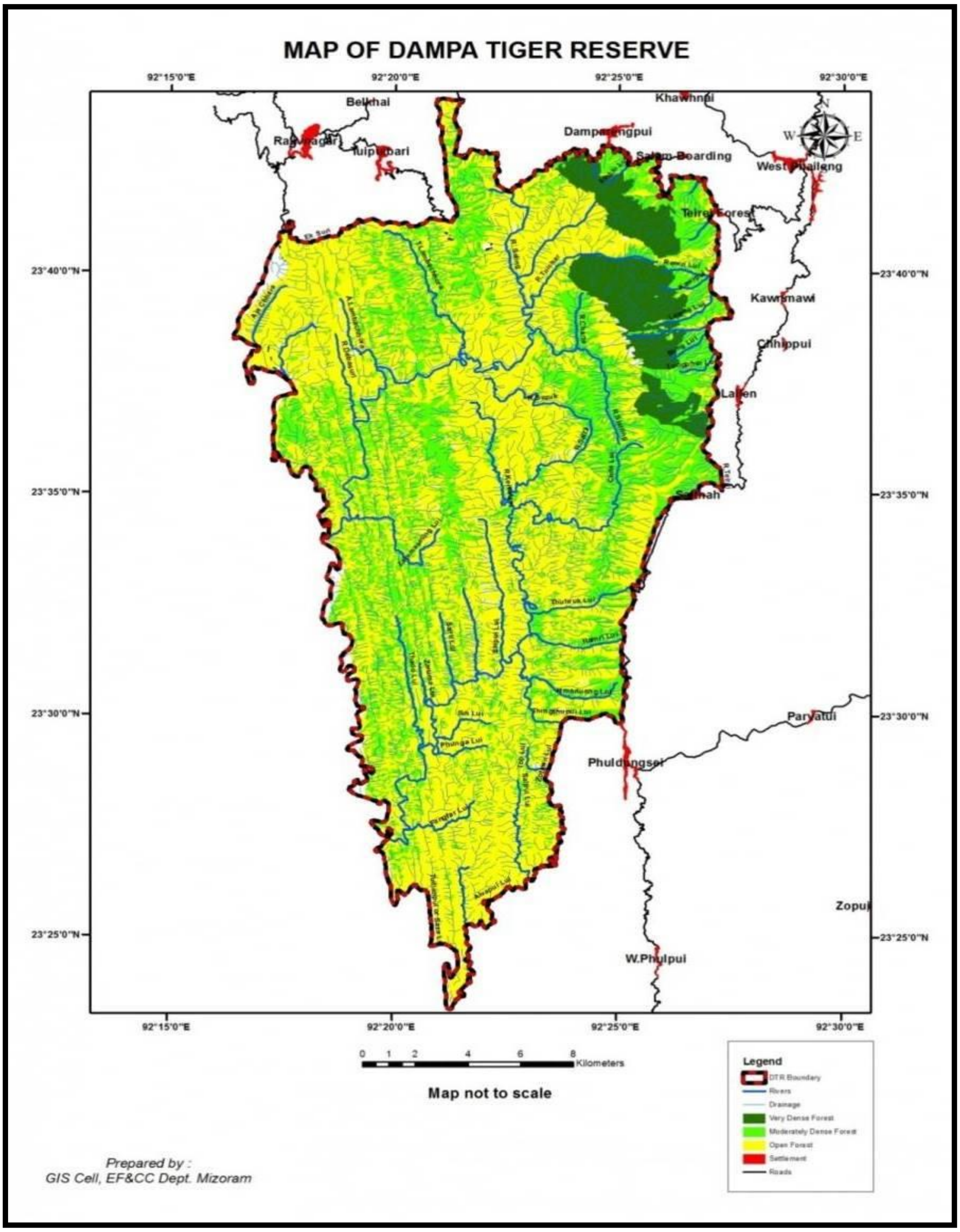

Figure 1 (B): The outline map of the study site of Dampa Tiger Reserve (green landscapes represent the core zone approximately 500 km^2 and surroundings white background is buffer zone 488 km^2 with red marking are fringe villages) located in Mamit district in Mizoram, India.

Figure 1.1 (A–I): Constraints faced during the survey period from 2018–2020 (A) inaccessible undulating terrains, (B) Undulating and rugged in nature DTR landscape, (C) Steep slopes with alternate ridges, (D) Crossing perennial upstream approach to feeding site (E) Racing after focal individuals under rain, (F) Tiger leech attached on clothing, (G) Tiger leech sucking through the cloth, (H) cuts and (I) bruise.

1.20: Study subjects

The feeding ecology and dietary pattern at DTR under these two primate species were studied namely; AM and CL was determined by marking and following a particular troop. The first animal study subject, AM in the study area is *Macaca assamensis assamensis* (Fig. 1.2), one of the two subspecies of AM that distributed in the east of Brahmaputra, southwestern China (Southeastern Xizang Autonomous Region Tibet, west and south of Yunnan, south Guizhou, southwestern Guanxi provinces), northeastern India (Eastern Arunachal Pradesh, eastern Assam, Nagaland, Meghalaya, Manipur, Mizoram, Tripura states, south and east through northern, eastern and western Myanmar, northern and western Thailand, Laos and northern Viet Nam **(Boonratana et al. 2020).** Another species, CL in the study area is *Trachypithecus pileatus pileatus* (Fig. 1.3) one of the four subspecies under CL occurs to the south of the Brahmaputra **(Choudhury, 2014).** Observation of their daily activities and feeding plants was done separately once the observation of other species was done, duration span from September, 2018 to August, 2020. The observation of AM and CL in the field were conducted continuously during the study period of 2018–2020 along the adjacent buffer fringe. The time spent for monitoring maximum both species AM and CL *i.e.* 10–12 hr during dry seasons (winter and spring) and minimal in monsoon (*i.e.* 6–7 hr). Feeding behavior were focused and observed mainly on one group comprising the one adult male and female. The individuals of the focal troop were identified with the help of different external characters and appearances such as body size and proportions, facial features, fur color, cut marks, skin pigmentation on the feet, hands and tail. The AM troop compositions consisted of two adult males, four adult females, six sub–adult females, four sub–adult males, two juveniles and two infants and similarly, troop composition of CL consisted two adult male, two adult females, three sub-adult females, two sub-adult males, two infants and no juvenile observed as classified by sex and age based on coloration, body size, and development of sexual characteristics following earlier established physical descriptions **(Ulibarri and Gartland, 2021)**.

1.21: Taxonomic position of Assamese Monkey

1. Kingdom: Animalia
2. Phylum: Chordata
3. Class: Mammalia
4. Order: Primates
5. Family: Cercopithecidae
6. Genus: ***Macaca***
7. Species: ***assamensis***
8. Vernacular (in Mizo): Zo/Khamzawng
9. IUCN status: Near Threatened
10. CITES category: Appendix II
11. IWPA, 1972: Scheduled II, Part I

Figure 1.2: Assamese Monkey at the study site in DTR during the study period 2018–2020.

1.22: Taxonomic position of Capped Langur

1. Kingdom: Animalia
2. Phylum: Chordata
3. Class: Mammalia
4. Order: Primates
5. Family: Cercopithecidae
6. Genus: ***Trachypithecus***
7. Species: ***pileatus***
8. Mizo: Ngaubuang
9. IUCN status: Vulnerable
10. CITES category: Appendix I
11. IWPA, 1972: Scheduled I, Part I

Figure 1.3: Capped Langur at the study site in DTR during the study period 2018–2020.

1.23: 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 (20x20 m^2) around Dampa watch tower, Sesih hnar and New Chikha and (23.41°N–92.24°E and 23.40°N–92.25°E) within 20.8 km^2 at an elevation of 507–770 m and located at the Teirei range. All sampling was made on foot on a transect line that were previously marked. The observation was made using a binocular (Olympus 10x50S), Handheld GPS navigator (60CSx) and digital camera (COOLPIX A900). All the trees within the quadrats were identified to the species level **(Sawmliana, 2013; Hegde and Manpoong, 2017)**, counted and their DBH (in cm) was measured at approximately 1.37 m above the ground (Fig. 2.4A–E). The dominance of each species within a plot was calculated as the relative density (RDen) and relative frequency (RF), following **(Ajayi and Obi, 2016; Irmayanti et al. 2022)** and ultimately determined the Important Value Index (IVI) value for each plant species in a plot by summing the RDen, Relative Basal Area (RBA) and RF **(Deori et al. 2016)**.

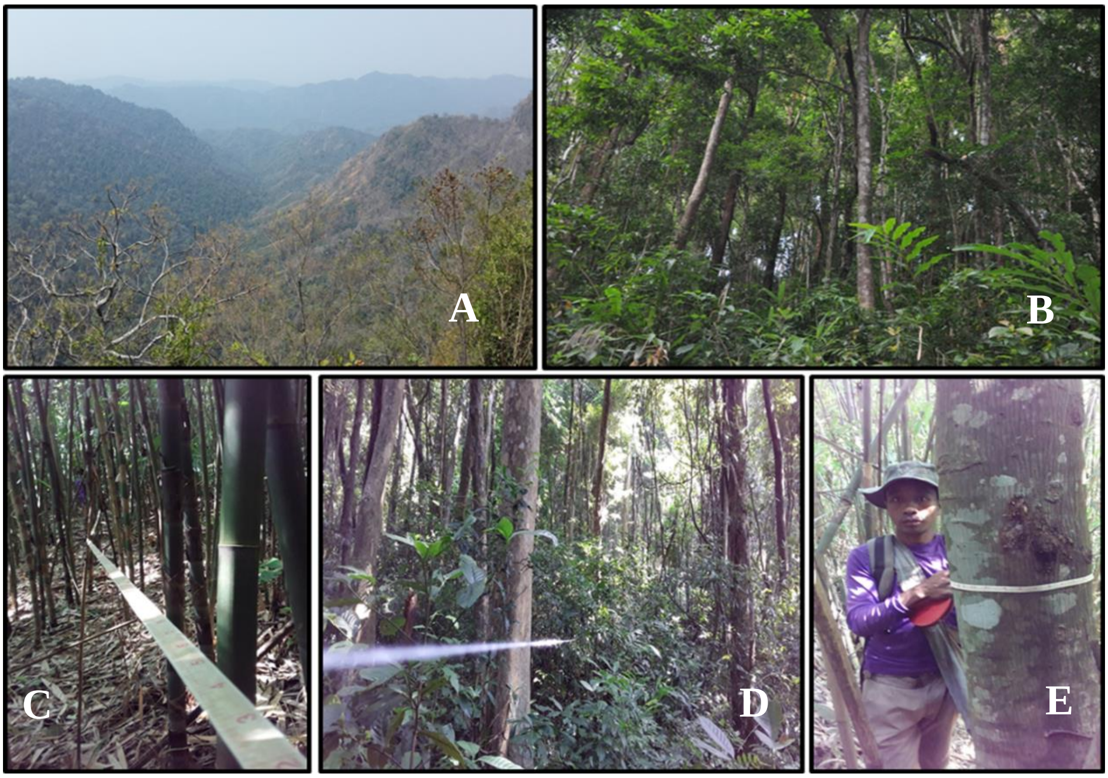

Figure 1.4 (A–E): Quadrats sampling in the study sites. (A) Habitat and vegetation sampling in DTR. (B) Landscape view from the Dampa tower watch, dense tree canopy. (D) Lying of quadrates with long white threads at bamboo brakes and tree cover areas. (E) Counting DBH measurement (in cm) of trees with the forest staff and field assistant at the study sites during the study period 2018–2020.

1.24: Dietary composition and feeding activity

Data on the dietary composition and feeding behavior both the AM and CL species were collected by direct observations in the field following **Chalise et al. (2013)**. The feeding data was collected for 24 months from September, 2018–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 0600–1700 hr (Fig.2.5A–D). Sampling was carried out for both the species separately for 5–10 consecutive days of every month 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 6–12 entries per day on information such as consumed food plants, food items, and feeding time based on the season (Fig.2.5E–I). The feeding items or plant parts consumed were categorized as leaves (both young and mature leaves), flowers, fruits, seeds, shoots. The time spent feeding on different food items was calculated as per **(Gupta and Kumar, 1994)**:

$$T_a = \frac{N_a \times 100}{N}$$

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.

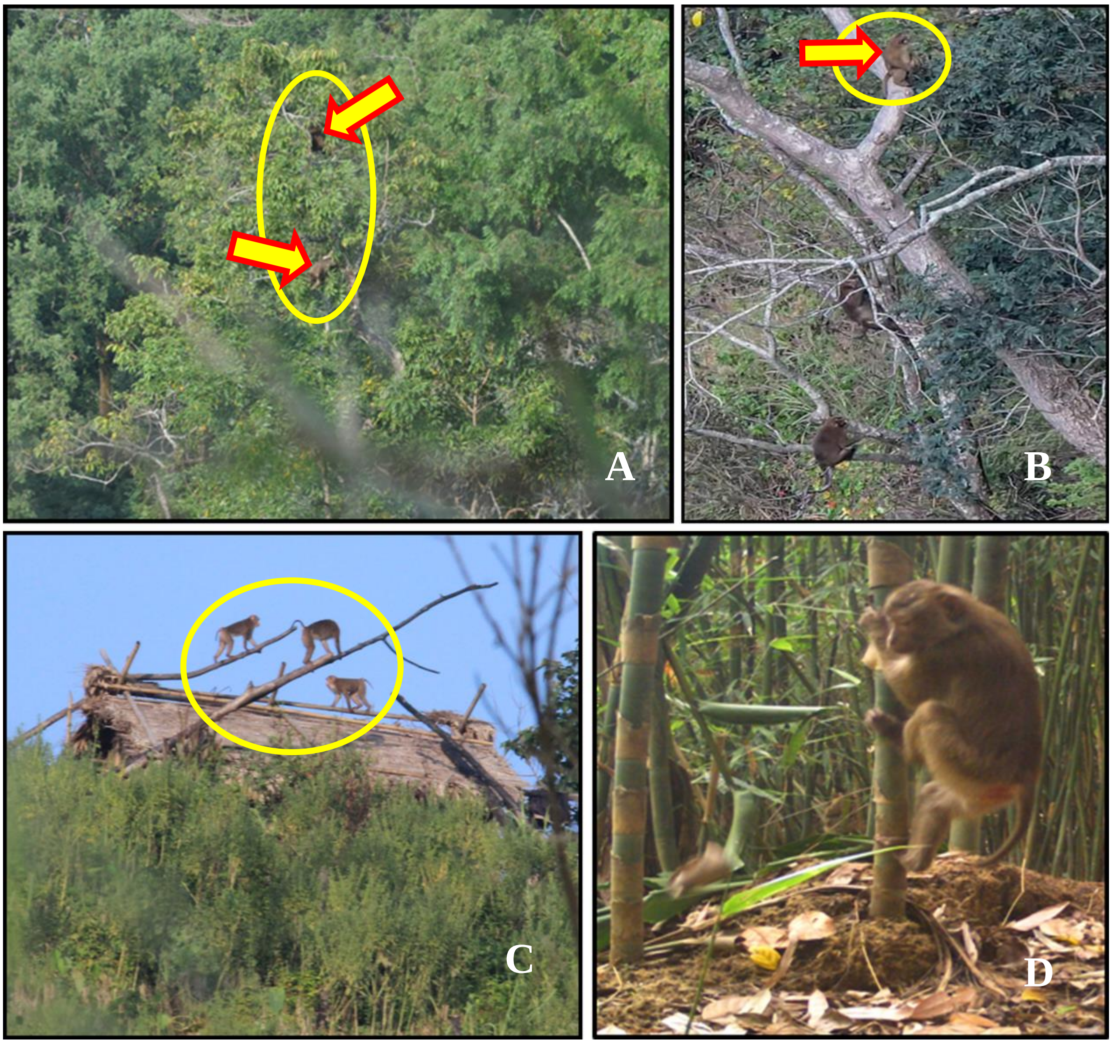

Figure 1.5 (A-D): (A) Atop tree canopy sleeping site of AM at steep cliff near Sesih hnar study site. (B) AM alpha male led the foraging in morning hr. (C) AM troop leisure loitering on top of jhum hut post cultivation a close proximity to the study area. (D) The adult male first inspects supposed to be their feeding surrounding and it descends on the ground having felt secured (bamboo spp; *Melocana baccifera* and *Dendrocalamus longispathus* is fed both by AM and CL during monsoon seasons).

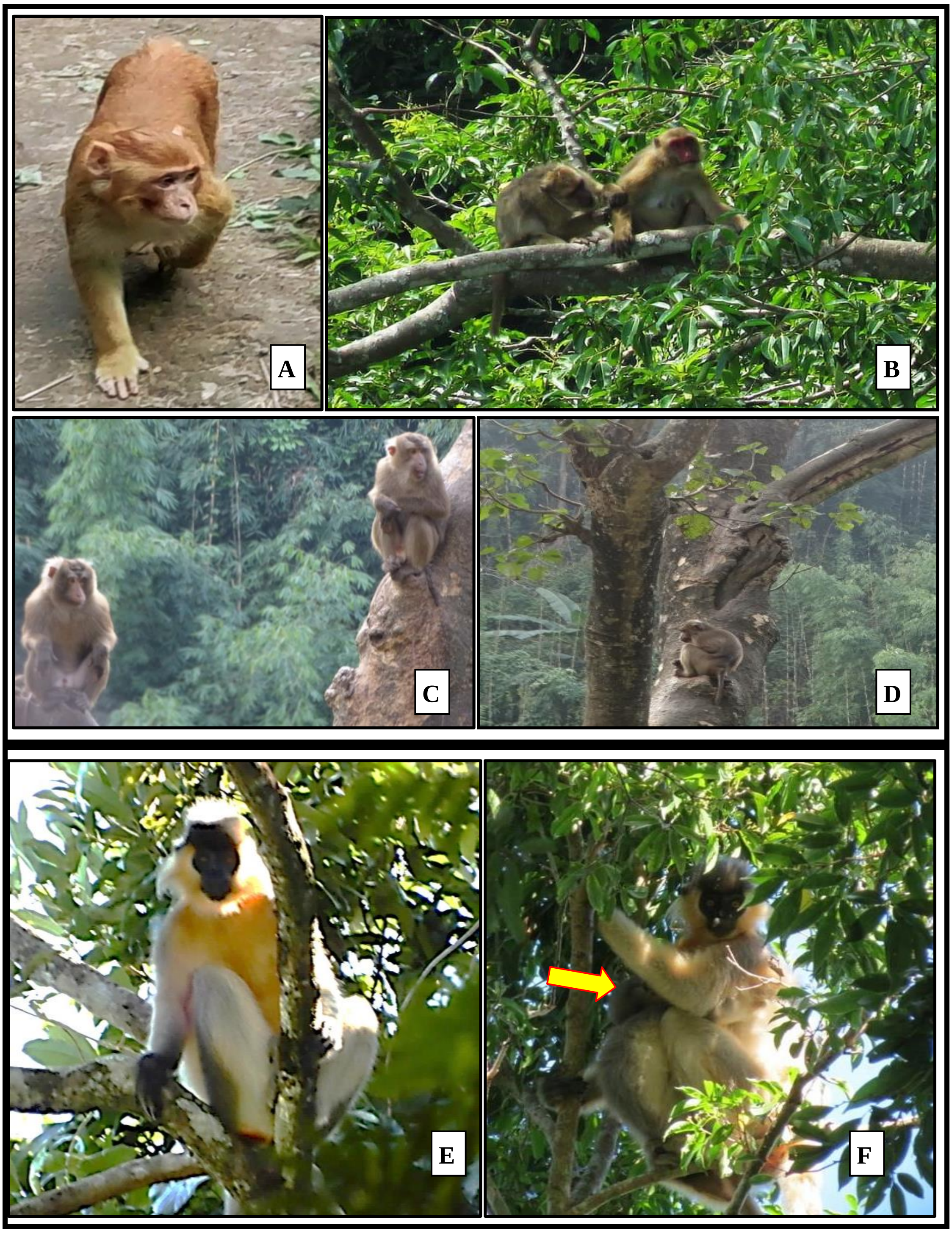

Figure 1.6 (A-F): (A) AM individual on the ground at rest. (B) Adult male and female grooming on tree trunk. (C) Subadult individual patiently wait for the male call to foraging. (E) Encounter of the adult CL male on terminal canopy. (F) A female cuddling infant at the Sesih hnar site during study period 2018–2020.

DATA ANALYSIS

Kruskal–Wallis H Test was performed to determine the monthly and seasonal variation in time devoted to each plant part and the number of plant species consumed. The PSPP version 1.6.2 (GNU Project 2015) and GraphPad Prism (online ver. 6.0) software was used for statistical and graphical analysis. A 'p' value of <0.05 was considered statically significant.

III. RESULTS

1.23: Habitat types and vegetation

Vegetation in the study sites was determined through vegetative sampling and manual counting on each individual of the species in the quadrats. The surveyed sites mainly consist of tropical deciduous forests and bamboo forests with ≥70% canopy cover. The distribution of 148 plant species at study sites in DTR including the RF, RDen, RDom and IVI (%) along with the habitat are represented in the Table 1.1 and with family in Fig. 1.7. Tree species such as *Acer laevigatum*, *Canarium bengalense*, *Trema orientalis*, *Schima wallichi*, *Albizia chinensis*, *Derris robusta*, *Albizia rumphii*, *Ficus racemosa*, *Ficus hirta* of basal width 40 to 80 cm were dominant in the surveyed sites. Bamboo species such as; *Dendrocalamus asper*, *Dendrocalamus longispathus*, *Cephalotachyum latifolium*, *Bambusa mizorameana*, *Bambusa tulda* and *Melocalamus compactiflorus* were also common in and around the habitat area. The highest Relative Frequency (RF) of the feeding plants was calculated for *Artocarpus lakoocha* (1.81%) and *Albizia chinensis* (1.44%), while the lowest encountered plant species are *Aphananthe cuspidata* and *Dysoxylum gotadhora* with values of 0.36% while the RDen value is highes for *Artocarpus lakoocha, Albizia chinensis* and *Magnolia oblonga* with 1.58%. Among all the plants in the study sites, the IVI was observed maximum for *Acrocarpus fraxinifolius* (5.17%), *Artocarpus lakoocha* (5.14%) and *Albizia chinensis* (4.78%) and the minimum was recorded for *Eriobotrya benghalensis* (0.62%) and *Hardina cordiflora* (0.62%).

Table 1.1: Distribution of plants with the RF, RDen, RDom and IVI (values in %) at the study sites during the study period 2018–2020.

Sl. no.	Plant species	Habit	RF	RDen	RDom	IVI
1.	***Acrocarpus fraxinifolius***	T	0.72	2.11	2.34	**5.17**
2.	*Artocarpus lakoocha*	T	1.81	1.58	1.75	5.14
3.	*Albizia chinensis*	T	1.44	1.58	1.75	4.78
4.	*Magnolia oblonga*	T	1.08	1.58	1.75	4.42
5.	*Albizia procera*	T	1.44	1.32	1.46	4.22
6.	*Artocarpus nitidus*	T	1.44	1.32	1.46	4.22
7.	*Baccaurea ramiflora*	T	1.44	1.32	1.46	4.22
8.	*Castanopsis tribuloides*	T	1.44	1.32	1.46	4.22
9.	*Ficus auriculata*	T	1.44	1.32	1.46	4.22
10.	*Mesua ferrea*	T	1.44	1.32	1.46	4.22
11.	*Aglaia edulis*	T	1.08	1.32	1.46	3.86
12.	*Cephalotaxus griffithii*	T	1.08	1.32	1.46	3.86
13.	*Albizia lebbeck*	T	1.44	1.05	1.17	3.67
14.	*Aporosa octandra*	T	1.44	1.05	1.17	3.67
15.	*Glochidion hyneanum*	T	1.44	1.05	1.17	3.67
16.	*Alstonia scholaris*	T	1.08	1.05	1.17	3.31
17.	*Bischofia javanica*	T	1.08	1.05	1.17	3.31
18.	*Bombax insigne*	T	1.08	1.05	1.17	3.31
19.	*Canarium bengalense*	T	1.08	1.05	1.17	3.31
20.	*Chukrasia tabularis*	T	1.08	1.05	1.17	3.31
21.	*Diospyros glandulosa*	T	1.08	1.05	1.17	3.31
22.	*Etlingera linguiformis*	T	1.08	1.05	1.17	3.31
23.	*Garuga pinnata*	T	1.08	1.05	1.17	3.31

Sl. no.	Plant species	Habit	RF	RDen	RDom	IVI
24.	*Macaranga pustulata*	T	1.08	1.05	1.17	3.31
25.	*Protium serratum*	T	1.08	1.05	1.17	3.31
26.	*Prunus ceylanica*	T	1.08	1.05	1.17	3.31
27.	*Syzygium acuminata*	T	1.08	1.05	1.17	3.31
28.	*Melocalamus compactiflorus*	H	1.44	1.58	0.00	3.02
29.	*Anogeissus acuminata*	T	0.72	1.05	1.17	2.94
30.	*Baalakata baccata*	T	0.72	1.05	1.17	2.94
31.	*Homelomena aromatica*	T	0.72	1.05	1.17	2.94
32.	*Melocana baccifera*	H	1.44	1.32	0.00	2.76
33.	*Albizia richardiana*	T	1.08	0.79	0.88	2.75
34.	*Drimycarpus racemosus*	T	1.08	0.79	0.88	2.75
35.	*Phyllanthus embelica*	T	1.08	0.79	0.88	2.75
36.	*Cyathocalyx martabanicus*	T	0.72	0.79	0.88	2.39
37.	*Dillenia indica*	T	0.72	0.79	0.88	2.39
38.	*Eugenia jambolana*	T	0.72	0.79	0.88	2.39
39.	*Ficus variegata*	T	0.72	0.79	0.88	2.39
40.	*Garuga floribunda*	T	0.72	0.79	0.88	2.39
41.	*Gmelina arborea*	T	0.72	0.79	0.88	2.39
42.	*Gmelina oblongifolia*	T	0.72	0.79	0.88	2.39
43.	*Hydnocarpus kurzii*	T	0.72	0.79	0.88	2.39
44.	*Irvingia gabonensis*	T	0.72	0.79	0.88	2.39
45.	*Leea indica*	T	0.72	0.79	0.88	2.39
46.	*Litsea monopetala*	T	0.72	0.79	0.88	2.39
47.	*Machilus gamblei*	T	0.72	0.79	0.88	2.39
48.	*Myristica longifolia*	T	0.72	0.79	0.88	2.39

Sl. no.	Plant species	Habit	RF	RDen	RDom	IVI
49.	*Schima wallichii*	T	0.72	0.79	0.88	2.39
50.	*Syzygium cumini*	T	0.72	0.79	0.88	2.39
51.	*Tetrameles nudiflora*	T	0.72	0.79	0.88	2.39
52.	*Thysanolaena latifolia*	T	0.72	0.79	0.88	2.39
53.	*Toona ciliata*	T	0.72	0.79	0.88	2.39
54.	*Aphananthe cuspidata*	T	0.36	0.79	0.88	2.03
55.	*Ardisia polycephala*	T	0.36	0.79	0.88	2.03
56.	*Dysoxylum gotadhora*	T	0.36	0.79	0.88	2.03
57.	*Amomum dealbatum*	H	0.36	1.58	0.00	1.94
58.	*Licuala peltata*	S	1.08	0.79	0.00	1.87
59.	*Alseodaphne petiolaris*	T	0.72	0.53	0.58	1.83
60.	*Calliandra umbrosa*	T	0.72	0.53	0.58	1.83
61.	*Daemonorops jenkinsianus*	T	0.72	0.53	0.58	1.83
62.	*Derris robusta*	T	0.72	0.53	0.58	1.83
63.	*Diospyros pilosiuscula*	T	0.72	0.53	0.58	1.83
64.	*Ervatamia coronaria*	T	0.72	0.53	0.58	1.83
65.	*Erythrina stricta*	T	0.72	0.53	0.58	1.83
66.	*Erythrina variegata*	T	0.72	0.53	0.58	1.83
67.	*Ficus retusa*	T	0.72	0.53	0.58	1.83
68.	*Ficus rumphii*	T	0.72	0.53	0.58	1.83
69.	*Garcinia loniceroides*	T	0.72	0.53	0.58	1.83
70.	*Garcinia sopsopia*	T	0.72	0.53	0.58	1.83
71.	*Heritiera papilio*	T	0.72	0.53	0.58	1.83
72.	*Ligustrum robustum*	T	0.72	0.53	0.58	1.83
73.	*Lindera nacusua*	S	0.72	0.53	0.58	1.83

Sl. no.	Plant species	Habit	RF	RDen	RDom	IVI
74.	*Mahonia napaulensis*	T	0.72	0.53	0.58	1.83
75.	*Parkia timoriana*	T	0.72	0.53	0.58	1.83
76.	*Polyalthia jenkensii*	T	0.72	0.53	0.58	1.83
77.	*Premna bengalensis*	T	0.72	0.53	0.58	1.83
78.	*Sapindus mukorossi*	T	0.72	0.53	0.58	1.83
79.	*Spondias pinnata*	T	0.72	0.53	0.58	1.83
80.	*Stereospermum chelonoides*	T	0.72	0.53	0.58	1.83
81.	*Terminalia myriocarpa*	T	0.72	0.53	0.58	1.83
82.	*Terminalia retusa*	T	0.72	0.53	0.58	1.83
83.	*Walsura robusta*	T	0.72	0.53	0.58	1.83
84.	*Dendrocalamus longispathus*	H	0.72	0.79	0.00	1.51
85.	*Heliconia rostrata*	H	0.72	0.79	0.00	1.51
86.	*Hibiscus macrophyllus*	H	0.72	0.79	0.00	1.51
87.	*Mammea suriga*	S	0.72	0.79	0.00	1.51
88.	*Alphonsea lutea*	T	0.36	0.53	0.58	1.47
89.	*Antidesma bunius*	T	0.36	0.53	0.58	1.47
90.	*Caesalpinia cucullata*	H	0.36	0.53	0.58	1.47
91.	*Camphora glanduliferum*	T	0.36	0.53	0.58	1.47
92.	*Caryota urens*	T	0.36	0.53	0.58	1.47
93.	*Cassia javanica*	T	0.36	0.53	0.58	1.47
94.	*Chisocheton cumingianus*	T	0.36	0.53	0.58	1.47
95.	*Chrysophyllum roxburghii*	T	0.36	0.53	0.58	1.47
96.	*Connarus paniculatus*	T	0.36	0.53	0.58	1.47
97.	*Cordia dichotoma*	T	0.36	0.53	0.58	1.47
98.	*Diospyros pilosula*	T	0.36	0.53	0.58	1.47

Sl. no.	Plant species	Habit	RF	RDen	RDom	IVI
99.	*Diospyros stricta*	T	0.36	0.53	0.58	1.47
100.	*Dysoxylum alliaria*	T	0.36	0.53	0.58	1.47
101.	*Elaeocarpus lanceifolius*	T	0.36	0.53	0.58	1.47
102.	*Ficus fistulosa*	T	0.36	0.53	0.58	1.47
103.	*Ficus religiosa*	T	0.36	0.53	0.58	1.47
104.	*Flacourtia jangomas*	T	0.36	0.53	0.58	1.47
105.	*Gnetum gnemon*	T	0.36	0.53	0.58	1.47
106.	*Knema linofolia*	T	0.36	0.53	0.58	1.47
107.	*Macropanax dispermus*	T	0.36	0.53	0.58	1.47
108.	*Persea minutiflora*	T	0.36	0.53	0.58	1.47
109.	*Phrynium pubinerve*	T	0.36	0.53	0.58	1.47
110.	*Pseudostachyum polymorphum*	T	0.36	0.53	0.58	1.47
111.	*Saraca indica*	T	0.36	0.53	0.58	1.47
112.	*Trema orientalis*	T	0.36	0.53	0.58	1.47
113.	*Bombax ceiba*	T	0.36	0.26	0.29	0.92
114.	*Calamus acanthospathus*	T	0.36	0.26	0.29	0.92
115.	*Calamus guruba*	T	0.36	0.26	0.29	0.92
116.	*Calamus* sp.	T	0.36	0.26	0.29	0.92
117.	*Callicarpa arborea*	T	0.36	0.26	0.29	0.92
118.	*Choerospondias axillaris*	T	0.36	0.26	0.29	0.92
119.	*Croton lissophyllus*	T	0.36	0.26	0.29	0.92
120.	*Dioscorea pentaphylla*	H	0.36	0.26	0.29	0.92
121.	*Diospyros lanceifolia*	T	0.36	0.26	0.29	0.92
122.	*Dipterocarpus retusus*	T	0.36	0.26	0.29	0.92
123.	*Duabanga grandiflora*	T	0.36	0.26	0.29	0.92

Sl. no.	**Plant species**	**Habit**	**RF**	**RDen**	**RDom**	**IVI**
124.	*Elaeocarpus rugosus*	T	0.36	0.26	0.29	0.92
125.	*Ficus elastica*	T	0.36	0.26	0.29	0.92
126.	*Ficus racemosa*	T	0.36	0.26	0.29	0.92
127.	*Ficus semicordata*	T	0.36	0.26	0.29	0.92
128.	*Flacourtia indica*	T	0.36	0.26	0.29	0.92
129.	*Garcinia succifolia*	T	0.36	0.26	0.29	0.92
130.	*Lannea coromandelica*	T	0.36	0.26	0.29	0.92
131.	*Mallotus macrostachyus*	T	0.36	0.26	0.29	0.92
132.	*Mangifera indica*	T	0.36	0.26	0.29	0.92
133.	*Musa ornata*	H	0.36	0.26	0.29	0.92
134.	*Phoebe hainesiana*	T	0.36	0.26	0.29	0.92
135.	*Phoebe lanceolata*	T	0.36	0.26	0.29	0.92
136.	*Polyalthia simiarium*	T	0.36	0.26	0.29	0.92
137.	*Pouteria grandifolia*	T	0.36	0.26	0.29	0.92
138.	*Sapium baccatum*	T	0.36	0.26	0.29	0.92
139.	*Terminalia bellirica*	T	0.36	0.26	0.29	0.92
140.	*Terminalia citrina*	T	0.36	0.26	0.29	0.92
141.	*Terminalia crenulata*	T	0.36	0.26	0.29	0.92
142.	*Vitex quinata*	S	0.36	0.26	0.29	0.92
143.	*Willughbeia edulis*	T	0.36	0.26	0.29	0.92
144.	*Xantolis tomentosa*	S	0.36	0.26	0.29	0.92
145.	*Zalacca beccarii*	T	0.36	0.26	0.29	0.92
146.	*Lepionarus sylvestris*	H	0.36	0.53	0.00	0.89
147.	***Eriobotrya bengalensis***	H	0.36	0.26	0.00	**0.62**
148.	***Hardina cordiflora***	H	0.36	0.26	0.00	**0.62**

Notes–RF=Relative Frequency, RDen=Relative Density, RDom=Relative Dominance, IVI=Important Value Index, T=Trees, H=Herbs, C=Climbers and S=Shrubs.

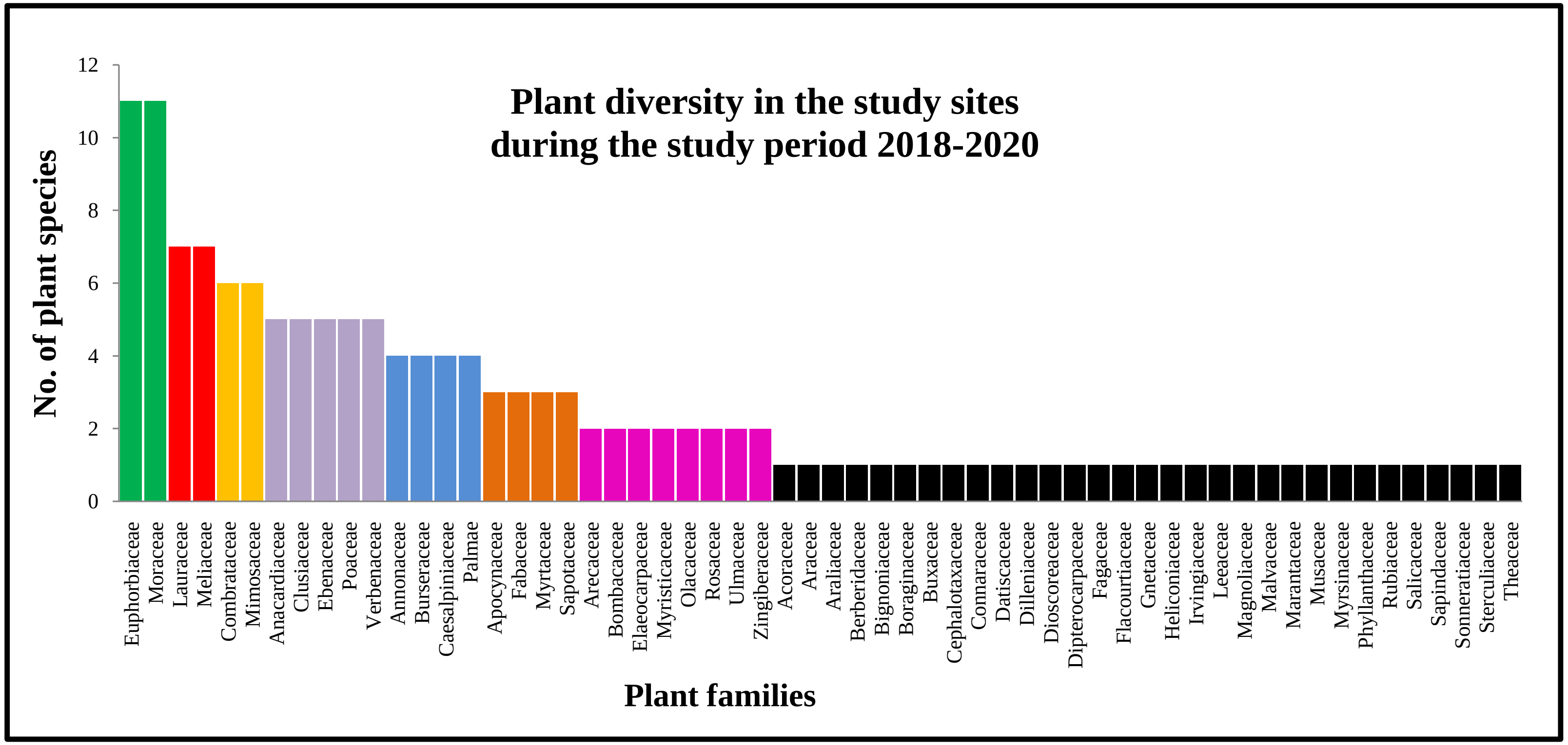

Figure 1.7: Diversity and composition of plant family present at the DTR study sites during the study period from 2018–2020.

1.24: Ecological parameters of AM feeding food plants

AM troop was observed to forage on 57 plant species under 46 genera belonging to 30 families (Table 1.2; Fig. 1.8A–N). Of the 57 feeding plants known to be consumed by AM with the highest time spent for feeding was calculated for *Artocarpus lakoocha* (15.65%), followed by *Albizia procera* (12.03%), *Glochidion hyneanum* (10.53%), *Diospyros glandulosa* (9.49%), *Albizia lebbeck* (7.28%) and while the minimum time spent less than 0.4% were *Schima wallichii* and *Xantolis tomentosa* (0.37%), *Terminalia crenulata* and *Castanopsis tribuloides* (0.36%), *Walsura robusta* (0.31%), *Phyllanthus emblica* (0.30%), *Terminalia myriocarpa* (0.21%) and the lowest was for *Vitex quinata* (0.12%).

Table 1.2: Food plants, plant parts consumed and time spent feeding (in %) for AM at study site during the study period 2018–2020.

Sl. No.	Food plants	Family	Vernacular (in Mizo)	Habit	Parts consumed	Time spent 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

Sl. No.	Food plants	Family	Vernacular (in Mizo)	Habit	Parts consumed	Time spent feeding (%)
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.	*Gmelina 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 richardiana*	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

Sl. No.	**Food plants**	**Family**	**Vernacular (in Mizo)**	**Habit**	**Parts consumed**	**Time spent feeding (%)**
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
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

Notes–L=Leaves, Fl=Flower, Fr=Fruits, Sh=Shoots Sd=Seeds.

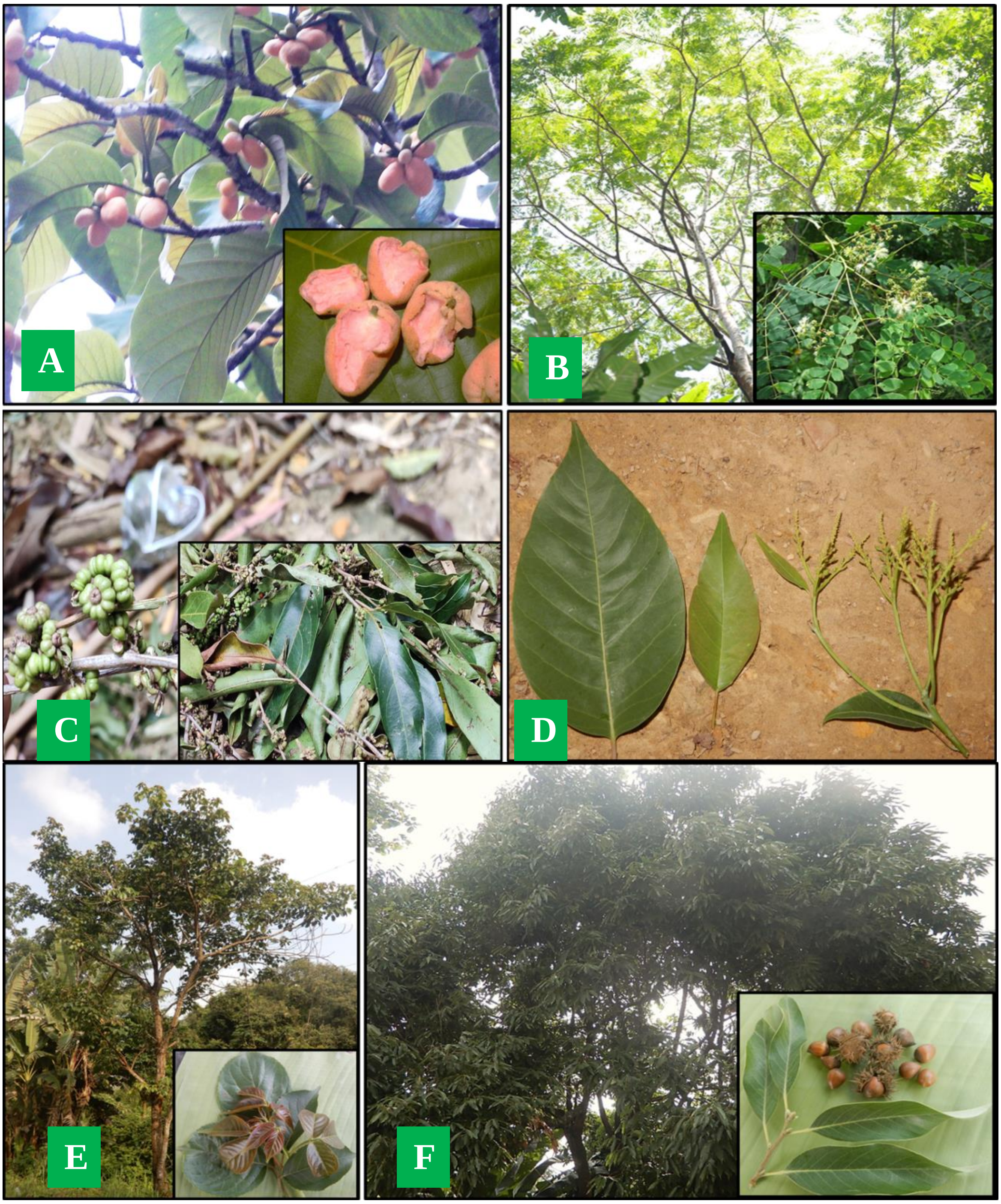

Figure 1.8 (A–F): Top food plants consumed both in AM and CL at the study sites from 2018–2020: (A) *Artocarpus lakoocha* tree (fruits), (B) *Albizia richardiana* tree (inset: Leaves and flowers), (C) *Diospyros glandulosa* (inset: Leaves, petioles and unripe fruits), (D) *Glochidion hyneanum* (Leaves and buds), (E) *Bischofia javanica* tree (Leaves), (F) *Castanopsis tribuloides* tree and its nut.

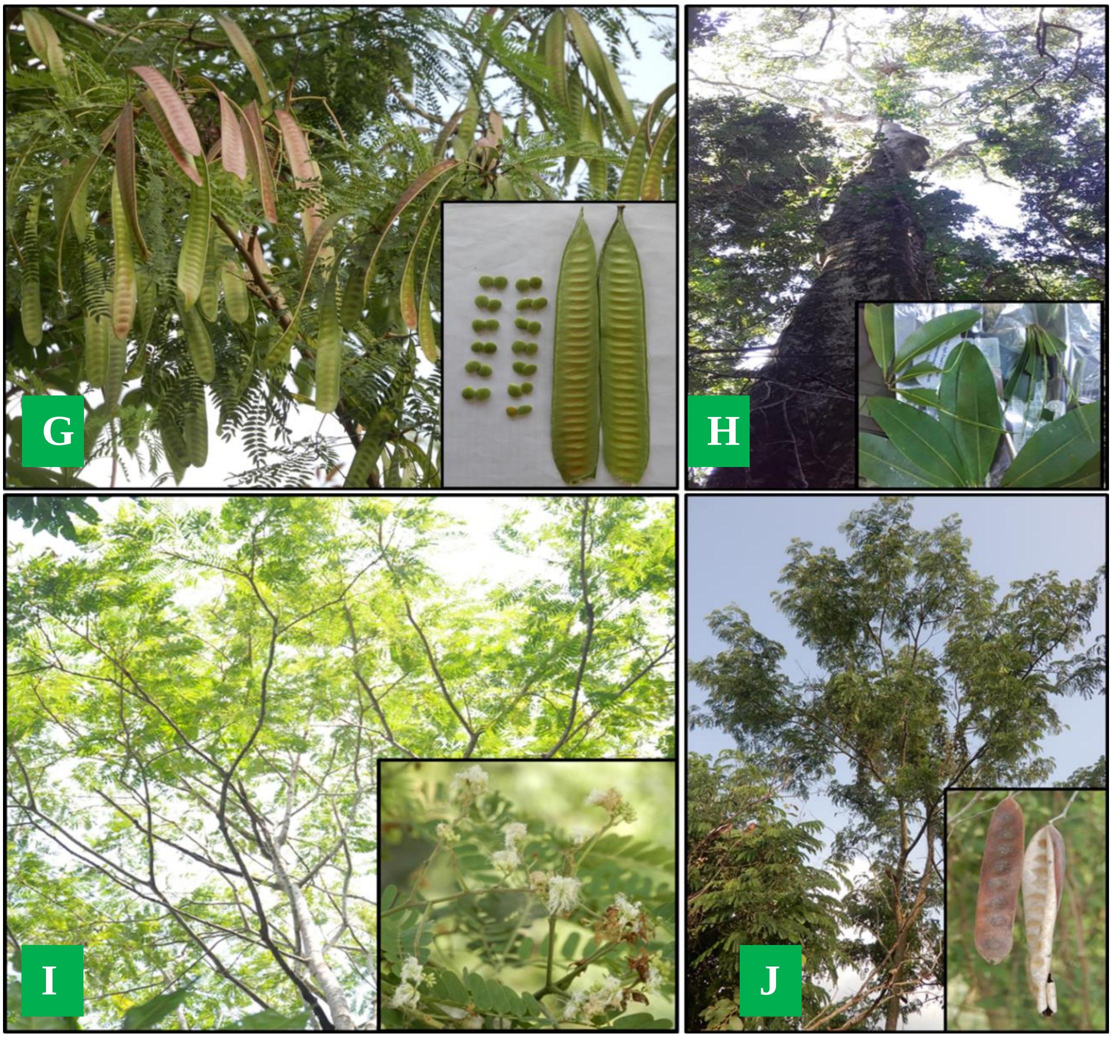

Figure 1.8 (G-J): (G) *Albizia chinensis* (Seeds and seed pod), (H) *Alstonia scholaris* tree (Leaves), (I) *Albizia lebbeck* tree and (Leaves and flowers), (J) *Albizia procera* (dry seed pods).

Figure 1.8 (K-N): (K) *Ficus auriculata* tree and bunch of ripe fruits, (L) *Protium serratum* tree (unripe fruit), (M) *Cephalotaxus graffithii* tree (fruit) and (N) *Bombax insigne* tree (petal blooming).

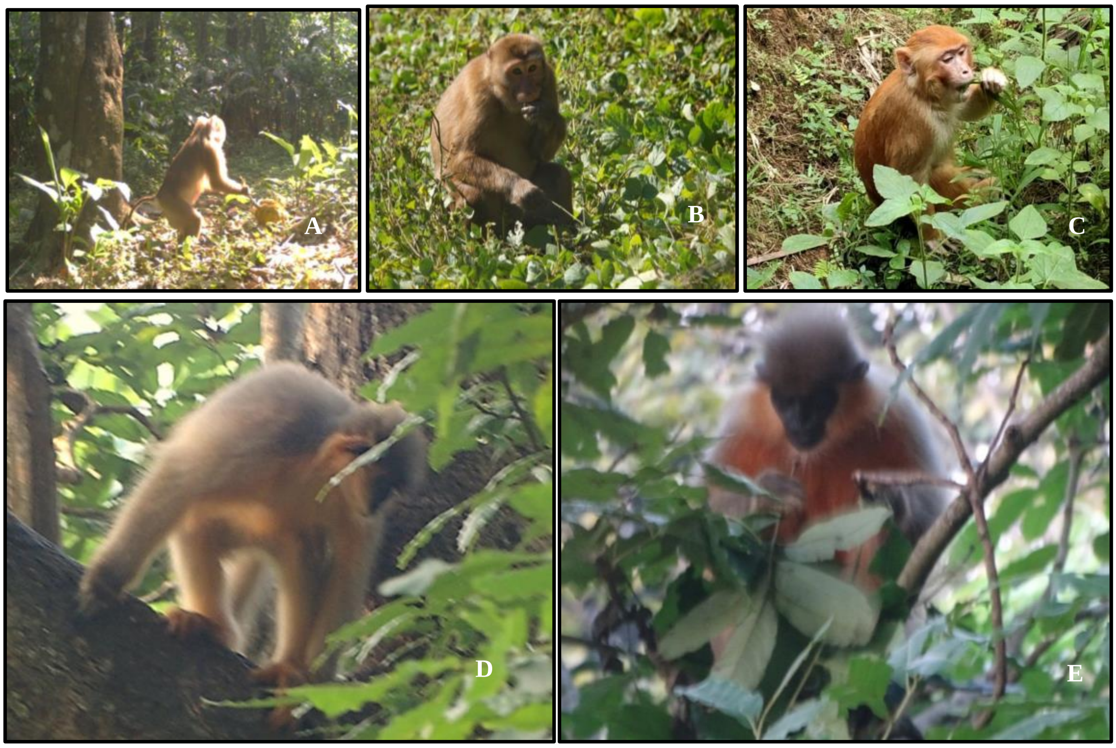

Figure 1.9 (A–E): Observation of focal individuals during feeding activity in DTR at study site during the study period 2018-2020; (A) AM adult male drags *Artocarpus heterophyllus* (Jackfruit) on the ground, (B) AM individual male feeding on herbs at forest floor, (C) Focal CL individual adult male active munching of leaves (D) Observation of adult while foraging and (E) Active chewing of petiole.

1.25: Ecological parameters and feeding activity of AM

In the study, 203 days of the survey resulted in 2233 scans and 16381 behavioural records AM troop were observed to forage on 57 plant species under 46 genera belongs to 30 families. 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%), *Glochidion hyneanum* (10.53%), *Diospyros glandulosa* (9.49%), *Albizia lebbeck* (7.28%), *Cephalotaxus graffithii* (4.53%), and *Ficus 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 least quantity (Fig. 1.9 A–E). The number of food plant species consumed in each observation month ranges from 20 to 43 (32.42 ±6.56) (Table 1.3). While plant species and its family were namely; *Artocarpus lakoocha* (Moraceae) and *Cephalotaxus graffithii* (Cephalotaxaceae) were fed throughout the year; however, species like; *Vitex quinata* (Verbenaceae) for one month during December, *Parkia timoriana* (Mimosaceae) for two months during February and March, and *Hydnocarpus kurzii* (Flacourtiaceae) for two months in December and January were consumed in the lowest number. Members of the family contributed the feeding plants of AM diet are such; Moraceae (9), Meliaceae (5), Mimosaceae and Euphorbiaceae (4), Combretaceae (3), Bombacaceae, Poaceae, Caesalpiniaceae, Magnoliaceae, Fabaceae, Verbenaceae and Anacardiaceae (2) and Ebenaceae, Cephalotaxaceae, Burseraceae, Rosaceae, Clusaceae, Musaceae, Gnetaceae, Myrtaceae, Dilleniaceae, Malvaceae, Lauraceae, Flacourtiaceae, Heliconiaceae, Sonnertiaceae, Theaceae, Sapotaceae, Fagaceaea and Phyllantaceae (1) (Fig.1.10). Among the feeding plant species, trees accounted for 91%, herbs 7% and climbers/vines 2%.

Table 1.3: Monthly variation of feeding time (in %) of AM for each plant species.

Sl no.	Plant species	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	No. of 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 acuminate*	-	-	-	-	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 nitidus*	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

Sl no.	Plant species	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	No. of months
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 semicordata*	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
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 hyneanum*	5.9	10.7	9.5	10.3	7.4	-	3.0	8.3	14.2	15.7	7.0	12.4	11
34.	*Gmelina 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

Sl no.	Plant species	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	No. of months
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

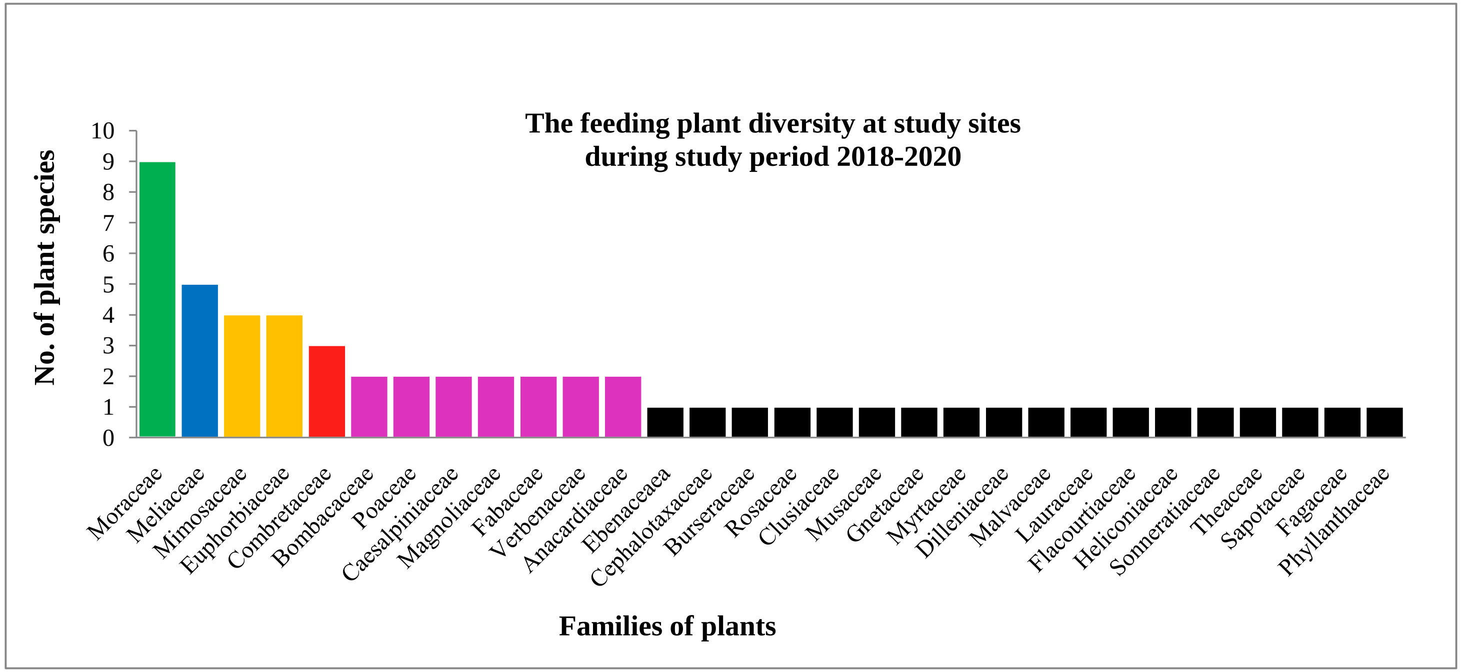

Figure 1.10: Plant families fed by AM at the study sites during study period 2018–2020.

AM troop was found to munch on different plant parts such as fruits, leaves (young and mature), 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%) (Fig. 1.11). The average diurnal feeding time spent for AM is 44%. The diurnal time invested of feeding was observed highest in January (59.03%) and lowest in July (35.19%) (Table 1.4). Plant species with family consumed belongs to such as; *Artocarpus lakoocha* (Moraceae), *Albizia procera* (Mimosacea), *Diospyros glandulosa* (Ebenaceae), *Protium serratum* (Burseraceae), *Dendrocalamus longispathus* (Poaceae) and *Duabanga grandiflora* (Sonneratiaceae) were identified to contribute with most number of consumable parts. Soft or tender shoots of *Dendrocalamus longispathus* and *Melocana baccifera* (Poaceae) were the plants whose shoots were fed by AM troops. Distribution of plant species indicates that *Acrocarpus fraxinifolius* (5.17%), *Magnolia oblonga* (4.42%), *Aporosa octandra* (3.67%) and *Canarium bengalense* (3.31%), and so on were present in the sampled quadrats although it does not represent the feeding utility by AM in its diet.

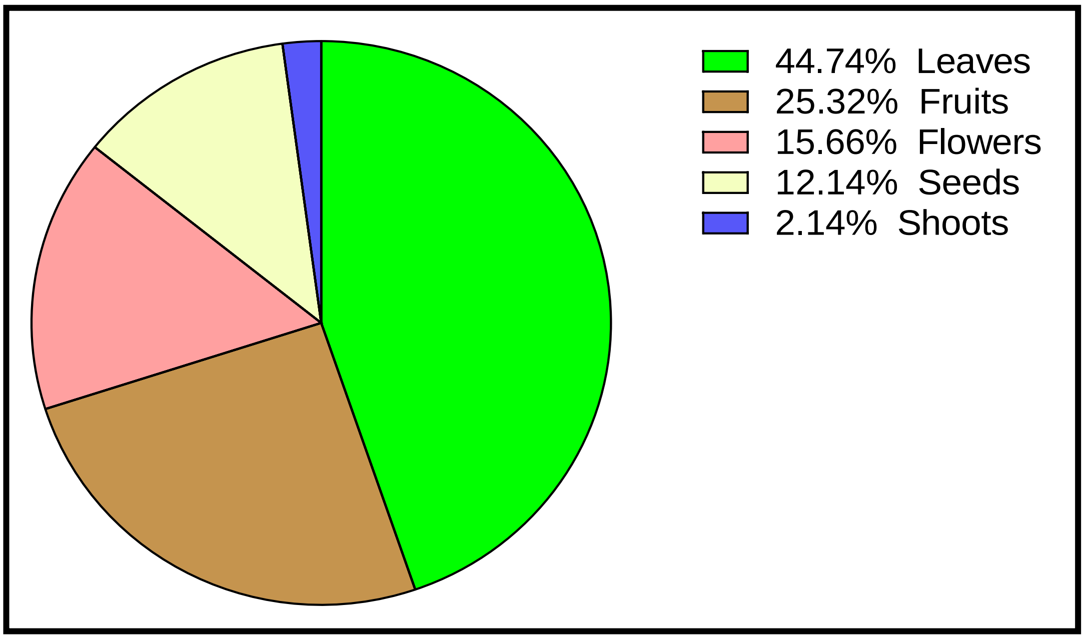

Figure 1.11: Pie–chart (in %) representation of AM consumption of the dietary components.

Table 1.4: Diurnal time invested by AM on feeding activity (average 44%) during study period 2018–2020.

Sl. No.	**Month**	**Leaves**			**Flowers**			**Fruits**			**Seeds**			**Shoots**			**Overall total**	**Diurnal time spent (in %)**
		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.	Sept	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**	564.80	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**	698.80	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**	676.00	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**	614.40	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**	850.10	**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**	671.70	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**	798.00	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**	601.10	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**	589.20	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**	7.60	0.00	**7.60**	506.80	**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	**46.0**	589.20	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**	583.60	40.52

1.26: Ecological parameters and feeding activity of CL

In this study, 196 days of the survey resulted in 2156 feeding scans and 16060 behavioral records for CL were observed to forage on 66 different plant species under 54 genera from 33 families (Table 1.5). The ten major feeding plants of CL identified were; *Albizia chinensis* (7.28%), *Alstonia scholaris* (5.61%), *Albizia richardiana* (4.77%), *Albizia lebbeck* (4.48%), *Bischofia javanica* (4.41%), *Castanopsis tribuloides* (4.14%), *Aglaia edulis* (3.86%), *Cephalotaxus graffithii* (2.86%), *Diospyros glandulosa* (3.64%) and *Albizia procera* (2.82%). While plants such as *Mallotus macrostachyus* (0.19%), *Terminalia crenulata* (0.17%), *Mammea suriga* (0.16%), *Parkia timoriana* (0.15%), *Terminalia myriocarpa* (0.13%) were found to be consumed in low quantity. While plants species such as *Alstonia scholaris* (Apocynaceae), *Bischofia javanica* (Euphorbiaceae), *Derris robusta* (Fabaceae), *Cephalotaxus graffithii* (Cephalotaxaceae), *Albizia* spp. (Mimosaceae) and *Choerospondias axillaris* (Anacardiaceae) were fed throughout the year; species such as *Mammea suriga* (Clusiaceae), *Parkia timoriana* (Mimosaceae), *Terminalia crenulata* and *Terminalia myriocarpa* (Combretaceae) were only during the certain months.

Table 1.5: Food plants, plant parts consumed and time spent feeding (in %) for CL at study site during study period from 2018–2020.

Sl. No.	Food plants	Family	Vernacular (in Mizo)	Habit	Parts consumed	Time spent feeding %
1.	***Albizia chinensis***	Mimosaceae	Vang	T	L, Fl, Fr	**7.28**
2.	*Alstonia scholaris*	Apocynaceae	Thuamriat	T	L, Fl, Fr	5.61
3.	*Albizia richardiana*	Mimosaceae	Thingchawl	S	L, Fl, Fr, Sd	4.77
4.	*Albizia lebbeck*	Mimosaceae	Kangtekpa	T	L, Fr, Fl, Sd	4.48
5.	*Bischofia javanica*	Euphorbiaceae	Khuangthli	T	L, Fr, Sd	4.41
6.	*Castanopsis tribuloides*	Fagaceae	Thingsia	T	L, Sd	4.14

Sl. No.	Food plants	Family	Vernacular (in Mizo)	Habit	Parts consumed	Time spent feeding %
7.	*Aglaia edulis*	Meliaceae	Raithei	T	L, Fl, Fr, Sd	3.86
8.	*Diospyros glandulosa*	Ebenaceae	Theivawkmit	T	L, Fr, Sd	3.64
9.	*Cephalotaxus graffithii*	Cephalotaxaceae	Thinglenbuang	T	Fr	2.86
10.	*Albizia procera*	Mimosaceae	Kangtek	T	L, Fr, Fl, Sd	2.82
11.	*Schima wallichii*	Theaceae	Khiang	T	L, Fr	2.48
12.	*Glochidion heynaenum*	Euphorbiaceae	Thingpawnchhia	T	L, Fl, Fr	2.20
13.	*Choerospondiasaxi llaris*	Anacardiaceae	Theikhuangchaw m	T	L, Fl	2.10
14.	*Artocarpus lakoocha*	Moraceae	Theitat	T	L, Fr, Sd	2.10
15.	*Protium serratum*	Burseraceae	Bil	T	L, Fl, Fr, Sd	2.01
16.	*Artocarpus nitidus*	Moraceae	Tatkawng	T	L, Sd	2.01
17.	*Antidesma bunius*	Euphorbiaceae	Tuaitit	T	L, Fr, Sd	1.97
18.	*Duabanga grandiflora*	Sonneratiaceae	Zuang	T	L, Fl, Sd	1.93
19.	*Anogeissus acuminata*	Combretaceae	Zairum	T	L, Fr	1.91
20.	*Cassia javanica*	Caesalpiniaceae	Makpazangkang	T	L, Fl, Sd	1.78
21.	*Aporosa octandra*	Euphorbiaceae	Chhawntual	T	L, Fr, Sd	1.65
22.	*Chrysophyllum roxburghii*	Sapotaceae	Theipabuan	T	L, Fl, Fr, Sd	1.56
23.	*Derris robusta*	Fabaceae	Thingkha	T	Fl, Fr	1.56
24.	*Ficus semicordata*	Moraceae	Bung	T	L, Fl, Fr	1.52
25.	*Dillenia indica*	Dilleniaceae	Kawrthindeng	T	Fl, Fr	1.40
26.	*Chukrasia tabularis*	Meliaceae	Zawngtei	T	L, Fl, Fr	1.39
27.	*Bombax ceiba*	Bombacaceae	Phunchawng	T	L, Fl	1.38
28.	*Bombax insigne*	Bombacaceae	Pang	T	L, Fl	1.36
29.	*Caesalpinia cucullata*	Caesalpiniaceae	Hlingkhang	C	L, Fr, Sd	1.35
30.	*Ficus variegata*	Moraceae	Chhohe	T	L, Fr	1.35
31.	*Dioscorea pentaphylla*	Dioscoreaceae	Vawkpuibahra	H	L	1.34

Sl. No.	Food plants	Family	Vernacular (in Mizo)	Habit	Parts consumed	Time spent feeding %
32.	*Camphora glanduliferum*	Lauraceae	Khiangzo	T	L, Fl	1.33
33.	*Ficus racemosa*	Moraceae	Theichek	T	L, Fl	1.21
34.	*Prunus ceylanica*	Rosaceae	Ruphir	T	L, Sd	1.13
35.	*Toona ciliata*	Meliaceae	Teipui	T	L, Fr	1.03
36.	*Gnetum gnemon*	Gnetaceae	Pelh	T	L, Fr	1.00
37.	*Hydnocarpus kurzii*	Flacourtiaceae	Khawitur	T	L, Fl, Fr	0.93
38.	*Dysoxylum gotadhora*	Meliaceae	Sahatah	T	L, Fl	0.90
39.	*Gmelina arborea*	Verbenaceae	Thlanvawng	T	L, Fl, Fr	0.86
40.	*Dendrocalamus longispathus*	Poaceae	Rawnal	H	Sh	0.83
41.	*Ficus retusa*	Moraceae	Rihnim	T	L, Fr	0.78
42.	*Terminalia bellirica*	Combretaceae	Thingvandawt	T	Fl, Fr	0.75
43.	*Xantolis tomentosa*	Sapotaceae	Maudo	S	L	0.74
44.	*Melocana baccifera*	Poaceae	Mautuai	H	Sh	0.72
45.	*Garcinia succifolia*	Clusiaceae	Tuaithleng	T	L, Fl, Sd	0.64
46.	*Sapindus mukorossi*	Sapindaceae	Hlingsi	T	L, Fl, Fr	0.61
47.	*Syzygium cumini*	Myrtaceae	Lenhmui	T	L, Sd	0.59
48.	*Phyllanthus emblica*	Phyllanthaceae	Sunhlu	T	L, Fr	0.52
49.	*Mangifera indica*	Anacardiaceae	Theihai	T	L, Fl, Fr	0.48
50.	*Vitex quinata*	Verbenaceae	Thlengreng	T	L, Fr	0.47
51.	*Ficus religiosa*	Moraceae	Hmawng	T	L, Fl, Fr	0.46
52.	*Walsura robusta*	Meliaceae	Perte	T	L, Sd	0.45
53.	*Ficus elastica*	Moraceae	Thialret	T	Fl	0.43
54.	*Magnolia oblonga*	Magnoliaceae	Ngiau	T	L, Fl, Fr, Sd	0.42
55.	*Heliconia rostrata*	Heliconiaceae	Changel	H	L, Fr, Fl	0.39
56.	*Musa ornata*	Musaceae	Changvandawt	H	Fl, Fr	0.31
57.	*Trema orientalis*	Ulmaceae	Belphuar	T	L, Fr	0.25
58.	*Spondius pinnata*	Anacardiaceae	Tawitaw	T	L, Fr	0.21
59.	*Litsea monopetala*	Lauraceae	Nauthak	T	L, Fl	0.21

Sl. No.	Food plants	Family	Vernacular (in Mizo)	Habit	Parts consumed	Time spent feeding %
60.	*Willughbeia edulis*	Apocynaceae	Vuakdup	C	L, Fl, Fr	0.19
61.	*Mallotus macrostachyus*	Euphorbiaceae	Kharpa	T	Fr	0.19
62.	*Terminalia crenulata*	Combretaceae	Tualram	T	L, Sd	0.17
63.	*Mammea suriga*	Clusiaceae	Suktlawng	T	Sd	0.16
64.	*Hibiscus macrophyllus*	Malvaceae	Vaiza	T	L, Fr	0.15
65.	*Parkia timoriana*	Mimosaceae	Zawngtah	T	Sd	0.15
66.	*Terminalia myriocarpa*	Combretaceae	Char	T	L, Fr	0.13

Note: T–Tree, H–Herb, C–Climber, S–Shrub, L–Leaves, Fl–Flowers, Fr–Fruits, Sd–Seeds and Sh–Shoots.

Among the feeding plant species, trees accounted for 86.36%, herbs 7.58%, shrubs and climbers 3.03%, respectively. The number of food plant species consumed in each observation month ranges from 34 to 57 (42.42 ±6.35) (Table 1.6). The diversity of plants were mainly observed and contributed greatest from the Moraceae (8), Malvaceae (6), Euphorbiaceae and Mimosaceae (5), Combretaceae (4), Anarcadiaceae (3), and Apocynaceae, Bombacaceae, Caesalpiniaceae, Clusiaceae, Fabaceae, Lauraceae, Poaceae, Sapotaceae, Verbenaceae (2) Burseraceae, Cephalotaxaceae, Dilliniaceae, Dioscoreaceae, Ebenaceae, Flacourtiaceae, Gnetaceae, Heliconiaceae, Magnoliaceae, Musaceae, Myrtaceae, Phyllanthaceae, Rosaceae, Sapindaceae, Sapotaceae, Sonnertaceae, Theaceae and Ulmaceae (1) of feeding plants of CL diet (Fig. 1.12).

Table 1.6: Monthly variation of feeding time (%) of CL for each plant species.

Sl. no.	Name of species	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	No. of months
1.	*Aglaia edulis*	2.91	-	5.53	-	4.17	4.94	4.94	3.38	2.93	4.11	3.76	8.55	10
2.	*Albizia chinensis*	4.39	8.56	9.68	8.85	6.42	4.29	3.16	7.97	4.99	9.54	5.58	11.82	12
3.	*Albizia lebbeck*	8.09	3.20	3.03	5.35	5.43	5.20	3.31	3.22	3.44	5.69	2.81	3.77	12
4.	*Albizia procera*	2.40	-	3.63	4.78	3.25	2.75	3.41	2.72	1.63	1.35	3.32	3.79	11
5.	*Albizia richardiana*	1.60	4.65	3.92	9.87	5.01	4.78	4.67	4.82	6.39	5.30	4.18	0.77	12
6.	*Alstonia scholaris*	3.77	6.35	4.75	6.28	6.55	8.08	4.98	3.08	5.05	6.63	5.40	4.87	12
7.	*Anogeisus acuminate*	2.64	3.15	2.25	-	2.69	2.40	2.23	1.88	2.16	1.61	0.44	0.88	11
8.	*Antidesma bunius*	1.73	-	2.89	1.70	2.24	2.77	2.23	2.90	2.23	1.25	0.58	2.61	11
9.	*Aporosa octandra*	2.22	-	3.05	-	1.28	0.50	1.71	2.35	4.00	1.53	0.83	1.81	10
10.	*Artocarpus nitidus*	1.79	-	4.56	3.14	2.44	2.75	1.65	0.85	1.65	1.79	0.96	1.92	11
11.	*Artocarpus lakoocha*	1.92	-	2.31	4.43	1.47	1.67	3.02	3.16	1.85	1.20	1.07	2.53	11
12.	*Bischofia javanica*	0.82	8.35	5.94	1.70	5.81	4.46	2.00	7.93	5.63	3.87	3.21	2.36	12
13.	*Bombax ceiba*	1.29	2.05	2.04	-	4.19	1.95	1.57	0.99	-	0.99	0.69	0.44	10
14.	*Bombax insigne*	1.34	2.89	1.28	-	3.85	3.01	0.51	0.53	-	1.35	0.81	0.38	10
15.	*Caesalpinia cucullata*	3.41	-	2.74	-	1.65	1.24	2.22	2.29	-	0.81	0.65	0.80	9
16.	*Cassia javanica*	3.19	0.52	2.43	0.91	2.07	2.77	3.18	2.27	-	1.51	1.14	0.91	11
17.	*Castanopsis tribuloides*	3.41	7.48	1.94	-	1.62	4.31	5.53	3.83	6.60	4.72	1.21	7.83	11
18.	*Cephalotaxus graffithii*	1.85	0.84	3.41	4.56	1.73	4.91	3.39	0.83	2.16	4.19	2.06	3.74	12
19.	*Choerospondias axillaris*	0.99	3.15	3.98	1.06	1.69	1.17	2.49	4.28	1.26	1.46	0.65	2.47	12
20.	*Chrysophyllum roxburghii*	0.55	3.67	3.12	-	2.50	0.67	0.84	1.65	1.92	1.77	0.99	0.63	11
21.	*Chukrasia tabularis*	0.33	2.55	2.97	-	2.14	0.87	2.53	0.73	1.98	1.38	-	0.85	10
22.	*Camphora glanduliferum*	1.68	-	1.46	-	1.50	1.39	2.59	1.22	2.35	2.91	0.38	0.16	10
23.	*Dendrocalamus longispathus*	1.63	0.71	-	-	-	-	-	-	-	1.74	2.01	3.63	5
24.	*Derris robusta*	0.41	2.05	1.94	2.29	2.41	1.23	1.18	0.61	3.26	2.21	0.21	0.44	12
25.	*Dillenia indica*	0.56	1.55	2.27	-	1.97	0.78	1.96	0.95	2.86	2.63	0.26	0.58	11
26.	*Dioscorea pentaphylla*	1.04	0.63	3.55	-	-	0.32	2.74	3.32	1.88	0.96	0.39	0.91	10

Sl. no.	**Name of species**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**No. of months**
27.	*Diospyros glandulosa*	7.48	-	4.02	0.89	-	3.68	3.61	3.38	4.12	5.88	2.24	7.31	10
28.	*Duabanga grandiflora*	1.46	-	2.35	2.97	-	0.72	2.00	5.98	2.93	2.08	-	2.14	9
29.	*Dysoxylum gotadhora*	0.27	-	1.75	-	-	1.02	1.80	1.30	1.63	0.91	-	1.87	7
30.	*Ficus auriculata*	1.32	1.02	2.10	1.93	-	1.26	0.88	1.88	1.65	1.98	2.17	1.68	11
31.	*Ficus elastic*	1.02	-	-	-	-	0.84	1.12	-	1.44	-	-	0.60	5
32.	*Ficus racemosa*	0.82	0.24	1.18	1.66	-	0.89	0.39	1.01	1.13	2.18	2.65	2.01	10
33.	*Ficus religiosa*	0.27	-	1.11	-	-	0.39	1.08	0.55	1.01	-	0.67	0.27	7
34.	*Ficus retusa*	1.02	1.63	0.33	-	-	1.21	0.65	0.87	1.17	-	0.83	1.43	9
35.	*Ficus variegata*	0.88	1.24	-	2.74	0.60	1.78	-	0.65	1.20	2.86	2.40	1.41	10
36.	*Garcinia succifolia*	0.52	-	-	3.31	-	1.19	-	1.14	0.39	-	0.97	-	6
37.	*Glochidion hyneanum*	3.52	-	-	5.03	-	3.20	3.63	-	3.81	-	2.39	4.18	7
38.	*Gmelina arborea*	1.76	-	-	1.93	-	-	2.47	1.88	0.68	-	1.39	-	6
39.	*Gnetum gnemon*	0.00	-	-	0.98	-	-	2.63	2.51	1.30	3.09	0.40	0.74	7
40.	*Heliconia rostrata*	0.82	-	-	2.27	-	-	-	1.46	-	-	-	-	3
41.	*Hibiscus macrophyllus*	0.25	-	-	1.19	-	-	-	-	0.35	-	-	-	3
42.	*Hydnocarpus kurzii*	0.38	1.42	0.97	1.99	2.71	1.99	0.00	1.48	-	-	-	-	7
43.	*Litsea monopetala*	1.76	-	0.02	0.38	-	0.28	-	-	-	-	-	-	3
44.	*Magnolia oblonga*	0.38	-	-	3.20	-	0.35	0.59	-	0.39	-	-	-	5
45.	*Mallotus macrostachyus*	-	-	-	-	-	-	0.10	-	1.03	1.04	-	-	3
46.	*Mammea suriga*	1.07	-	-	-	-	-	0.63	-	-	-	-	0.19	2
47.	*Mangifera indica*	0.17	1.84	-	0.66	0.41	-	0.39	2.19	-	-	-	-	6
48.	*Melocana baccifera*	1.87	-	-	-	-	-	-	-	-	1.48	1.94	3.19	4
49.	*Musa ornate*	0.60	2.07	-	0.23	-	-	-	-	0.72	-	-	-	4
50.	*Parkia timoriana*	-	-	-	-	0.94	0.80	-	-	-	-	-	-	2
51.	*Phyllanthus emblica*	0.55	2.23	-	-	2.72	-	-	0.95	-	-	-	-	4
52.	*Protium serratum*	0.42	5.14	-	2.95	-	3.49	2.29	-	2.66	1.33	2.97	1.40	9
53.	*Prunus ceylanica*	1.93	-	-	2.34	1.63	1.71	2.12	1.07	0.56	0.91	1.53	-	9

Sl. no.	**Name of species**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**No. of months**
54.	*Sapindus mukorossi*	-	2.23	-	1.40	2.31	-	1.25	-	-	-	-	-	4
55.	*Schima wallichii*	4.71	6.76	-	2.86	2.68	1.77	2.18	1.32	2.45	0.77	2.61	2.12	11
56.	*Spondius pinnata*	1.24	-	-	-	1.03	-	0.20	-	-	-	-	-	3
57.	*Syzygium cumini*	0.30	2.07	-	0.95	3.01	-	-	-	0.56	-	-	-	5
58.	*Terminalia bellirica*	1.54	3.33	-	-	1.47	0.82	-	0.75	-	-	0.83	-	6
59.	*Terminalia crenulata*	1.37	-	-	-	-	-	-	-	-	-	0.61	-	2
60.	*Terminalia myriocarpa*	0.58	-	-	-	-	-	-	-	-	-	0.89	-	2
61.	*Toona ciliate*	-	3.15	-	-	-	2.25	1.24	1.85	1.22	1.73	0.61	-	7
62.	*Trema orientalis*	0.55	-	-	1.55	-	0.46	-	-	-	-	0.36	-	4
63.	*Vitex quinata*	0.27	0.60	0.85	0.28	2.27	-	0.74	-	-	-	0.42	-	7
64.	*Walsura robusta*	-	-	-	0.70	-	-	-	-	1.22	1.27	2.06	-	4
65.	*Willughbeia edulis*	1.37	-	-	0.62	-	-	-	-	-	-	0.28	-	3
66.	*Xantolis tomentosa*	1.54	2.36	0.68	0.08	2.57	1.49	-	-	-	-	-	-	6

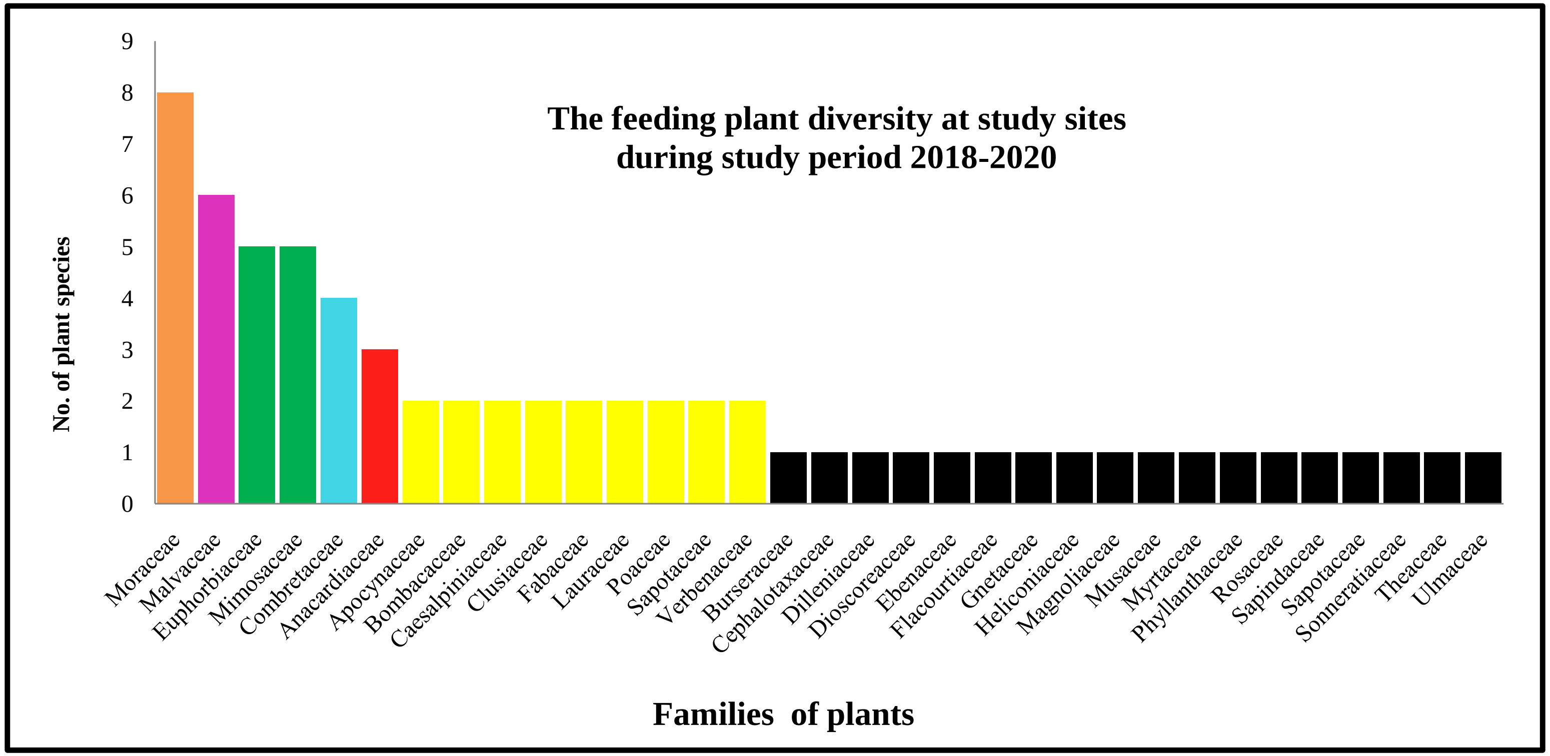

Figure 1.12: 66 food plants families observed for CL at the feeding site during the study site during 2018–2020.

CL troop ate different plant parts such as; fruits, leaves (young and mature), flowers, shoots, and seeds. Leaves formed the highest proportion of CL diet with 46.24% followed by fruits 21.66%, flowers 18.19%, seeds 11.52%, and shoots 2.39% (Fig. 1.13). The diurnal time invested of feeding was observed highest in January (40.77%) and lowest in July (35.29%) (Table 1.7). Plants species and their parts consumed are follows; *Albizia chinensis* (Mimosaceae), *Alstonia scholaris* (Apocynaceae), *Aglaia edulis* (Meliaceae), *Protium serratum* (Burseraceae), *Cephalotaxus graffithii* (Cephalotaxaceae) and *Melocana baccifera* (Poaceae), respectively were identified to contribute with most number of consumable parts. Soft or tender shoots of *Dendrocalamus longispathus* (Poaceae) and *Melocana baccifera* were the plants whose shoots were fed by CL troop. Distribution of feeding plant species indicates that *Acrocarpus fraxinifolius* (5.17%), *Magnolia oblonga* (4.42%), *Aporosa octandra* (3.67%), *Canarium bengalense* (3.31%), *Melocalamus compactiflorus* (3.02%), *Anogeissus acuminata* (2.94%) and *Drimycarpus racemosus* (2.75%), and so on were present in the sampled quadrats though it does not represent the feeding utility by CL in its diet.

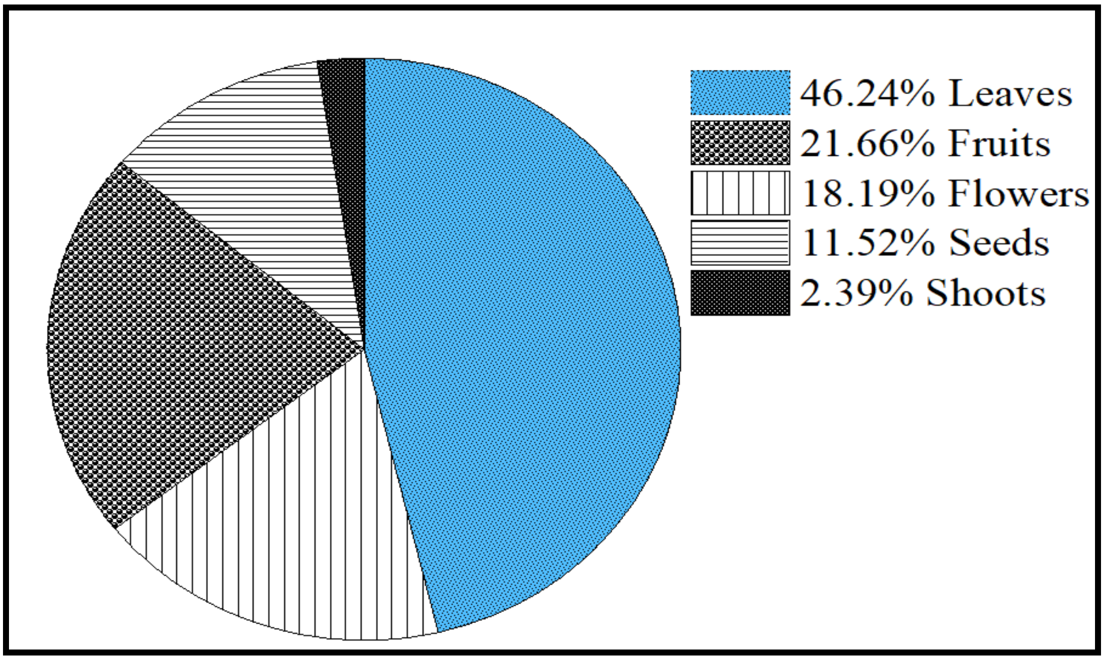

Figure 1.13: Pie–chart representing the proportions of dietary components (%) consumed by CL.

Table 1.7: Diurnal time invested by CL on feeding activity (average 38.70%) during study period 2018–2020.

Sl. No.	**Months**	**Leaves**			**Flowers**			**Fruits**			**Seeds**			**Shoots**			**Overall total**	**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.	Sept	55.68	59.51	**115.19**	31.95	30.95	**61.9**	30.5	32.2	**62.7**	13.5	5.7	**19.2**	5.6	9	**14.6**	273.59	38.00
2.	Oct	67.53	79.68	**147.21**	30	22.38	**52.38**	31.68	33	**64.68**	10.5	15.5	**26**	0	0	**0**	290.27	40.32
3.	Nov	58.54	49.17	**107.71**	28.25	18.25	**46.5**	36.26	36.28	**72.44**	32.46	28.63	**61.09**	0	0	**0**	287.74	39.96
4.	Dec	59.64	55.73	**104.9**	28.25	10.7	**38.95**	29.18	34.6	**63.78**	33.5	41.4	**74.9**	0	0	**0**	282.53	39.24
5.	**Jan**	41.16	55.07	**106.22**	23.78	22.1	**45.88**	24.88	17.6	**42.48**	52.78	46.18	**98.95**	0	0	**0**	293.53	**40.77**
6.	Feb	76.94	68.19	**145.14**	20.1	27.85	**47.95**	30.4	28.58	**58.98**	15.05	17.1	**32.15**	0	0	**0**	284.22	39.48
7.	Mar	88.7	80.53	**169.23**	35.55	37.75	**73.3**	15.95	8.65	**24.6**	10.35	5	**15.35**	0	0	**0**	282.48	39.23
8.	Apr	63.61	79.16	**142.76**	45.93	29.28	**75.2**	24.4	22.75	**47.15**	3.83	6.2	**10.03**	0	0	**0**	275.14	38.21
9.	May	66.75	76.09	**142.84**	40.85	38.35	**79.2**	33.23	29.8	**63.03**	0	0	**0**	0	0	**0**	285.05	39.59
10.	Jun	58.67	58.02	**116.69**	23.7	18.93	**42.63**	47.25	32.75	**70**	8.15	6.1	**14.25**	8.65	14.5	**23.15**	266.72	37.04
11.	**Jul**	56.7	68.25	**114.95**	8.85	8.7	**17.55**	49.95	34.98	**84.93**	4.6	1.13	**15.73**	12.05	8.9	**20.95**	254.11	**35.29**
12.	Aug	65.51	67.73	**133.23**	16	10.8	**26.8**	27.45	42.05	**69.5**	8.33	9.1	**17.43**	10.8	10.55	**21.35**	268.31	37.27

1.27: Monthly and seasonal effect on feeding phenology of AM

In the present observation, leaves (young and mature) and fruits constituted the major food items of AM troop 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 (44.74%) as they were available throughout the years. No significant variation was observed on time spent on feeding leaves in different months of the year (H=19.46, df=11, p>0.05). Similarly, there was no significant variation in the time spent on feeding of leaves in different seasons (H=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 (H=15.87, df=11, p>0.05) and seasons (H=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. 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 species; *Melocana baccifera* and *Dendrocalamus longispathus* were fed only in monsoon (June to 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*, *Artocarpus lakoocha*, *Albizia chinensis* and *Bombax insigne* were observed to be consumed throughout the year and thus represent the primary sources of nutrients for AM troop (Fig. 1.14).

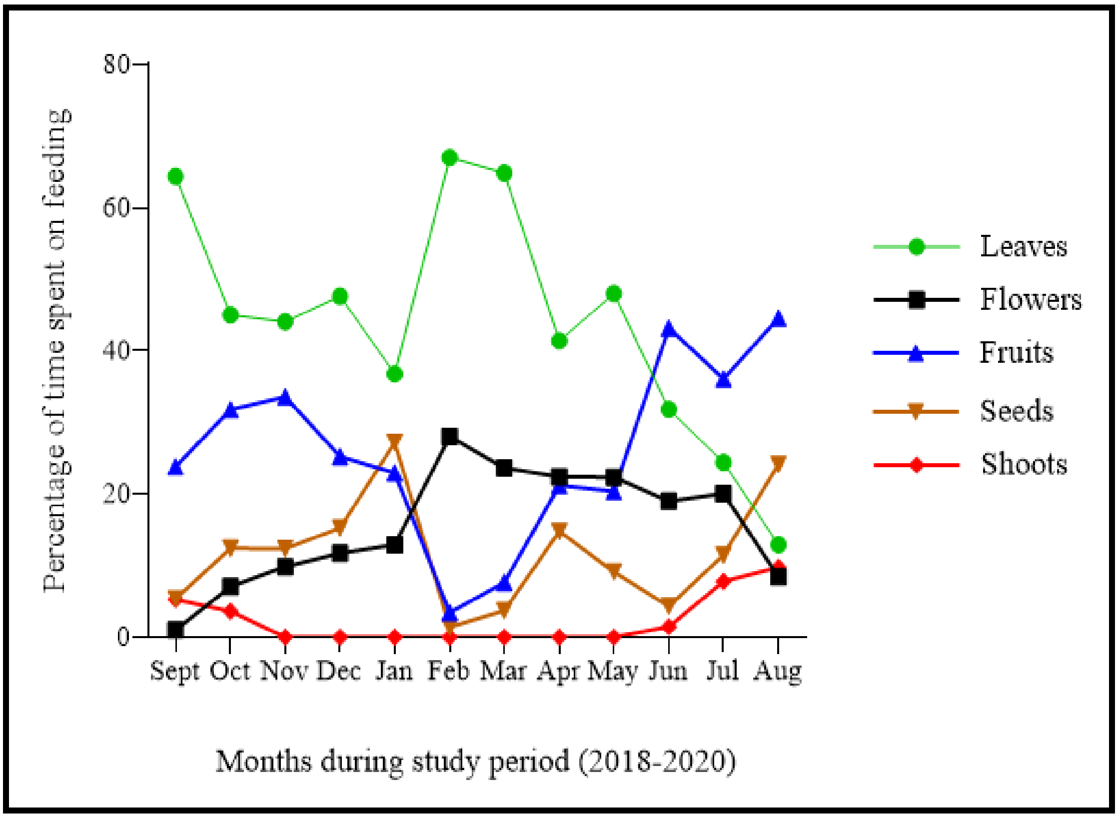

Figure 1.14: Graphical lines representing the monthly variation (%) of AM feeding budget.

In the present observation for CL, leaves (young and mature) and fruits constituted the major food items eaten by CL and they invested more time for feeding on these food items. Leaves formed the highest bulk of CL diet (46.24%), as it is available throughout the years. No significant variation was observed on time spent on feeding leaves in different months of the year (H=18.66, df=11, p=0.06). Similarly, there is no significant variation in the time spent on feeding of leaves in different seasons (H=4.86, df=2, p=0.08). Fruits were most abundant during monsoon/summer and constituted the major food item during the month of June to August (22.90% to 33.42%). CL were observed to feed maximum fruits in the month of July (33.42% of the total food items), and the least consumption of fruits was recorded in the month of March (22% of the total food items). Time spent on feeding of fruits did not show significant variation in different months (H=18.22, df=11, p=0.07) and seasons (H=3.18, df=2, p=0.20). The highest consumption of flowers was observed in the month of May (27.78%), there is no significant variation in the time spent on feeding of flowers observed monthly (H=19.27, df=11, p=0.05), however there is a significant variation seasonally (H=7.28, df=2, p=<0.05). Seeds were found to be consumed mainly in winters (H=16.09, df=2, p<0.01 when there was a scarcity of fleshy fruits, and the highest seed consumption was recorded in January (33.71%) there is monthly significance of seeds consumption (H=21.37, df=11, p<0.05), with a seasonally significant variation (H=16.09, df=2, p<0.01). Shoots of bamboo species were fed only in monsoon (June to September) with highest consumption of shoots in the month of July (8.68%) while the least consumption was observed in September month (5.34%) with seasonally significant variation (H=9.20, df=2, p<0.05) and the total time spent on feeding of shoots during the observation period was only 2.39% and also observed the monthly significant variation (H=22.120, df=11, p<0.05). Plant species such as; *Albizia chinensis*, *Albizia lebbeck*, *Albizia richardiana*, *Alstonia scholaris*, *Bischofia javanica*, *Castanopsis tribuloides* and *Cephalotaxus graffithii* were observed to be consumed throughout the year and thus represent the primary sources of nutrients for CL (Fig. 1.15).

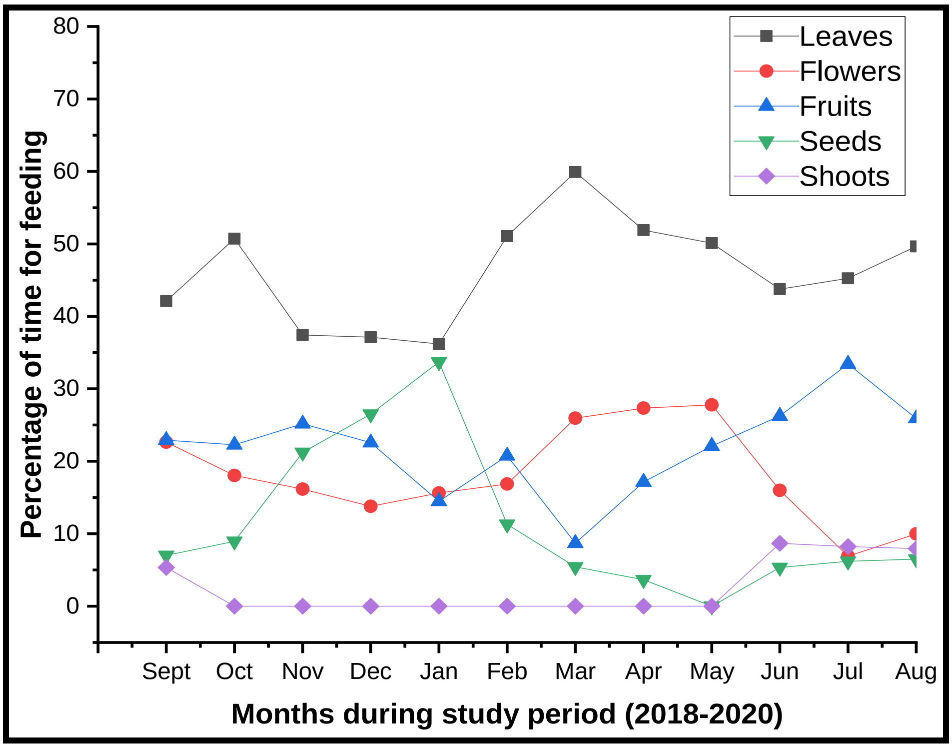

Figure 1.15: Graphical lines showing the monthly variation (%) of CL feeding budget.

IV. 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 and Duckworth, 2013; Mazumder et al. 2014; Huang et al. 2015; Koirala et al. 2017 and Boonaratana et al. 2020)**. A higher percentage of the diet of AM was provided by tree species **(Zhou et al. 2011; Kaewpanus et al. 2015; Ghimire et al. 2021)**, consistent with the results of this study, which found that trees accounted for 91%, herbs 7% and climbers/vines 2%. **Koirala et al. (2017)** reported more than 57% of food plants for AM in Shivapuri Nagarjun National Park in Nepal were trees, followed by herbs, shrubs and climbers, as well as insects and their secretions. In addition to this, **Huang et al. (2015)** from their study on dietary adaptations of AM in Limestone forests at Southwest China, documented out of food plants species, trees were the most common type consumed (65% of food species), followed by vines (23%), bushes (8%), herbs (3%), and epiphytes (1%)**.** A total of 66 species of plants belonging to 33 families comprising of 86.36% trees, 7.58% herbs and for both shrubs and climbers 3.03% each were eaten by CL across the seasons during the study. This agreed with the observations conducted by previous workers (**Stanford, 1991; Monirujjaman and Khan, 2017; Hasan et al. 2018)**. Moreover, **Solanki et al. (2008a, 2008b)** recorded that CL ate 52 food plant species that belong to 30 families. Out of which, 90% of them were trees, 6% were climbers, 2% were aquatic plants, and 2% were bamboo. According to **Borah et al. (2021),** 24 species of tree, 11 species of lianas, three species of herb and three species of shrub were used for feeding by CL in the study area at Goalpara district in Assam. Recently, **Khan et al. (2022)** also published a similar results on the various food plants of CL from Madhupur National Park in Bangladesh where a total of 77 plant species belonging to 38 families were included in the diet, of which 72.73% (n=56 species) were trees, 6.49% (n=5) were shrubs, 19.48% (n=15) were climbers and 1.30% (n=1).

Although total number of trees and density of tree species did not influence the preference of food tree **(Solanki et al. 2008a)**, trees of Moraceae family dominated the AM and CL during the study period as also reported by previous studies, such as the diet of *Trachypithecus auratus* at Pangandaran, Indonesia **(Kool, 1989),** *Colobus guereza* at Kakamega Forest, western Kenya **(Fashing, 2001),** AM at Shivapuri Nagarjun National Park, Nepal **(Koirala et al. 2017),** central Nepal **(Ghimire et al. 2021)**, Chiang Rai Province, Northern Thailand **(Kaewpanus et al. 2015)**, Nonggang National Nature Reserve **(Zhou et al. 2011; Huang et al. 2015; Li et al. 2019**) and CL at Arunachal Pradesh **(Solanki et al. 2008a; 2008b),** Assam, northeastern India **(Borah et al. 2021),** Madhupur National Park, Bangladesh **(Khan et al. 2022)**, Satchari National Park **(Hasan, 2017)**. Trees of the family Moraceae are large in size, have large canopy and different plant species keep providing young leaves consistently during winter months. Terminal canopy is the preferred feeding site of *Trachypithecus pileatus* **(Solanki et al. 2008b)**. Thus folivorous primates may save energy through steady foraging for long periods of time with little movement from branch to branch or tree to tree **(Clutton–Brock and Harvey, 1976)**. This is especially advantageous to pregnant animals **(Chapman, 1990; Nakagawa, 1990)**. Large trees with dense canopy also provide protection from natural predators. **Stevenson et al. (1994)** and **Yiming et al. (2002)** also indicate that size of the tree is an important parameter for its selection as food tree for arboreal primates.

In this study, a total number of 57 plant species were consumed by AM troop. Other studies like; **Mitra (2002)** reported 63 species from Darjeeling, West Bengal, India, 37 species **(Koirala and Chalise, 2014)** and 38 species **(Khatiwada et al. 2020)** from Sivapuri Nagarjun National Park, Kathmandu Valley, Nepal, 118 species from Phu Khieo Wildlife Sanctuary, Northern Thailand **(Heesen et al. (2013)**, 55 species from Tham Pla Temple, Chiangrai Province, Northern Thailand **(Kaewpanus et al. 2015)**, 78 species **(Huang et al. 2015)**, 69 species **(Zhou et al. (2011; 2018)** and 25 species **(Li et al. 2020)** were reported from Nonggang National Nature Reserve, southwest Guangxi, China. Recently, 71 species of plants were reported as the food items of AM from the study carried out at Kaligandaki and Budhigandaki River Basins of central Nepal **(Ghimire et al. 2021)**. In this study, a total number of

57 plant species were consumed by AM and for comparison of AM feeding ecology with previous works is presented at Table 1.8.

Table 1.8: Discussion and comparison of feeding ecology for AM and † symbol denoted the closest value of present and earlier works.

Sl. no:	**Sources**	***Present study***	**Mitra (2002)**	**Chalise et al. (2013)**	**Koirala & Chalise (2014)**	**Koirala et al. (2017)**	**Paudel and Chalise (2017)**	**Hasan et al. (2018)**	**Khatiwada et al. (2020)**	**Heesen et al. (2014)**	**Kaewpanus et al. (2015)**	**Huang et al. (2015)**	**Zhou et al. (2011)**	**Zhou et al. (2018)**	**Li et al. (2020)**	**Ghimire et al. (2021)**
	Locality	**DTR, India**	Darjeeling, India	SNNP, Nepal	SNNP, Nepal	SNNP, Nepal	KRB/P Nepal	SNP, Bangladesh	SNNP, Nepal	PKWS, Thailand	Chiang Rai, Thailand	NNNR, China	NNR, China	NNR, China	NNNR, China	K/BRB, Nepal
1.	No. of plant species	**57**†	63	-	37	123	58	30	38	**55**	43	75	69	69	25	71
2.	Family	**30**†	39	-	22	56	-	19	-	-	15	-	**34**	9	-	-
3.	Leaves %	44.74	-	38.24	13.60	11.10	-	-	-	-	29.00	-	74.10	77.40	-	49.58 - 49.74
4.	Fruits %	**25.31**†	-	-	80.48	22.50	-	-	-	-	54.70	-	17.40	20.10	-	23.80 **-25.96**
5.	Flowers %	15.66	-	-	5.92		-	-	-	-	8.70	-	2.70	1.30	-	0.85 -0.95
6.	Seeds %	12.14		35.29	-	-	-	-	-	-	5.00	-	3.30	1.30	-	2.07-2.71
7.	Shoots %	**2.14**†	-	-	-	-	-	-	-	-	-	-	2.50		-	1.50-**2.00**
8.	Diurnal average %	**44**†	-	46.00	37.86		47.25	-	-	-	**45.30**	85.20	77.40	48.80-94.10	-	>40.00

Similar to other findings in Southeast Asia, in this work the AM troop are primary folivorous as leaves constitute 44.74% of their daily dietary intake compared to fruit 25.32% **(Srivastava, 1999; Zhou et al. 2011; Chalise et al. 2013; Huang et al. 2015** and **Ghimire et al. 2021)**. 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*, *Albizia lebbeck*, *Albizia procera*, *Artocarpus lakoocha*, *Bombax insigne* and *Protium serratum*. Apart from leaves, the amount of time invested among other food items such as, fruits, flowers, and seeds were high (55.26%) maybe 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. 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* spp., *Ficus* spp., *Artocarpus lakoocha,* etc. which are in accordance with reports of **Zhou et al. (2011)** and **Ghimire et al. (2021)**. AM troop 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)**.

In the present study, AM troop spent majority (>44% on average) of their diurnal time on feeding and they devoted more time in search of food items during the winter months (November–February) when resources were limited in cold and dry periods. This observation was more or less similar with AM troop in central Nepal which invested >40% where they devoted more than half of the diurnal time of feeding and foraging during the winter months, *i.e.*, December to February **(Ghimire et al. 2021)**. 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. AM was recorded feeding throughout the year at study site of food plants include mainly; *Artocarpus lakoocha*, *Cephalotaxus graffithii* and *Glochidion hyneanum*. The maximum record of feeding frequency was observed in AM supports; 8 month (19.30%) and minimum 10 month (0.00%) followed by 9, 7 and 5 months (12.28%), 11 and 6 months (10.53%) and then 4 and 3 months 7.02% and then 12 and 2 months (3.21%), respectively. The quantity of low frequency feeding observed in 1 month was 1.75% contributed to the monthly frequency for food consumed. However, the studied animals were observed not feeding of food plants species along these months; *Bombax insigne* (May), *Ficus auriculata* (January), *Albizia richardiana* (January) and *Aglaia edulis* (October) were non–consumed food plants. Food choice and time investment on the feeding of different plant parts may differ depending on the food availability in the area **(Ghimire et al. 2021)**. This may be because groups in the present study foraged in natural habitats in association with regulating their diets in response to seasonal food fluctuations **(Bennett, 1983; Davies, 1994)**.

In this present work, a total number of 66 plant species were consumed by CL troop and comparison of feeding ecology for CL with other works given at Table 1.9, while studies by **Islam and Husain (1982)** reported 26 species from a study conducted in Madhupur National Park, Bangladesh, **Stanford (1991)** reported 35 species from the same location, **Solanki et al. (2008a, 2008b)**, reported 52 species from Pakhui Wildlife Sanctuary, Arunachal Pradesh, India, 52 species by **Hasan (2018)** from Satchari National Park, Bangladesh, 70 species in the Rema Kalenga Wildlife Sanctuary (RKWS), Bangladesh by **Kabir (2002)**, 51 species by **Monirujjaman and Khan (2017)** from Madhupur National Park, Bangladesh, 41 species by **Borah et al. (2021)** from Sri Surya Pahar near Goalpara town in Assam, India and 77 species by **Khan et al. (2022)** from Madhupur National Park, Bangladesh. The geographical area and climatic conditions in a habitat affects the vegetation structure and composition, which in turn affect the diet selection in colobines **(Kirkpatrick, 2007; Matsuda et al. 2009; Kirkpatrick and Grueter, 2010; Tsuji et al. 2013; Akbar et al. 2019).** Floristic composition of the habitat appears to determine the spectrum of food plant species in their diets, and larger habitat supports a greater variety of plants and phenological stages **(Solanki et al. 2008b; Borah et al. 2021)**.

Table 1.9: Discussion and comparison of feeding ecology for CL and † symbol denoted the closest value of present and earlier works.

Sl. no:	**Sources**	***Present study***	**Islam & Husain (1982)**	**Stanford (1991)**	**Feeroz et al. (1994)**	**Kabir (2002)**	**Solanki et al. (2008a)**	**Solanki et al. (2008b)**	**Hasan (2017)**	**Hasan et al. (2018)**	**Monirujjaman and Khan (2017)**	**Borah et al. (2021)**	**Khan et al. (2022)**	**Barbhuiya et al. (2022)**
	Locality	**DTR, India**	MNP, Bangladesh	MNP, Bangladesh	Bangladesh	SG, Bangladesh	PWS, India	PWS, India	SNP, Bangladesh	SNP, Bangladesh	MNP, Bangladesh	SSP, India	MNP, Bangladesh	BWS, India
1.	No. of plant species	**66†**	26	35	**63**	70	53	52	52	30	51	41	77	89
2.	Family	**34†**	-	21	-	-	27	**30**	-	19	28	24	38	-
3.	Leaves %	**46.24†**	61	66.8	20	**40.5**	57	68	-	57	48	78.25	61.81	-
4.	Fruits %	**21.66†**	**21**	24.4	67	37.5	17	16	-	17	28	20.79	29.10	-
5.	Flowers %	**18.19†**	4	7	-	**18**	22	16	-	7	5	20.78	6.36	-
6.	Seeds %	**11.52†**	5	9.3	-	-	3	-	-	**10**	4	-	1.09	-
7.	Shoots %	**2.39†**	**2**	1.6	-	-	1	-	-	9	3	-	1.09	-
8.	Diurnal average %	**38.70†**	-	-	34	-	36.8	44	-	-	42	26.08-**37.87**	-	40.57

Observation on CL troop at DTR showed that they are primarily folivores as leaves constitute 46.24% of their daily dietary intake, it was 48% from Bangladesh reported by **Monirujjaman and Khan (2017)** which roughly is closed to present findings from DTR. However, leaves consumption comprised 68.00% (**Islam and Husain, 1982),** 66.80% **(Stanford, 1991**), 61.81% **(Khan et al. 2022)** from Madhupur NP, Bangladesh, 40.50% from Rema Kalenga, Bangladesh **(Kabir, 2002), Solanki et al. (2008a)** reported 57% during winter while 68% was reported by **Solanki et al. (2008b)** throughout the year from Pakhui Wildlife Sanctuary, Arunachal Pradesh, India, and 78.25% was reported by **Borah et al. (2021).** A high level of leaves was maintained in the diet of CL almost year–round mostly from the February to October months; leaves are the major and the preferred food items. The availability of young leaves decreased markedly from November to January. The scarcity of most leaves during the dry winter season was compensated by some of the major food plants that thrived throughout the year by species like; *Albizia chinensis*, *Albizia chinensis*, *Albizia lebbeck*, *Albizia procera*, *Alstonia scholaris*, *Artocapus nitidus*, *Bischofia javanica*, *Cephalotaxus graffithii*, *Caesalpinia cucullata*, and *Derris robusta*. Apart from leaves, Flowers, fruits and seeds are important constituents of langur diets and the phenological stage of food plant species influences their availability **(Solanki et al. 2008b).** The amount of time invested among other food items such as, fruits, flowers, and seeds were high (53.76%). The abundance of plant species was found to have no correlation with the selection of feeding items in this study. Although plant species such as *Ficus auriculata, Bombax ceiba* and *Melocana baccifera* were dominant and widely distributed, more preference was given to species like *Albizia* spp., *Ficus* spp. and *Bombax* spp. which supports to previous reports **(Solanki, 2008a, 2008b; Borah et al. 2021; Khan et al. 2022)**. CL is adaptable foragers who can change their diet seasonally, becoming more granivorous in the dry season and frugivorous from pre–monsoon season (April to June) to monsoon (July to September) during which CL mainly fed on available fruiting plants such as; *Aglaia edulis*, *Albizia chinensis*, *Albizia lebbeck*, *Albizia procera*, *Albizia richardiana*, *Alstonia scholaris*, *Anogeissus acuminata*, *Antidesma bunias*, *Aporosa octandra*, *Cephalotaxus graffithii*, etc. and during October to December other fruiting plants fed were; *Artocarpus chaplasha, Artocarpus lakoocha, Bischofia javanica, Derris robusta* and *Ficus racemosa*.

Seasonal variation in the diet of CL was clearly linked to seasonal fluctuation in food availability which is a common observation across their home ranges. It greatly altered their diet with a mixture of plant items including fruits, flowers, leaves, shoots and even seeds. Their diet is influenced by a number of environmental factors, including the condition of their habitat, and the availability, quality, dispersion, and abundance of resources available to them **(Ganguli et al. 1964; Tejwani, 1994)**. The phenological stages of a plant influence the food choice of primates **(Freeland and Janzen, 1974; Milton, 1980; Solanki et al. 2008b)** and they may alter their feeding strategy in relation to the availability of specific resources **(Chapman, 1988)**. Seasonal resource abundance affects the dietary composition **(Remis, 1997; Tutin et al. 1997)**.

In the present work, CL spent majority (>38.70% on average) of their diurnal time feeding. They devoted more time in search of food items during the winter months, especially around January (40.77%) when resources were limited in cold and dry periods. Lesser time was dedicated during rainy season (June to August), lowest during July (35.29%). In the present wok, it was recorded on average (>38.70%) on diurnal feeding time, which more or less agreed with 35.67% **(Mandal and Raman, 2014)**, 42% **(Monirujjaman and Khan, 2017)**, 36.80% ranging from 33.40% in October to 39.70% in December **(Solanki et al. 2008b)**, 48% **(Decemson et al. 2018)** and from 26.08% to 37.87% **(Borah et al. 2021)** and in Barail Wildlife Sanctuary, average time for diurnal feeding was 34%, where it spent maximum (36%) time in April and lowest (30%) in August **(Barbhuiya et al. 2022)**. However, a study conducted on the status and ecology of its sister sympatric species Phayre's leaf monkey (*Trachypithecus phayrei phayrei*) at DTR showed average 43% diurnal feeding time, lowest (63.19%) in the month of June and highest (55.86%) during August **(Parida, 2019).** It is clear that CL devoted minimal time during wet season where food resources are in abundance. CL feeding record throughout the year at the study site of food plants mainly includes *Albizia chinensis*, *Albizia lebbeck*, *Alstonia scholaris*, *Bischofia javanica*, *Castanopsis tribuloides* and *Cephalotaxus graffithii*.

CL maximum record of feeding frequency contributed in 11 months (16.67%) followed by 10 months (15.15%), 12 months (12.12%), 7 months (10.61%), 4 and 3 months (9.09%), 9 and 6 months (7.58%), 5 and 2 months (6.06%) and the minimum was recorded in 8 and 1 months (0.00%), respectively. Nonetheless, the percentage of overall feeding both for sympatric species was recorded maximum in CL (52.24%) than compared to AM (47.76%). Time spent by herbivores on various activities including feeding is influenced by various environmental factors, habitat condition and food availability. The availability of food, its distribution in natural habitat and food value of plant species are subject to seasonal variations **(Ganguly et al. 1964; Tejwani, 1994)**. This has profound influence on the activity pattern of the animals **(Solanki, 2000, 2003)**.

While primate species such as Hoolock gibbon (*Hoolock hoolock*), Assamese macaque (*Macaca assamensis*) Stump–tailed macaque (*Macaca arctoides*) and Rhesus macaque (*Macaca mulatta*) in Assam are frequently observed in crop fields **(Mazumder, 2014)**, despite reports of crop raiding at home range by other studies **(Regmi et al. 2013; Adhikari et al. 2018)** but no such observation on these two studied primates (AM and CL) was made in this present study. The abundance of fruiting plants appears to meet dietary needs for AM and CL troops as no incident of human–primate conflict were reported from the study site and co–habitation has been is observed between other primate species. However, with the expansion of settlement areas along the Dampa periphery, increased reliance on forest resources, the construction of road networks, and the clearing of forests for cultivation, such conflict is unavoidable in the near future.

V. CONCLUSION

From the results, both AM and CL consumed a diverse of different parts of plants as **Richard (1985)** reported the diet of most primate species includes a wide variety of plant foods. Nevertheless, most primates are highly selective feeders and display marked preferences for certain types of plants or plant parts **(Hughes, 1993; Chivers, 1998)**. Field studies on both primates and other herbivores suggest that their food choices can be attributed to two main factors: the nutritional and/or toxic content of the plant part in question **(Barton and Whiten, 1994; Felton et al. 2009a)** and its relative spatial and temporal distribution **(Leighton, 1993).** The order of most consumed food plants in both AM and CL troops were leaves followed by fruits, flowers, seeds and shoots. The overall diet was calculated as the average 2 years (September, 2018–August, 2020). Several studies emphasized the importance of leaves and stems of terrestrial herbaceous vegetation in primate diets **(Nishihara, 1995)** and L'Hoest's monkeys **(Kaplin and Moermond, 2000)**. AM 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 while CL became granivous in dry seasons and more folivorous during the rest seasons. Seasonal variation in the diet of AM and CL was clearly linked to seasonal fluctuation in food availability. Animals that live in seasonally changing environments concentrate on specific food sources that are available all year round or vary their diet in relation to seasonal changes in availability **(Guo et al. 2007)**. 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. 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. In India, primate conservation requires three main issues to be addressed—forest conservation, hunting pressure and legal status

(Srivastava, 2006). However, some species clearly learned to co–exist with humans by raiding crops. Understanding the feeding ecology of both these primates and adapting timely measures is critical to prevent conflict with human as well as primate conservation. Based on this findings of richness of fruiting plants in this work justify dietary requirement of the studied animals partly maybe due to sympatric species and no incident of conflict with human was reported or observed between them. However, increase in settlement areas along the periphery of study area and more dependency of forest resources and clearing of forests for cultivation, such conflict are inevitable in future. Conflicts are likely to increase in the future as the human population continues to grow exponentially in this region and encroachment on primate habitats continues. Understanding the role that primates play in their community ecology as predators, prey, competitors, seed dispersers, etc. may assist in the conservation of entire ecosystems. As the habitats of primates shrink and become increasingly surrounded by human settlement, primates may be forced into marginal habitat and/or resort to crop raiding **(Marsh and Chapman, 2003)**. Knowledge of the dietary patterns of primates may assist in designing management strategies to reduce human–wildlife conflict. Studies of primate feeding ecology have revealed a great deal of flexibility in ecological patterns. Loss of habitat may cause populations of a species to adapt their diet to a less varied repertoire, or to incorporate agricultural foods into their diet in crop raiding (*e.g.*, **McLennan, 2012**). Data collection needs to be expanded in all directions: more study sites, more long-term data, more detailed analysis of diet through nutritional analysis, etc. The key to understanding why primates eat the food they eat is hidden in the physical and chemical properties of food items on one hand, and the sensory skills and digestive strategies of primates on the other **(Robbins and Hohmann, 2006)**. Therefore, research should be focused to serve the dual purposes of answering questions relevant to understanding the evolution of primate feeding ecology and to conserving primates intact in their natural habitats.

CHAPTER 2: NUTRIENT COMPOSITIONS OF FOOD PLANTS AND FECAL MATTER

I. INTRODUCTION

Different food species and plant parts vary significantly in nutritional content and provides a single food type are often suboptimal, forced primates to develop generalist feeding strategies to meet their nutritional requirements **(Altmann, 2009; Felton et al. 2009a; Rothman et al. 2011; Donati et al. 2017; Eppley et al. 2017; Ganzhorn et al. 2017)**. Foods represent complex mixtures of different organic and inorganic compounds **(Milton, 1984; Oftedal, 1991; Lambert, 2011)** and some of them may be difficult to masticate or digest, or may contain potentially harmful substances that consumers must avoid or denature **(Norconk et al. 2009; Lambert, 1998, 2011)**. Majority of the primate feed on large variety of food plants **(Richard, 1985)**. Primate are selective feeders, spent a considerate proportion of their time searching preferred foods **(Hughes, 1993)**. Studies in fields have shown that they did not randomly feed on plants; however display marked preferences **(Chivers, 1998)**. Food preferences involved interactions between taste and consequences of food ingestion **(Provenza, 1996)**. Among the primate, frugivores tend to have longer daily travel distances than folivore because fruits are usually more patchily distributed than leaves **(Chapman et al. 1995)**. In response to seasonal food shortages, primates often display behavioral plasticity by incorporation of alternate plant parts and human foods including crops and provisioned items. Primates display a wide array of dietary and behavioral adaptations to maintain adequate food during periods of food scarcity **(Serckx et al. 2015; Clink et al. 2017)**. Dietary selectivity may be influenced by the content of food items, and micronutrient regulation can drive food selection and affect population growth **(Rode et al. 2006; Rothman et al. 2006a)**. The precise mechanical, behavioral, physiological, and hormonal mechanisms used by foragers to obtain a nutritionally balanced diet remain unclear; however, laboratory studies have demonstrated that individuals alter food choice based on their nutrient needs and the nutrient composition of available foods **(Ruohonen et al. 2007; Simpson and Raubenheimer, 2005)**.

Nutritional ecology studies how animals cope with the spatial, temporal, and nutritional heterogeneity of their environment to obtain macro and micronutrients required for growth, and maintenance **(Milton, 2006; Raubenheimer and Simpson, 2016)**. Nutritional ecology of primate involves the interactions between the environment and a primate nutrient intake and the individual resultant physiological state. It is a diverse field that includes physiology **(Ross, 1992)**, morphology **(Vinyard et al. 2003)**, ontogeny, growth, development **(Leigh, 1994)** and ecology **(Oates et al. 1990)**. The requirement of nutrient is not uniform among different species or individuals nonetheless may vary depending on factors such as body size, metabolic requirements, lifestyle and digestive system **(Parra, 1978; Milton, 1993)**. Differences in palatability and/or in novelty of the food items might also affect choice behavior **(Fragaszy et al. 1997)**. Understanding the decisions animals make in selecting and avoiding foods is critical for addressing questions related to feeding ecology and social behavior and their effects on reproductive success and life history strategies **(Milton, 1981; Garber, 1987; Giraldeau and Caraco, 2000; Karasov and Martínez del Rio, 2007; Lambert, 2011; Simpson and Raubenheimer, 2012)**. Generally, it is agreed that the primates choices of food mainly attributed broadly into two major factors: (i) the nutritional and/or the toxic content of the particular plant parts **(Rusterholz, 1984; Barton and Whiten, 1994; Forbes, 1995; Van Wiesen, 1996)** and (ii) its relative spatial and temporal availability **(Belovsky, 1990; Belovsky and Schmitz, 1991, 1994; Castellanos and Chanin, 1996)**. The primates are able to assess food quality through the sensory information that comes from the food. Senses help primates to make efficient decisions about food, and taste gives an immediate and powerful feedback used to select foods **(Dominy et al. 2001)**. The use of a nutritional framework can be effective in conservation efforts by identifying the nutritional requirements and moreover use of analytical techniques to estimate daily amounts of food ingested; calculation of food selectivity indices based on measures of food availability rather than on plant species abundance; the integration of tools from digestive physiology need studies of the feeding ecology, food choice, and decision-making of wild primates **(Righini, 2017)**. Regardless of the feeding and food categories, **Lambert et al. (2011)** employed to describe primate diet, primates require the full suite of nutrients required by most mammals in general 45–47 in total of amino acids, fatty acids, vitamins and minerals **(Oftedal and Allen, 1996)** from the principal classes of carbohydrates, protein, lipids, vitamins and minerals. Like all animals, primates require a full complement of carbohydrates, protein, lipids, vitamins, and minerals for growth, development, survival, and reproduction. Obtaining an adequate balance of these nutrients, while minimizing the ingestion of toxins, is challenging **(Chapman et al. 2012).**

Carbohydrates are a major source of energy in primate diets. Carbohydrates are the most abundant of the compounds in living plants, other than water, and serve as a principal repository of photosynthetic energy. They are in above ground parts (stem, leaves, flowers, fruits and seeds) and belowground parts (roots and tubers); constitute about 50–80% of the dry matter in leaves, fruits, and seeds; and generally furnish 40% or more of the metabolizable energy in the diets of most primate species, including humans **(Asp, 1994)**. They fall into three umbrella categories: simple sugars, which include glucose and fructose, and their conjugates; storage reserve compounds, which include starch, sucrose, and fructans; and the structural polysaccharides, which include the pectins, hemicelluloses, and celluloses **(Van Soest, 1994)**. In the animal nutrition literature, these plant compounds are divided into 2 categories: nonstructural carbohydrates and structural carbohydrates (plant cell wall) **(Rothman et al. 2006b)**.

Another important energy sources are proteins. Protein provides energy and is critical for growth and replacement of tissues in the body**.** Proteins are composed of amino acids; primates require 20 amino acids for body maintenance, nine of which are considered essential because they are not synthesized endogenously–*i.e.,* they must be derived from dietary sources **(Leonard, 2000)**. Protein requirements are greatest during growth and reproduction and increase by as much as 30% during such critical periods **(Oftedal, 1991)**. Not including water, protein comprises the highest percentage of lean primate body tissue (approximately 17% total body weight) and is critical for growth and replacement of tissue in the body **(NRC, 2003)**. Only 60–70% of the crude protein in domesticated plant species is "true protein" that is composed of amino acids **(Van Soest, 1994)**, and in wild plants, the true protein content is probably even less **(Milton and Dintzis, 1981)**. Approximately, 75% of protein synthesis comes from protein breakdown in the body; the other 25% comes from dietary input. The major sources of dietary protein in primate diets are leaves, insects, and other animal matter **(Lambert, 2011)**.

Lipids (or fats) are the body's most highly concentrated source of energy, providing more than two times the energy per unit weight as either carbohydrates or proteins **(Lambert, 2011)**. High–fat foods are important energy sources for primates; their caloric value exceeds that of carbohydrates, protein, and any energetic returns from fiber **(NRC, 2003)**. Fats are divided into three main classes: simple, compound, and derived. The simple fats comprise triglycerides, which are made up of two types of molecule: glycerol and fatty acids. Fatty acids are divided into saturated and unsaturated types, based on differences in bonding between carbon atoms **(Leonard, 2000)**. The major sources of fat for primates are insects and other animal matter, seeds, and the arils of some fruit species (*e.g.*, *Virola* spp.). Most plant foods do not have appreciable quantities of fat, aside from some fatty fruits and seeds, such as palms **(Norconk and Conklin, 2004; Norconk et al. 2009)**, and fruits of Virola (>30%) **(Milton, 2008)**.

Dietary fiber is typically considered the carbohydrate portion that animal enzymes cannot digest **(Van Soest et al. 1966)**. This portion includes structural carbohydrates that occur in the plant cell wall and are either insoluble (hemicellulose and cellulose) or soluble (gums, pectin, β-glucans, and various other carbohydrates such as fructans). Some primates may choose foods based on their water content, particularly if they are faced with a water-limited environment **(Camperio et al. 2001)**. The moisture of food samples can vary greatly; *e.g.*, gorilla foods vary from 7% to 97% **(Rothman et al. 2006a)**. Therefore, investigating the chemical basis of dietary selection in primates has provided a unique understanding of their foraging strategies **(Whiten et al. 1991)**, facilitated evaluations of socio–ecological explanations of social organization **(Byrne et**

al. 1993), and provided means to explore determinants of abundance **(Chapman et al. 2002; Oates et al. 1990)**. Such information is specifically vital for the conservation efforts of rare or endangered species, because it helps to identify habitats or food sources that need to be maintained **(Ward et al. 2012; Aryal et al. 2016)**. There are two procedures for assessing the dietary ecology of wild animal populations are direct observations of feeding activity and analysis of fecal samples **(Moreno–Black, 1978; Altmann, 1991; Gilby et al. 2010; Koirala et al. 2016)**. The diets of wild primates have been studied using a variety of methods. These fall into two main categories: Direct, *i.e*., those recorded by observation of the subjects ingesting foods; and indirect, *i.e*., those recorded from characteristic remains of foods, either left in situ or found in feces. Behavioral data collection is the main method used to evaluate the ecological traits of primate species, in a general manner, and it is especially important for early descriptions of the autoecology of any given species **(***e.g*., **Alonso and Langguth, 1989; Passamani, 1998; Silva et al. 2011)**. While providing useful data on primate ecology, behavioral studies are susceptible to observational bias, mostly related to differential visibility of specific behaviour and intrinsic limitations to observers or those imposed by field conditions **(Ferrari and Rylands, 1994).** Direct methods are preferable as they are precise (although it is sometimes difficult, with small food items, to determine exactly what is being eaten) and give not only a qualitative lists of food items, but also quantitative data on the contribution of each item to the total diet of the study species **(Tutin and Fernandez, 1993)**. Indirect methods have a number of drawbacks but are sometimes the most feasible way of studying diet **(Moreno–Black, 1978).**

Macroscopic fecal inspection is used to assess diet in a wide range of species **(**birds: **Inger et al. 2006;** elephants and antelope: **Kos et al. 2012;** bears: **Koike et al. 2013)**, including primates **(Julliot and Sabatier, 1993; Tutin and Fernandez, 1993; Doran et al. 2002; Hanya et al. 2003; Surbeck et al. 2009; Phillips and McGrew, 2014; Johnson, 2015)**. Macroscopic analysis of primate fecal specimens in order to infer diet has been done for at least 50 years by field primatologists **(***e.g*., **Goodall, 1968)**. Fecal analysis, as a technique for studying diet, has been used to supplement observations of feeding in a number of studies of wild apes. Interest in the natural diets of nonhuman primates has been growing in the last decade for a number of reasons. First, information concerning food habits is of particular value to researchers interested in ecology since the food habits of an animal are an integral part of the organism's evolution and adaptation, directly related to behavior, morphology and physiology **(Jay, 1965)**.

Knowledge of the natural diet of a species, especially in different habitats, would be invaluable for management programs in the wild as well as for proper maintenance of the animal in captivity. Second, quantitative scientific studies may be influenced by such nutritionally related factors as deficiencies or excesses, growth, and development, and disease susceptibility, all of which necessitate the establishment of nutritional guidelines and requirements. In addition, medical research is beginning to concentrate on diet-disease correlations (cancer, diabetes, heart disease etiology, etc.) which ultimately will entail animal studies. To use non–human primates in this type of research requires a more complete knowledge of their natural diets than now exists. Fecal analysis, as a technique for studying diet, has been used to supplement observations of feeding in a number of studies of wild apes **(Tutin and Fernandez, 1993)**. It has proven particularly useful in constructing lists of fruit foods as many seeds are swallowed whole and can be identified to species level **(Kano and Mulavwa, 1984; McGrew et al. 1988; Williamson et al. 1990)**.

Fecal analysis remains a useful and informative means of gaining data about diet and other aspects of the natural lives of primates **(Matthews et al. 2020)**. Since there is no work and literature available for AM and CL in regard to nutrient compositions of food plants and fecal matter, therefore this present study will provide the proximate nutrients assessment of food plants consumed and analysis of fecal samples for the first time in both study animals.

II. REVIEW OF LITERATURES

Milton (1979, 1980, 1981, 1993) pioneering research on the differences in nutritional ecology of spider monkeys and howlers demonstrated that dietary adaptations had substantial implications for primate social behavior, sociality, and cognition. **Chapman et al. (2003)** conducted a study on variation in the nutritional value of primate foods (among trees, time periods and areas) and suggested that there was considerable variation in nutrient content of colobus food items among trees, time periods, and areas in a tropical forest. **Rothman et al. (2012)** reviewed nutritional methods and provided practical guidelines to measure nutrient intake by primates in field settings by conducting an assessment of how to estimate food intake by primates using behavioral observations. Then they described how to collect, prepare and preserve food samples and suggested appropriate nutritional assays for estimating diet nutritional quality and point to the merits and limitations of each.

Other studies investigated the nutrient content in primate diet **(Casimir, 1975; Goodall, 1977; Waterman, 1984; Watts, 1984; Rogers et al. 1990; Plumptre, 1995; Popovich et al. 1997; Remis et al. 2001)**. Many studies have focused on the importance of protein in primate diets, suggesting that protein is an important criterion for food selection **(Milton, 1979; Oates et al. 1990; Chapman and Chapman, 2002; Chapman et al. 2002a). Milton (1979)** observed that howlers (*Alouatta palliata*) selected leaves that were higher in protein and lower in fiber than those avoided, suggesting that protein was an important criterion for leaf choice in folivore. **Milton (1979)** and **Wasserman and Chapman (2003)** suggested that the protein to fiber ratio is a good predictor of food choice in small mammalian herbivores. They also suggested that areas that generally have food items that are low in fiber and high in protein are able to support high biomasses of these consumers. Few studies have analyzed the amino acid composition of primate foods **(Curtis, 2004)**, probably because amino acid analysis is quite expensive and requires a specialized technique.

A detailed overview of the carbohydrates and lignin is available elsewhere **(Van Soest, 1994)**, as well as a glossary of nutritional terminology **(Conklin–Brittain et al. 2006). Sukhija and Palmquist (1988)** reported that the best way to assess the fat contents in a sample is to estimate its fatty acid composition, whereby fats are placed in a hydrophobic solvent, purified, esterified, and then analyzed via gas chromatography. However, few studies have analyzed the actual fatty acid composition of primate foods **(Chamberlain et al. 1993; Reiner and Rothman, 2011)**, probably because this analysis is time consuming and expensive.

Matthews et al. (2020) reported that direct observations for assessing the dietary ecology of wild animal populations are not always possible since many wild animals are difficult to locate and reliably observe and they suggested that combining methods of observational and indirect where possible is most useful for accurate monitoring of dietary trends of wild animals, particularly for species that experience significant seasonal shifts in their diet.. Therefore, non-invasive methods, such as macroscopic fecal sampling **(Tutin and Fernandez, 1993; Basabose, 2002)**, microscopic and molecular fecal analysis **(Phillips, 2011)**, DNA barcoding of fecal samples **(Que´me´re´ et al. 2013; Mallot et al. 2018)**, and examination of trail signs and feeding remains **(Rogers et al. 1990; Doran et al. 2002)**, can be important for determining animal diets, particularly of shy or at–risk species. Some studies have directly compared diet composition estimated from observations with macroscopic fecal analysis **(McInnis et al. 1983; Mills, 1992; Parker and Bernard, 2006; Bakaloudis et al. 2012; Phillips and O'Connell, 2016).** Various studies have compared totals calculated from quantified food-items in feces with observational feeding data to investigate seasonal variability and dietary adaptability **(Julliot and Sabatier, 1993; Rogers et al. 2004; McLennon, 2013)**.

Macroscopic visual inspection of feces has been widely used to assess dietary composition of primates **(Goodall, 1968; Moreno–Black, 1978; Harcourt and Nash, 1986; Doran et al. 2002; Hanya et al. 2003; Tutin and Fernandez, 1993; Head et al. 2011)**. Sieves of multiple sizes have been widely used for macroscopic inspection of feces in primate studies to assess food–item size in feces **(Julliot and Sabatier, 1993;**

Hohmann and Fruth, 2008). The most obvious limitation of macroscopic fecal analysis is that vegetative foods (leaves, stems and piths), flowers and soft bodied invertebrates can rarely be identified taxonomically and this results in these categories being under–represented on food lists. Microscopic identification of foliage fragments has been made in studies of the diet of some temperate mammals **(***e.g.*, **Fitzgerald, 1978)** but the difficulty of constructing a comprehensive reference collection of foliage samples from species–rich tropical forest sites has proven daunting **(Tutin and Fernandez, 1993)**. **Malenky and Wrangham (1994)** developed a more refined method to study the importance of vegetative foods in the diets of chimpanzees and bonobos, involving the separation and weighing of the fiber and undigested fragments of leaves (F&UFL) portions of each fecal sample. For chimpanzees, dietary composition calculated from the quantification of food-items in feces **(***e.g.*, **Stanford and Nkurunungi, 2003; Tutin and Fernandez, 1985)** rarely has been compared with dietary composition from direct observation of feeding at community level **(***e.g.*, **Morgan and Sanz, 2006)** and not before at individual level. **McGrew et al. (2009)** presented a proven technique, including equipment and supplies, protocol and procedure for primate fecal analysis, which yields quantitative data suitable for systematic investigation within and across primate taxa. **Phillips and McGrew (2014)** calculated dietary composition totals from macroscopic inspection data of fecal samples and observational feeding data from ten adult chimpanzees of the Kanyawara community in Kibale National Park (KNP), Uganda. **Silvestre et al. (2016)** conducted fecal analysis as a complementary approach to the study of feeding ecology in the common marmoset (*Callithrix jacchus* Linnaeus, 1758). Their results indicated that animal foods might be more commonly consumed (based on fecal samples–FS; 61.48% of diet) than previously thought (*e.g.*, only 22.83% based on observational data–OD) and concluded that, whereas FS provide better data on animal prey, it was less effective than OD in identifying plant items. **Matthews et al. (2020)** assessed the congruence of methods in estimating the diet of a montane community of eastern chimpanzees *Pan troglodytes schweinfurthii* in Nyungwe National Park (NNP), Rwanda using observational scan samples and macroscopic fecal inspection and reported the differences in diet composition and diversity estimated by the two sampling methods used highlighted some of the key considerations to be made when using one single method to calculate wild animal diets.

III. MATERIALS AND METHODS

2.1: Collection of samples

For nutritive value analysis, samples were collected from the same plants consumed by focal individuals and the remains or left behind at the feeding sites were collected. Approximately 500 g to 1 kg of fresh plant parts were collected for analysis. Dried at hot air oven at 70°C and weighed, stored in dry inside zip–pouch and then based for laboratory processing.

2.2: Laboratory processing

Determination or estimation of Dry Matter, Moisture, Ash, Acid in insoluble Ash, Fat, Protein, and Fiber were performed using **AOAC (2019)**. Calibration curves were prepared for all the nutrients to be analysed (*e.g.*, carbohydrate and protein as in Figs. 2.1 and 2.2, respectively).

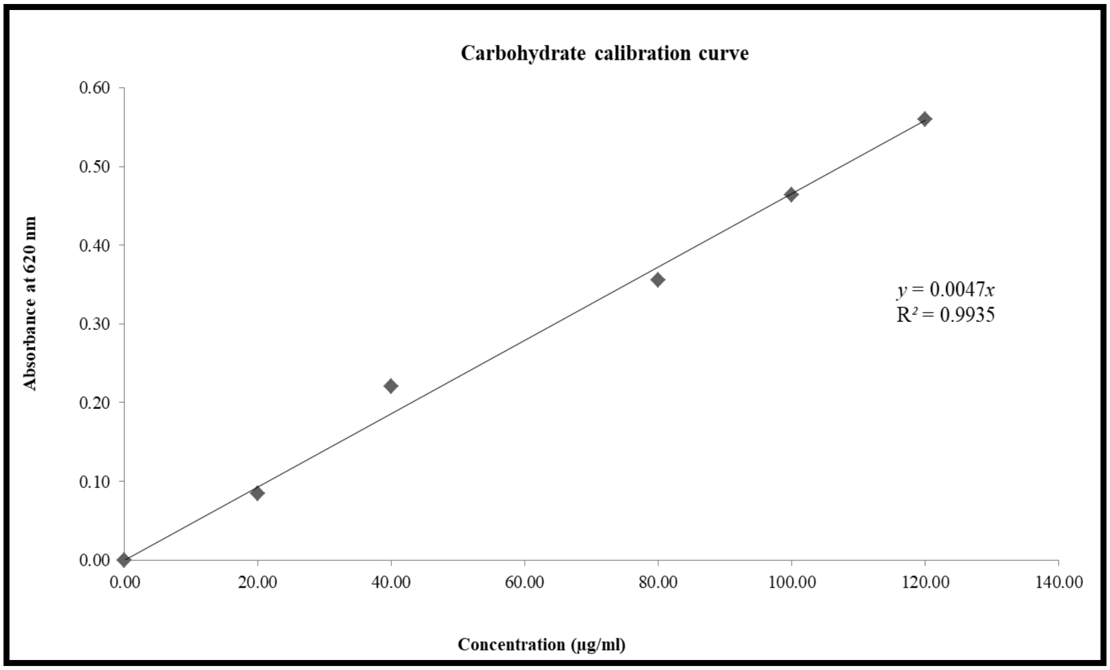

Figure 2.1: Calibration curve of carbohydrate with absorbance of 620 nm.

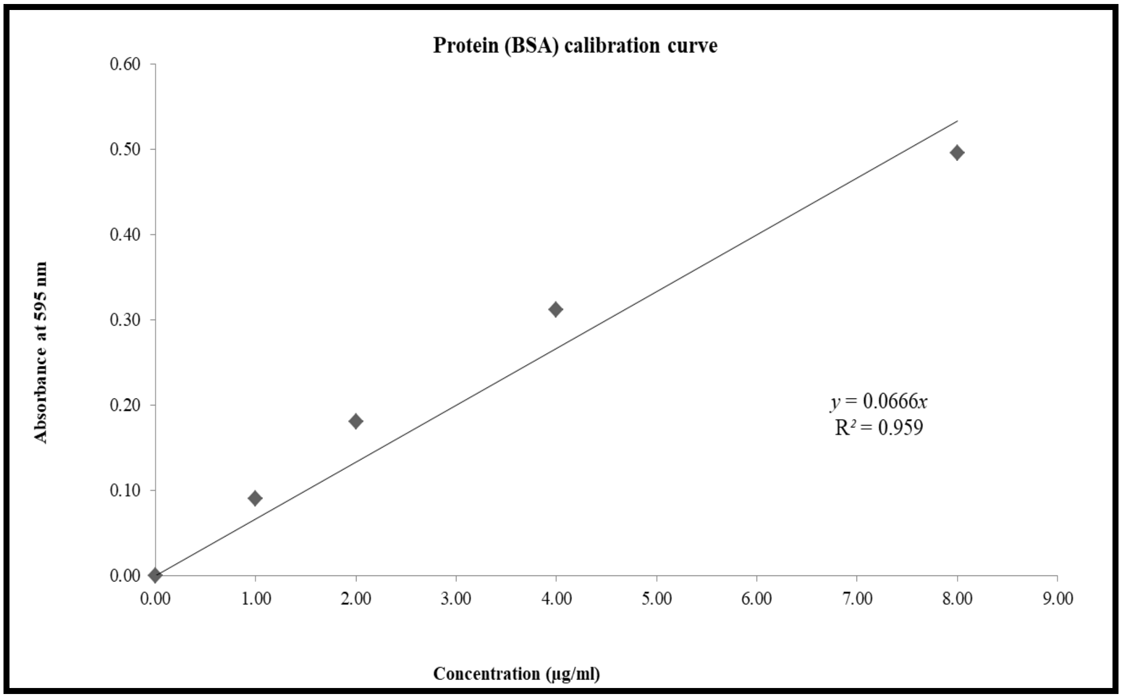

Figure 2.2: Calibration curve of protein (BSA) with absorbance of 595 nm.

2.3: Analysis of fecal matter

Fresh fecal samples of AM and CL were collected mainly from their sleeping sites and opportunistically (n=20). Fecal samples of primates were identified using **Chame (2003)**. The method for fecal analysis followed those procedures prepared by **McGrew et al. (2009); Phillips and McGrew, (2014); Matthews et al. (2020)**. Sluicer wore disposable latex surgical gloves or reusable ordinary dish–washing gloves, the more tightly fitting the better for precision gripping. One should have at least two pairs of forceps, one needlenosed and one flat–nosed, for picking up items left in the sieve.

The standard protocol for analysis of primate fecal matter was done macroscopically of fresh fecal samples both AM and CL of <24 hr old (n=20 samples) were opportunistic collection from the field sites, however it was not able to link the fecal to a known individual (adult) or specific age–sex class. The sluicer processes the specimens by swirling water through the sieve, so that the matrix is washed away downstream in the current, leaving only the undigested proportion of the gut contents. Agitating the contents by swirling, bouncing, sliding, until the entire matrix is washed away, *i.e*. until the liquid draining through the sieve is clear. Now the fecal contents are ready to scrutinize (Fig. 2.3A–E).

Figure 2.3 (A–E): Fresh fecal samples of (A) Assamese Monkey, (B) Capped Langur and (C–E) sluicing and now fecal contents ready to scrutinize of undigested materials following the traditional method of McGrew et al. (2009); Phillips and McGrew (2014); Matthews et al. (2020).

Removing extraneous a foreign matter, *e.g.*, accidental dead leaves, twigs, etc. and dung beetles and discarded. The large seeds is pick out and counted; if identified, dictate the number and species to the scribe; if not identified, use an agreed descriptor and examined macroscopically from the fecal sample of each item categorized (leaf, fruit, seed and nut) and then later identifying them **(McGrew et al. 2009; Matthews et al. 2020)**. The samples were packed in air–tight plastic containers (10 ml), stored cold deep freezer and analyzed at the Developmental Biology and Herpetology (DB&H) Laboratory, Department of Zoology, Mizoram University in Aizawl, Mizoram, India.

DATA ANALYSIS

The statistical analysis of the data was performed using the Windows excel 2010, version 21H2 and GaphPad Prism (online ver.). All the experiments were carried out in triplicates. Data was expressed in mean ±standard deviation (kcal/g) represented the percentages for carbohydrate, protein, ash, crude fats and Acid Detergent Fiber (ADF) both for AM and CL, respectively. A multiple Pearson correlation was performed to see any probable relationships among the proportion of different nutrient values (carbohydrate, protein, ash, fat, fiber). For this, we combined the top 10 preferred food plant species of AM and CL which accumulated to 15 plant species as five species are common between them.

IV. RESULTS

In the present work, the evaluation results for chemical components of the top ten preferred food plants species for both AM and CL and the food items identified from analysis of fecal samples of both AM and CL are presented.

2.4: Nutrient compositions in food plants

In this work, AM and CL were observed to feed mostly leaves, followed by fruits and then seeds. Commonly, these primates utilized seeds of *Albizia* spp. leaves of *Alstonia scholaris*, *Bischofia javanica*, *Diospyros glandulosa* and *Glochidion hyneanum*. Fruits of species like *Artocarpus lakoocha*, *Cephalotaxus graffithii*, *Ficus auriculata*, *Protium serratum* and *Aglaia edulis* were largely fed. Flower buds and flowers of the *Bombax insigne* and the nuts of *Castanopsis tribuloides* were recorded to feed as well.

2.5: Proximate content of DM % and Moisture % of top food plants of AM and CL

In the present work, the content of DM % for AM is observed highest for *Albizia procera* (40.99±0.61%) and the least is the *Artocarpus lakoocha* (13.67±1.18%), while the highest content of moisture % is observed for *Artocarpus lakoocha* (86.33±1.18%). In case of CL, the highest DM% is observed for *Albizia lebbeck* (38.39±0.99%) and the lowest was observed for *Castanopsis tribuloides* (14.73±2.96%), while maximum and minimum content of moisture % were *Aglaia edulis* (86.37±0.74%) and *Albizia lebbeck* (61.61±0.99%), respectively.

The evaluation of nutrient compositions for both top ten preferred food plant species of AM and CL are shown in the Table 2.1–2.2.

Table 2.1: Proximate content of DM % and Moisture % of the top ten preferred food plants of AM expressed in Mean ±SD.

Sl. No.	Food plants	Plant parts	DM %	Moisture %
1.	*Albizia chinensis*	Seeds	33.22 ±8.91	66.78 ±8.91
2.	*Albizia lebbeck*	Seeds	38.39 ±0.99	61.61 ±0.99
3.	***Albizia procera***	Seeds	**40.99 ±0.61**	**59.01 ±0.61**
4.	***Artocarpus lakoocha***	Fruits	**13.67 ±1.18**	**86.33 ±1.18**
5.	*Bombax insigne*	Flowers	19.36 ±1.10	80.64 ±1.10
6.	*Cephalotaxus graffithii*	Fruits	30.68 ±1.08	69.32 ±1.08
7.	*Diospyros glandulosa*	Leaves	33.72 ±1.41	66.28 ±1.41
8.	*Ficus auriculata*	Fruits	33.53 ±3.68	66.47 ±3.68
9.	*Glochidion hyneanum*	Leaves	21.09 ±1.02	78.91 ±1.02
10.	*Protium serratum*	Fruits	27.24 ±3.18	72.76 ±3.18

Table 2.2: Proximate content of DM % and Moisture % of the top ten preferred food plants of CL expressed in Mean ±SD.

Sl. No.	Food plants	Plant parts	DM %	Moisture %
1.	*Albizia chinensis*	Seeds	33.22 ±8.91	66.70 ±8.91
2.	*Alstonia scholaris*	Leaves	19.58 ±0.74	80.42 ±0.74
3.	*Albizia richardiana*	Seeds	24.05 ±0.96	71.39 ±0.96
4.	***Albizia lebbeck***	Seeds	**38.39 ±0.99**	**61.61 ±0.99**
5.	*Bischofia javanica*	Leaves	19.09 ±1.22	80.91 ±1.22
6.	*Castanopsis tribuloides*	Nuts	14.73 ±2.96	85.27 ±2.96
7.	***Aglaia edulis***	Fruits	**13.63 ±0.74**	**86.37 ±0.74**
8.	*Diospyros glandulosa*	Leaves	33.72 ±1.41	66.28 ±1.41
9.	*Cephalotaxus graffithii*	Fruits	30.68 ±1.08	69.32 ±1.08
10.	*Albizia procera*	Seeds	24.85 ±1.02	78.91 ±1.02

2.6: Nutrients content in top ten preferred food plants of AM

The data is expressed in mean ±SD and the unit in terms of percentage (in %). The nutrients content of the known top ten preferred food plants consumed by AM are shown as below and in the Table 2.1.

2.7: Carbohydrate content:

The carbohydrate content was observed highest in *Albizia chinensis* with 13.71 ±1.55%, but observed lowest in *Diospyros glandulosa* which is 6.42 ±0.57% among all the nutrient components and the other food plants carbohydrate content are; *Protium serratum* 12.59 ±2.13%, *Cephalotaxus graffithii* 12.01 ±2.44%, *Bombax insigne*

11.78±2.42%, *Artocarpus lakoocha* 10.94 ±1.48%, *Albizia lebbeck* 10.36 ±3.11%, *Ficus auriculata* 8.99 ±0.67%, *Glochidion hyneanum* 8.93 ±2.54% and *Albizia procera* 7.52 ±0.81%.

2.8: Protein content:

The protein content is highest in *Bombax insigne* 8.98 ±1.23% and lowest in *Protium serratum* is 2.15 ±1.48%. The content of protein in order are; *Albizia chinensis* 8.72 ±2.53%, *Artocarpus lakoocha* 6.75 ±1.42%, *Albizia lebbeck* 6.02 ±1.52%, *Glochidion hyneanum* 5.37 ±0.54%, *Diospyros glandulosa* 5.3 ±2.43%, *Albizia procera* 5.23 ±0.53%, *Cephalotaxus graffithii* 4.07 ±0.92% and *Ficus auriculata* 2.42 ±0.53%.

2.9: Ash content:

The ash content is highest for *Cephalotaxus graffithii* 11.70 ±1.24% and the lowest in *Bombax insigne* 2.55 ±0.28% comparatively to other ash contents in *Albizia chinensis* 11.29 ±0.67%, *Albizia procera* 11.04 ±0.24%, *Albizia lebbeck* 11.00 ±0.50%, *Protium serratum* 10.31 ±2.03%, *Diospyros glandulosa* 6.30 ±0.94%, *Glochidion hyneanum* 5.10 ±0.63%, *Artocarpus lakoocha* 4.42 ±1.10% and *Ficus auriculata* 3.57 ±0.74%.

2.10: Fat content:

The percent of fat content is maximum in *Glochidion hyneanum* 5.70 ±0.46% and the minimum *Albizia lebbeck* 0.58 ±0.47%, while other contents in order are; *Artocarpus lakoocha* 4.91 ±0.21%, *Bombax insigne* 1.79 ±0.20%, *Cephalotaxus graffithii* 1.54 ±0.36%, *Ficus auriculata* 1.45 ±0.16%, *Albizia chinensis* 1.03 ±0.52%, *Diospyros glandulosa* 0.89 ±0.10%, *Albizia procera* 0.73 ±0.17% and *Protium serratum* 0.62 ±0.07%.

2.11: Acid Detergent Fiber (ADF) content

Artocarpus lakoocha contains the highest ADF 38.06 ±0.87% and the lowest fiber contained is *Protium serratum* 3.06 ±0.87% than other. *Albizia procera* 29.33 ±0.61%, *Albizia chinensis* 27.47 ±0.83%, *Albizia lebbeck* 25.56 ±0.73%, *Diospyros glandulosa* 24.36 ±0.59%, *Ficus auriculata* 17.92 ±0.42%, *Bombax insigne* 16.07 ±0.52%, *Glochidion hyneanum* 12.88 ±1.31% and *Cephalotaxus graffithii* 11.43 ±0.62%, respectively.

Table 2.3: Detail nutrient compositions and range of proximate analysis of top ten food plants of AM.

Sl. No.	Food plants	Carbo %	Prot %	Ash %	Fat %	Fiber %	Prox %	Prot: fiber
1.	*Artocarpus lakoocha*	10.94±1.48	6.75±1.42	4.42±1.10	4.91±0.21	38.06±0.87	65.08	0.18
2.	*Albizia procera*	7.52±0.81	5.23±0.53	11.04±0.24	0.73±0.17	29.33±0.61	53.85	0.18
3.	*Glochidion hyneanum*	8.93±2.54	5.37±0.54	5.10±0.63	5.70±0.46	12.88±1.31	37.98	0.42
4.	*Diospyros glandulosa*	6.42±0.57	5.30±2.43	6.30±0.94	0.89±0.10	24.36±0.59	43.27	0.22
5.	*Albizia lebbeck*	10.36±3.11	6.02±1.52	11.00±0.50	0.58±0.47	25.56±0.73	53.52	0.24
6.	*Cephalotaxus graffithii*	12.01±2.44	4.07±0.92	11.70±1.24	1.54±0.36	11.43±0.62	40.75	0.36
7.	***Ficus auriculata***	8.99±0.67	2.42±0.53	3.57±0.74	1.45±0.16	17.92±0.42	34.35	**0.14**
8.	***Protium serratum***	12.59±2.13	2.15±1.48	10.31±2.03	0.62±0.07	3.06±0.87	28.73	**0.70**
9.	*Albizia chinensis*	13.71±1.55	8.72±2.53	11.29±0.67	1.03±0.52	27.47±0.83	62.22	0.32
10.	*Bombax insigne*	11.78±2.42	8.98±1.23	2.55±0.28	1.79±0.20	16.07±0.52	41.17	0.56

Notes–Carbo %=Carbohydrate %, Prot %=Protein %, Prox %=Proximate % and Prot: fiber=Protein: fiber.

AM devoted maximum time for feeding (15.65%) on *Artocarpus lakoocha* that contains protein (6.75%) with fiber content 38.06% and Protein: fiber is 0.18. The protein: fiber is highest (0.70) for *Protium serratum* and minimal (0.14) for *Ficus auriculata* with feeding time spent 3.04% and 4.20%, respectively.

2.12: Nutrients content of the top food plants for CL

The nutrients content of top ten preferred food plants consumed by CL are shown as below and in the Table 2.2; Fig. 2.4.

2.13: Carbohydrate content

The carbohydrate content is found to be maximum in *Albizia chinensis* 13.71 ±1.55%, but observed minimum in *Diospyros glandulosa* 6.42 ±0.57% among all the nutrient components and the other carbohydrate contents in ascending order accordingly; *Bischofia javanica* 13.63 ±2.51%, *Alstonia scholaris* 12.72 ±1.54%, *Albizia richardiana* 9.59 ±2.13%, *Cephalotaxus graffithii* 12.01 ±2.44%, *Albizia lebbeck*10.36 ±3.11%, *Aglaia edulis* 12.11 ±1.32%, *Castanopsis tribuloides* 9.32 ±2.32% and *Diospyros glandulosa* 6.42 ±0.57%.

2.14: Protein content

The protein content is maximum in *Albizia chinensis* 8.72 ±2.53%, but observed minimum in *Albizia richardiana*2.15 ±1.48% among all the nutrient components and the other protein contents in ascending is accordingly; *Bischofia javanica* 8.23 ±1.21%, *Albizia procera* 6.53 ±0.54%, *Albizia lebbeck* 6.02 ±1.52%, *Aglaia edulis* 5.14 ±0.78%, *Diospyros glandulosa* 5.30 ±2.43 ±3.11%, *Alstonia scholaris* 4.77 ±2.63%, *Cephalotaxus graffithii* 4.07 ±0.92% and *Castanopsis tribuloides* 4.01 ±1.48%.

2.15: Ash content

The highest ash content is found in *Cephalotaxus graffithii* 11.70 ±1.24% and lowest in *Bischofia javanica* 4.80 ±0.40% comparatively to other ash contents in *Albizia richardiana*2.64 ±0.47%, *Albizia chinensis* 11.29 ±0.67%, *Albizia lebbeck* 11.00 ±0.50%, *Castanopsis tribuloides* 7.99 ±1.13%, *Alstonia scholaris* 7.97 ±0.51%, *Aglaia edulis* 5.54 ±1.06%, *Diospyros glandulosa* 6.30 ±0.94% and *Albizia procera* 3.78 ±0.24.

2.16: Fat content

Alstonia scholaris is found to contain highest fat 3.39 ±1.06% and the lowest in *Albizia lebbeck* 0.58 ±0.47%, while fat contents in other are; *Albizia procera* 2.70 ±0.46%, *Castanopsis tribuloides* 2.57 ±1.08%, *Bischofia javanica* 1.87 ±0.93%, *Cephalotaxus graffithii* 1.54 ±0.36%, *Albizia chinensis* 1.03 ±0.52%, *Diospyros glandulosa* 0.89 ±0.10%, *Aglaia edulis* 0.79 ±0.72% and *Albizia richardiana* 0.62 ±0.07%.

2.17: Acid Detergent Fiber (ADF) content

The fiber content is found to be highest in *Albizia chinensis* 27.47 ±0.83% and the lowest contained in fiber in *Albizia richardiana* 0.78 ±0.48% and then followed by *Albizia lebbeck* 25.56 ±0.73%, *Diospyros glandulosa* 24.36 ±0.59%, *Aglaia edulis* 1.34 ±0.25%, *Alstonia scholaris* 14.29 ±1.89%, *Albizia procera* 12.88 ±1.31%, *Cephalotaxus graffithii* 11.43 ±0.62%, *Bischofia javanica* 6.28 ±1.56% and *Castanopsis tribuloides* 5.79 ±0.84%, respectively.

Table 2.4: Detail nutrient compositions and range of proximate analysis of top ten food plants of CL.

Sl. No.	Food plants	Carbo %	Prot %	Ash %	Fat %	Fiber %	Prox %	Prot: fiber
1.	*Albizia chinensis*	13.71±1.55	8.72±2.53	11.29±0.67	1.03±0.52	27.47±0.83	62.22	0.32
2.	*Alstonia scholaris*	12.72±1.54	4.77±2.63	7.97±0.51	3.39±1.06	14.29±1.89	43.14	0.33
3.	*Albizia richardiana*	9.59±2.13	2.15±1.48	2.64±0.47	0.62±0.07	0.78±0.48	15.78	2.76
4.	*Albizia lebbeck*	10.36±3.11	6.02±1.52	11.00±0.50	0.58±0.47	25.56±0.73	53.52	0.24
5.	*Bischofia javanica*	13.63±2.51	8.23±1.21	4.80±0.40	1.87±0.93	6.28±1.56	34.81	1.31
6.	*Castanopsis tribuloides*	9.32±2.32	4.01±1.48	7.99±1.13	2.57±1.08	5.79±0.84	29.68	0.69
7.	***Aglaia edulis***	12.11±1.32	5.14±0.78	5.54±1.06	0.79±0.72	1.34±0.25	24.92	**3.84**
8.	***Diospyros glandulosa***	6.42±0.57	5.30±2.43	6.30±0.94	0.89±0.10	24.36±0.59	43.27	**0.22**
9.	*Cephalotaxus graffithii*	12.01±2.44	4.07±0.92	11.70±1.24	1.54±0.36	11.43±0.62	40.75	0.36
10.	*Albizia procera*	9.67±2.54	6.53±0.54	3.78±0.24	2.70±0.46	29.33±0.61	35.56	0.51

The protein: fiber is highest (3.84) for *Aglaia edulis* and minimal (0.22) for *Diospyros glandulosa* with feeding time spent more or less the same, 3.86% and 3.64%, respectively. CL spent highest time for feeding (7.28%) on *Albizia chinensis* that contains protein (8.72%) with fiber content 27.47% and protein: fiber is 0.32.

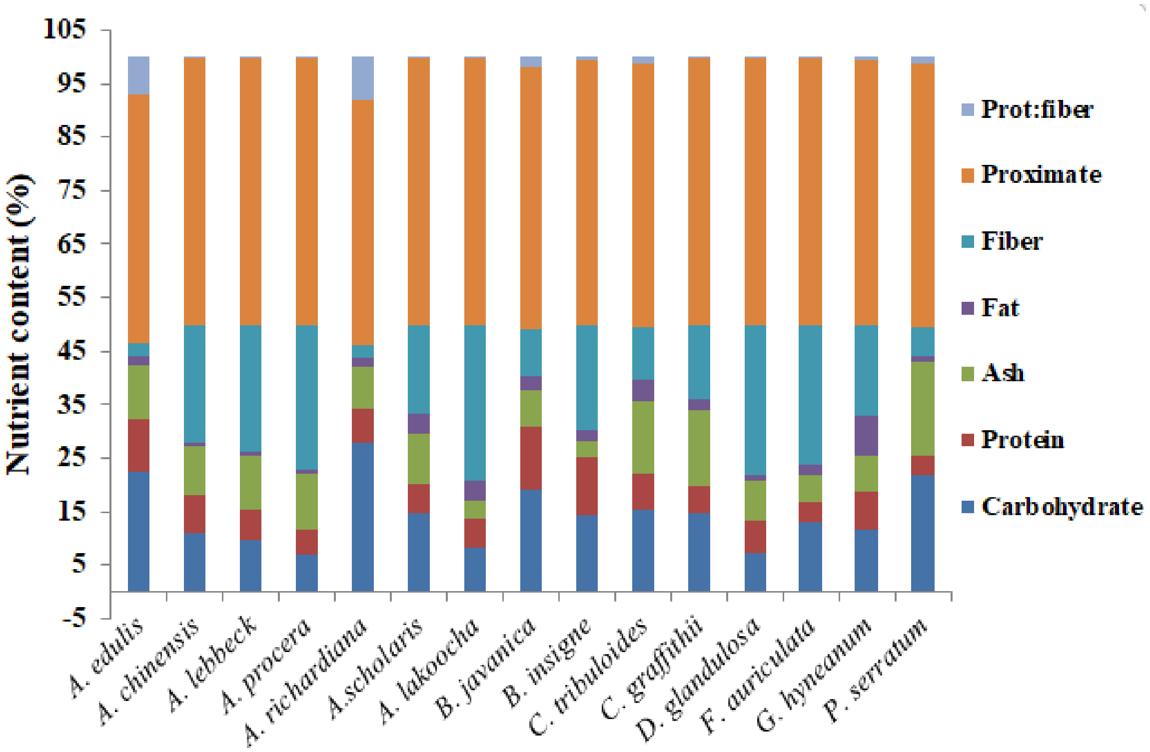

Figure 2.4: Proximate nutrient contents (%) of major food plants fed by AM and CL.

2.18: Correlation among the different nutrient values

The assessment of the combined preferred food plant species of AM and CL (n=15) revealed no statistically significant correlations across all the different nutrient values ($p>0.05$) (Table 2.5).

Table 2.5: Correlation among the different nutrient values (Carbohydrate, Protein, Ash, Fat and Fiber).

Correlations		Carbohydrate	Protein	Ash	Fat	Fiber
Carbohydrate	Pearson Correlation	1	0.359	0.145	-0.010	-0.261
	Sig. (2-tailed)		p=0.189	p=0.606	p=0.970	p=0.348
	N	15	15	15	15	15
Protein	Pearson Correlation	0.359	1	-0.035	0.174	0.439
	Sig. (2-tailed)	p=0.189		p=0.902	p=0.534	p=0.102
	N	15	15	15	15	15
Ash	Pearson Correlation	0.145	-0.035	1	-0.303	0.211
	Sig. (2-tailed)	p=0.606	p=0.902		p=0.272	p=0.451
	N	15	15	15	15	15
Fat	Pearson Correlation	-0.010	0.174	-0.303	1	0.204
	Sig. (2-tailed)	p=0.970	p=0.534	p=0.272		p=0.466

	N	15	15	15	15	15
Fiber	Pearson Correlation	-0.261	0.439	0.211	0.204	1
	Sig. (2-tailed)	p=0.348	p=0.102	p=0.451	p=0.466	
	N	15	15	15	15	15

However, none of the tested parameters showed zero correlation between them (r>0.0), and the correlation coefficient signified that there is moderate positive correlation between protein and fiber (r=0.439); weak positive correlations between carbohydrate and protein (r=0.359), between fiber and fat (r=0.204), between fiber and ash (r=0.211); very weak positive correlation between protein and fat (r=0.174), between carbohydrate and ash (r=0.145). Also, weak negative correlations are seen between fat and ash (r=-0.303), between carbohydrate and fiber (r=-0.261); and very weak negative correlations between protein and ash (r=-0.035), between carbohydrate and fat (r=-0.010) (Table 2.5; Figs. 2.5 (A–D) and 2.6 (A–D).

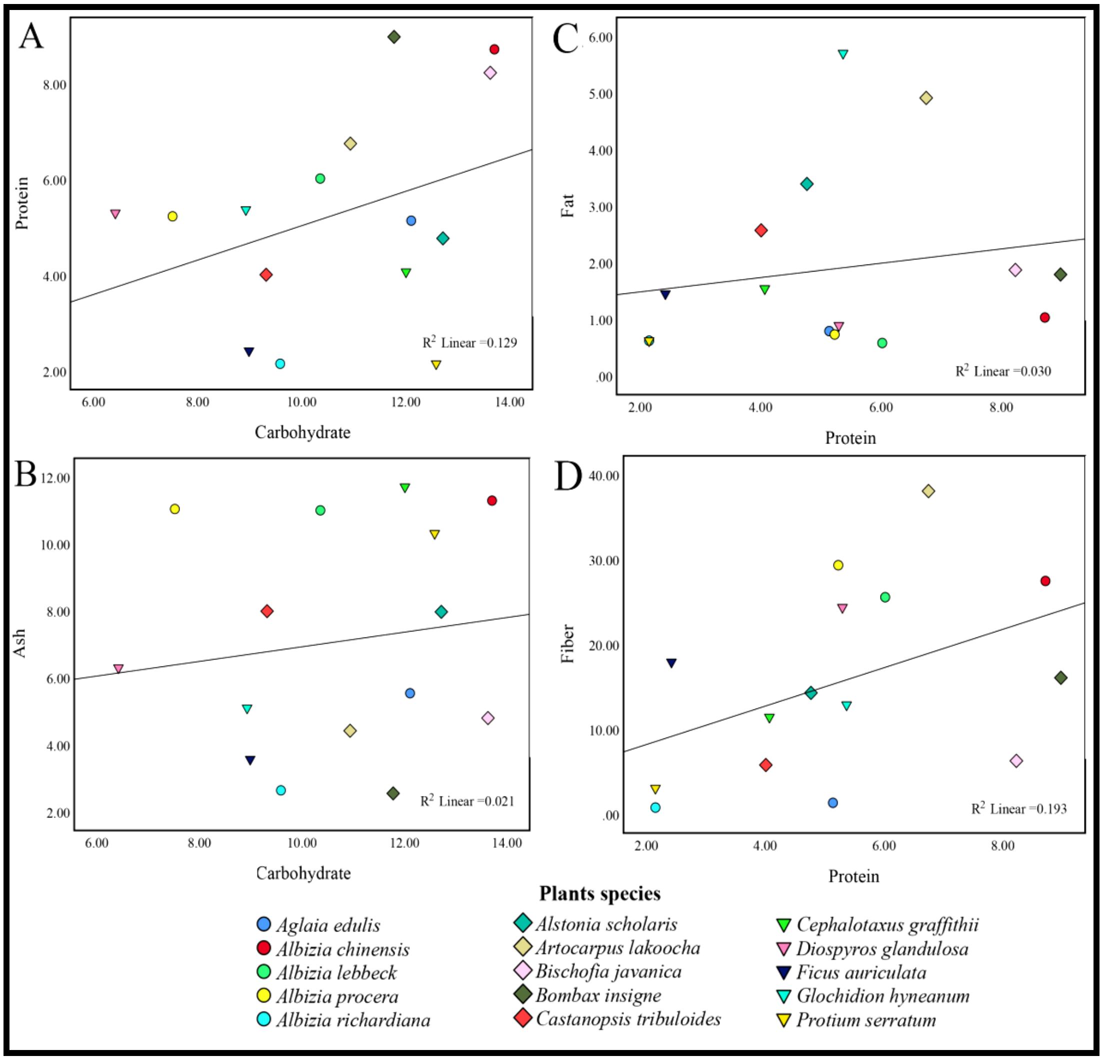

Figure 2.5 (A–D): Scatter plot of 15 food plants for AM and CL relationship between (A) Protein–Carbohydrate, (B) Ash–Carbohydrate, (C) Fat–Protein and (D) Fiber–Protein.

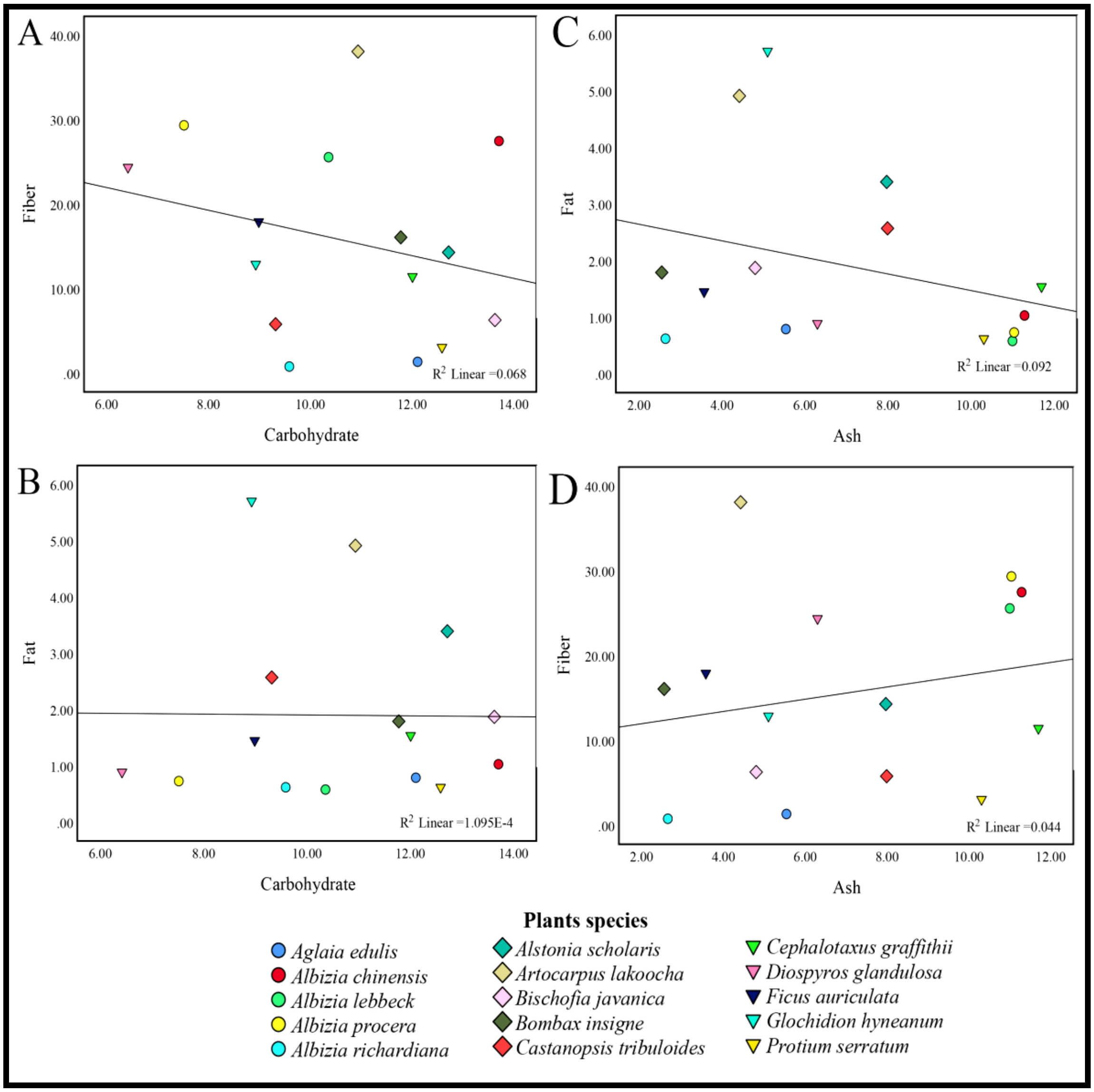

Figure 2.6 (A–D): Scatter plot of 15 food plants of AM and CL relationship between (A) Fiber–Carbohydrate, (B) Fat–carbohydrate, (C) Fat–Ash and (D) Fiber–Ash.

2.19: Macroscopic content of fecal matter

The macroscopic analysis of primate fecal specimens with the help of magnifying lens was used for scrutinizing sediment or floated such as tiny items of indigested matter *e.g.*, leaf, tiny seeds, exocarpic layers of fruits or insect parts. After cleaning, visually it is distinct from the fecal matter and compared with the collected plant parts such as seeds (*Ficus* spp.), leaves (*Albizia* spp., *Diospyros glandulosa*, *Glochidion hyneanum* etc.) and fruit (*Cephalotaxus grafitthii* and *Artocarpus lakoocha*) from the study sites fecal matter showed at Figs. 2.7 (A–D) and 2.8 (E–I).

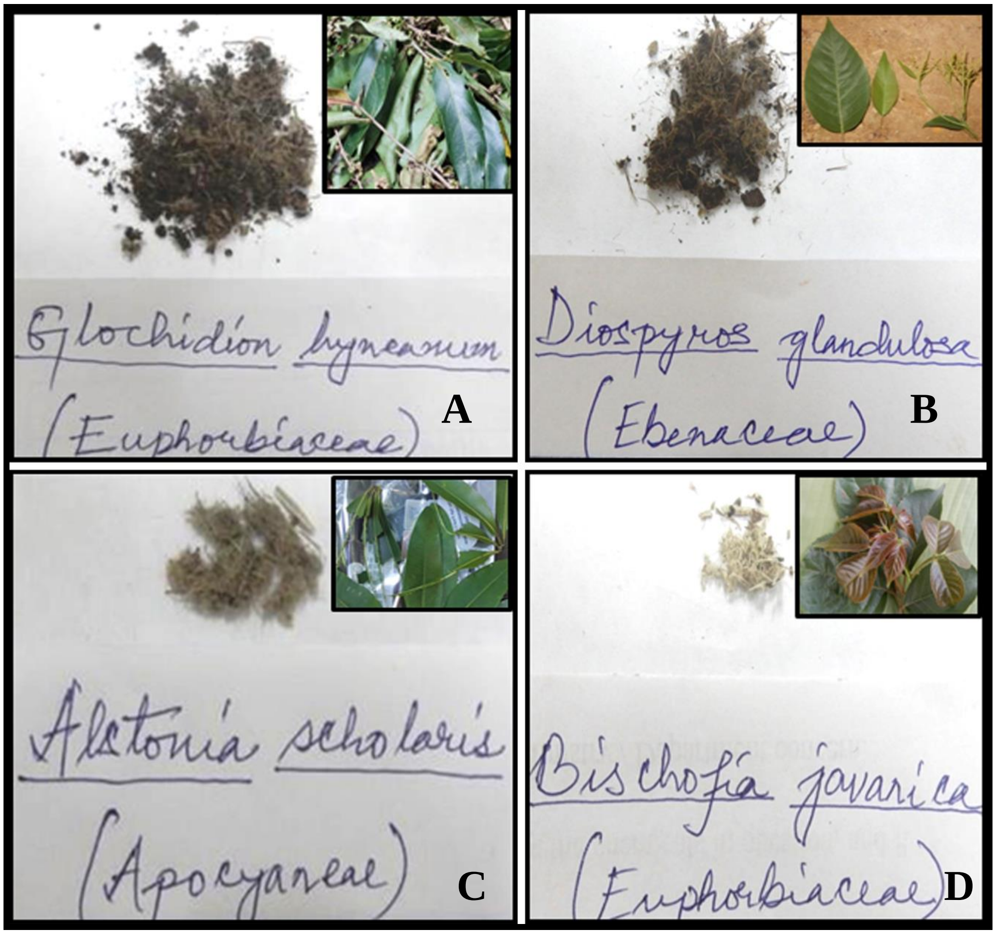

Figure 2.7 (A–D): Comparison of the fecal remnants (n=9 fecals) after sluiced for AM four identified and CL five identified with the original external morphology of the plant parts fed by the study animals during the study period 2018–2020 *viz*. (A) *Glochidion hyneanum*, (B) *Diospyros glandulosa*, (C) *Alstonia scholaris*, (D) *Bishchofia javanica*.

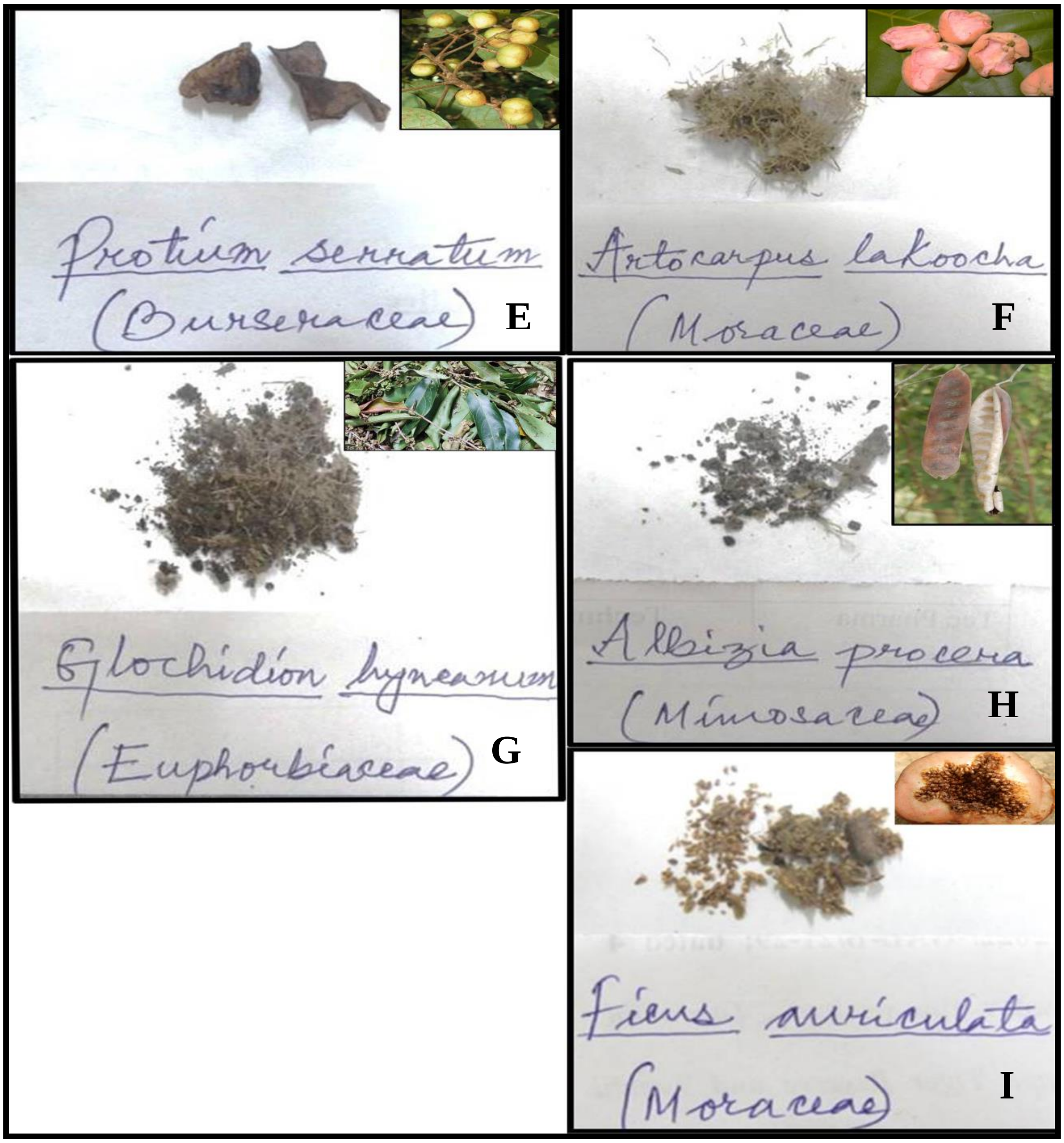

Figure 2.8 (E-I): (E) *Protium serratum*, (F) *Artocarpus lakoocha*, (G) *Glochidion hyneanum*, (H) *Albizia procera* and (I) *Ficus auriculata*.

In this study, the food plant parts of fruit epicarp of *Protium serratum* is recovered from fecal matters of AM, but it is absent in CL. The remnants of fruit fibers in *Artocarpus lakoocha* and leave fibers of *Glochidion hyneanum* are present in both fecal matters of AM and CL. In addition for CL, leave fibers of *Diospyros glandulosa*, *Alstonia* *scholaris* and *Bishchofia javanica* were extracted from fecal matters which were the most exploited food species. The seeds part of *Albizia procera* and *Ficus auriculata* seeds in the formed of fine granules were observed in the fecal samples of AM (Table 2.6).

Table 2.6: Undigested food plants present in fecal matter of AM and CL.

Sl. No.	Study animals	No. of fecal samples	Fruits epicarp	Fibers from leave and fruit	Seeds	No. of food plants identified from fecal
1.	AM	10	(i) *Protium serratum*	(i) *Artocarpus lakoocha* and (ii) *Glochidion hyneanum*	(i) *Albizia procera* and (ii) *Ficus auriculata*	5
2.	CL	10	-	(i) *Glochidion hyneanum*, (ii) *Diospyros glandulosa*, (iii) *Alstonia scholaris* and (iv) *Bishchofia javanica*	-	4

The maximum content of undigested plant parts in fecal matters observed and identified for both AM and CL is fiber (5), followed by seeds (2) and then fruit/epicarp (1) Though, other food plant parts which are present in the fecal matter could not be identified.

V. DISCUSSION

Understanding the nutritional aspects of food choice by animals is relevant to several areas of study, including foraging strategy, food selection, habitat choice, movement patterns, and social behavior. Determining the nutrients influencing food choice can provide an important insight into the feeding strategy of primates, which is crucial to understand their behavioral responses to environmental changes **(Altmann, 1998; Felton et al. 2009a)**. Nutritional composition of plants is affected by various factors like soil, weather and climate as well as fertilizer **(Hornick, 1992)**. The range of moisture content in the top ten preferences for both AM and CL were 61.61±0.99% in *Albizia lebbeck* and 86.37±0.74% *Aglaia edulis.* Water is an indispensable medium for thermoregulation, as evaporation requests a large amount of water **(Houser et al. 2005)**. Thus, water is considered determinant in driving food choice. The ripening stage of fruits may be attributed to soil factors, climatic factors and geographical variations **(Hornick, 1992; Haque et al. 2009)**.

During the scarcity of high–energy foods, animals reduce most energy demanding activities, travel less and over shorter distances, but use their home range more broadly **(Nagy–Reis and Setz, 2017)**. In this study, amongst the top ten major food plants, the carbohydrate content of dry matter for AM in *Albizia chinensis* 13.71% and *Cephalotaxus graffithii* 12.01%. Whereas, the carbohydrate content for CL in *Albizia chinensis* 13.71% and *Bischofia javanica* 13.63% and marginally followed by species like *Alstonia scholaris* 12.72% and *Aglaia edulis* 12.11%. For AM, in *Bombax insigne* reaches up to 8.98% and *Albizia chinensis* 8.72% relatively explaining for all the leaves they eat (44.74%). Few studies of carbohydrates in wild food plants have identified or measured the specific carbohydrates found in plant parts consumed by free–ranging primates. Pigtailed macaques and white handed gibbons include a high proportion of carbohydrate rich foods in their natural diet **(Bollard, 1970; Chivers, 1984; Simmen et al. 1999)**.

Fruit is a good source of carbohydrate **(DellaPenna and Grusak, 1999; Shrestha et al. 2021)**. **Calvert (1985)** calculated the total carbohydrate concentrations were about 55% in leaves, 67% in shoots, 69% in stems and 58% in fruits from 36 samples of stems, leaves, shoots, and fruits from 27 species of plants eaten by western gorillas (*Gorilla g. gorilla*) in Cameroon, West Africa. He estimated mean nonstructural–carbohydrate concentrations (dry basis) were to be 28, 5, 24, and 20% in leaves, shoots, stems, and fruits, respectively. In addition to this, estimates of mean structural-carbohydrate concentrations (cellulose plus hemicelluloses) were 27, 62, 45, and 38%, respectively. **Edwards (1995)** collected plant parts (representing 90% of feeding time) consumed by red howlers (*Alouatta seniculus*) in the central llanos of Venezuela. He estimated mean dietary nonstructural-carbohydrate concentrations (dry basis) were 29% during the wet season and 37% during the dry season. Structural carbohydrate concentrations (dry basis) were 32% and 31% during the wet and dry seasons, respectively. Thus, total carbohydrate concentrations were 61% and 68%. **Conklin–Brittain et al. (1997)** analyzed 408 samples of 194 plant parts representing 94% of the plant feeding time among chimpanzees (*Pan troglodytes*), Gray Cheeked Mangabeys (*Cercocebus albigena*), Blue Monkeys (*Cercopithecus mitis*), and Redtail Monkeys (*Cercopithecus ascanius*) in the Kibale Forest, Uganda. Reported mean concentrations (dry basis) of simple sugars were 10–15% and of total nonstructural carbohydrates from 34%–39%. **(Conklin–Brittain et al. 1998)** reported mean concentrations of structural carbohydrates (cellulose plus hemicelluloses) were 23%–26%. Thus, total carbohydrate concentrations in the plant parts eaten were 57%–65%. It is impossible to estimate the actual amount of protein daily diet without data on the specific quantities foods eaten, **(Rothman et al. 2006a)**. Plant foods are the great source of organic and mineral nutrients but a minor source of protein for human **(DellaPenna and Grusak, 1999)**. A common assumption in the literature is that colobines should select high–protein diets **(Mowry et al. 1996; Chapman and Chapman, 2002)**. Younger leaves has high protein content than fruits or mature leaves **(Amato and Garber, 2014; Nie et al. 2019)**.

Huang et al. (2015) reported that AM in China consumed young bamboo leaves throughout the year, and young bamboo leaves are richer in protein and less in fiber than other plant parts **(Richard, 1985; Nie et al. 2019)**. In the present work, the protein level found in *Albizia chinensis* reached up to 8.72% and *Bischofia javanica* 8.23% for CL from leaves eaten 51.76% normally in their diet. Protein concentration varies in different plant species and plant parts **(Richard, 1985)**. Protein provides energy and is critical for growth and replacement of tissues in the body **(Leonard, 2000**), and on a DM basis, crude protein is recommended 15%–22% for adequate nutrition of primates **(NRC, 2003)**. Most primates require about 4% to 7% protein for growth and maintenance, and 8% to 10% protein for reproduction if the protein is of high quality **(Oftedal, 1992; NRC, 2003).** The requirements are greatest during growth and reproduction by as much as 30% **(Oftedal, 1991)**. Several factors impact the availability of plant protein to primates **(Lambert, 2011)**. The protein requirements of primates depend on protein quality and available energy **(NRC, 2003)**. Tannins (polyphenolic compounds) are common in tropical plants and can render protein inaccessible to animals **(Robbins et al. 1987)**.

Among AM food plants, the fat content is high in species like *Glochidion hyneanum* 5.70% and *Artocarpus lakoocha* 4.91%, and for CL it is high in *Alstonia scholaris* 3.39%, *Albizia procera* 2.70% and *Castanopsis tribuloides* 2.57%. Rich fat content depends in different stages of fruit **(Ayaz and Kadioglu, 1999)** and also the contents in fruit depend on type of sample used **(Shrestha et al. 2021)**. High–fat foods are important energy sources for primates; their caloric value exceeds that of carbohydrates, protein, and any energetic returns from fiber **(NRC, 2003)**. Most plant foods do not have appreciable quantities of fat, aside from some fatty fruits and seeds, such as palms **(Norconk and Conklin–Brittain, 2004; Norconk et al. 2009)**, and fruits of Virola (>30%) **(Milton, 2008)**. Fat serves as an energy reserve of the animal body, and primates usually store surplus energy as fat in preparation for the impending period of food scarcity **(Felton et al. 2009a)**. However, few studies have analyzed the actual fatty acid composition of primate foods **(Chamberlain et al. 1993; Reiner and Rothman,**

2011), probably because this analysis is time consuming and expensive. Ether extract is a simple method that is commonly employed to estimate the crude fat in a sample. Although ether extract gives a crude measure of fats and is appropriate for the measurement of triglycerides, plants have nonfat components that are extracted by ether, such as wax, cutin, galactose, essential oils, chlorophyll, glycerol, and other compounds that cannot be saponified and that are frequently indigestible **(Palmquist and Jenkins, 2003)**. Forage leaves contained 5.3% fat as determined by ether extract, but 57% of the ether extract was composed of non-nutritive substances **(Palmquist and Jenkins, 2003)**. Thus, in the agricultural industry, it is recommended that one is subtracted from the percentage of ether extract in forage leaves to account roughly for these compounds when fatty acid analysis is not available **(Palmquist and Jenkins, 2003)**, and some have adopted this technique in primatology **(Rothman et al. 2011)**. Using this method, if the ether extract of a sample is below 1%, it should be converted to zero. Minimal required dietary concentrations of specific kinds of fiber, such as cellulose, or of a broad fiber category, such as NDF, have not been—and perhaps cannot be—established in the same sense as minimal requirements for essential nutrients. However, adverse effects of inappropriate fiber intakes have been reported in nonhuman primates, particularly in species with specialized foregut of hindgut fermentation, and it might be helpful to draw analogies with other well–studied species. The National Research Council has recommended that the dietary DM of the dairy cow (a foregut fermenter) should contain no more than 30%–40% nonstructural carbohydrate to avoid acidosis and other metabolic problems **(NRC, 2001).** Minimum recommended NDF concentrations for dairy cattle of various ages and productive states range from 25%–33% of dietary DM **(NRC, 2001).** When expressed as ADF, the recommended minimal range is 17%–21%.

Among the nutritional factors influencing food choice, protein and fiber have been considered vital determinants **(Zhao et al. 2013; Amato and Garber, 2014; DeGabriel et al. 2014; Dröscher et al. 2016; Ganzhorn et al. 2017; Ma et al. 2017)**. Therefore, knowledge of a species' or a population's specific nutritional goals can be important in the construction of informed conservation or restoration plans for endangered species **(Chapman et al. 2004; Felton et al. 2010).** For example, the protein–to–fiber ratio of mature leaves in a habitat is a good predictor of the biomass of colobines across forests **(Wasserman and Chapman, 2003; Chapman et al. 2004; Fashing et al. 2007)**, and forest managers could use information about a species' nutritional needs to pinpoint specific trees and areas to protect **(Chapman et al. 2004; Felton et al. 2010).** The present estimation shows that the most consumed part of both the primates, that is, seeds of all the *Albizia* spp. are higher than most of the other food plants. Because seeds are typically high in protein and lipid, and the seed coat high in fiber, estimations of seeds in fruit samples will probably elevate estimations of fiber, lipid, and protein intake **(Conklin and Wrangham, 1994; Milton, 2008; Urquiza–Haas et al. 2008).** Although there is evidence that a portion of the seed is altered as it is passed through primate guts **(Wrangham et al. 1994; Chapman, 1995)**, the majority of the seed is not. In addition, seeds fill the gut and reduce the amount of additional food the consumer can obtain **(Rothman et al. 2012)**. Statistical correlation among the different nutrient values showed that none of the tested parameters showed zero correlation between them (r>0.0), and the correlation coefficient signified that there is moderate positive correlation between protein and fiber (r=0.439), as also observed between higher protein and higher crude fiber contents in Western hoolock gibbon food plants (r=0.48) studied from Cachar district in Assam, India by **Deb et al. (2019)**.

AM devoted maximum time for feeding (15.65%) on *Artocarpus lakoocha* that contains highest protein (6.75%) with fiber content 38.06 and Protein: fiber is 0.18. CL spent highest time for feeding (7.28%) on *Albizia chinensis* that contains protein (8.72%) with fiber content 27.47% and Protein: fiber is 0.32. This observation agreed with **DaSilva (1992)** and **Ganzhorn (1992)**, while more or less agreed with **Milton (1979)**, where he reported that the howlers (*Alouatta palliata*) selected leaves that were higher in protein and lower in fiber than those avoided, suggesting that protein was an important criterion for leaf choice in folivore. **Kumar and Solanki (2004)** reported from the Pakhui Wildlife Sanctuary, India that a rare observation of CL fed on the stalks, leaves and flowers of the water lily (*Nymphaea alba*), which was rich in protein (22.87%) and low fiber (6.99%), highlighted reason that the lactating adult females require more food and energy than non–lactating females and males and to compensate for deficiency of their usual food resources.

Nonetheless, in the present study the primates selected food plants bearing fruits and seeds like *Artocarpus lakoocha* and *Albizia chinensis*, respectively. It is also reported that most species in one lemur community selected foods with high levels of protein **(Ganzhorn, 1988, 1989)**. By measuring overall mature–leaf acceptability as the ratio of protein to fiber, several subsequent studies have found positive correlations between colobine biomass and this index of leaf quality at local **(Chapman and Chapman, 2002; Chapman et al. 2002, 2004; Ganzhorn, 2002)** and regional scales **(Waterman et al. 1988; Oates et al. 1990)**. In addition to studies concerning the protein–fiber ratio for folivore, there are three key concepts that need further consideration when evaluating how food resources act as selection pressures to influence species conservation potential: ideal free distribution, ecological sinks, and fallback foods **(Chapman et al. 2012)**.

In this study, fruit epicarp of *Protium serratum* from AM fecal, remnants of fruit fibers in *Artocarpus lakoocha* and leave fibers of *Glochidion hyneanum* in both fecal matters of AM and CL were determined. In addition, leave fibers of *Diospyros glandulosa*, *Alstonia scholaris* and *Bishchofia javanica* were extracted from fecal matters of CL. The seeds parts of *Albizia procera* and *Ficus auriculata* were observed in the fecal samples of AM. A comparison of the plant foods consumed discovered that the number of plant species based on the observed time spent and fed upon predicted the number of plant species detected through macroscopic fecal inspection. Overall, then, while the analysis of fecal samples provided a useful complementary approach to the understanding of the composition of both the primates' diet, and underscored the problems of sampling biases, more work will be required in order to guarantee the reliable and systematic analysis of diets. This may include the refinement of both behavioral (*e.g.*, events vs. records) and fecal (*e.g.*, application of molecular techniques) procedures. **Silvestre et al. (2016)** believed that the behavioral monitoring of groups, which usually measures time spent in feeding, is a better option for evaluating the relative importance of different item categories (*e.g.*, fruits, gum and arthropods) in the diet of primates, including insectivorous species. However, if the frequencies of consumption are to be analyzed, complementary approaches, such as the estimation of observed feeding events and the frequency of different items in feces should be adopted. Furthermore, the data presented suggests that the main application of the fecal analysis is to access the composition of the diet of study subjects complementarily to the data collected through behavioral monitoring, especially for undigested food items.

VI. CONCLUSION

Describing the diets of wild animals is a crucial task and central theme in the field of biology, because understanding the dietary ecology of different species provides essential information about habitat requirements, trophic interactions, and food webs **(Chapman, 1995; Bridgeland et al. 2010; VelezLiendo et al. 2013, Singer et al. 2014)**. Characterizing the resource base of wild animals can also address questions related to nutritional ecology **(Felton et al. 2009a; Birnie–Gauvin et al. 2017)**, resource partitioning **(Wrangham et al. 1998; Pardo et al. 2015)**, and selective pressures that shape morphology and socio–ecology **(Marshall and Wrangham, 2007; Chapman et al. 2012)**. Dietary studies also play a central role in assessing the responses of wild populations to anthropogenic habitat alteration **(McLennan, 2013; Birnie–Gauvin et al. 2017)**. In conclusion, this study we focus on the nutritional composition of the foods consumed by AM and CL adds to the information on the nutritional content in their range of habitats. Macaques and Langurs living in the wild at comparable ecological setups with similar nutrient concentrations of staple foods have analogous food choices and time investments. The idea is that an estimate of the nutritional composition of foods eaten by wild macaques and langur can provide useful information for evaluation of vegetation quality available in the natural habitat and in the zoos that feed captive primate species.

Therefore, the present study deal with the nutrient contents and the analysis of fecal matter both in the sympatric species, AM and CL at study site. Direct observations for assessing the dietary ecology of wild animal populations are not always possible since many wild animals are difficult to locate and reliably observe **(Matthews et al. 2020)**. Therefore, non–invasive methods, such as macroscopic fecal sampling **(Tutin and Fernandez, 1993; Basabose, 2002)**, microscopic and molecular fecal analysis **(Phillips, 2011)**, DNA barcoding of fecal samples **(Que'me're' et al. 2013; Mallot et al. 2018)**, and examination of trail signs and feeding remains **(Rogers et al. 1990; Doran et al. 2002)**, can be important for determining animal diets, particularly of shy or at–risk species. Some studies have directly compared diet composition estimated from observations with macroscopic fecal analysis **(McInnis et al. 1983; Mills, 1992; Parker and Bernard, 2006; Bakaloudis et al. 2012; Phillips O'Connell, 2016)**. The most obvious limitation of macroscopic fecal analysis is that vegetative foods (leaves, stems and piths), flowers and soft bodied invertebrates can rarely be identified taxonomically and this results in these categories being under–represented on food lists **(Tutin and Fernandez, 1993)**. Over 12 months in estimating the diet of a montane community of eastern chimpanzees *Pan troglodytes schweinfurthii* in Nyungwe National Park, Rwanda, **Matthews et al. (2020)** suggested that combining methods of observational and indirect where possible is most useful for accurate monitoring of dietary trends of wild animals, particularly for any species that experience significant seasonal shifts in their diet.

Macroscopic analysis of primate feces as a way to study diet is well established, that yields quantitative data suitable for systematic investigation within and across primate taxa and thus the application of such indirect methods could increase uses. However, the potential for comparison across taxa and populations will be realized only when data collection is thorough and systematic **(Matthews et al. 2020).** So, while fecal analysis alone cannot give a complete picture of diet, it is a valuable tool for studying poorly habituated ape populations and in allowing inter-specific and inter-annual comparisons within sites. The major limitation of fecal analysis as a method of studying diet is the bias introduced against food classes that leave no recognizable remains. These include plant parts that are completely digested: leaf and flower buds, flowers and the young leaves of some species; and soft-bodied invertebrates such as larvae, grubs and caterpillars. In addition, leaves, pith from stems and woody fiber from bast, leave remains that can rarely be identified to species level and this leads to an underestimation of the diversity of these foods in the diet. Most fruit foods do leave recognizable remains, particularly seeds and the same is true of insects with chitinous bodies such as ants and bees. Thus, a bias towards fruit foods is likely in a food list constructed uniquely from fecal analysis. However, if combined with observation and trail evidence, over a period of several years, the bias will be much reduced **(Tutin and Fernandez, 1993).**

Analysis of dietary by comparison found congruency in the results from direct observations and fecal analysis identified of the major top ten food plants. Evidently, an integrative approach that utilizes macroscopic fecal analyses and/or behavioral observations to confirm DNA results would be the most effective. In this study, the comparative data sets for the interspecies (AM and CL) revealed that features of their foraging behaviors and its environment (*e.g.*, diurnal, selective feeder and in closed habitat) influences the suitability, thus provided for assessing the dietary diversity, composition and also along seasonal shift.

CHAPTER 3: DIGESTIBILITY AND ENERGY DYNAMICS

I. INTRODUCTION

Energy is the amount of food required to maintain body size, body composition, and a degree of essential and desirable physical activity consistent with long-term good health. This provides the energy required for proper growth and development **(FAO, 2001)**. It is maintained for a long period of time and is then designated in a new steady state. It is attained when input (dietary energy intake) equals output (total energy expenditure). Some of the alterations are significant and may potentially improve survival chances in times of food scarcity. Energy requirements are considerably affected by habitual physical activity, which is defined according to the degree of a population's habitual physical activity **(WHO, 1985)**. The primary goal for assessing energy requirements is to determine dietary energy intakes that are compatible with long–term well health **(FAO, 2001)**. Daily energy expenditure measurements demonstrate that primates, including humans, utilize only half the calories expected for mammals of similar body size. Although energy expenditure is crucial to organism biology, it has important implications for primates and other animals' life cycles, biological evolution, and foraging ecology. It has been suggested that primates' unusually low metabolic rates account for their unusually sluggish rates of growth, reproduction, and aging **(Pontzer et al. 2014)**. A perspective that energy consumption is exactly proportional to physical activity may hold true across the zoological records studied in primates **(Pontzer, 2015)**. The development of accurate, non–invasive technologies for measuring or estimating energy expenditure in free–living subjects has significantly enhanced our understanding of activity and energy expenditure in primates. In anthropology, these methods were used to recreate non-human primate energy budgets **(Coelho et al. 1977; Leonard and**

Robertson, 1997; Knott, 1998; Key and Ross, 1999; Aiello and Key, 2002; Steudel–Numbers, 2006; Froehle and Churchill, 2009; Snodgrass and Leonard, 2009).

Primates exhibit a wide range of digestive adaptations while occupying a variety of trophic niches ranging from folivory to frugivory and omnivory **(Lambert, 1998; Campbell, 2010)**. Food intake and nutrient digestibility need a full day of tracking of the studied individual in the wild for targeted sampling, and precise knowledge and quantification of food consumption is logistically impossible. However, it is essentially the first step to improve in–situ and ex–situ conservations in terms of habitat requirements conservation with the improvement of captive management, breeding programs, rehabilitation, and release, particularly for species that are critically endangered in the wild **(Coudrat and Cabana, 2019)**. As a result, one of the goals for animal management is to establish an adequate diet that takes into account nutritional differences among plant species and seasons in connection to their digestive physiology **(Hoshino et al. 2021)**. Large primates have high energy requirements but low mass-specific requirements. They can eat a broader variety of lower-quality meals (for example, leaves and other foliage). They have a bigger gut for more efficient nutrition extraction. Except for Lorises, small primates (700 g) have increased energy requirements for mass. As a result, they tend to eat more insects, small vertebrates, saps, and gums-food that is scarce but high in energy or nutrients **(Rothschild and Naples, 2015)**.

Digestibility evaluates the ability to break down and absorb nutrients, such as fiber found in browse/leaves, and thus measuring digestibility allows for insights into a species' digestive adaptations and capacities, as well as perhaps more importantly comparisons between species or species groups. To get information relevant for measuring digestive capacity, one technique is to evaluate apparent digestibility, *i.e*. the ratio of the difference between swallowed and fecal nutrients to the ingested nutrients **(Hoshino et al. 2021)**. Arboreal species exhibit lower metabolic rates within primate families, but not across families **(McNab, 1980; 1986)** (including the current study of AM and CL). This emphasized the significance of local ecology and activity levels in determining daily energy requirements for reproductive investment **(Pontzer, 2015)**.

In this work, we focused on the unidirectional flow of energy from food plants ingested by primates using a non–invasive targeted sampling technique. A virtual energy flow model was employed in this work to analyse digestibility and energy dynamics and the goal of the present study was to estimate the available energy and predict energy expenditure for primates in DTR.

II. REVIEW OF LITERATURES

Food scarcity is a big issue for primates who live in seasonal habitats. Primates have behavioral, physiological, and morphological adaptations that help them survive food deprivation. They modify diet compositions ranging patterns, and activity budgets in response to temporal variation in food availability **(Hemingway and Bynum, 2005)**. Species that live in settings with severe seasonality acquire a decreased metabolic rate, torpor, fat buildup, and/or oral and digestive tract morphology that is ideal for processing and digesting fallback meals **(Marshall and Wrangham, 2007)**. Furthermore, reproductive seasonality is prevalent among primates that live in seasonal settings **(Brockman and Van Schaik, 2005; Janson and Verdolin, 2005)**. Primates rely on their immediate energy for reproduction (income breeders) in settings with consistent food availability. They time the most energetically costly phase (weaning or mid to late breastfeeding) to coincide with food abundance peaks, resulting in a peak in births preceding the food abundance peak **(Crockett and Rudran, 1987; Nakagawa, 2000)**.

Primates utilise stored energy for reproduction (capital breeders) in unpredictable situations, resulting in a high in births following a peak in food abundance **(McCabe and Emery Thompson, 2013)**. Relaxed income breeders are species that use a combination of income and capital breeding strategies **(Brockman and Van Schaik, 2005; Tian et al. 2013)**. Under the circumstances that food availability fluctuates significantly across seasons, these characteristics could optimize energy methods and enhance fitness gains. Quantifying seasonal fluctuations in primates' energy budgets (*i.e.*, energy intake, expenditure, and balance) could aid in understanding their adaptations to seasonal food scarcity. Coping with seasonal fluctuations in food availability is crucial, especially for temperate primates. Temperate primates in Asia demonstrate eating patterns in response to two aspects of forest phenology: fruiting and flushing **(Hanya et al. 2013b)**. The seasonal changes in the availability of fruits and young leaves, which are preferred foods for most monkeys, are more significant in temperate forests than in Asian tropical forests. Non-fig fruits and young leaves frequently contain high in energy and protein **(Iwamoto, 1982; Nakagawa, 2009; Lambert and Rothman, 2015)**, and fruits have greater ingestion rates (dry matter intake per unit of feeding time) than other foods **(Nakagawa, 2009)**. Temperate primates in Asia rely on low-quality foods such as mature leaves, winter buds, bark, and lichens when such preferred foods are scarce **(Grueter et al. 2009; Tsuji et al. 2013; Hou et al. 2018)**, whereas tropical primates in Asia can feed on figs and young leaves **(Vogel et al. 2009; Hanya and Bernard, 2012)**. The Japanese macaque is a well-studied species distributed in temperate regions **(Hanya, 2010)**. They favor fruits and seeds, but during lean seasons, they switch to lower-quality meals **(Agetsuma 1995; Hill 1997; Nakayama et al. 1999; Tsuji et al. 2006)** and shift their activity patterns **(Agetsuma and Nakagawa, 1998; Tsuji, 2010)**.

As a result, Japanese macaques in cool-temperate forests consumed the most energy in the fall (fruit/seed–feeding period), followed by spring (young-leaf feeding period), summer (mature–leaf–feeding period), and winter (winter buds/bark-feeding period), corresponding to seasonal variations in energy balance **(Nakagawa, 1997; Nakayama et al. 1999; Tsuji et al. 2008)**. In Japanese macaques, seasonal fluctuation in energy balance is related to reproductive seasonality. This species mates and conceives in the fall (when food is abundant) and gives birth in the spring **(Fujita et al. 2004; Fooden and Aimi, 2005)**. Positive energy balance enhances the beginning of estrous and raises conception rates in the fall, while body fat buildup raises birth rates in the spring **(Suzuki et al. 1998; Takahashi, 2002; Garcia et al. 2011)**. Females eat young leaves in the spring to offset the costs of breastfeeding **(Nakagawa, 1997)**.

The rate at which organisms grow, reproduce, and age must eventually correspond to their physiological energy consumption; new tissue growth (self or offspring), as well as body maintenance and repair, all require metabolic investment. In theory, the total energy budget, also known as "total energy expenditure" (TEE) (kilocalories per day), or allocation within the energy budget, might fluctuate across evolutionary time to accommodate variations in life cycle patterns **(Charnov and Berrigan, 1993; Brown et al. 2004; Kozłowski and Weiner, 1997; West et al. 2001; Stearns (1992).** When body mass and phylogenetic relatedness are taken into consideration, the basal metabolic rate (BMR) (kilocalories per day), which is commonly employed as an indication of overall energy budget, is unrelated to rates of growth, reproduction, or aging in placental animals **(Speakman, 2005; De Magalhães et al. 2007; Lovegrove, 2009)**. Variation in allocation clearly influences life history schedules, but using BMR as an energy budget indicator can obscure the complementing function of variation in energy throughput **(Speakman, 2005)**.

III. MATERIALS AND METHODS

3.1: Sampling and process of plant materials

The parts of food plants including leaves, flowers, fruits and seeds were collected from the study site, DTR. Approximately, 100 g of leaves, flowers, fruits and seeds were collected as representative sample and these food items were weighed using analytical balance (Model KAB–200). Leaf, flowers, fruits and seeds samples were ground into fine powder using an electric grinder.

3.2: Estimation of digestibility

Following **Kurihara et al. (2020)**, experiments on the digestibility of plant samples were carried out. The plant samples that were collected from DTR were subjected to processing in accordance with Chapter 2. The following formula was used to determine the digestibility: Digestibility % = -1.10 x %ADF + 98.15.

3.3: Estimation of total energy available from food plants

Nagy and Milton (1979) approach was used to calculate the total predictable energy. Crude fat (CF), total protein (TP), total non-structural carbohydrates (TNC), and fiber (ADF) were used to assess the overall amount of energy available.

The formula Energy content = (9 x %Fat + 4 x %Protein + 4 x %TNC + 3 x %ADF) x (Digestibility–4).

Where, Crude fat (CF), total protein (TP), total non-structural carbohydrates (TNC), and fiber (ADF) all have physiological values of 9 kcal/g, 4 kcal/g, 4 kcal/g, and 3 kcal/g, respectively, **(NRC, 2003)**.

3.4: Total energy expected expenditure (TEE) in primates

Based on baseline energy expenditure (BEE), thermic energy of meals, and physical activity, total energy expenditure (TEE) is calculated **(Gaba et al. 2008)**. According to **Frankenfield et al. (2003)**, is a reliable way to calculate an individual's basal energy expenditure after adjusting for height, weight, age, and gender. The energy required to maintain body temperature, muscular tone, breathing, and autonomic processes is known as basal energy expenditure. The **Harris–Benedict (1919)** equation is used to convert the energy for research subjects' basal metabolic rate (BMR) and total energy expenditure (TEE) with respect to their levels of physical activity **(Frankenfield et al. 2003)**. The energy expected expenditure (TEE) calculated by this formula:

$$\text{Energy expenditure} = 121.13 \times (\text{Body Mass})^{0.77}.$$

IV. RESULTS

3.5: Digestibility (in %) of top ten plants food plants preferred by AM

The digestibility food plants consumed by AM are summarized in the Table 3.1; Fig. 3.1. The digestibility from the minimum to maximum of the top ten plant species are expressed in % and their values as follows *Artocarpus lakoocha* (56.284±3.47), *Albizia chinensis* (67.933±4.16), *Albizia procera* (65.887±3.54), *Albizia lebbeck* (70.034±3.14), *Diospyros glandulosa* (71.354±5.16), *Bombax insigne* (80.473±2.51), *Cephalotaxus graffithii* (85.577±3.47), *Glochidion hyneanum* (83.982±4.15), *Ficus auriculata* (88.438±2.64) and *Protium serratum* (94.784±3.68). The range of the digestibility (%) and the significantly high values was found to be between 56.284±3.47 and 94.784±3.68.

Table 3.1: Determination of proximate nutrients value and digestibility (%) of top ten plant species of AM (*n*=4) (*Digestibility %= -1.10 x %ADF + 98.15*).

Sl. No.	Food plants	Total Ash %	Carbohydrate (%)	TNC (%)	Protein (%)	Fat (%)	ADF (%)	Digestibility (%)
1.	***Artocarpus lakoocha***	4.42	10.94	45.86	6.75	4.91	38.06	**56.28**
2.	*Albizia chinensis*	11.29	13.71	51.49	8.72	1.03	27.47	67.93
3.	*Albizia procera*	11.04	7.52	53.67	5.23	0.73	29.33	65.89
4.	*Albizia lebbeck*	11	10.36	56.84	6.02	0.58	25.56	70.03
5.	*Diospyros glandulosa*	6.3	6.42	63.15	5.3	0.89	24.36	71.35
6.	*Bombax insigne*	2.55	11.78	70.61	8.98	1.79	16.07	80.47
7.	*Cephalotaxus graffithii*	11.7	12.01	71.26	4.07	1.54	11.43	85.58
8.	*Glochidion hyneanum*	5.1	8.93	70.95	5.37	5.7	12.88	83.98
9.	*Ficus auriculata*	3.57	8.99	74.64	2.42	1.45	17.92	88.44
10.	***Protium serratum***	10.31	12.59	83.86	2.15	0.62	3.06	**94.78**

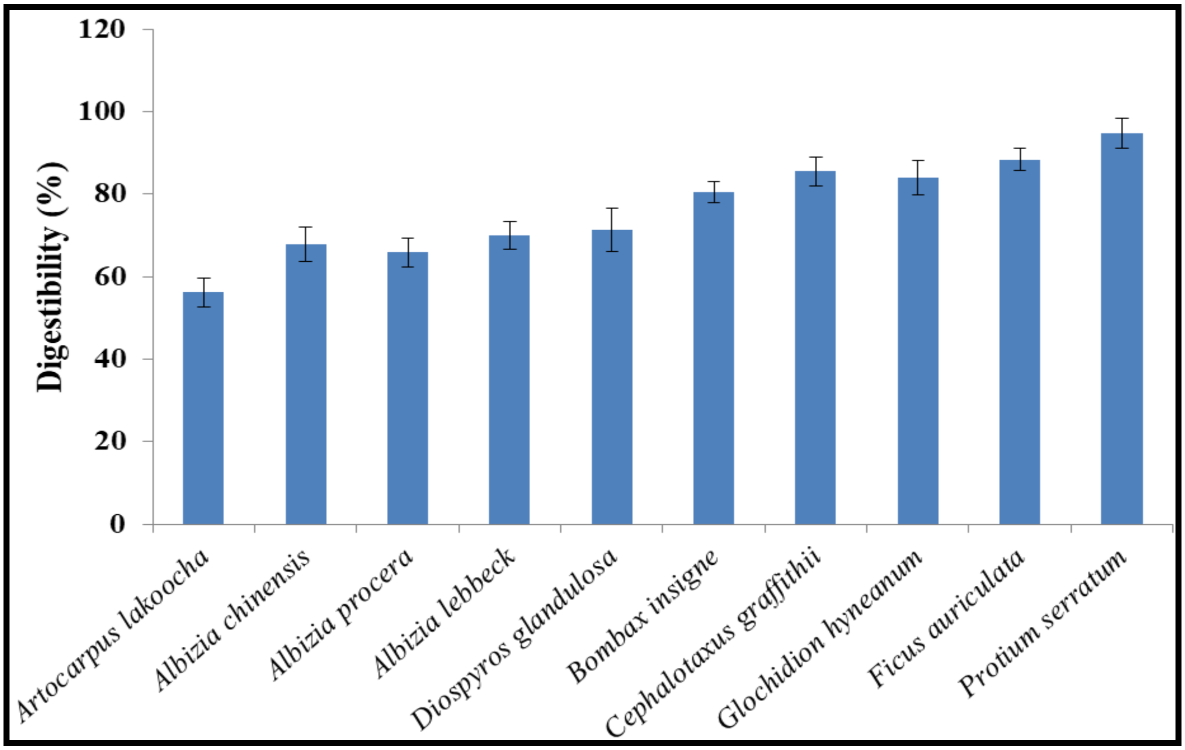

Figure 3.1: Estimation of digestibility (%) of top ten plant species preferred by AM.

3.6: Total energy content (kcal/g of DM) of top ten plants fed by AM

The amount of the energy content of the top ten plant species are expressed in kcal/g and summarized in Table 3.2. The energy content for the top ten plants were as follows *Artocarpus lakoocha* (2.358±0.150), *Albizia chinensis* (2.058±0.210), *Albizia procera* (2.180±0.340), *Albizia lebbeck* (2.245±0.140), *Diospyros glandulosa* (2.714±0.270), *Bombax insigne* (3.122±0.590), *Cephalotaxus graffithii* (2.795±0.640), *Glochidion hyneanum* (2.942±0.120), *Ficus auriculata* (3.405±0.134), and *Protium serratum* (3.485±0.124). Overall, the energy content was ranging between 2.058±0.210 (*Artocarpus lakoocha*) and 3.485±0.124 (*Protium serratum*).

3.7: The expected energy expenditure (TEE kcal/day) of AM

The expected energy expenditure from the top ten plant species was expressed in kcal/g and summarized in Table 3.2. The value of the expected total energy expenditure (TEE) for AM was estimated as 718.75±22.85 kcal/day. To suffice the energy required per day was found to be 266.21±12.31 g of top ten preferred food plants.

Table 3.2: The Total Energy Expenditure (TEE, kcal/day) of AM.

Sl. No.	Food plants	Digestibility (%)	Energy content (kcal/g)	Expected Energy (kcal /day)	Required quantity of DM (g)
1.	***Artocarpus lakoocha***	**56.284±3.47**	2.358±0.150	**718.75±22.85**	**266.21±12.31**
2.	***Albizia chinensis***	67.933±4.16	**2.058±0.210**		
3.	*Albizia procera*	65.887±3.54	2.180±0.340		
4.	*Albizia lebbeck*	70.034±3.14	2.245±0.140		
5.	*Diospyros glandulosa*	71.354±5.16	2.714±0.270		
6.	*Bombax insigne*	80.473±2.51	3.122±0.590		
7.	*Cephalotaxus graffithii*	85.577±3.47	2.795±0.640		
8.	*Glochidion hyneanum*	83.982±4.15	2.942±0.120		
9.	*Ficus auriculata*	88.438±2.64	3.405±0.134		
10.	***Protium serratum***	**94.784±3.68**	**3.485±0.124**		

3.8: Digestibility (%) of top ten plants food plants preferred by CL

The digestibility food plants consumed by CL are summarized is represented in the Table 3.3; Fig. 3.2. The digestibility from the minimum to maximum of the top ten plant species are expressed in % and their values as follows *Albizia chinensis* (67.93±4.10), *Albizia lebbeck* (70.03±4.67), *Diospyros glandulosa* (71.35±5.26), *Alstonia scholaris* (82.43±3.47), *Cephalotaxus graffithii* (85.57±2.98), *Albizia procera* (83.98±4.54), *Bischofia javanica* (91.24±3.54), *Castanopsis tribuloides* (91.78±3.28), *Aglaia edulis* (96.67±3.28), *Albizia richardiana* (97.29±4.21) The range of the digestibility (%), which was significantly high, was found to be between 67.93±4.10 and 97.29±4.21.

Table 3.3: Determination of proximate nutrient values and digestibility (%) of top ten plant species of CL (*n*=4).

Sl. No.	Species name	Total Ash (%)	Carbohydrate (%)	TNC (%)	Protein (%)	Fat (%)	ADF (%)	Digestibility (%)
1.	***Albizia chinensis***	11.29	13.71	51.49	8.72	1.03	27.47	**67.93**
2.	*Albizia lebbeck*	11	10.36	56.84	6.02	0.58	25.56	70.03
3.	*Diospyros glandulosa*	6.3	6.42	63.15	5.3	0.89	24.36	71.35
4.	*Alstonia scholaris*	7.97	12.72	69.58	4.77	3.39	14.29	82.43
5.	*Cephalotaxus graffithii*	11.7	12.01	71.26	4.07	1.54	11.43	85.57
6.	*Albizia procera*	3.78	9.67	74.11	6.53	2.7	12.88	83.98
7.	*Bischofia javanica*	4.8	13.63	78.82	8.23	1.87	6.28	91.24
8.	*Castanopsis tribuloides*	7.99	9.32	79.64	4.01	2.57	5.79	91.78
9.	*Aglaia edulis*	5.54	12.11	87.19	5.14	0.79	1.34	96.67
10.	***Albizia richardiana***	2.64	9.59	93.81	2.15	0.62	0.78	**97.29**

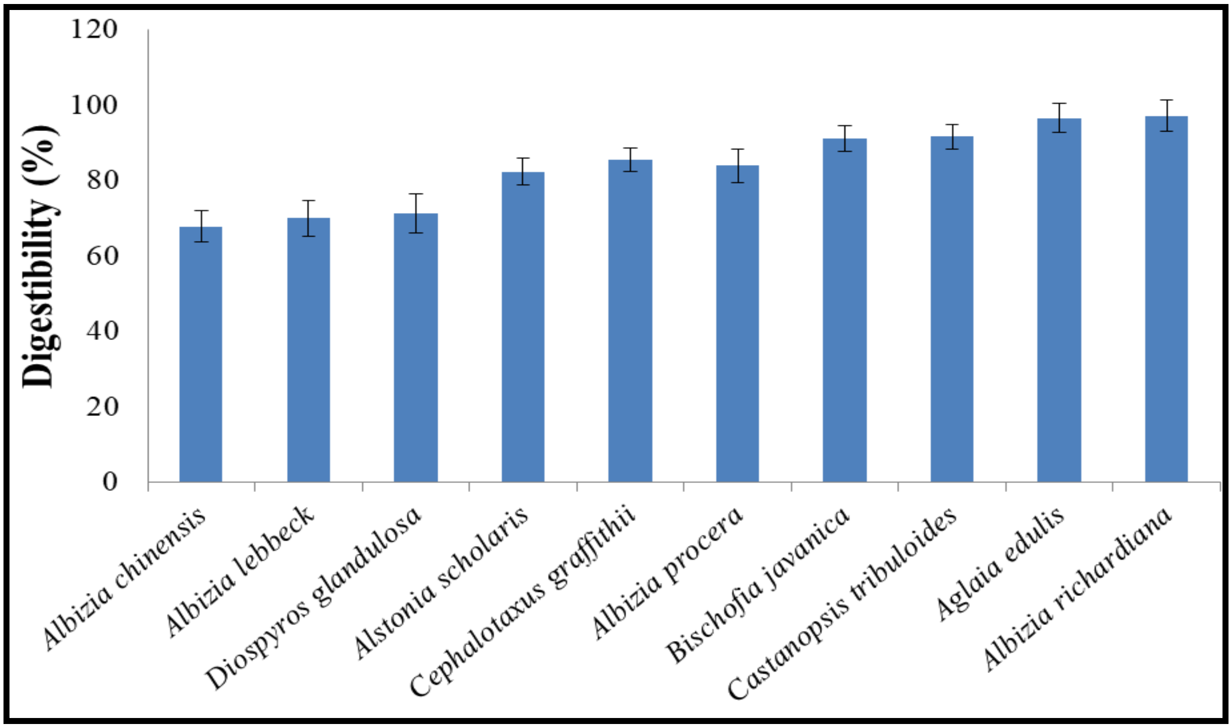

Figure 3.2: Estimation of digestibility (%) of top ten plant species preferred by CL.

3.9: Total energy content (kcal/g of DM) of top ten plants fed by CL

The amount of the energy content of the top ten plant species are expressed in kcal/g and summarized in Table 3.4; Fig. 3.3**.** The energy content for the top ten plants were as follows; *Albizia chinensis* (2.05±0.21), *Albizia lebbeck* (2.24±0.14), *Diospyros glandulosa* (2.74±0.27), *Alstonia scholaris* (2.24±0.21), *Cephalotaxus graffithii* (2.79±0.64), *Albizia procera* (2.18±0.34), *Bischofia javanica* (2.79±0.10), *Castanopsis tribuloides* (2.96±0.05), *Aglaia edulis* (3.48±0.08) and *Albizia richardiana* (3.58±0.11). The total energy content was found to be highest in *Albizia richardiana* (3.58±0.11) and lowest in *Albizia chinensis* (2.05±0.21).

4.0: The expected energy expenditure (TEE kcal/day) of CL

The expected energy expenditure from the top ten plant species was expressed in kcal/g and summarized at Table 3.4. The values of the expected total energy expenditure (TEE) for *Trachypithecus pileatus* was estimated as 826.03±12.19 kcal/day. The required amount of energy per day was found to be 305.93±8.22 g of top ten preferred food plants.

Table 3.4: The Total Energy Expenditure (TEE kcal/day) of CL.

Sl. No.	Top ten food plants	Digestibility (%)	Energy content (kcal/g)	Expected Energy (kcal /day)	Required quantity of DM (g)
1.	***Albizia chinensis***	**67.93±4.10**	**2.05±0.21**	**826.03±12.19**	**305.93±8.22**
2.	*Albizia lebbeck*	70.03±4.67	2.24±0.14		
3.	*Diospyros glandulosa*	71.35±5.26	2.74±0.27		
4.	*Alstonia scholaris*	82.43±3.47	2.24±0.21		
5.	*Cephalotaxus graffithii*	85.57±2.98	2.79±0.64		
6.	*Albizia procera*	83.98±4.54	2.18±0.34		
7.	*Bischofia javanica*	91.24±3.54	2.79±0.10		
8.	*Castanopsis tribuloides*	91.78±3.28	2.96±0.05		
9.	*Aglaia edulis*	96.67±3.28	3.48±0.08		
10.	***Albizia richardiana***	**97.29±4.21**	**3.58±0.11**		

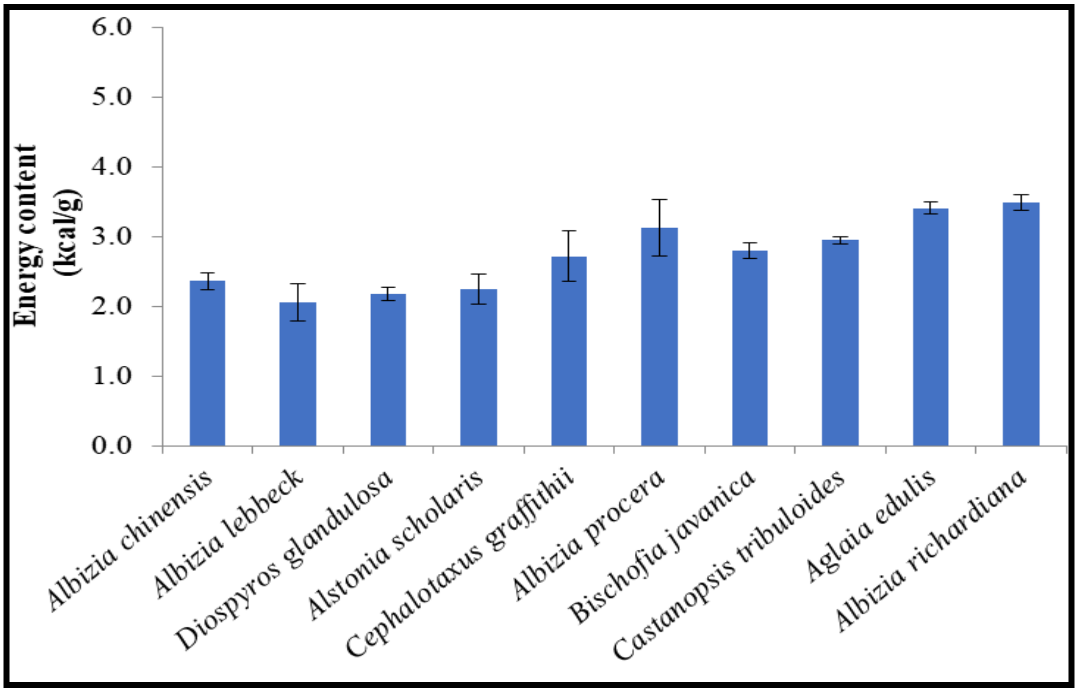

Figure 3.3: Energy content (kcal/g) of top ten food plants of CL.

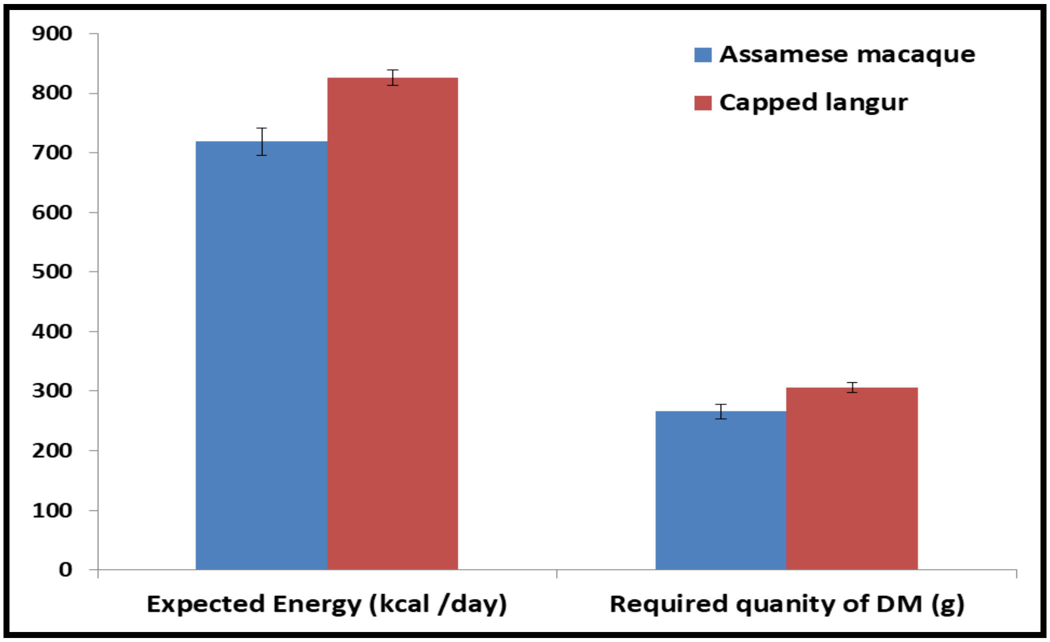

Figure 3.4: Expected energy (kcal/day) with required quantity of DM (g) of AM and CL.

V. DISCUSSION

Digestibility is an important factor of forage quality, which can be defined as an animal's relative performance when fed forages for consumption. Nutrient concentration, intake, digestibility, and metabolic efficiency of ingested nutrients all contribute to animal performance **(Mertens and Grant, 2020)**. Though nutrient content influences intake potential and digestibility, it is the animal's response to these forage qualities that ultimately determines the nutritional quality of forages **(Ball et al. 2001)**. Voluntary intake often accounts for the majority of the difference in animal productivity among forages, but digestibility is significant because feces are the primary source of nutrient loss **(Coleman and Moore, 2003)**. Forages provide a distinctive challenge to an animal's ability to consume and digest dietary needs **(Felton et al. 2009a)**. Forages have a high volume to dry matter (DM) weight ratio, causing them to be bulky and harder to digest in compared to grains and concentrate diets. Forages' hinders can be attributed to their higher content of dietary fibre when compared to concentrate feeds **(Pond et al. 2004)**. Many studies have been conducted to investigate the quantity of time that primates dedicate to feeding food, but surprisingly little is known about the intake rates associated with each nutritional consequence of foraging **(Oftedal, 1991, 1992)**.

From the study, the digestibility of top ten preferred plants by AM ranges from *Artocarpus lakoocha* (56.284±3.47) to *Protium serratum* (94.784±3.68) (Table 3.1; Fig. 3.1), whereas CL preferred the digestibility (%) ranged between 67.93±4.10 (*Albizia chinensis*) and 97.29±4.21 (*Albizia richardiana*) (Table 3.3; Fig. 3.2). Typically, changes in intake account for 60-90% of the variable in digested DM or energy intake **(Crampton et al. 1960; Reid, 1961; Oftedal, 1991)**. It can be reported that, the digestibility of food plants are also within the range of digestibility reported by **Davies et al. (1988)**. The present work study suggests that due to medium (56.28%) to high (97.29%) digestibility the of top ten food plants, both study subject preferred these plants for food. The amount of energy available to primates from ingested diets is determined by the composition of the food as well as the extent to which various ingredients, particularly fibre fractions, are digested **(Oftedal, 1991)**. The availability of energy content in the food plants were mostly influenced by the seasonal changes. It is depending on the availability plants parts such as buds, leaves, flowers, fruits and seeds. The amount of energy available to primates from swallowed food is determined by the form of the diet and the concentration of specific elements **(Oftedal, 1992)**. **Kurihara et al. (2020)** reported 77 species of wild plants fed by *Macaca fucata yakui*, with energy contents ranging from 0.68 to 6.53 kcal/g.

In this study, AM consumed food plants with energy contents ranging from 2.06±0.21 kcal/g (*Albizia chinensis*) to 3.49±0.12 kcal/g (*Protium serratum*) (Table 3.2), whereas CL fed on food plants with energy contents ranging from 2.06±0.21 kcal/g (*Albizia chinensis)* 3.58±0.11 kcal/g (*Albizia richardiana*) (Table 3.4). These findings showed that the energy content of top ten plants consumed by AM and CL are moderately high which might be one of the reason they inhabited in the Dampa Wildlife Sanctuary. The rate at which primates grow, reproduce, and age must eventually reflect their physiological energy consumption; new tissue growth (self or offspring) as well as bodily maintenance and repair all necessitate metabolic input. In theory, the total energy budget, also known as "total energy expenditure" (TEE) (kilocalories per day), or allocation within the energy budget, might fluctuate across evolutionary time to accommodate variations in life cycle patterns **(Pontzer et al. 2014)** and BMR has always been less than half of TEE in most mammals **(Westerterp and Speakman, 2008)**. The hypothesis test among primates that developed disparities in the size of the energy budget contributes among these monkeys. However, BMR of physical activity does not explain the substantial fall in TEE in primates. TEE, in addition to BMR and physical activity, may influence metabolic variations amongst primates **(Ravussin et al. 1982; Bass, 2012)**.

From the present study, the estimated energy requirement for AM (718.75±22.85 kcal/day) and CL (826.03±12.19 kcal/day) is logically sound as per method provided **(Vogel et al. 2015; Kurihara et al. 2017; Sha et al. 2018)**. Other researchers have found that energy expenditure is similar across wild groups. When energy intake is limited and/or expenditure is elevated during reproductive activities, animals may counteract these costs by increasing intake prior to the commencement of costly reproductive processes **(Di Bitetti and Janson, 2000)**. Earlier research on food intake in wild populations supports the current findings of primate TEE, including multiple full-day observations of food intake by adult primates in the wild, nutritional analyses of available foods eaten such spider monkeys (*Ateles chamek*) **(Felton et al. 2009b)**, Chacma baboons (*Papio hamadryas ursinus*) **(Johnson et al. 2013)**. To obtain the anticipated amount of energy from plant material for both AM as well as CL, this was projected to be 718.75±22.85 kcal/day and 826.03±12.19, respectively (Table 3.2 and 3.4; Fig. 3.4). And to acquire sufficient quantity of the energy required per day will be obtained from 266.21±12.31 g and 305.93±8.22 g of top ten preferred food plants (Table 3.2 and 3.4). This can be achieved by available food plants sources throughout the year.

VI. CONCLUSION

One of the first tasks in developing conservation management plans and standards is to understand the ecology of these two sympatric species. During fieldwork at DTR from 2018 to 2020, troops of macaques and langurs species were studied and focused primarily on their feeding with the other dietary compositions, accounting mostly for the top ten plant species based on the orders of highest time spent feeding percentage, of which only leaves consumption contributed the maximum percent, besides other components. Understanding the nutrients and, in particular, how these two species (AM and CL) absorb nutrients is one facet of their ecology research. This information enables us to assess how much of the nutrients they consume in the wild are physiologically utilized, and hence can assist suggest nutritional needs for the species.

This is a crucial initial step toward improving in–situ conservation in terms of habitat requirements, as well as ex–situ conservation management, breeding programs, rehabilitation, and release, particularly for species that are critically endangered in the wild. Captive settings are ideal for studying food intake and nutritional digestion. Furthermore, due to physical barriers and numerous environmental conditions, it would be practically logistically impossible to follow known individuals for focal sampling and gained specific knowledge and measurement of their food intake in the field. When data collection is extensive and systematic, the potential for comparison across species and populations will be fulfilled.

CHAPTER 4: HABITAT EVALUATION FOR NUTRITIONAL STATUS OF FOOD

I. INTRODUCTION

The important goal of primatology is to decipher the ecological factors that influence primate abundance, diversity, life history, and social behavior **(Rothman et al. 2011)**. The behavior of every animal is closely linked and determined by its habitat **(Krebs and Davies, 1997)**. Nutritional ecology is at the core of these questions because primates must acquire adequate nutrition under a suite of environmental and social constraints to reproduce successfully **(Cameron, 1996).** However, the field of primate nutritional ecology is still in its infancy **(Rothman et al. 2011)**. Underpinning all aspects of nutritional ecology is the need for individuals to procure appropriate quantities of certain macronutrient and micronutrient from their habitat requirement which is not uniform among different species or individuals but may vary depending on factors such as body size, metabolic requirements, lifestyle and digestive system **(Parra, 1978; Milton, 1993)**. One of the primary goals in animal ecology is to reveal how environmental factors determine habitat quality for animal abundance. Although various factors, such as climate **(Iwamoto and Dunbar, 1983; Barton and Zalewski, 2007)**, predation **(Peek 1980; Isbell, 1990)**, and stress or disease **(Milton 1996; Harvell et al. 1999; Berger et al. 2001; Chapman et al. 2006a)**, can affect animal abundance, the effect of food has typically been considered of paramount importance **(Hanya and Chapman, 2013a; Bach et al. 2017; Wang et al. 2022)**. That is because food is a fundamentally important resource of animals, and the adequacy of food directly affects animal behavior, growth, reproduction, population structure, and population dynamics **(Zhao et al. 2013)**.

Primates are generalist consumers and are dependent on a diverse array of resources, such as leaves, fruits/seeds, flowers, gum/sap, barks, and insects **(Kay, 1984)**. These food resources vary in their nutritional and distributional properties, thus comparative primate research can clarify various mechanisms concerning how food affects abundance **(Hanya and Chapman, 2013a)**. Although animals select habitats based on a complex interaction of factors including the distribution of predators, competitors, and abiotic properties of the environment **(Tews et al. 2004)**, the availability of food resources is undoubtedly one of the most fundamental factors shaping primates distribution, abundance, ranging, and grouping patterns **(Stevenson, 2001; Chapman et al. 2004)**. The availability of food resources is a main indicator for habitat quality **(Zhang and Zang, 2018)**. **Wang et al. (2022)** stated that food plant diversity and nutrients are key determinants of many primate population dynamics. The influence of food availability on behavior has received particular attention among primates and has been considered one of the main evolutionary factors selecting for variation in primate social organization **(Wrangham, 1980; Sterck et al. 1997).** Multiple dimensions of food availability exist, including quantity and quality **(Chapman et al. 2003)** can influence behavior and life history in multiple ways, the understanding of which is a fundamental goal in behavioral ecology.

Quantifying food diversity and nutrients is also a prerequisite for exploring the interaction mechanism between animals and habitats **(Clink et al. 2017; Deng and Zhou, 2018)**. Primates will select a home range with high food tree diversity and high calorie likely as an adaptation for fluctuating food environments **(Hladik and Simmen, 1996; Jang et al. 2021)**. Maintaining the required calorie value is essential for the survival of primates **(Grether et al. 1992)**. Importantly, this “high-calorie bias” in primates’ spatial memory seems to yield consequences for individual eating behavior in food abundant settings **(Arce et al. 2010; De Vries et al. 2022).**

It has been found that food abundance and distribution can directly determine primate ranging patterns and home range area **(Milton and May, 1976; Kim et al. 2011; Simmen et al. 2014; Ning et al. 2019)**. Since nutrition is a key to primate survival, understanding the drivers of feeding behaviors and the consequences of nutritional shortfalls is essential; **Rothman and Bryer (2019)** suggested that researchers measure not only food availability over time, but nutrient availability as well where resources are available. According to **Rothman and Bryer (2019)**, **a**dequate nutrition in the habitat is necessary for survival and reproduction of individual non–human primates, influencing the growth of populations. Climate change is already shifting the suitable ranges of animal and plant communities, with implications for the feeding ecology of primates. Three effects of climate change that affect the feeding and nutrition of primates are: (1) A change in the phenology of primate foods; (2) A change in the distribution of primate food plants; and (3) A change in the nutritional composition of the same trees.

Many studies have reported dietary differences, but few report actual nutritional composition of foods and diets. It is clear long–term research to continue is needed, and that these long-term studies must monitor both availability and nutritional quality of foods, as these measures will give insight into primate health **(Rothman and Bryer, 2019)**. Acute food supply is believed to cause deficiency of nutrients which may ultimately lead to a variety of immune dysfunctions and an impaired resilience **(Deb et al. 2019)**. Living in degraded habitats may also lead to increased parasitic load **(Deb et al. 2014)** which may affect their survival, growth and fecundity.

Tropical forests are rapidly declining **(Steininger et al. 2008)** and those remaining are suffering severe damage and fragmentation due to extensive local human activities as well as human-induced global environmental change **(Zhang et al. 2010; Laurance et al. 2011).** The resulting habitat loss and degradation severely affects forest dwelling animals, especially primates **(Rode et al. 2006; Arroyo–Rodríguez and Dias, 2010).** Globally, approximately 60% of primate species are at threat of extinction **(Estrada et al. 2017).** Habitat conversion from original habitat to highly disturbed habitats is one of the main reasons for the decline in primate populations **(Arroyo–Rodríguez and Dias, 2010).** Forest fragmentation results in population declines in some primates and complete extirpation in others **(Estrada and Coates–Estrada, 1996; Chapman et al. 2007; Boyle, 2008).** Dampa Tiger Reserve harbors several species of primate that inhabits around the forest very close to the buffer areas and thereby has high chances of encroaching on the agricultural crop fields that are adjacent to the core. The scarcity of wild foods and destruction of natural habitats tend the monkeys to enter the crop fields and raid the crops. Such situation forces them to survive on human crop field and settlements **(Ghimire et al. 2021).** Such encroachment may lead to human-primate conflict due to crop loss suffered by local farmers. Thus knowledge of habitat and feeding ecology is essential for developing an effective conservation management plan for threatened primates **(Fan et al. 2021).** Hence understanding the feeding ecology comprising habitat evaluation for nutritional status of food for the two species and developing suitable measures to mitigate them is necessary in the area.

Till date, how both AM and CL response to such habituations 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 nutritional status of food in the habitat, requirements to cope with dietary needs, and ranging behavior, or ability to respond to habitat fragmentation, this work intend to provide new insight to the detail assessment of the habitat in terms of nutritional food plants of AM and CL in the tropical forest of DTR in Mizoram, India for the first time. This investigation might possibly contribute for better management and conservation of both the species, the nationally endangered and protected species in and around the reserve area.

II. REVIEW OF LITERATURES

There is a scanty of research information on the evaluation of habitat of primates for their nutritional status based on availability and quality of food plants. The availability of food resources is a main indicator for habitat quality **(Hanya and Chapman, 2013a; Bach et al. 2017; Zhang and Zang, 2018; Wang et al. 2022)**, and its abundance and distribution can directly determine primate ranging patterns and home range area **(Milton and May, 1976; Kim et al. 2011; Simmen et al. 2014; Ning et al. 2019).** Although there are some studies on the feeding ecology and behavioral activities of AM (**Mitra, 2003; Zhou et al. 2011; Chalise et al. 2013a, 2013b; Huang et al. 2015; Kaepawnus et al. 2015; Koirala et al. 2017; Khanal et al. 2019; Li et al. 2019; Ghimire et al. 2021; Decemson et al. 2022)** and CL **(Stanford, 1991; Kumar and Solanki, 2004; Solanki and Kumar, 2008a, 2008b; Mandal and Kabir, 2014; Monirujjaman and Khan, 2017; Decemson et al. 2018; Hasan et al. 2018; Borah et al. 2021; Barbhuiya et al. 2022; Khan et al. 2022)** in their distributional range, there is no information on the nutritive value and status of food plants consumed in the habitat.

All the previous works focused on either floral diversity or food preference, or both. **Deb et al. (2019)** analyzed nutritional status of food plants and distribution of Western hoolock gibbons in forest patches of Cachar district, Assam and reported a moderate positive correlation was noted between higher protein content and higher crude fiber content in food plants (r=0.48), which is likely to influence food selection and feeding pattern.

Various workers **(Freese et al. 1982; Weisenseel et al. 1993; White, 1994; Yoshihiro et al. 1999; Mathews and Matthews, 2002; McConkey and Chivers, 2004)** speculated on environmental drivers of habitat quality supporting density, the majority only make qualitative comparisons among vegetation types or study sites. Other studies examined vegetational correlates of primate abundance, such as tree density, basal area, shrub cover, and tree species diversity **(Butynski, 1990; Balcomb et al. 2000; Chapman and Chapman, 2002; Wieczkowski, 2004; Worman and Chapman, 2006; Hamard et al. 2010).** In contrast to these studies, **Hanya and Chapman (2013a)** reviewed food resource limitation on primates by linking feeding ecology and population abundance and suggested the importance of fallback foods (foods that are eaten during the scarcity of preferred foods), or the type of resource limiting the animal and vegetation structure evaluates food quantity only in the most general way.

Furthermore, they discussed such studies examining vegetational correlates of primate abundance can be used in meta–analyses; however, since it is usually difficult to collect data on both primate and habitat variables in a comparable fashion, primate abundance is usually correlated with indirect measure of forest productivity, such as rainfall or forest type. However, **Stevenson (2001)** found significant results using direct measures of food abundance, such as fruit fall. In an earlier study, **Chapman et al. (2002)** demonstrated that the protein–fiber ratio of the mature leaves in forest fragments predicted the abundance of red colobus and black-and-white colobus monkeys, accounting for 87 % of their variance in abundance **(Chapman et al. 2004)**. **Rothman and Bryer (2019)** stated this model strongly suggested that the quality of foods, specifically the protein–fiber ratio, has an impact on monkey abundance. **Milich (2012)** reported the impact of habitat quality on female red colobus monkey (*Procolobus rufomitratus*) reproduction in which she found that habitat quality impacts diet and behaviors, which ultimately effect reproductive success. **Campera et al. (2014)** explained the effects of habitat quality and seasonality on ranging patterns of collared brown lemur (*Eulemur collaris*) in littoral forest fragments. **Hambali et al. (2014)** explained why Long–Tailed Macaques (*Macaca fascicularis*) at the Entrance of Kuala Selangor Nature Park (Anthropogenic Habitat) can survive in a wide diversity of habitats including in the area of human leading to human-macaque conflict. **Nila et al. (2014)** reported the habitats of Long–Tailed Macaques (*Macaca fascicularis*) in Telaga Warna, Bogor, West Java strongly influenced the dietary variation of the populations and the dietary variation of the macaques reflected ecological plasticity in coping with differences both in availability and abundance of food. They also highlighted macaques are plastic in taking any kind of food that available in their home range and adjust their behaviour according to its abundance.

Foerster et al. (2016) reported feeding habitat quality and behavioral trade–offs in chimpanzees and documented an increase in feeding habitat quality with community residence time in both sexes during the dry season, suggesting an influence of familiarity on foraging decisions in a highly heterogeneous landscape. **Zhang and Zang (2018)** suggested understanding of the diversity and distribution patterns of Hainan gibbon (*Nomascus hainanus*) foods is essential to its conservation. **Rothman and Bryer (2019)** reanalyzed the mature leaves from the same tree community in Kibale National Park and found a 10 per cent increase in fiber over 30 years. They reported that protein–fiber ratio of young leaves declined as well over a 15–year period.

Ghimire et al. (2021) studied on the feeding ecology of AM troops in KRB and BRB of central Nepal and reported that two study troops inhabiting highly similar habitats of food plants have analogous food choices and time investments. **Wang et al. (2022)** reported that food plant diversity was one key determinant of the formation of a new family group and choosing high food plant diversity was also one key motivation for Hainan gibbons to select their home range.

III. MATERIALS AND METHODS

4.1: Habitat analysis

To estimate nutrients containing food availability on smaller spatial scales, perhaps the most common method in primate behavioral ecology is to conduct vegetation surveys in which presence and basal area are recorded in randomly or semi- randomly located plots **(Foerster et al. 2016)**. The total basal area of specific food species can give an estimate of its abundance **(Chapman et al. 1992)**, and multiple species can be combined to estimate total availability of food in an area of interest **(Newton–Fisher et al. 2000; Mitani et al. 2002)**. This approach is frequently used to calculate indices of food abundance and their temporal variation, in conjunction with the monitoring of tree phenology **(Fashing, 2001; Savini et al. 2008; Foerster et al. 2012)**. Total of nine quadrats of (20×20) m^2 sized were laid down randomly in the possible habitat of AM and CL is used to analyze the vegetation pattern of habitat. The vegetation data collected was assessed based on the shrubs and herbs were calculated from the values of relative frequency and relative density and diameter of trees measured at 1.37 m from the base during sampling **(Deka et al. 2012; Deori et al. 2016)**, and quantitatively analyzed following equations as per **Irmayanti et al. (2022)**.

To evaluate the nutritional status of the food plants in the habitat, different ecological parameters such as; the IVI, RDom, RDen and RF of tree plants were determined. From the 148 plant species documented within the habitat, the habitat status was evaluated by testing whether there are significant differences between the overall plants consumed and non–consumed based on the various ecological parameters such as the IVI, RDom, RDen and RF. For this test, the data was analyzed separately for AM and CL where the number of plants eaten are 57 and 66 species, respectively.

4.2: Statistical analysis

In this study, the variables do not show a normal distribution and the homogeneity test was not passed, a non-parametric Mann–Whitney U test was conducted at the alpha level of 0.05. Pearson correlation was also used to assess the relationship of proximate nutrient values of the combined top preferred food plant species for AM and CL with respect to the habitat ecological parameters (IVI, RDom, RDen and RF).

For this test, the combined of top ten preferred plants in both AM and CL of five plant species are found similar between them, so a total of 15 plants are gathered for both the species. Scatter plots were also generated between the aforesaid parameters in order to show the degree of effect one variable is having upon another. The PSPP ver. 1.6.2 (GNU Project 2015) was used for all the statistical analysis and the 'p' value was considered significant at 0.05.

IV. RESULTS

4.3: Relationship between habitat parameters and consumed and non–consumed plants

In this study, the habitat quality in terms of nutritional food plants of AM and CL in the tropical forest of DTR is assessed. Among the overall 148 plant species documented in the studied habitats Fig. 4.1(A–H) and Fig. 4.2 (I-K), the highest value of RF is recorded in *Artocarpus lakoocha* (1.81%), while RDen, RDom and IVI are highest in *Acrocarpus fraxinifolius* (2.11%, 2.34% and 5.17%, respectively).

The RF value of 1.44% is followed by 12 plant species *viz*; *Albizia chinensis, Albizia lebbeck, Albizia procera, Aporosa octandra, Artocarpus nitidus, Baccaurea ramiflora, Castanopsis tribuloides, Ficus auriculata, Glochidion hyneanum, Melocalamus compactiflorus, Melocana baccifera, Mesua ferrea*. The RF value of 1.08% were observed in 19 species like; *Aglaia edulis*, *Albizia richardiana*, *Alstonia scholaris*, *Bischofia javanica*, *Bombax insigne*, *Canarium bengalense*, *Cephalotaxus griffithii*, *Chukrasia tabularis*, *Diospyros glandulosa*, *Drimycarpus racemosus*, *Etlingera linguiformis*, *Garuga pinnata*, *Licuala peltata*, *Macaranga pustulata*, *Magnolia oblonga*, *Phyllanthus embelica*, *Protium serratum*, *Prunus ceylanica* and *Syzygium acuminata*. The RF value of 0.72% was observed in 33 species like; *Acrocarpus fraxinifolius*, *Alseodaphne petiolaris*, *Anogeissus acuminata*, *Baalakata baccata*, *Calliandra umbrosa*, *Cyathocalyx martabanicus*, *Daemonorops jenkinsianus*, *Dendrocalamus longispathus*, *Derris robusta*, *Dillenia indica*, *Diospyros pilosiuscula*, *Ervatamia coronaria, Erythrina stricta*, *Erythrina variegata*, *Eugenia jambolana*, *Ficus variegata*, *Ficus retusa*, *Ficus rumphii*, *Myristica longifolia*, *Parkia timoriana*, *Polyalthia jenkensii*, *Premna benghalensis*, *Sapindus mukorossi*, *Schima wallichii*, *Spondias pinnata*, *Stereospermum chelonoides*, *Syzygium cumini*, *Terminalia myriocarpa*, *Terminalia retusa*, *Tetrameles nudiflora*, *Thysanolaena latifolia*, *Toona ciliata* and *Walsura robusta*. The RF value of 0.36% was observed in 68 species and as follows; *Alphonsea lutea*, *Amomum dealbatum*, *Antidesma bunius*, *Aphananthecus pidata*, *Ardisia polycephala*, *Bombax ceiba*, *Caesalpinia cucullata*, *Calamus acanthospathus*, *Calamus guruba*, *Calamus* sp., *Callicarpa arborea*, *Camphora glanduliferum*, *Caryota urens*, *Cassia javanica*, *Chisocheton cumingianus*, *Choerospondias axillaris*, *Chrysophyllum roxburghii*, *Connarus paniculatus*, *Cordia dichotoma*, *Croton lissophyllus*, *Dioscorea pentaphylla*, *Diospyros lanceifolia*, *Diospyros pilosula*, *Diospyros stricta*, *Dipterocarpus retusus*, *Duabanga grandiflora*, *Dysoxylum alliaria*, *Dysoxylum gotadhora*, *Elaeocarpus lanceifolius*, *Elaeocarpus rugosus*, *Eriobotrya benghalensis*, *Ficus elastica*, *Ficus fistulosa*, *Ficus racemosa*, *Ficus religiosa*, *Ficus semicordata*, *Flacourtia indica*, *Flacourtia jangomas*, *Garcinia succifolia*, *Gnetum gnemon*, *Hardina cordiflora*, *Knemalino folia*, *Lannea coromandelica*, *Lepionarus sylvestris*, *Macropanax dispermus*, *Mallotus macrostachyus*, *Mangifera indica*, *Musa ornata*, *Persea minutiflora*, *Phoebe hainesiana*, *Phoebe lanceolata*, *Phrynium pubinerve*, *Polyalthia simiarium*, *Pouteria grandifolia*, *Pseudostachyum polymorphum*, *Sapium baccatum*, *Saraca indica*, *Terminalia bellirica*, *Terminalia citrina*, *Terminalia crenulata*, *Trema orientalis*, *Vitex quinata*, *Willughbeia edulis*, *Xantolis tomentosa* and *Zalacca beccarii*.

The RDen value of 1.58% was recorded for these five species *viz*; *Albizia chinensis*, *Amomum dealbatum*, *Artocarpus lakoocha*, *Magnolia oblonga* and *Melocalamus compactiflorus*. The RDen value of 1.32% were recorded in nine species *viz. Mesua ferrea*, *Albizia procera*, *Artocarpus nitidus*, *Baccaurea ramiflora*, *Castanopsis tribuloides*, *Cephalotaxus griffithii*, *Ficus auriculata*, *Melocana baccifera* and *Aglaia edulis*. The RDen value of 1.05% was observed in 18 species such as; *Syzygium acuminata*, *Alstonia scholaris*, *Anogeissus acuminata*, *Aporosa octandra*, *Baalakata baccata*, *Bischofia javanica*, *Bombax insigne*, *Canarium bengalense*, *Chukrasia tabularis*, *Diospyros glandulosa*, *Etlingera linguiformis*, *Garuga pinnata*, *Glochidion hyneanum*, *Homelomena aromatic*, *Macaranga pustulata*, *Protium serratum*, *Prunus ceylanica* and *Albizia lebbeck*. The RDen value of 0.79% was observed in 29 species such as; *Albizia richardiana*, *Aphananthecus pidata*, *Ardisia polycephala*, *Cyathocalyx martabanicus*, *Dendrocalamus longispathus*, *Dillenia indica*, *Drimycarpus racemosus*, *Dysoxylum gotadhora*, *Eugenia jambolana*, *Ficus variegata*, *Garuga floribunda*, *Gmelina arborea*, *Gmelina oblongifolia*, *Heliconia rostrata*, *Hibiscus macrophyllus*, *Hydnocarpus kurzii*, *Irvingia gabonensis*, *Leea indica*, *Licuala peltata*, *Litsea monopetala*, *Machilus gamblei*, *Mammea suriga*, *Myristica longifolia*, *Phyllanthus embelica*, *Schima wallichii*, *Syzygium cumini*, *Tetrameles nudiflora*, *Thysanolaena latifolia* and *Toona ciliata*. The RDen value of 0.53% was observed in 52 species like; *Alphonsea lutea*, *Alseodaphne petiolaris*, *Antidesma bunius*, *Caesalpinia cucullata*, *Calliandra umbrosa*, *Camphora glanduliferum*, *Caryota urens*, *Cassia javanica*, *Chisocheton cumingianus*, *Chrysophyllum roxburghii*, *Connarus paniculatus*, *Cordia dichotoma*, *Daemonorops jenkinsianus*, *Derris robusta*, *Diospyros pilosiuscula*, *Diospyros pilosula*, *Diospyros stricta*, *Dysoxylum alliaria*, *Elaeocarpus lanceifolius*, *Ervatamia coronaria*, *Erythrina stricta*, *Erythrina variegata*, *Ficus elastica*, *Ficus religiosa*, *Ficus retusa*, *Ficus rumphii*, *Flacourtia jangomas*, *Garcinia loniceroides*, *Garcinia sopsopia*, *Gnetum gnemon*, *Heritiera papilio*, *Knemalino folia*, *Lepionarus sylvestris*, *Ligustrum robustum*, *Lindera nacusua*, *Macropanax dispermus*, *Mahoniana paulensis*, *Parkia timoriana*, *Persea minutiflora*, *Phrynium pubinerve*, *Polyalthia jenkensii*, *Premna benghalensis*, *Pseudostachyum polymorphum*, *Sapindus mukorossi*, *Saraca indica*, *Spondias pinnata*, *Stereospermum chelonoides*, *Terminalia myriocarpa*, *Terminalia retusa*, *Trema orientalis*, *Walsura robusta* and *Xantolis tomentosa*.

However, the lowest RF value was recorded in 34 species *viz*. *Bombax ceiba*, *Calamus acanthospathus*, *Calamus guruba*, *Calamus* sp., *Callicarpa arborea*, *Choerospondias axillaris*, *Croton lissophyllus*, *Dioscorea pentaphylla*, *Diospyros lanceifolia*, *Dipterocarpus retusus*, *Duabanga grandiflora*, *Elaeocarpus rugosus*, *Eriobotrya benghalensis*, *Ficus elastica*, *Ficus racemosa*, *Ficus semicordata*, *Flacourtia indica*, *Garcinia succifolia*, *Hardina cordiflora*, *Lannea coromandelica*, *Mallotus macrostachyus*, *Mangifera indica*, *Musa ornata*, *Phoebe hainesiana*, *Phoebe* *lanceolata*, *Polyalthia simiarium*, *Pouteria grandifolia*, *Sapium baccatum*, *Terminalia bellirica*, *Terminalia citrina*, *Terminalia crenulata*, *Vitex quinata*, *Willughbeia edulis* and *Zalacca beccarii*.

The RDom value 1.75% was recorded in 3 species *viz*. *Albizia chinensis*, *Artocarpus lakoocha* and *Magnolia oblonga*. The RDom value 1.46% was recorded in eight species such as; *Aglaia edulis*, *Albizia procera*, *Artocarpus nitidus*, *Baccaurea ramiflora*, *Castanopsis tribuloides*, *Cephalotaxus griffithii*, *Ficus auriculata* and *Mesua ferrea*. The RDom value 1.17% was documented in 17 species such as; *Albizia lebbeck*, *Alstonia scholaris*, *Anogeissus acuminata*, *Aporosa octandra*, *Baalakata baccata*, *Bischofia javanica*, *Bombax insigne*, *Canarium bengalense*, *Chukrasia tabularis*, *Diospyros glandulosa*, *Etlingera linguiformis*, *Garuga pinnata*, *Glochidion hyneanum*, *Homelomena aromatica*, *Macaranga pustulata*, *Protium serratum*, *Prunus ceylanica* and *Syzygium acuminata*. The RDom value 0.88% was recorded 24 in species *viz*. *Albizia richardiana*, *Aphananthecus pidata*, *Ardisia polycephala*, *Cyathocalyx martabanicus*, *Dillenia indica*, *Drimycarpus racemosus*, *Dysoxylum gotadhora*, *Eugenia jambolana*, *Ficus variegata*, *Garuga floribunda*, *Gmelina arborea*, *Gmelina oblongifolia*, *Hydnocarpus kurzii*, *Irvingia gabonensis*, *Leea indica*, *Litsea monopetala*, *Machilus gamblei*, *Myristica longifolia*, *Phyllanthus embelica*, *Schima wallichii*, *Syzygium cumini*, *Tetrameles nudiflora*, *Thysanolaena latifolia* and *Toona ciliata*. The RDom value 0.58% was recorded in 50 species were; *Alphonsea lutea, Alseodaphne petiolaris, Antidesma bunius, Calliandra umbrosa, Camphora glanduliferum, Caryota urens, Cassia javanica, Chisocheton cumingianus, Chrysophyllum roxburghii, Connarus paniculatus, Cordia dichotoma, Daemonorops jenkinsianus, Derris robusta, Diospyros pilosiuscula, Diospyros pilosula, Diospyros stricta, Dysoxylum alliaria, Elaeocarpus lanceifolius, Ervatamia coronaria Erythrina stricta, Erythrina variegata, Ficus fistulosa, Ficus religiosa, Ficus retusa, Ficus rumphii, Flacourtia jangomas, Garcinia loniceroides, Garcinia sopsopia, Gnetum gnemon, Heritiera papilio, Knemalino folia, Ligustrum robustum, Lindera nacusua, Macropanax dispermus, Mahoniana paulensis, Parkia* *timoriana*, *Persea minutiflora*, *Phrynium pubinerve*, *Polyalthia jenkensii*, *Premna bengalensis*, *Pseudostachyum polymorphum*, *Sapindus mukorossi*, *Saraca indica*, *Spondias pinnata*, *Stereospermum chelonoides*, *Terminalia myriocarpa*, *Terminalia retusa*, *Trema orientalis*, *Walsura robusta* and *Xantolis tomentosa*. The RDom value 0.29% was recorded in 31 species *viz*. *Bombax ceiba*, *Calamus acanthospathus*, *Calamus guruba*, *Calamus* sp., *Callicarpa arborea*, *Choerospondias axillaris*, *Croton lissophyllus*, *Diospyros lanceifolia*, *Dipterocarpus retusus*, *Duabanga grandiflora*, *Elaeocarpus rugosus*, *Ficus elastica*, *Ficus racemosa*, *Ficus semicordata*, *Flacourtia indica*, *Garcinia succifolia*, *Lannea coromandelica*, *Mallotus macrostachyus*, *Mammea suriga*, *Mangifera indica*, *Phoebe hainesiana*, *Phoebe lanceolata*, *Polyalthia simiarium*, *Pouteria grandifolia*, *Sapium baccatum*, *Terminalia bellirica*, *Terminalia citrina*, *Terminalia crenulata*, *Vitex quinata*, *Zalacca beccarii* and *Willughbeia edulis*. The lowest RDom value of 0.00% was noted in species *viz*. *Amomum dealbatum*, *Caesalpinia cucullata*, *Dendrocalamus longispathus*, *Dioscorea pentaphylla*, *Musa ornata*, *Hardina cordiflora*, *Heliconia rostrata*, *Hibiscus macrophyllus*, *Lepionarus sylvestris*, *Licuala peltata*, *Melocalamus compactiflorus*, *Melocana baccifera* and *Eriobotrya bengalensis*.

The IVI value of 5.14% was observed in one species *i.e*., *Artocarpus lakoocha*. The IVI value of 4.78% was recorded in one species *i.e*., *Albizia chinensis*. The IVI value of 4.22% was recorded in species like; *Albizia procera*, *Artocarpus nitidus*, *Baccaurea ramiflora*, *Castanopsis tribuloides*, *Ficus auriculata* and *Mesua ferrea*. The IVI value of 3.86% was recorded in two species such as; *Aglaia edulis* and *Cephalotaxus griffithii*. The IVI value of 3.31% was recorded in 12 species as follows; *Alstonia scholaris*, *Bischofia javanica*, *Bombax insigne*, *Canarium bengalense*, *Chukrasia tabularis*, *Diospyros glandulosa*, *Etlingera linguiformis*, *Garuga pinnata*, *Macaranga pustulata*, *Protium serratum*, *Prunus ceylanica* and *Syzygium acuminata*. The IVI value of 2.94% was recorded in three species *i.e*., *Homelomena aromatica*, *Baalakata baccata* and *Anogeissus acuminata*. The IVI value of 2.75% was recorded in three species;

Albizia richardiana, *Drimycarpus racemosus* and *Phyllanthus embelica*. The IVI value of 2.39% was observed in 18 species like; *Cyathocalyx martabanicus*, *Dillenia indica*, *Eugenia jambolana*, *Ficus variegata*, *Toona ciliata, Gmelina arborea*, *Gmelina oblongifolia*, *Hydnocarpus kurzii*, *Irvingia gabonensis*, *Leea indica*, *Litsea monopetala*, *Machilus gamblei*, *Myristica longifolia*, *Schima wallichii*, *Syzygium cumini*, *Tetrameles nudiflora*, *Thysanolaena latifolia* and *Garuga floribunda*. The IVI value of 2.03% was recorded in three species *i.e*., *Aphananthecus pidata*, *Ardisia polycephala* and *Dysoxylum gotadhora*. The IVI value of 1.94% was recorded in one species *i.e*., *Amomum dealbatum*. The IVI value of 1.83% was recorded in 25 species such as; *Alseodaphne petiolaris*, *Calliandra umbrosa*, *Daemonorops jenkinsianus*, *Derris robusta*, *Diospyros pilosiuscula*, *Ervatamia coronaria*, *Erythrina stricta*, *Erythrina variegata, Ficus religiosa*, *Ficus retusa*, *Ficus rumphii*, *Garcinia loniceroides*, *Garcinia sopsopia*, *Heritiera papilio*, *Ligustrum robustum*, *Lindera nacusua*, *Mahoniana paulensis*, *Parkia timoriana*, *Polyalthia jenkensii*, *Pouteria grandifolia*, *Sapindus mukorossi*, *Spondias pinnata*, *Terminalia myriocarpa*, *Terminalia retusa* and *Walsura robusta*. The IVI value of 1.51% was recorded in four species like; *Dendrocalamus longispathus*, *Heliconia rostrata*, *Hibiscus macrophyllus* and *Mammea suriga*. The IVI value of 1.47% was recorded in 26 species *i.e*., *Alphonsea lutea*, *Antidesma bunius*, *Caesalpinia cucullata*, *Camphora glanduliferum*, *Caryota urens*, *Cassia javanica*, *Chisocheton cumingianus*, *Chrysophyllum roxburghii*, *Connarus paniculatus*, *Cordia dichotoma*, *Diospyros pilosula*, *Diospyros stricta*, *Dysoxylum alliaria*, *Elaeocarpus lanceifolius*, *Ficus fistulosa*, *Ficus religiosa*, *Flacourtia jangomas*, *Gnetum gnemon*, *Knemalino folia*, *Macropanax dispermus*, *Persea minutiflora*, *Phrynium pubinerve*, *Pseudostachyum polymorphum*, *Saraca indica Trema orientalis* and *Xantolis tomentosa*.

The IVI value of 0.92% was recorded in species like; *Bombax ceiba*, *Calamus acanthospathus*, *Calamus guruba*, *Calamus* sp., *Callicarpa arborea*, *Choerospondias axillaris*, *Croton lissophyllus*, *Dioscorea pentaphylla*, *Diospyros lanceifolia*, *Dipterocarpus retusus*, *Duabanga grandiflora*, *Elaeocarpus rugosus*, *Ficus elastica*, *Ficus racemosa*, *Ficus semicordata*, *Flacourtia indica*, *Garcinia succifolia*, *Lannea coromandelica*, *Mallotus macrostachyus*, *Mangifera indica*, *Musa ornata*, *Phoebe hainesiana*, *Phoebe lanceolata*, *Polyalthia simiarium*, *Pouteria grandifolia*, *Sapium baccatum*, *Terminalia bellirica*, *Terminalia citrina*, *Terminalia crenulata*, *Vitex quinata*, *Willughbeia edulis* and *Zalacca beccarii*. The IVI value of 0.62% was recorded in two species *i.e.*, *Eriobotrya bengalensis* and *Hardina cordiflora*.

Table 4.1: The overall food plants (consumed and non–consumed) with ecological parameters (species consumed by AM is denoted by *, CL by # and *# denoted consumed by both primate).

Consumed food plants						Non–consumed food plants					
Sl no	**Plant species**	**RF**	**RDen**	**RDom**	**IVI**	**Sl no**	**Plant species**	**RF**	**RDen**	**RDom**	**IVI**
1	*Aglaia edulis*#*	1.08	1.32	1.46	3.86	**1**	*Acrocarpus fraxinifolius*	0.72	2.11	2.34	5.17
2	*Albizia chinensis*#*	1.44	1.58	1.75	4.78	**2**	*Alphonsea lutea*	0.36	0.53	0.58	1.47
3	*Albizia lebbeck*#*	1.44	1.05	1.17	3.67	**3**	*Alseodaphne petiolaris*	0.72	0.53	0.58	1.83
4	*Albizia procera*#*	1.44	1.32	1.46	4.22	**4**	*Amomum dealbatum*	0.36	1.58	0.00	1.94
5	*Albizia richardiana*#*	1.08	0.79	0.88	2.75	**5**	*Aphananthecus pidata*	0.36	0.79	0.88	2.03
6	*Alstonia scholaris#*	1.08	1.05	1.17	3.31	**6**	*Ardisia polycephala*	0.36	0.79	0.88	2.03
7	*Anogeissus acuminata*#*	0.72	1.05	1.17	2.94	**7**	*Baalakata baccata*	0.72	1.05	1.17	2.94
8	*Antidesma bunius*#*	0.36	0.53	0.58	1.47	**8**	*Calamus acanthospathus*	0.36	0.26	0.29	0.92
9	*Aporosa octandra*#*	1.44	1.05	1.17	3.67	**9**	*Calamus guruba*	0.36	0.26	0.29	0.92
10	*Artocarpus lakoocha*#*	1.81	1.58	1.75	5.14	**10**	*Calamus* sp.	0.36	0.26	0.29	0.92
11	*Artocarpus nitidus*#*	1.44	1.32	1.46	4.22	**11**	*Calliandra umbrosa*	0.72	0.53	0.58	1.83
12	*Baccaurea ramiflora*	1.44	1.32	1.46	4.22	**12**	*Callicarpa arborea*	0.36	0.26	0.29	0.92
13	*Bischofia javanica*#*	1.08	1.05	1.17	3.31	**13**	*Canarium bengalense*	1.08	1.05	1.17	3.31
14	*Bombax ceiba*#*	0.36	0.26	0.29	0.92	**14**	*Caryota urens*	0.36	0.53	0.58	1.47
15	*Bombax insigne*#*	1.08	1.05	1.17	3.31	**15**	*Chisocheton cumingianus*	0.36	0.53	0.58	1.47

Consumed food plants						Non–consumed food plants					
Sl no	**Plant species**	**RF**	**RDen**	**RDom**	**IVI**	**Sl no**	**Plant species**	**RF**	**RDen**	**RDom**	**IVI**
16	*Caesalpinia cucullata**	0.36	0.53	0	1.47	**16**	*Connarus paniculatus*	0.36	0.53	0.58	1.47
17	*Camphora glanduliferum#*	0.36	0.53	0.58	1.47	**17**	*Cordia dichotoma*	0.36	0.53	0.58	1.47
18	*Cassia javanica*#*	0.36	0.53	0.58	1.47	**18**	*Croton lissophyllus*	0.36	0.26	0.29	0.92
19	*Castanopsis tribuloides**	1.44	1.32	1.46	4.22	**19**	*Cyathocalyx martabanicus*	0.72	0.79	0.88	2.39
20	*Cephalotaxus griffithii**	1.08	1.32	1.46	3.86	**20**	*Daemonorops jenkinsianus*	0.72	0.53	0.58	1.83
21	*Choerospondias axillaris#*	0.36	0.26	0.29	0.92	**21**	*Diospyros lanceifolia*	0.36	0.26	0.29	0.92
22	*Chrysophyllum roxburghii#*	0.36	0.53	0.58	1.47	**22**	*Diospyros pilosiuscula*	0.72	0.53	0.58	1.83
23	*Chukrasia tabularis*#*	1.08	1.05	1.17	3.31	**23**	*Diospyros pilosula*	0.36	0.53	0.58	1.47
24	*Dendrocalamus longispathus*#*	0.72	0.79	0	1.51	**24**	*Diospyros stricta*	0.36	0.53	0.58	1.47
25	*Derris robusta*#*	0.72	0.53	0.58	1.83	**25**	*Dipterocarpus retusus*	0.36	0.26	0.29	0.92
26	*Dillenia indica*#*	0.72	0.79	0.88	2.39	**26**	*Drimycarpus racemosus*	1.08	0.79	0.88	2.75
27	*Dioscorea pentaphylla*#*	0.36	0.26	0	0.92	**27**	*Dysoxylum alliaria*	0.36	0.53	0.58	1.47
28	*Diospyros glandulosa*#*	1.08	1.05	1.17	3.31	**28**	*Elaeocarpus lanceifolius*	0.36	0.53	0.58	1.47
29	*Duabanga grandiflora*#*	0.36	0.26	0.29	0.92	**29**	*Elaeocarpus rugosus*	0.36	0.26	0.29	0.92
30	*Dysoxylum gotadhora*#*	0.36	0.79	0.88	2.03	**30**	*Eriobotrya bengalensis*	0.36	0.26	0.00	0.62
31	*Ficus auriculata*#*	1.44	1.32	1.46	2.39	**31**	*Ervatamia coronaria*	0.72	0.53	0.58	1.83

Consumed food plants							Non-consumed food plants				
Sl no	**Plant species**	**RF**	**RDen**	**RDom**	**IVI**	**Sl no**	**Plant species**	**RF**	**RDen**	**RDom**	**IVI**
32	*Ficus elastica*#*	0.36	0.26	0.29	4.22	**32**	*Erythrina stricta*	0.72	0.53	0.58	1.83
33	*Ficus racemosa*#*	0.36	0.26	0.29	1.47	**33**	*Erythrina variegata*	0.72	0.53	0.58	1.83
34	*Ficus religiosa#*	0.36	0.53	0.58	0.92	**34**	*Etlingera linguiformis*	1.08	1.05	1.17	3.31
35	*Ficus retusa*#*	0.72	0.53	0.58	1.47	**35**	*Eugenia jambolana*	0.72	0.79	0.88	2.39
36	*Ficus rumphii*#*	0.72	0.53	0.58	1.83	**36**	*Ficus fistulosa*	0.36	0.53	0.58	0.92
37	*Ficus semicordata*#*	0.36	0.26	0.29	1.83	**37**	*Flacourtia indica*	0.36	0.26	0.29	0.92
38	*Ficus variegata#*	0.72	0.79	0.88	2.39	**38**	*Flacourtia jangomas*	0.36	0.53	0.58	1.47
39	*Garcinia succifolia*#*	0.36	0.26	0.29	0.92	**39**	*Garcinia loniceroides*	0.72	0.53	0.58	1.83
40	*Glochidion hyneanum*#*	1.44	1.05	1.17	3.67	**40**	*Garcinia sopsopia*	0.72	0.53	0.58	1.83
41	*Gmelina arborea*#*	0.72	0.79	0.88	2.39	**41**	*Garuga floribunda*	0.72	0.79	0.88	2.39
42	*Gnetum gnemon*#*	0.36	0.53	0.58	1.47	**42**	*Garuga pinnata*	1.08	1.05	1.17	3.31
43	*Heliconia rostrata*#*	0.72	0.79	0	1.51	**43**	*Gmelina oblongifolia*	0.72	0.79	0.88	2.39
44	*Hibiscus macrophyllus*#*	0.72	0.79	0	1.51	**44**	*Hardina cordiflora*	0.36	0.26	0.00	0.62
45	*Hydnocarpus kurzii*#*	0.72	0.79	0.88	2.39	**45**	*Heritiera papilio*	0.72	0.53	0.58	1.83
46	*Litsea monopetala*#*	0.72	0.79	0.88	2.39	**46**	*Homelomena aromatica*	0.72	1.05	1.17	2.94
47	*Magnolia oblonga*#*	1.08	1.58	1.75	4.42	**47**	*Irvingia gabonensis*	0.72	0.79	0.88	2.39

Consumed food plants						Non-consumed food plants					
Sl no	**Plant species**	**RF**	**RDen**	**RDom**	**IVI**	**Sl no**	**Plant species**	**RF**	**RDen**	**RDom**	**IVI**
48	*Mallotus macrostachyus*#*	0.36	0.26	0.29	0.92	**48**	*Knemalino folia*	0.36	0.53	0.58	1.47
49	*Mammea suriga#*	0.72	0.79	0.29	1.51	**49**	*Lannea coromandelica*	0.36	0.26	0.29	0.92
50	*Mangifera indica*#*	0.36	0.26	0.29	0.92	**50**	*Leea indica*	0.72	0.79	0.88	2.39
51	*Melocana baccifera*#*	1.44	1.32	0	2.76	**51**	*Lepionarus sylvestris*	0.36	0.53	0.00	0.89
52	*Musa ornata*#*	0.36	0.26	0	0.92	**52**	*Licuala peltata*	1.08	0.79	0.00	1.87
53	*Parkia timoriana*#*	0.72	0.53	0.58	1.83	**53**	*Ligustrum robustum*	0.72	0.53	0.58	1.83
54	*Phyllanthus embelica*#*	1.08	0.79	0.88	2.75	**54**	*Lindera nacusua*	0.72	0.53	0.58	1.83
55	*Protium serratum*#*	1.08	1.05	1.17	3.31	**55**	*Macaranga pustulata*	1.08	1.05	1.17	3.31
56	*Prunus ceylanica*#*	1.08	1.05	1.17	3.31	**56**	*Machilus gamblei*	0.72	0.79	0.88	2.39
57	*Sapindus mukorossi#*	0.72	0.53	0.58	1.83	**57**	*Macropanax dispermus*	0.36	0.53	0.58	1.47
58	*Schima wallichii*#*	0.72	0.79	0.88	2.39	**58**	*Mahoniana paulensis*	0.72	0.53	0.58	1.83
59	*Spondias pinnata*#*	0.72	0.53	0.58	1.83	**59**	*Melocalamus compactiflorus*	1.44	1.58	0.00	3.02
60	*Syzygium cumini*#*	0.72	0.79	0.88	2.39	**60**	*Mesua ferrea*	1.44	1.32	1.46	4.22
61	*Terminalia bellirica#*	0.36	0.26	0.29	0.92	**61**	*Myristica longifolia*	0.72	0.79	0.88	2.39
62	*Terminalia crenulata*#*	0.36	0.26	0.29	0.92	**62**	*Persea minutiflora*	0.36	0.53	0.58	1.47
63	*Terminalia myriocarpa*#*	0.72	0.53	0.58	1.83	**63**	*Phoebe hainesiana*	0.36	0.26	0.29	0.92

Consumed food plants						Non-consumed food plants					
Sl no	**Plant species**	**RF**	**RDen**	**RDom**	**IVI**	**Sl no**	**Plant species**	**RF**	**RDen**	**RDom**	**IVI**
64	*Toona ciliata*#*	0.72	0.79	0.88	2.39	**64**	*Phoebe lanceolata*	0.36	0.26	0.29	0.92
65	*Trema orientalis#*	0.36	0.53	0.58	1.47	**65**	*Phrynium pubinerve*	0.36	0.53	0.58	1.47
66	*Vitex quinata*#*	0.36	0.26	0.29	0.92	**66**	*Polyalthia jenkensii*	0.72	0.53	0.58	1.83
67	*Walsura robusta*#*	0.72	0.53	0.58	1.83	**67**	*Polyalthia simiarium*	0.36	0.26	0.29	0.92
68	*Willughbeia edulis*#*	0.36	0.26	0.29	0.92	**68**	*Pouteria grandifolia*	0.36	0.26	0.29	0.92
69	*Xantolis tomentosa*#*	0.36	0.53	0.58	1.47	**69**	*Premna bengalensis*	0.72	0.53	0.58	1.83
						70	*Pseudostachyum polymorphum*	0.36	0.53	0.58	1.47
						71	*Sapium baccatum*	0.36	0.26	0.29	0.92
						72	*Saraca indica*	0.36	0.53	0.58	1.47
						73	*Stereospermum chelonoides*	0.72	0.53	0.58	1.83
						74	*Syzygium acuminata*	1.08	1.05	1.17	3.31
						75	*Terminalia citrina*	0.36	0.26	0.29	0.92
						76	*Terminalia retusa*	0.72	0.53	0.58	1.83
						77	*Tetrameles nudiflora*	0.72	0.79	0.88	2.39
						78	*Thysanolaena latifolia*	0.72	0.79	0.88	2.39
						79	*Zalacca beccarii*	0.36	0.26	0.29	0.92

Figure 4.1 (A–H): Assessment of study sites for habitat quality at DTR: (A) Dense tall tree canopy habitat, (B) Quadrat sampling, (C) Clearing shrubs and bushes along the forest path, (D) Following path between big boulders cleared by wild elephant (*Elephas maximus*), (E) Counting of the tree cover at study sites, (F) Stream inside bamboo forested, (G) Bamboo species *Melocana baccifera* trampled by AM troop, (H) Rocky boulders at perennial stream.

Figure 4.2 (I-K): Assessment of study sites for habitat quality at DTR: (I) Well–flourished bushy forest suitable for primates, (J) Cross examined of any indirect signs left by the study animals at study site and (K) Foraging ground and sleeping tree (~40 m from ground level) of the study animals at DTR.

In AM, the assessment on the ecological parameters between the consumed plants (*n*=57) and non–consumed plants (*n*=91) revealed higher mean values across all the habitat parameters in the consumed plants, and the differences are also statistically significant in all the ecological parameters at the alpha level of 0.05 (Table 4.2). The comparison on the various parameters between consumed and non-consumed plants for AM are represented graphically using box plot where the median is shown in red horizontal line; 50% of the numerical data is depicted by the box; 25th percentile of the data are found between the minimum and the first quartile, 75th percentiles between the third quartile and maximum, and the outliers are presented in dots. The consumed plants are denoted in light–brown color and the non-consumed plant in bluish-green color box. The box plot clearly partitioned the data in IVI, RDen, RDom in four percentiles except in RF where the data is partitioned into two parts in 50% each which signified the uniformity of the data. Moreover, the median line is also seen overlapped and bound at the upper limit of first quartile in RDen and lower limit of first quartile in RF which signified that the data is having skewed distribution thereby we utilized a non-parametric Mann-Whitney U test for the statistical analysis Fig. 4.1 (A-D).

Table 4.2: Descriptive statistics along with comparison of the consumed plants and non–consumed plants by AM based on the IVI, RDen, RDom and RF using Mann–Whitney U test. Significance at the alpha level of 0.05 is given in bold.

Parameters	**Consumed plants**				**Non–consumed plants**				**Difference**	
	Mean	SD	Min	Max	Mean	SD	Min	Max	U	**p values**
IVI	2.38	1.2	0.92	5.14	1.81	0.87	0.62	5.17	1875.0	**<0.05**
RDen	0.78	0.39	0.26	1.58	0.61	0.34	0.26	2.11	1945.0	**<0.05**
RDom	0.79	0.48	0.00	1.75	0.60	0.38	0.00	2.34	2017.0	**<0.05**
RF	**0.81**	**0.4**	**0.36**	**1.81**	**0.59**	**0.28**	**0.36**	**1.44**	**1800.5**	**<0.05**

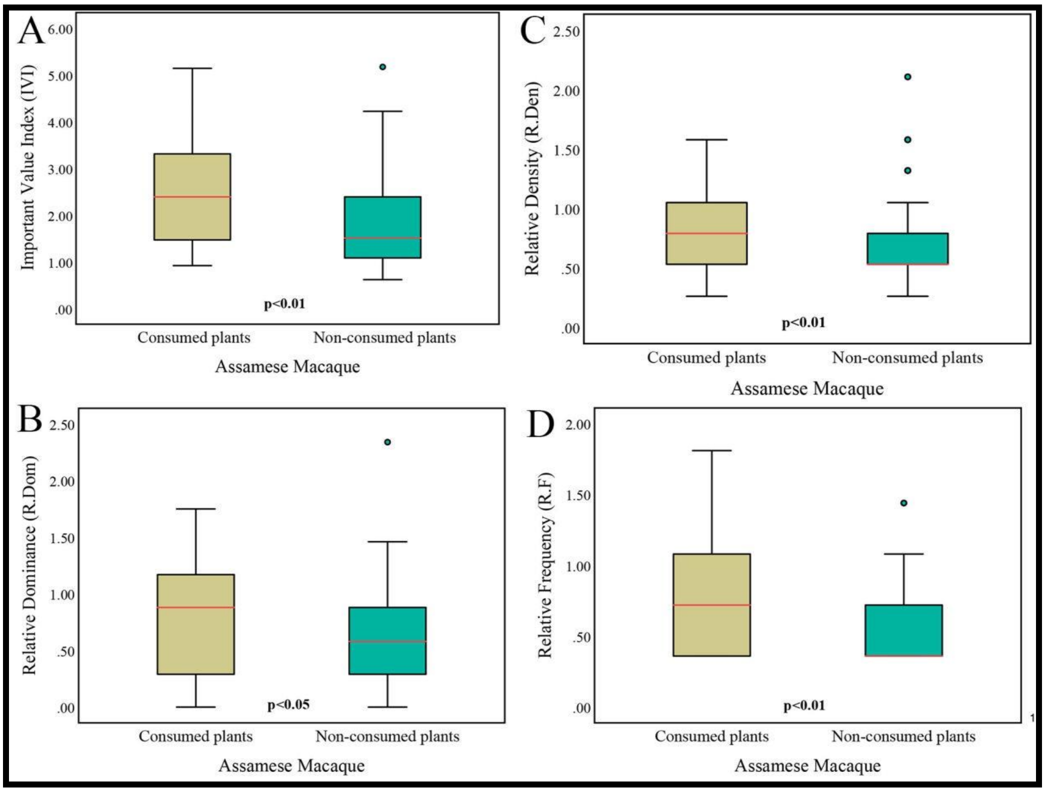

Figure 4.1 (A–D): Box plot showing the median, range, interquartile range and outliers of the consumed plants and non–consumed plants by AM of the parameters (A) IVI (B) RDom (C) RDen and (D) RF. The p values from the Mann–Whitney U test are given in each plot.

In CL, the current assessment on the ecological parameters between the consumed plants (*n*=66) and non–consumed plants (*n*=82) revealed higher mean values across all the habitat parameters in the consumed plants, and the differences are also statistically significant in RDen and RF at the alpha level of 0.05 (Table 4.3). The comparison on the various parameters between consumed and non-consumed plants for CL are represented graphically using box plot where the median is shown in red horizontal line; 50% of the numerical data is depicted by the box; 25th percentile of the data are found between the minimum and the first quartile, 75th percentiles between the third quartile and maximum, and the outliers are presented in dots. The consumed plants are denoted in light-brown color and the non-consumed plant in bluish-green color box. The box plot clearly partitioned the data in IVI, RDen, RDom in four percentiles except in RF where the data is partitioned into two parts in 50% each which signified the uniformity of the data. Moreover, the median line is also seen overlapped and bound at the upper limit of first quartile in RDen and lower limit of first quartile in RF which signified that the data is having skewed distribution thereby we utilized a non-parametric Mann-Whitney U test for the statistical analysis Fig. 4.4 (A-D).

Table 4.3: Descriptive statistics along with comparison of the consumed plants and non–consumed plants by CL based on the IVI, RDen, RDom and RF using Mann–Whitney U test. Significance at the alpha level of 0.05 is given in bold.

Parameters	**Consumed plants**			**Non–consumed plants**				**Difference**		
	Mean	SD	Min	Max	Mean	SD	Min	Max	U	**p value**
IVI	2.26	1.18	0.92	5.14	1.84	0.88	0.62	5.17	2209.5	**<0.05**
RDen	0.74	0.39	0.26	1.58	0.62	0.34	0.26	2.11	2208.0	**<0.05**
RDom	0.75	0.47	0.00	1.75	0.61	0.39	0.00	2.34	2302.5	**>0.05**
RF	**0.76**	**0.40**	**0.36**	**1.81**	**0.60**	**0.28**	**0.36**	**1.44**	**2135.5**	**<0.05**

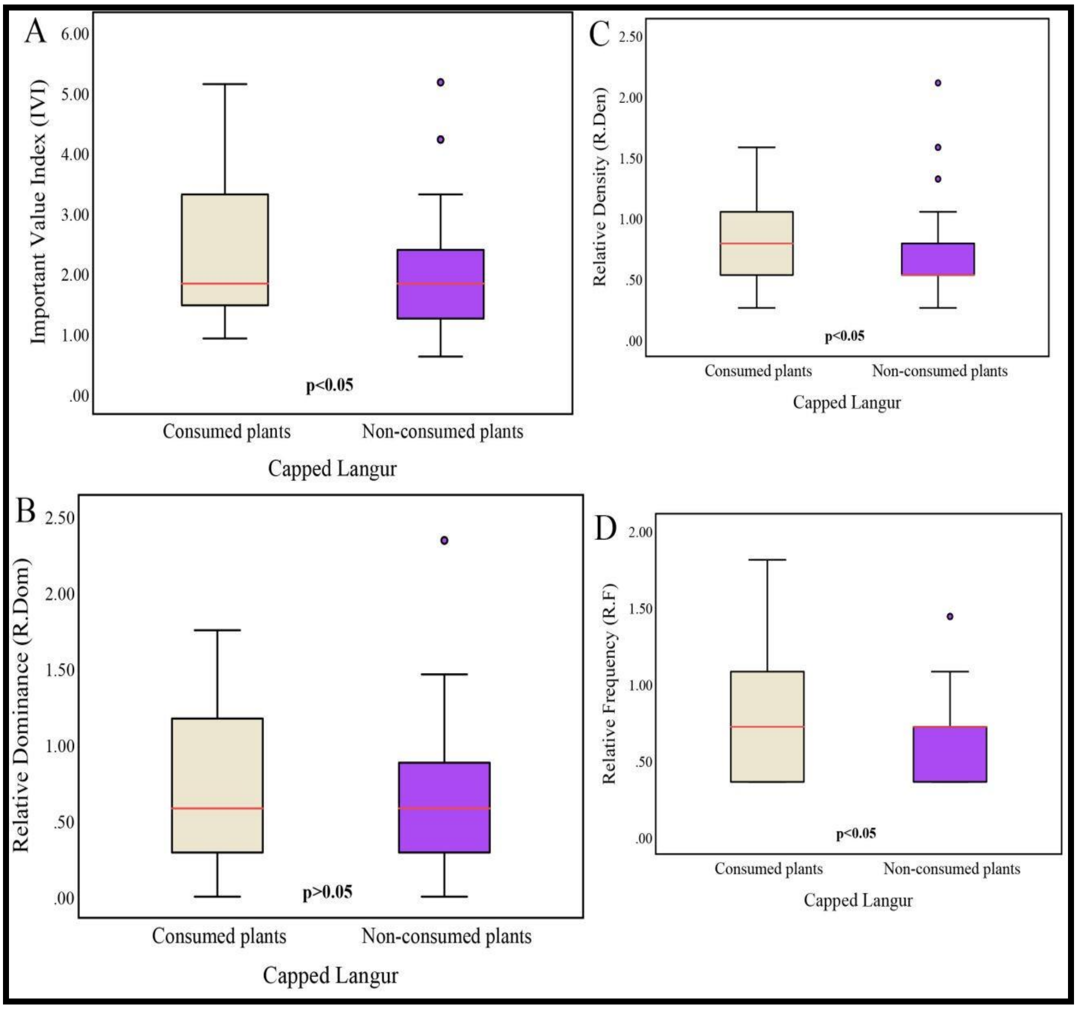

Figure 4.4 (A-D): Box plot showing the median, range, interquartile range and outliers of the consumed plants non–consumed plants by CL of the parameters IVI (A) RDom (B) RDen (C) and RF (D) The p values from the Mann–Whitney U test are given in each plot.

4.4: Relationship of habitat parameters and the top ten consumed plants by each primate with proximate nutrients

Out of preference food plants, 57 plant species in AM and 66 species in CL, top ten preferred food plants selected for both the primates are scrutinized for various ecological parameters such as RF, RDen, RDom and IVI to reflect the quality of the habitat. Combining the top 10 preferred food plant species which accumulating to 15 species (5 species *viz. Albizia chinensis*, *Albizia lebbeck*, *Albizia procera*, *Cephalotaxus graffithii* and *Diospyros glandulosa* are common between them). These 15 food plants species were utilized for evaluating the habitat quality in relation to nutrition value. The habitat ecological parameters, relative frequency (RF), relative density (RDen), relative dominance (RDom) and interest value index (IVI) of the 15 preferred food plants species consumed by both AM and CL provided at Table 4.4.

The maximum value of RF was for *Artocarpus lakoocha* (1.81%) and followed by the value of 1.44% in seven species such as; *Albizia chinensis*, *Albizia lebbeck*, *Albizia procera*, *Albizia richardiana*, *Castanopsis tribuloides*, *Ficus auriculata* and *Glochidion hyneanum*. The lowest RF value of 1.08% were observed in seven species like; *Aglaia edulis*, *Alstonia scholaris*, *Bischofia javanica*, *Bombax insigne*, *Cephalotaxus graffithii*, *Diospyros glandulosa* and *Protium serratum*.

The highest RDen value of 1.58% was observed in two species *viz. Artocarpus lakoocha* and *Albizia chinensis*. Followed by RDen value of 1.32% in five species like; *Aglaia edulis*, *Albizia procera*, *Castanopsis tribuloides*, *Cephalotaxus graffithii* and *Ficus auriculata*. Next followed by the RDen value of 1.05% in seven species such as; *Albizia lebbeck*, *Alstonia scholaris*, *Bischofia javanica*, *Bombax insigne*, *Diospyros glandulosa*, *Glochidion hyneanum* and *Protium serratum*. The lowest RDen value (0.79%) was observed in one species *Albizia richardiana*.

The maximum RDom value of 1.75% recorded was in two species like; *Artocarpus lakoocha* and *Albizia chinensis*, while the value of 1.46% were noted in five species *viz. Ficus auriculata*, *Albizia procera*, *Castanopsis tribuloides*, *Cephalotaxus graffithii* and *Aglaia edulis*. Then followed by the value of 1.17% in seven species like; *Albizia lebbeck*, *Alstonia scholaris*, *Bischofia javanica*, *Bombax* *insigne*, *Diospyros glandulosa*, *Glochidion hyneanum* and *Protium serratum* and then followed by the minimum RDom value of 0.88% in one species *Albizia richardiana*.

The highest IVI value of 5.14% is recorded in one species *Artocarpus lakoocha* and closely followed by the *Albizia chinensis* (4.78%). Other three species with value of 4.22% are; *Albizia procera*, *Castanopsis tribuloides* and *Ficus auriculata*. Another, two species with value of 3.86% for *Aglaia edulis* and *Cephalotaxus graffithii* and two more species having value of 3.67% in *Albizia lebbeck* and *Glochidion hyneanum*. It is followed by the value of 3.31% in five species which are; *Alstonia scholaris, Bischofia javanica, Bombax insigne, Diospyros glandulosa* and *Protium serratum*. The lowest IVI value of 2.75% was observed in *Albizia richardiana*.

The fifteen food plants proximate nutrient values with respect to habitat ecological parameters observed both in AM and CL were highest for *Artocarpus lakoocha* (65.08) and lowest for *Albizia richardiana* (15.78) and followed by; *Albizia chinensis* (62.22), *Albizia procera* (53.85), *Albizia lebbeck* (53.52), *Diospyros glandulosa* (43.27), *Alstonia scholaris* (43.14), *Bombax insigne* (41.17), *Cephalotaxus graffithii* (40.75), *Glochidion hyneanum* (37.98), *Bischofia javanica* (34.81), *Ficus auriculata* (34.35), *Castanopsis tribuloides* (29.68), *Protium serratum* (28.73) and *Aglaia edulis* (24.92).

Table 4.4: 15 food plants species consumed both in AM and CL with respect to habitat ecological parameters (RF, RDen, RDom and IVI) with proximate nutrient values.

Sl. No:	Food plants	Habit	RF	RDen	RDom	IVI	Proximate nutrient
1.	*Aglaia edulis*	T	1.08	1.32	1.46	3.86	24.92
2.	*Albizia chinensis*	T	1.44	1.58	1.75	4.78	62.22
3.	*Albizia lebbeck*	T	1.44	1.05	1.17	3.67	53.52
4.	*Albizia procera*	T	1.44	1.32	1.46	4.22	53.85
5.	***Albizia richardiana***	T	1.44	0.79	0.88	**2.75**	**15.78**
6.	*Alstonia scholaris*	T	1.08	1.05	1.17	3.31	43.14
7.	***Artocarpus lakoocha***	T	1.81	1.58	1.75	**5.14**	**65.08**

8.	*Bischofia javanica*	T	1.08	1.05	1.17	3.31	34.81
9.	*Bombax insigne*	T	1.08	1.05	1.17	3.31	41.17
10.	*Castanopsis tribuloides*	T	1.44	1.32	1.46	4.22	29.68
11.	*Cephalotaxus graffithii*	T	1.08	1.32	1.46	3.86	40.75
12.	*Diospyros glandulosa*	T	1.08	1.05	1.17	3.31	43.27
13.	*Ficus auriculata*	T	1.44	1.32	1.46	4.22	34.35
14.	*Glochidion hyneanum*	T	1.44	1.05	1.17	3.67	37.98
15.	*Protium serratum*	T	1.08	1.05	1.17	3.31	28.73

The proximate nutrient values of the combined top preferred food plant species for AM and CL (*n*=15) showed statistically significant positive correlations with respect to IVI ($p<0.05$, $r=0.692$), RDom ($p<0.05$, $r=0.610$), RDen ($p<0.05$, $r=0.603$), and RF ($p<0.05$, $r=0.627$) at the alpha level of 0.05 Tables 4.2–4.3; Figs. 4.1 (A–D) and 4.4 (A-D), respectively.

Table 4.5: Table showing the correlation between proximate nutrient values and Important Value Index (IVI) of the combined top 15 preferred foods of AM and CL. Significance at the alpha level of 0.05 is shown in bold.

Correlations		**Proximate nutrient values**	**IVI**
Proximate nutrient values	Pearson Correlation	1	**0.692****
	Sig. (2-tailed)		**<0.05**
	N	15	**15**
IVI	Pearson Correlation	0.692**	**1**
	Sig. (2-tailed)	<0.05	
	N	**15**	**15**

Table 4.6: Table showing the correlation between proximate nutrient values and relative dominance of the combined top 15 preferred foods of AM and CL. Significance at the alpha level of 0.05 is shown in bold.

Correlations		**Proximate nutrient values**	**RDom**
Proximate nutrient values	Pearson Correlation	1	**0.610***
	Sig. (2-tailed)		**<0.05**
	N	15	**15**
RDom	Pearson Correlation	0.610*	**1**
	Sig. (2-tailed)	**<0.05**	
	N	**15**	**15**

Table 4.7: Table showing the correlation between proximate nutrient values and relative density of the combined top 15 preferred foods of AM and CL. Significance at the alpha level of 0.05 is shown in bold.

Correlations		**Proximate nutrient values**	**RDen**
Proximate nutrient values	Pearson Correlation	1	**0.603***
	Sig. (2-tailed)		**<0.05**
	N	15	**15**
RDen	Pearson Correlation	0.603*	**1**
	Sig. (2-tailed)	<0.05	
	N	**15**	**15**

Table 4.8: Showing the correlation between proximate nutrient values and relative frequency of the combined top 15 preferred foods of AM and CL. Significance at the alpha level of 0.05 is shown in bold.

Correlations		Proximate nutrient values	RF
Proximate nutrient values	Pearson Correlation	1	**0.627***
	Sig. (2-tailed)		**<0.05**
	N	15	**15**
RF	Pearson Correlation	0.627*	**1**
	Sig. (2-tailed)	**<0.05**	
	N	**15**	**15**

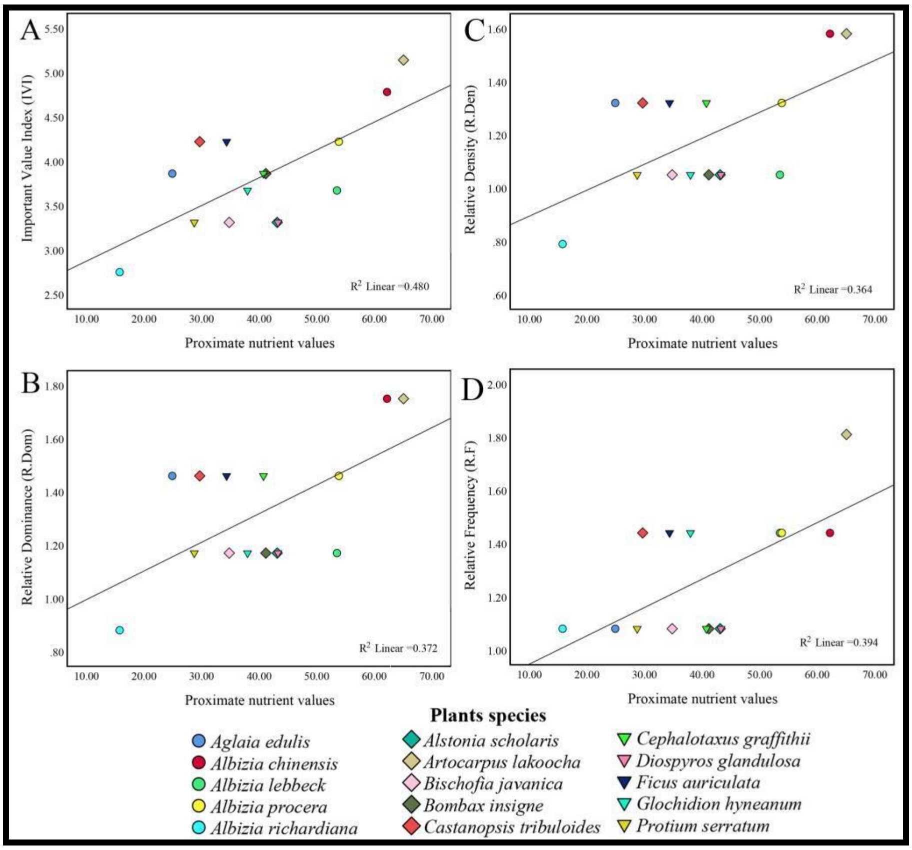

Figure 4.5 (A–D): Scatter plot for 15 nutrients of AM and CL showing (A) IVI and proximate nutrient values (R^2 Linear=0.480), (B) RDom and proximate nutrient values (R^2 Linear=0.372), (C) RDen and proximate nutrient values (R^2 Linear=0.364) and (D) RF and proximate nutrient values (R^2 Linear=0.394).

Therefore, the present assessment on the ecological parameters between the consumed plants and non–consumed plants of both AM and CL revealed higher mean values across all the habitat parameters in the consumed plants, and the differences are also statistically significant in all the ecological parameters at the alpha level of 0.05, and the proximate nutrient values of the combined top preferred food plant species for AM and CL (*n*=15) showed statistically significant positive correlations with respect to all the habitat ecological parameters at the alpha level of 0.05. The results clearly showed that the habitats in the selected study sites at DTR were flourished with high quality of food plants diversity in relation to the nutrition value which is sufficient and important for the studied primates.

V. DISCUSSION

From the present study area, although **Raman et al. (1995)** and **Parida (2019)** have provided distribution of AM and CL in DTR, however no previous works has been done on the evaluation of the habitats with regard to the nutritional status of their preferred foods. In this study, whether food plant diversity in the habitat was quantified and determined adequate nutrients for both the species. The present study indicates the total 57 food plant species of AM comprised of 135.27 for IVI, 46.09% for RF, 44.23% for RDen and 44.95% for RDom.

The assessment on the ecological parameters between the consumed plants (*n*=57) and non–consumed plants (*n*=91) revealed higher mean values across all the habitat parameters, such as IVI (Mean=2.38±1.2 for consumed plants and 1.81±0.87 for non–consumed plants; U=1875.0; p<0.05), RDen (Mean=0.78±0.39 for consumed plants and 0.61±0.34 for non–consumed plants; U=1945.0; p<0.05), RDom (Mean=0.79±0.48 for consumed plants and 0.38±0.00 for non–consumed plants; U=2017.0; p<0.05) and RF (Mean=0.81±0.4 for consumed plants and 0.59±0.28 for non–consumed plants; U=1800.5; p<0.05). Similarly in CL, the total 66 food plant species comprised of 146.86 for IVI, 49.69% for RF, 48.44% for RDen 48.73% RDom.

Ecological parameters between the consumed plants (*n*=66) and non–consumed plants (*n*=82) revealed the mean values across all the habitat parameters; IVI (Mean=2.26±1.18 for consumed plants and 1.84±0.88 for non–consumed plants; U=2209.5; $p<0.05$), RDen (Mean=0.74±0.39 for consumed plants and 0.34±0.26 for non–consumed plants; U=2208.0; $p<0.05$), RDom (Mean=0.75±0.47 for consumed plants and 0.61±0.39 for non–consumed plants; U=2302.5; $p>0.05$) and RF (Mean=0.76±0.40 for consumed plants and 0.60±0.28 for non–consumed plants; U=2135.5; $p<0.05$). The proximate nutrient values and IVI of the combined top preferred food plant species for AM and CL (*n*=15) showed statistically significant positive correlations between proximate nutrient values and IVI (**$p<0.05$**, r=0.692) as shown in Table 4.4, IVI and RDom (**$p<0.05$**, r=0.610) as shown in Table 4.6, IVI and RDen (**$p<0.05$**, r=0.603) as shown in Table. 4.7, and IVI and RF (**$p<0.05$**, r=0.627) as shown in Table 4.8 at the alpha level of 0.05. The scatter plots for 15 nutrients in AM and CL are shown at Fig. 4.5 (A–D); (A) between IVI and proximate nutrient values (R^2 Linear=0.480), (B) RDom and proximate nutrient values (R^2 Linear=0.372), (C) RDen and proximate nutrient values (R^2 Linear=0.364) and (D) RF and proximate nutrient values (R^2 Linear=0.394), respectively.

From the above assessments, it is determined that tropical evergreen DTR forest harbors high food plant species diversity that contained adequate nutrients for both the primates throughout the year. The results agreed with other reports **(Worman and Chapman, 2006; Hamard et al. 2010)** where vegetation correlates with primate abundance to basal area of tree, density, species diversity and shrub covers. **Zhang and Zang (2018)** stated that the availability of food resources is a main indicator for habitat quality. Changes in food availability are a driving force of changes in primate populations **(Rode et al. 2006; Worman and Chapman, 2006; Mammides et al. 2009)**. Spending more time resting in high quality habitats may be the result of having plenty of food and requiring less time spent foraging and feeding.

In support of this, baboons **(Iwamoto and Dunbar, 1983; Altmann and Muruthi, 1988; Eley et al. 1989)**, gorillas **(Watts, 1988)**, and bonnet macaques **(Singh and Vivanthe, 1990)** all spent less time foraging and feeding in high quality areas. The density of frugivorous primates is related to the presence of preferred food trees **(Worman and Chapman, 2006)** and influenced by food availability measured as the richness **(Mammides et al. 2009)** or the density **(Mbora and Meikle, 2004)** of food trees. The preference of food trees was not only influenced by the number and density of trees **(Solanki et al. 2008b; Hasan, 2017)** but also the different floristic compositions of their habitats **(Mohnot, 1971; Hladik, 1977; Gupta and Kumar, 1994; Solanki et al. 2008a).** The geographical area and climatic conditions in a habitat affects the vegetation structure and composition, which in turn affect the diet selection in colobines **(Kirkpatrick 2007; Matsuda et al. 2009; Kirkpatrick and Grueter, 2010; Tsuji et al. 2013; Akbar et al. 2019)**. It is reported that the phenological stages of a plant influence the food choice of primates **(Freeland and Janzen, 1974; Milton, 1980; Solanki et al. 2008b)** and they may alter their feeding strategy in relation to the availability of specific resources **(Chapman, 1988)**. It is reported that larger habitat supports a greater variety of plants and phenological stage **(Borah et al. 2021)**. Most colobines often occupy a small home range (<100 ha) and use short daily path lengths (<1000 m) **(**see **Kirkpatrick et al. 1998)**. Previous studies have shown that the size of the home range is mainly affected by the abundance of food resources **(Li et al. 2014)**. An increased or decreased home range indicates a primate’s positive behavior or coping mechanism in periods of food scarcity **(Zhou et al. 2011b; Shaffer, 2013; Campera et al. 2014; Li et al. 2014).** Primates living in lower food abundance habitat tend to devote more time to feeding **(Hanya, 2004; Li and Rogers, 2004)**. **Richard (1985)** stated that covering a smaller home range could reduce energy expended in the search for food.

Other studies of arboreal frugivorous primate species showed that food abundance and distribution also influenced ranging patterns as well as frequency of habitat use **(Olupot et al. 1997; Moscovice et al. 2010)**. Similar to the present study sites, the mid–hills area with amenable temperature and ample precipitation provide the suitable habitat for AM **(Khanal et al. 2018)**, but that remains outside the protected area system of the country. Because of this, at many places of the mid-hill districts the species has been described as the notorious crop raiders bringing them into negative interactions with subsistence farmers **(Chalise, 1999, 2003, 2010, 2013).** Extending protected areas benefits to resource–dependent smaller landholders who experience higher losses from human–wildlife conflicts **(Karanth and Nepal, 2012)**. Establishment of protected areas in mid hills would conserve the AM habitat together with other plant and animal species. In Pakke Wildlife Sanctuary of Arunachal Pradesh in India, they occupied all habitat types inside and outside the sanctuary, but the tropical evergreen and semi-evergreen, deciduous forests with trees such as *Ficus benghalensis, Ficus racemosa, Bombax ceiba., Altingia excelsa, Gmelina arborea* and *Morus macroura* have been found to be important in influencing the distribution of CL in the region **(Kumar, 2006)**, and the availability of food trees may be a limiting factor **(Joseph and Ramachandran, 2003)**. Attenuation of habitat and reduction of food plants and shelter trees have led to the incursion of primates into human habitation resulting in primate-human conflict. Overall, understanding the distribution patterns of food resources and maintaining viable food trees for primates are crucial factors in primate conservation **(Mwavu and Witkowski, 2009)**. **Naher and Khan (2018)** suggested that reconciliation between the two is possible if local communities and government agencies evolve a partnership to conserve the habitats, with critical support from NGOs and independent researchers.

VI. CONCLUSION

Habitat loss is arguably the gravest threat facing primates inhabiting tropical forests today **(Chapman et al. 2006b; IUCN, 2012)**. The primate taxa with the greatest flexibility to cope with this threat will be the ones most likely to persist through the 21st century and beyond **(Onderdonk and Chapman, 2000; Marsh and Chapman, 2003; Chapman et al. 2006b)**. One of the most common outcomes of human–induced habitat loss in tropical forest ecosystems is forest fragmentation **(Laurance et al. 1998; Harrison and Bruna, 1999; Ritters et al. 2000)**. Many forest–dwelling animals, including some primates, are adversely affected by the fragmentation of their habitat **(Andren, 1994; Turner, 1996; Marsh and Chapman, 2003; Isabirye–Basuta and Lwanga, 2008)**. Forest fragmentation results in population declines in some primates and complete extirpation in others **(Estrada and Coates–Estrada, 1996; Chapman et al. 2007; Boyle, 2008)**. Despite being a relatively small order, primates occupy a wide range of habitats and exhibit a huge diversity of grouping patterns and behavior **(Robbins and Hohmann, 2006)**. To effectively conserve the remaining primate populations, extensive knowledge of habitat requirements and resource distribution in fragmented tropical forest landscapes is needed.

The abundance of fruiting plants and other variety of food plants appears to meet dietary needs for AM and CL troops as no incident of human–primate conflict and population decline were reported from the study site and co–habitation has been is observed between other primate species. Food abundance and forest type likely have a stronger influence on primate habitat selection than any other factors **(Furuichi and Hashimoto, 2004).** However, with the expansion of settlement areas along the buffer area of DTR, various encroachments, increased reliance on forest resources, the construction of transportation networks, and the clearing of forests for jhuming cultivation, forest fragmentation and human–primate conflict leading to population decline might be unavoidable in the near future.

Preferences of food plants are likely to vary across study sites, however, as the relative quality of different habitats available to primates depends on specific forest composition and spatiotemporal availability of food. Thus, understanding which forest types related to different successional stages providing different food resources is vital for the long-term survival of primates **(Zhang and Zang, 2018)**. Tropical forest succession may be related to the structural and floristic changes, such as changes in plant species richness, stem density and plant species composition **(Gibson et al. 2014)**, which should lead to changes in food resource availability for primates **(Pinotti et al. 2015; Bryson–Morrison et al. 2016)**. Accordingly, future priority actions in DTR have to be aimed at (1) extending continuous research to predict the potential distributions of important food tree species and analyzing the effect of food availability on primates; (2) further surveying and protecting, high–quality food plants, large food trees and habitat-exclusive food species in each habitat; (3) promoting recovery and reforestation of natural forest fragments and plantations where most of the important food plant species are associated, and (4) implementing special measures (such as directional felling for construction) to avoid damaging food trees and reducing the degree of forest canopy damage so as to preserve important food resources and nesting sites for primates.

SUMMARY

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. Therefore, the underlying factor is to record primate food intake (*i.e.*, the amount of food consumed by an individual) in the wild which is a crucial measure for studying feeding behavior. In the present study site, DTR some works from previous has been conducted for DTR primates species like; Hoolock gibbon and Phayre’s leaf monkey was done on the aspects of distribution, abundance and habitat ecology. Nonetheless, no work for AM and CL nutritional ecology was conducted, therefore it was aptly carried out. Data generated on the feeding behavior were collected through direct and indirect observations in the field. The feeding data generated was pooled in collectively of two years data from September, 2018–August, 2020. The present study was covered broadly divided into four chapters and the major findings highlighted summarized under;

Chapter 1: To study the food plants preference and the composition of the diet.

Chapter 2: To analyze chemical compositions in food plants and fecal matter.

Chapter 3: To study the energy dynamics and digestibility.

Chapter 4: To evaluate the habitat for nutritional status of food.

In the study, 203 days of the survey resulted in 2233 scans and 16381 behavioural records AM troop were observed to forage on 57 plant species under 46 genera belongs to 30 families. Food plants belonging to 13 species contributed for >1% feeding times. Among the feeding plant species, trees accounted for 91%, herbs 7% and climbers/vines 2%. The top ten major feeding plants of AM identified and observed time spent range from 1.44% to 15.65% including *Bombax insigne*, *Albizia chinensis*, *Protium serratum*, *Ficus auriculata*, *Cephalotaxus graffithii*, *Albizia lebbeck*, *Diospyros glandulosa*, *Glochidion hyneanum* *Albizia procera* and *Artocarpus lakoocha*. The monthly observation number of food plant species consumed range from 20 to 43 (32.42 ±6.56).

The diversity of the family contributed the feeding plants of AM diet family consists as follows, Moraceae with 9 species, Meliaceae with 5 species, Mimosaceae and Euphorbiaceae both 4 species, Combretaceae with 3 species, Bombacaceae, Poaceae, Caesalpiniaceae, Magnoliaceae, Fabaceae, Verbenaceae and Anacardiaceae were 2 species each and Ebenaceae, Cephalotaxaceae, Burseraceae, Rosaceae, Clusaceae, Musaceae, Gnetaceae, Myrtaceae, Dilleniaceae, Malvaceae, Lauraceae, Flacourtiaceae, Heliconiaceae, Sonnertiaceae, Theaceae, Sapotaceae, Fagaceaea and Phyllantaceae with 1 species each.

Significant variation was not observed for time spent on feeding leaves in different months of the seasons (H=3.429, df=2, p>0.05) and in different year (H=19.46, df=11, p>0.05). Fruits were most abundant during monsoon/summer (June to August) constituting the major food item. Maximum feeding on fruits was in the month of August (44.62% of the total food items) and the lowest consumption recorded in February (3.48% of the total food items). The time spent feeding of fruits did not show significant variation in different months (H=15.87, df=11, p>0.05) and seasons (H=4.571, df=2, p>0.05).

The highest consumption of flowers was observed in the month of February (28.05%), but, no significant variation was observed monthly and seasonally for time spent on feeding of flowers. The highest seed consumption was recorded in January (12.4%) and it was observed mainly during winters when there was scarcity of fleshy fruits. Bamboo shoots of species such as; *Melocana baccifera* and *Dendrocalamus longispathus* were fed only in monsoon (June to October). The total time spent on feeding of shoots during the observation period was 2.14% only. 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%). The average diurnal feeding time spent for AM is 44% and observed during July to January (35.19% to 59.03%).

In this study, 196 days of the survey resulted in 2156 feeding scans and 16060 behavioral records for CL were observed to forage on 66 different plant species under 54 genera from 33 families. Among the feeding plant trees species in CL accounted for shrubs and climbers 3.03%, herbs 7.58% and trees 86.36%, respectively. The top ten major feeding plants identified and the time spent feeding range from 2.82% to 7.28% for CL were *Albizia procera*, *Diospyros glandulosa*, *Cephalotaxus graffithii*, *Aglaia edulis*, *Castanopsis tribuloides*, *Bischofia javanica*, *Albizia lebbeck*, *Albizia richardiana*, *Alstonia scholaris* and *Albizia chinensis*. The observed number of food plant species consumed in each month range from 34 to 57 (42.42 ±6.35).

The diversity of plants were mainly observed and contributed greatest of feeding plants of CL diet from the family, Moraceae consisting of 8 species, 6 species from Malvaceae, 5 species for both Euphorbiaceae and Mimosaceae, 4 species for Combretaceae, 3 species for Anarcadiaceae, and 2 species each for Apocynaceae, Bombacaceae, Caesalpiniaceae, Clusiaceae, Fabaceae, Lauraceae, Poaceae, Sapotaceae, Verbenaceae and 1 species each under Burseraceae, Cephalotaxaceae, Dilliniaceae, Dioscoreaceae, Ebenaceae, Flacourtiaceae, Gnetaceae, Heliconiaceae, Magnoliaceae, Musaceae, Myrtaceae, Phyllanthaceae, Rosaceae, Sapindaceae, Sapotaceae, Sonnertaceae, Theaceae and Ulmaceae.

In the present observation for CL, no significant variations were observed on time spent on feeding leaves in different seasons (H=4.86, df=2, p=0.08) and in different months of the year (H=18.66, df=11, p=0.06). Fruits were abundant during monsoon/summer constituting the major food item during June to August (22.90% to 33.42%). CL were observed to feed maximum fruits in July (33.42% of the total food items), and the lowest consumption recorded in the month of March (22% of the total food items). Time spent on feeding of fruits did not show significant variation in different months (H=18.22, df=11, p=0.07) and seasons (H=3.18, df=2, p=0.20).

The highest consumption of flowers was observed in May (27.78%), there was no significant variation in the time spent on feeding of flowers observed monthly (H=19.27, df=11, p=0.05), but a significant variation was observed seasonally (H=7.28, df=2, p=<0.05). Seeds were consumed mainly in winters (H=16.09, df=2, p<0.01), when there was a scarcity of fleshy fruits, and the highest seed consumption recorded in January (33.71%) with a monthly significance (H=21.37, df=11, p<0.05) of seeds consumption and seasonally variation (H=16.09, df=2, p<0.01). Shoots of bamboo species were fed only in monsoon (June to September) with highest consumption of shoots during July (8.68%), while the lowest consumption observed in September (5.34%) with a seasonally significant variation (H=9.20, df=2, p<0.05) and the monthly significant variation (H=22.120, df=11, p<0.05). The total time spent on feeding of shoots during the whole observation periods was 2.39% only. Leaves formed the highest bulk of CL diet (46.24%), due to availability throughout the year and it is followed by fruits (21.66%), flowers (18.19%), seeds (11.52%) and shoots (2.39%). The diurnal time invested of feeding (>38.70% on average) and observed highest in July to January (35.29% to 40.77%).

Seasonal variation in the diet of AM and CL was clearly linked to seasonal fluctuations in food availability and influenced by a number of environmental factors which is a common observation across home ranges. Their diet was primarily folivorous which was consistent with the results in this study. This agrees and similar to other observations and findings of earlier works.

In the present work, the proximate content value of DM % for AM lowest to highest was observed for *Artocarpus lakoocha* and *Albizia procera* (13.67 ±1.18 to 40.99 ±0.61), while the proximate content of moisture (%) was observed for *Albizia procera* and *Artocarpus lakoocha* (59.01 ±0.61 to 86.33 ±1.18). For CL, the proximate content of DM (%) lowest to highest was observed for *Castanopsis tribuloides* and *Albizia lebbeck* (14.73 ±2.96 to 38.39 ±0.99), while the lowest to highest proximate content of moisture (%) was observed for *Albizia lebbeck* and *Aglaia edulis* (61.61 ±0.99 to 86.37 ±0.74), respectively.

The range of proximate content of nutrients value (%) from lowest to highest for both AM and CL in carbohydrate content was observed for *Diospyros glandulosa* and for *Albizia chinensis* (6.42 ±0.57 to 13.71 ±1.55). Protein content was observed for *Protium serratum* and *Bombax insigne* (2.15 ±1.48 to 8.98 ±1.23). The ash content was observed for *Bombax insigne* and *Cephalotaxus graffithii* (2.55 ±0.28 to 11.70 ±1.24). Fat content was observed for *Albizia lebbeck* and *Glochidion hyneanum* (0.58 ±0.47 to 5.70 ±0.46). The fiber content was recorded for *Protium serratum* and *Artocarpus lakoocha* (3.06 ±0.87 to 38.06 ±0.87). Similarly, for CL the range of proximate content of nutrients value (in %) from lowest to highest of carbohydrate was found for Protein content was observed for *Albizia richardiana* and *Albizia chinensis* (2.15 ±1.48 to 8.72 ±2.53). The content of ash was observed for *Bischofia javanica* and *Cephalotaxus graffithii* (4.80 ±0.40 to 11.70 ±1.24). Fat content observed for *Albizia lebbeck* and *Alstonia scholaris* (0.58 ±0.47 to 3.39 ±1.06). Fiber content recorded for *Albizia richardiana* and *Albizia chinensis* (0.78 ±0.48 to 27.47 ±0.83).

Amongst the nutritional factors influencing food choice, protein and fiber have been considered vital determinants. AM devoted maximum time for feeding (15.65%) on *Artocarpus lakoocha* that contains protein (6.75%) with fiber content 38.06% and Protein: fiber is 0.18. The protein: fiber is highest (0.70) for *Protium serratum* and minimal (0.14) for *Ficus auriculata* with feeding time spent 3.04% and 4.20%, respectively. The protein: fiber was observed highest for *Aglaia edulis* (3.84) and lowest for *Diospyros glandulosa* (0.22) with feeding time spent more or less the same, 3.86% and 3.64%, respectively. CL spent highest time for feeding (7.28%) for *Albizia chinensis* that contains protein (8.72%) with fiber content 27.47% and protein: fiber is 0.32. This agreed to observations made by others. The statistical correlation among the different nutrient values showed that none of the tested parameters showed zero correlation between them (r>0.0), and the correlation coefficient signified that there is moderate positive correlation between protein and fiber (r=0.439), as also observed between higher protein and higher crude fiber contents reported in Western hoolock gibbon food plants (r=0.48) from Assam, India. In addition to studies concerning the protein–fiber ratio for folivore, three key concepts needs consideration when evaluating how food resources act as selection pressures to influence species conservation potential which is ideal free distribution, ecological sinks and fallback foods.

The assessment of the combined preferred food plant species of AM and CL (n=15) revealed no statistically significant correlations across all the different nutrient values (p>0.05). But, none of the tested parameters showed zero correlation between them (r>0.0), and the correlation coefficient signified a moderate positive correlation between protein and fiber (r=0.439); weak positive correlations between carbohydrate and protein (r = 0.359), between fiber and fat (r=0.204), between fiber and ash (r=0.211); very weak positive correlation between protein and fat (r=0.174), between carbohydrate and ash (r=0.145) and also, weak negative correlations was observed between fat and ash (r=-0.303), between carbohydrate and fiber (r=-0.261); and very weak negative correlations between protein and ash (r=-0.035), between carbohydrate and fat (r=-0.010).

In this work, the fruit epicarp of *Protium serratum* was recovered from fecal matter for AM, however absent in CL. The remnants of fruit fibers in *Artocarpus lakoocha* and leave fibers of *Glochidion hyneanum* are present in both fecal matters of AM and CL. In addition to it for CL, leave fibers of *Diospyros glandulosa*, *Alstonia scholaris* and *Bishchofia javanica* were extracted from fecal matters which were the most exploited food species. Moreover, seeds part of *Albizia procera* and *Ficus auriculata* in the formed of fine granules were observed for AM fecal sample. Fecal specimen analysis such as tiny items of undigested matter recovered from the study sites contained number of food plants identified for fruit epicarp was 1 species, 2 species for seeds and 5 species for fibers. Some fecal remnants present in the fecal matter could not be identified. The analysis of fecal samples provided a useful complementary approach to the understanding of the composition of primate diet. Furthermore, the data presented suggests that the main application of the fecal analysis is to access the composition of the diet of study subjects complementarily to the data collected through behavioral monitoring, especially for undigested food items.

The digestibility expressed in % values minimum to maximum range 56.28 ±3.47 to 94.78 ±3.68 for AM of top ten plant species for *Artocarpus lakoocha*, *Albizia procera*, *Albizia chinensis*, *Albizia lebbeck*, *Diospyros glandulosa*, *Bombax insigne*, *Glochidion hyneanum*, *Cephalotaxus graffithii*, *Ficus auriculata* and *Protium serratum*.

For CL, digestibility (%) range from 67.93 ±4.10 to 97.29 ±4.21 for *Albizia chinensis*, *Albizia lebbeck*, *Diospyros glandulosa*, *Alstonia scholaris*, *Albizia procera*, *Cephalotaxus graffithii*, *Bischofia javanica*, *Castanopsis tribuloides*, *Aglaia edulis* and *Albizia richardiana*. It can be reported that, the digestibility of food plants are also within the range of digestibility reported by other worker. The present work study suggests that due to medium to highest (56.28% to 97.29%) digestibility the of top food plants, both study subject preferred these plants for food. Since digestibility is an important factor of forage quality, in which an animal's relative performance when fed forages for consumption and nutrient concentration, intake, digestibility and metabolic efficiency all contribute to animal performance.

The lowest to highest proximate energy content for AM range from 2.058 ± 0.210 to 3.485 ±0.124 kcal/g DM of top ten plants were *Albizia chinensis*, *Albizia procera*, *Albizia lebbeck*, *Artocarpus lakoocha*, *Diospyros glandulosa*, *Cephalotaxus graffithii*, *Glochidion hyneanum*, *Bombax insigne*, *Ficus auriculata* and *Protium serratum*. The proximate energy content for CL range from 2.05±0.21 to 3.58 ±0.11 kcal/g DM of top ten plants *Albizia chinensis*, *Albizia procera*, *Albizia lebbeck*, *Alstonia scholaris*, *Diospyros glandulosa*, *Cephalotaxus graffithii*, *Bischofia javanica*, *Castanopsis tribuloides*, *Aglaia edulis* and *Albizia richardiana*. These findings showed that the energy content of top ten plants consumed by AM and CL are moderately higher which might be one of the reason they inhabited in the DTR forest. The estimated energy requirement for AM and CL was reasonable ranging between 718.75 ±22.85 to 826.03 ±12.19 kcal/day. The amount of energy available to primates from ingested diets is determined by the composition of the food as well as the extent to which various ingredients, particularly fiber fractions, are digested. The availability of energy content in the food plants were mostly influenced by the seasonal changes. Other researchers have found that energy expenditure is similar across wild groups.

The expected energy expenditure (TEE kcal/day) from the top plant species was expressed in kcal/g. For AM was estimated value of 718.75 ±22.85 kcal/day and then energy required per day was found to be 266.21 ±12.31 g of top preferred food plants. However, for CL, it was estimated 826.03 ±12.19 kcal/day and the required amount of energy per day was 305.93 ±8.22 g. The TEE, in addition to BMR and physical activity, may influence metabolic variations amongst primates. However, BMR of physical activity does not explain the substantial fall in TEE in primates. Thus, to acquire sufficient quantity of the energy required per day will be obtained from top preferred food plants which are achievable from availability of food plants sources throughout the year.

To evaluate the nutritional status of the food plants for DTR habitat, different ecological parameters such as; the IVI, RDom, RDen and RF of tree plants were determined. 148 plant species was documented within the habitat, the habitat status was evaluated by testing whether there are significant differences between the overall plants consumed and non–consumed based on the various ecological parameters. The present study indicates the total 57 food plant species of AM comprised 135.27 for IVI, 46.09% for RF, 44.23% for RDen and 44.95% for RDom. Likewise, for CL the total 66 food plant species comprised 146.86 for IVI, 49.69% for RF, 48.44% RDen and 48.73% for RDom.

In AM, assessment on the ecological parameters between the consumed plants (n=57) and non–consumed plants (n=91) reveals higher mean values across all the habitat parameters in the consumed plants, and the differences are also statistically significant in all the ecological parameters at the alpha level of 0.05; such as IVI (Mean=2.38 ±1.2 for consumed plants and 1.81 ±0.87 for non–consumed plants; U=1875.0), RDen (Mean=0.78 ±0.39 for consumed plants and 0.61 ±0.34 for non–consumed plants; U=1945.0; $p<0.05$), RDom (Mean=0.79 ±0.48 for consumed plants and 0.38 ±0.00 for non–consumed plants; U=2017.0; $p<0.05$) and RF (Mean=0.81 ±0.4 for consumed plants and 0.59 ±0.28 for non–consumed plants; U=1800.5; $p<0.05$).

In CL, the current assessment on the ecological parameters between the consumed plants (n=66) and non–consumed plants (n=82) revealed higher mean values across all the habitat parameters in the consumed plants, and the differences are also statistically significant in RDen and RF at the alpha level of 0.05; IVI (Mean=2.26 ±1.18 for consumed plants and 1.84 ±0.88 for non–consumed plants; U=2209.5; $p<0.05$) RDen (Mean=0.74 ±0.39 for consumed plants and 0.34 ±0.26 for non–consumed plants; U=2208.0; $p<0.05$), RDom (Mean=0.75 ±0.47 for consumed plants and 0.61 ±0.39 for non–consumed plants; U=2302.5; $p>0.05$) and RF (Mean=0.76 ±0.40 for consumed plants and 0.60 ±0.28 for non–consumed plants; U=2135.5; $p<0.05$).

Among the fifteen food plants, the highest RF value was observed both in AM and CL was lowest for *Albizia richardiana* (15.78%) and highest for *Artocarpus lakoocha* (65.08%). The proximate nutrient values of the combined top preferred food plant species for AM and CL (n=15) showed statistically significant positive correlations with respect to all the habitat ecological parameters. The proximate nutrient values of the combined top preferred food plant species for AM and CL (n=15) showed statistically significant positive correlations with respect to IVI ($p<0.05$, $r=0.692$), RDom ($p<0.05$, $r=0.610$), RDen ($p<0.05$, $r=0.603$) and RF ($p<0.05$, $r=0.627$) at alpha level 0.05. The scatter plots for 15 nutrients in AM and CL between IVI and proximate nutrient values (R^2 Linear=0.480), RDom and proximate nutrient values (R^2 Linear=0.372), RDen and proximate nutrient values (R^2 Linear=0.364) and RF and proximate nutrient values (R^2 Linear=0.394), respectively.

The results clearly showed that the habitats in the selected study sites at DTR forest is flourished with high quality of food plants diversity in relation to the nutrition value which is sufficient and important for the studied primates. This agrees with other reports in which vegetation correlated with primate abundance to basal area of tree, density, species diversity and shrub covers, since such availability of food resources is the key indicator for habitat quality. Spending more time resting in high quality habitats may be the result of having plenty of food and requiring less time spent foraging and feeding.

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BRIEF BIO-DATA OF THE CANDIDATE

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Educational qualifications:

Sl. No.	Examinations	Board/Council/ University/Institute	Subjects offered	Percent (%)	Division	Year
1.	H.S.L.C	Board of Secondary Education, Manipur	General	58.34	2nd	2004
2.	H.S.S.L.C	Council of Higher Secondary Education, Manipur	Science	49.20	2nd	2006
3.	B.Sc	Manipur University	Zoology	59.11	2nd	2009
4.	M.Sc	Mizoram University	Zoology	62.00	1st	2014
5.	D.El.Ed	District Institute for Education and Training	Diploma in Elementary Education	68.90	1st	2017

ACADEMIC PROFICIENCY

AWARD/DISTINCTION

Best Oral Presentation for the Technical Session 2C (Animal Technology) *"Feeding habits and sleeping site selection by Phayre's Leaf Monkey (Tarchypithecus phayrei) and Capped Langur (Tarchypithecus pileatus) in Dampa Tiger Reserve, Mizoram"* at the National Conference: "Recent Advances in Biotechnology" organized by the Dept. of Biotechnology, Mizoram University (MZU) (A Central University) at Dean School of Life Sciences Conference Hall, MZU, Aizawl-796004 from 9th–10th November, 2017.

PAPERS PRESENTED AT NATIONAL AND INTERNATIONAL EVENTS

1. *"Feeding habits and sleeping site selection by Phayre's Leaf Monkey (Tarchypithecus phayrei) and Capped Langur (Tarchypithecus pileatus) in Dampa Tiger Reserve, Mizoram"* at the National Conference "Recent Advances in Biotechnology" organized by the Dept. of Biotechnology, MZU at Dean School of Life Sciences Conference Hall, MZU, Aizawl-796004 from 9th–10th November, 2017.
2. *"Shifting Cultivation and its Potential Impact around Dampa Tiger Reserve, Mizoram, India"* at the 12th Annual Convention of Biotechnology and Pharmacy (ABAP) & International Conference on Biodiversity, Environment and Human Health: Innovations and Emerging Trends (BEHEIT, 2018) organized in collaboration by School of Life Sciences, Mizoram University, Aizawl, Mizoram with Association of Biotechnology and Pharmacy (ABAP), India from 12th–14th November, 2018.
3. *"Food Plant Preferences and dietary compositions of Trachypithecus pileatus (Capped Langur) in Dampa Tiger Reserve, Mizoram, India"* at the International Conference on Recent Advances in Animal Sciences (ICRAAS) organized by the Dept. of Zoology, Pachhunga University College (PUC), Aizawl, India at the PUC, Mizoram from 6th–8th November, 2019.

4. *"Current Trends in Biological Sciences"* organized by School of Life Sciences, MZU venue at Dept. of Education Conference Hall from 18th–20th March, 2024.

5. *"Recent Trends in Biodiversity Status & Conservation"* organized by Dept. of Zoology, Assam Don Bosco University (ADBU) in collaboration with Dept. of Zoology, St. Edmund's College & Dept. of Zoology, Pragjyotish College, Guwahati at ADBU, Tapesia, Sonapur–782402, Assam, India from 27th-28th March, 2024.

CONFERENCE/WORKSHOP/SEMINAR PARTICIPATED

1. *"Statistical Methods in Biological Research"* organized by the Bioinformatics Infrastructure Facility (BIF), Dept. of Biotechnology, MZU by Dept. of Biotechnology (DBT), New Delhi from 3th–5th November, 2017.

2. *"Feeding habits and sleeping site selection by Phayre's Leaf Monkey (Tarchypithecus phayrei) and Capped Langur (Tarchypithecus pileatus) in Dampa Tiger Reserve, Mizoram"* at National Conference "Recent Advances in Biotechnology" organized by the Dept. of Biotechnology, MZU at Dean of School of Life Sciences Conference Hall, MZU, Aizawl-796004 from 9th–10th November, 2017.

3. *"Statistical and Computational Methods for Life Science Data Analysis"* organized by the Dept. of Zoology, MZU, Aizawl–796004, Mizoram from 5th–10th March, 2018.

3. *"Science and Technology for a Sustainable Future"* organized by the Mizo Academy of Sciences, Mizoram Science, Technology & Innovation Council (MISTIC) and PUC, catalyzed and supported by the National Council for Science & Technology Communication, Dept. of Science and Technology, New Delhi at Seminar Hall, PUC, Mizoram, India on 30th April, 2018.

4. *"Plant Growth-Promoting Rhizobacteria (PGPR) for Sustainability of Agriculture and Environment"* at the MZU Auditorium jointly organized by the Dept. of Biotechnology, MZU, Aizawl-796004, Mizoram and India Chapter of Asian PGPR Society for Sustainable Agriculture from 11th–12th May, 2018.

5. National Conference organized by Mizoram Science Congress, 2018 at PUC, Aizawl–796001, Mizoram from 4th–5th October, 2018.

6. *"Chemistry & Environmental Sustainability (ICCES–2019)"* organized by the Dept. of Chemistry, MZU, Aizawl-796004, Mizoram from 19th–22nd February, 2018.
7. *"General Orientation to Geospatial Technology and Applications"* organized by Dept. of Environmental Science, MZU, Aizawl-796004, Mizoram and supported by Natural Resources Data Management System-Department of Science and Technology (NRMS–DST), Govt. of India, New Delhi from 24th–26th July, 2019.
8. *"Understanding the Impact of Forest Fire on the Faunal Resources of North–Eastern States"* organized by the Zoological Society of India (ZSI), Kolkata under the MoEF&CC, Govt. of India from 13th–14th April, 2019.
9. *"Hands–on Workshop on Geographic System (GIS) using QGIS"* organized by the Developmental Biology & Herpetology (DB&H) Laboratory, Dept. of Zoology, MZU, Aizawl-796004, Mizoram from 31st July, 2020.
10. *"Nature Walk"* organized in collaboration with Eco Club, MZU and Mizoram Pollution Control Board under sponsorship of MoEF&CC, Govt. of India venue Zoological Park, Aizawl, Mizoram from 14th October, 2023.
11. *"Current Trends in Biological Sciences"* organized by School of Life Sciences, MZU from 18th–20th March, 2024.
12. *"Recent Trends in Biodiversity Status & Conservation"* organized by Dept. of Zoology, ADBU in collaboration with Dept. of Zoology, St. Edmund's College & Dept. of Zoology, Pragjyotish College, Guwahati at ADBU, Tapesia, Sonapur–782402, Assam, India from 27th-28th March, 2024.

RESEARCH PUBLICATIONS

1. **Decemson Ht**, Parida A and Solanki GS. Feeding Behavior of Phayre's Leaf Monkey (*Trachypithecus phayrei*) and Capped Langur (*Trachypithecus pileatus*) in Dampa Tiger Reserve, Mizoram. *Science and Technology Journal*, 6: I, January, 2018.
2. **Decemson Ht**, Gouda S, Siama Z and Lalremsanga HT. Dietary preference of Assamese Macaque *Macaca assamensis* McClelland, 1840 (Mammalia: Primates: Cercopithecidae) in Dampa Tiger Reserve, India. *Journal of Threatened Taxa* 14 (8): 21487-21500, 26 August, 2022.

3. Vanlalsiammawii, Remruatpuii, Malsawmhriatzualli VL, Lalmuansanga, Hmar GZ, Sailo S, **Decemson Ht**, Biakzuala L and Lalremsanga HT. An additional record of the Tamdil Leaf–Litter Frog *Leptobrachella tamdil* (Sengupta Sailo, Lalremsanga, Das, and Das, 2010) (Amphibia: Megophryidae) from Dampa Tiger Reserve, Mizoram, India. *Journal of Threatened Taxa* 12 (8): 15951-15954, 26 May, 2020.

4. **Decemson Ht**, Biakzuala L and Lalremsanga HT. Interspecific amplexus between two sympatric species, *Amnirana nicobariensis* (Stoliczka, 1870) and *Microhyla berdmorei* (Blyth, 1856) at Tuitun stream, Mizoram, India. *Herpetology Notes*, 13: 433-434, 29 May, 2020.

5. Gouda S, **Decemson Ht**, Parida A and Solanki GS. Impact of shifting cultivation on mammalian diversity and distribution in fringe areas of Dampa Tiger Reserve, Mizoram, India. *Environment Conservation Journal*, 21 (1&2): 103-115, June, 2020.

6. **Decemson Ht**, Biakzuala L, Solanki GS, Barman BK and Lalremsanga HT. The Twin–Spotted Treefrog (*Rhacophorus bipunctatus* Ahl 1927) in Mizoram, India. *IRCF REPTILES & AMPHIBIANS*, 27 (2): 242-244, August, 2020.

7. Muansanga L, **Decemson Ht**, Biakzuala L, Hmar GZ, Lalremsanga HT, Das M and Purkayastha J. First Record of the Jampui Bent–Toed Gecko, *Cyrtodactylus montanus* Agarwal, Mahony, Giri, Chaitanya, and Bauer 2018 (Squamata: Gekkonidae), from Mizoram, India. *IRCF REPTILES & AMPHIBIANS*, 27 (2): 267-268, August, 2020.

8. Lalhruaitluangi TBC, Malsawma R, Biakzuala L, Muansanga L, **Decemson Ht**, Vabeiryureilai M, Rinsanga L and Lalremsanga HT. Notes on the Diet and Feeding Behavior of the Khumhzi Striped Ichthyophis, *Ichthyophis khumhzi* Kamei, Wilkinson, Gower, and Biju 2009 (Amphibia: Gymnophiona: Ichthyophiidae), from Mizoram in Northeastern India. *REPTILES & AMPHIBIANS*, 27 (3): 464-466, December, 2020.

9. **Decemson Ht**, Gouda S, Biakzuala L, Muansanga L, Hmar GZ, Vabeiryureilai M and Lalremsanga HT. An annotated checklist of amphibians in and around

Dampa Tiger Reserve, Mizoram, India. *Journal of Threatened Taxa*, 13 (3): 17918-17929, 26 March, 2021.

10. Kundu S, Lalremsanga HT, Biakzuala L, **Decemson Ht**, Muansanga L, Tyagi K, Chandra K and Kumar V. Genetic diversity of the Pegu Rice Frog, *Microhyla berdmorei* (Anura: Microhylidae) based on mitochondrial DNA, *Mitochondrial DNA Part B*, 6: 5, 1586-1591, 30 Apr, 2021.

11. Muansanga L, Sailo S, Biakzuala L, Hmar GZ, Zothanzama J, **Decemson Ht** and Lalremsanga HT. Interspecific Amplexus of a Male Terai Treefrog, *Polypedates teraiensis* (Dubois 1897), and a Female Cope's Assam Frog, *Hydrophylax leptoglossa* (Cope 1868), at Pualreng Wildlife Sanctuary in Mizoram, India. *REPTILES & AMPHIBIANS*, 28 (1): 84-85, April, 2021.

12. Hmar GZ, Biakzuala L, Muansanga L, Zote D, Hruaia VL, Ramengmawii HB, **Decemson Ht**, Das KC and Lalremsanga HT. First Record of the Exotic Red–Eared Slider, *Trachemys scripta elegans* (Wied 1838) (Emydidae), from Mizoram, India. *REPTILES & AMPHIBIANS*, 28 (1): 52-53, April, 2021.

13. **Decemson Ht**, Vanlalsiammawii, Biakzuala L, Vabeiryureilai M, Malsawmdawngliana F and Lalremsanga HT. Occurrence of Tamdil Leaf–Litter Frog *Leptobrachella tamdil* (Sengupta Sailo, Lalremsanga, Das, and Das, 2010) (Amphibia: Megophryidae) from Manipur, India and its phylogenetic position. *Journal of Threatened Taxa*, 13 (6): 18624-18630, 26 May, 2021.

14. Purkayastha J, Lalremsanga HT, Bohra SC, Biakzuala L, **Decemson Ht**, Muansanga L, Vabeiryureilai M, Chauhan S and Rathee YS. Four new Bent–Toed Geckos (*Cyrtodactylus* Gray: Squamata: Gekkonidae) from northeast India. *Zootaxa*, 4980 (1): 451-489, June, 2021.

15. Muansanga L, Biakzuala, Rinsanga L, Vanlalchhuana M, GZ Hmar, **Decemson Ht**, Malsawma R and Lalremsanga HT. *Rhabdophis subminiatus helleri*. Reproduction. Natural History Notes. *Herpetological Review*, 52 (1): 170, 2021.

16. **Decemson Ht**, Vanlalsiammawii and Lalremsanga HT. *Fejervarya multistriata* (Paddy Frog). Geographic Distribution. *Herpetological Review*, 52 (2): 2021.

17. Lalremsanga HT, Purkayastha L, Vabeiryureilai M, Muansanga L, **Decemson Ht** and Biakzuala L. Range extension of *Ichthyophis multicolor* Wilkinson, Presswell, Sherratt, Papadopoulou, and Gower, 2014 to India and first molecular identification of *Ichthyophis moustakius* Kamei, Wilkinson, Gower, and Biju, 2009 2009. *Check List*, 17 (4): 1021-1029, 12 July, 2021.

18. Lalremsanga HT, Muansanga L, **Decemson Ht** and Biakzuala L. Interspecific Amplexus by a Male Terai Treefrog, *Polypedates teraiensis* (Dubois 1987) (Anura: Rhacophoridae), and a Female Serchhip Horned Frog, *Xenophrys serchhipii* Mathew and Sen 2007 (Anura: Megophryidae), from Mizoram, India. *REPTILES & AMPHIBIANS*, 28 (2): 278-279, August, 2021.

19. **Decemson Ht**, Vabeiryureilai M, Vanlalsiammawii, Biakzuala L, Sailo S and Lalremsanga HT. A New Record of the Bangladeshi Cricket Frog, *Minervarya asmati* (Howlader 2011) from Manipur, India, with Comments on the Occurrence of the Paddy Frog, *Fejervarya multistriata* (Hallowell 1861) (Anura: Dicroglossidae) in Mizoram, India. *REPTILES & AMPHIBIANS*, 28 (2): 250-254, August, 2021.

20. Muansanga L, Vanlalsiammawii, Hmar GZ, Malsawmdawngliana F, Biakzuala L, **Decemson Ht**, Sangi Z and Lalremsanga HT. New Elevational and Locality Records and Notes on the Natural History of the Tamdil Leaf–Litter Frog, *Leptobrachella tamdil* (Sengupta, Sailo, Lalremsanga, Das, and Das 2010) (Megophryidae), in Mizoram, India. *REPTILES & AMPHIBIANS*, 28 (2): 295-297, August, 2021.

21. Muansanga L, **Decemson Ht**, Biakzuala L, Laltlanhlui LH, Malsawmdawngliana F, Hmar GZ, Vabeiryureilai M, Kumar NS and Lalremsanga HT. On the Phylogenetic Relationships of the Indian Gliding Frog, *Pterorana khare* Kiyasetuo and Khare 1986 (Anura: Ranidae), with New Distributional Records from Mizoram, India. *REPTILES & AMPHIBIANS*, 28 (2): 205-212, August, 2021.

22. **Decemson Ht**, Vabeiryureilai M and Lalremsanga HT. First report on limb anomalies in *Sphenomorphus indicus* (GRAY, 1853) and *Sphenomorphus maculatus* (BLYTH, 1853) at the Dampa Tiger Reserve in Mizoram, India. *SAURIA*, 69-72.

23. **Decemson Ht**, Vanlalsiammawii, Vabeiryureilai M, Biakzuala L and Lalremsanga HT. First record of *Duttaphrynus chandai* (Anura: Bufonidae) from Manipur State, northeastern India, with updated information on its distribution and natural history. *Herpetology Notes*, 14: 1219-1223, 22 September, 2021.

24. Gouda S, **Decemson Ht**, Lalremsanga HT and Solanki GS. Community–based approaches for wildlife conservation and livelihood options: a case study from Dampa Tiger Reserve, Mizoram, India. *CURRENT SCIENCE*, 121: 7, 10 October, 2021.

25. **Decemson Ht**, Biakzuala L, GZ Hmar, Muansanga L, Malsawmdawgliana F, Vabeiryureilai M and Lalremsanga HT. *Calotes versicolor* (Indian Garden Lizard). Ectoparasite. Natural History Notes. *Herpetological Review*, 52 (3): 646, 2021.

26. **Decemson Ht**, Vabeiryureilai M, Biakzuala L and Lalremsanga HT. Confirmation on the occurrence of *Calotes geissleri* Wagner, Ihlow, Hartman, Flecks, Schmitz and Böhme, 2021 (Sauria: Agamidae) in Manipur, India, with comments on its phylogenetic position. *Journal of Animal Diversity*, 3 (4): 14-19, 2021.

27. Biakzuala L, **Decemson Ht**, GZ Hmar, Muansanga L, Rinsanga L, Lalremsanga HT, Sailo L, Laltlanchhuaha H, Lalhmingliana A and Vanchhawng V. *Leptobrachium smithi* (Southern Bicolor–Eyed Toadfrog) and *Polypedates teraiensis* (Perching Frog). Interspecific Amplexus. Natural History Notes. *Herpetological Review*, 52 (4), 2021.

28. Sinate RR, **Decemson Ht**, Biakzuala L and Lalremsanga HT. *Bungarus niger* (Greater Black Krait). India. Manipur. Geographic Distribution. *Herpetological Review*, 52 (4): 797, 2021.

29. **Decemson Ht** and Lalremsanga HT. *Herpetoreas xenura* (Wall's Keelback). Diet. Natural History Notes. *Herpetological Review*, 52 (4): 873, 2021.

30. Sinate RR, **Decemson Ht**, Biakzuala L and Lalremsanga HT. *Boiga quincunciata* (Assamese Cat Snake). India. Manipur. Geographic Distribution. *Herpetological Review*, 53 (1): 78, 2022.

31. Tariang AD, Malsawmdawgliana F, Biakzuala L, **Decemson Ht**, Muansanga L, Rinsanga L, Vabeiryureilai M and Lalremsanga HT. Confirmation on the occurrence of *Calotes irawadi* Zug, Brown, Schulte & Vindum 2006 (Squamata: Agamidae) in Mizoram, Northeast India. *Hamadryad*, 39, 88-94, July, 2022.

32. Biakzuala L, Muansanga L, **Decemson Ht**, Hmar GZ, Malsawmdawngliana F, Vabeiryureilai M and Lalremsanga HT. New Distributional Records of the Baibung Small Treefrog, *Theloderma baibungense* (Jiang, Fei, and Huang 2009) (Anura: Rhacophoridae) from Mizoram, India, with Comments on Taxonomy, Natural History, and Conservation Status. *REPTILES & AMPHIBIANS*, 29: 66-70, 2022.

33. Lalremsanga HT, Chinliansiama H, Bohra SC, Biakzuala L, Vabeiryureilai M, Muansanga L, Malsawmdawngliana F, GZ Hmar, **Decemson Ht**, Vanlalsiammawii, Das M and Purkayastha J. A new Bent–Toed Gecko (*Cyrtodactylus* Gray: Squamata: Gekkonidae) from the state of Mizoram, India. *Zootaxa*, 5093 (4): 465-482, January, 2022.

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PARTICULARS OF THE CANDIDATE

NAME OF THE CANDIDATE: HT. DECEMSON

DEGREE: DOCTOR OF PHILOSOPHY

DEPARTMENT: ZOOLOGY

TITLE OF THE THESIS: Nutritional Ecology of Assamese Macaque (*Macaca assamensis*) and Capped Langur (*Trachypithecus pileatus*) in Dampa Tiger Reserve in Mizoram, India

DATE OF ADMISSION: 21.09.2017

APPROVAL OF RESEARCH PROPOSALS -

DEPARTMENT RESEARCH COMMITTEE (DRC): 07.04.2018

BOARD OF STUDIES (BOS): 27.04.2018

SCHOOL BOARD (SB): 03.05.2018

MIZORAM UNIVERSITY REGISTRATION NO: 3095 of 2012

Ph.D REGISTRATION NO. & DATE: MZU/Ph.D./1110 of 03.05.2018

EXTENSION APPROVED BY SCHOOL BOARD LIFE SCIENCE & DATE:

2 yrs. extension put up to the School Board of Agenda Part–III: iii(a) of 29.05.2023

Academic Council Approved File No: 16-2/MZU(Acad)/21/313-318 of 12.07.2023

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Department of Zoology,
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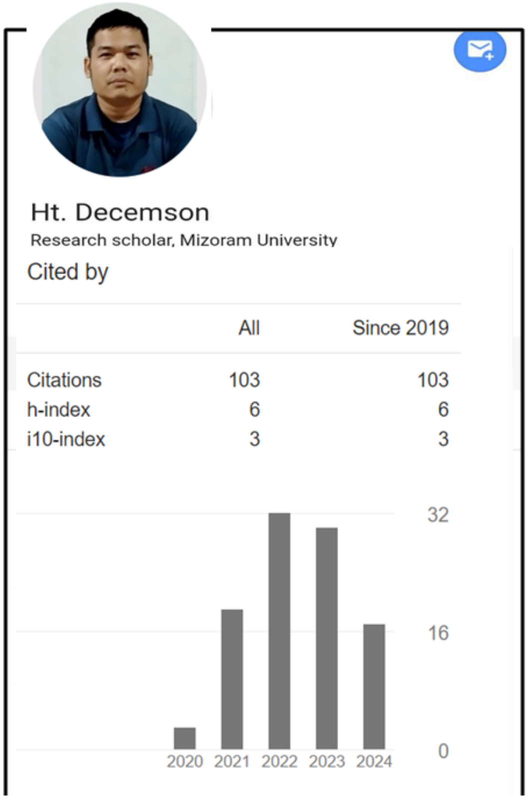

Ht. Decemson

Research scholar, Mizoram University

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Citations	103	103
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Citations: 103

H-index: 6

i10-index: 3

Conference/Seminar/Workshop Attended:

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2. **Nationals**: **12**

ANNEXURE-I

MIZORAM UNIVERSITY (A central university)

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Name of Research Scholar/Student	**Ht. Decemson**	
Ph.D. Registration Number	MZU/Ph.D./No. 1110 of 03.05.2018	
Title of Ph.D. Thesis	"Nutritional ecology of Assamese Macaque (*Macaca assamensis*) and Capped Langur (*Trachypithecus pileatus*) in Dampa Tiger Reserve in Mizoram, India''	
Name & Institutional Address of the Supervisor	Prof. H.T. Lalremsanga, Department of Zoology Mizoram University (MZU), Aizawl-796004, India	
Name of the Department and School	Department of Zoology, School of Life Sciences, MZU.	
Date of submission	18.01.2024	
Date of plagiarism check	15.09.2023	
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Percentage of similarity detected by URKUND software	**Core Areas**	0%
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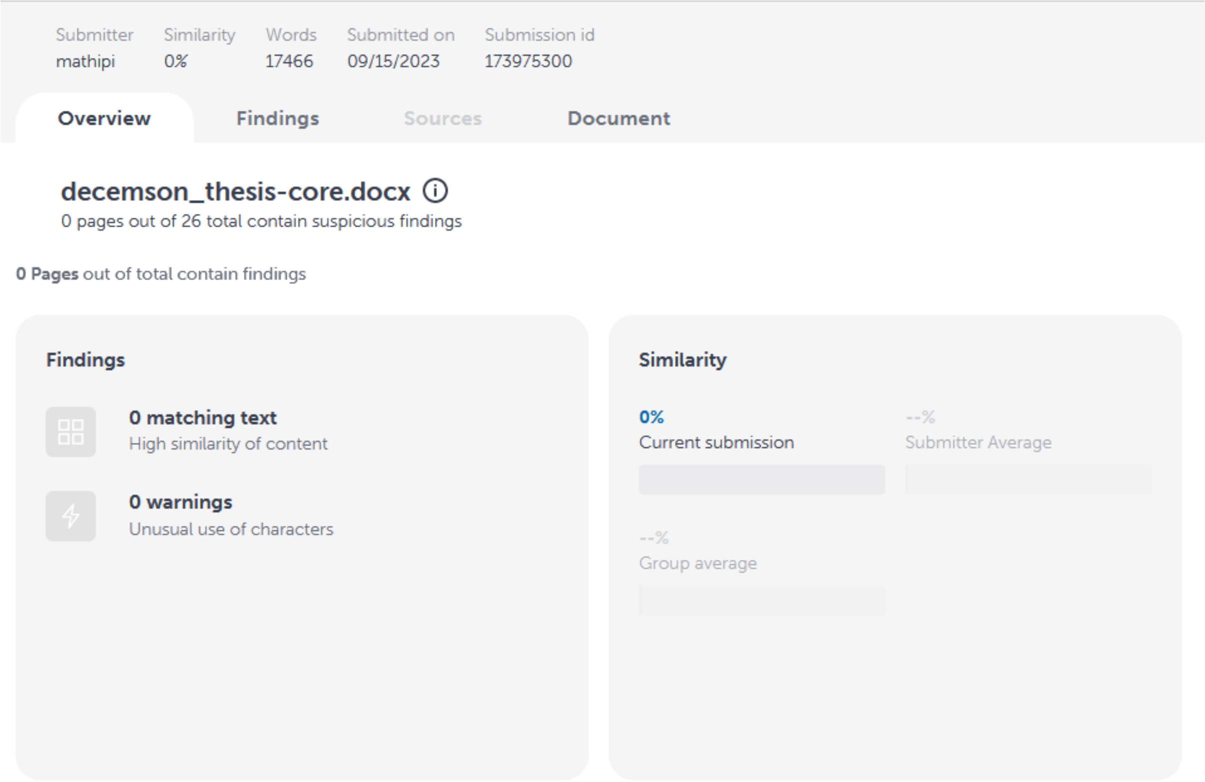

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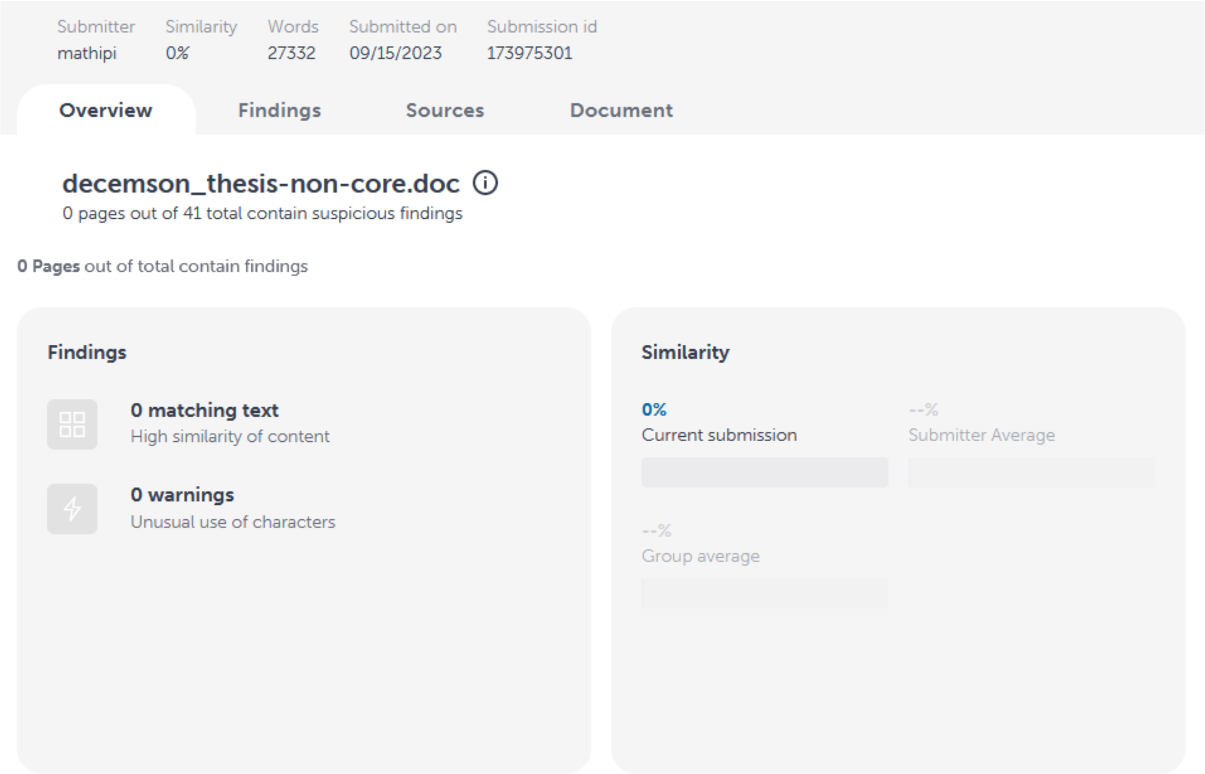

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ABSTRACT

NUTRITIONAL ECOLOGY OF ASSAMESE MACAQUE (*MACACA ASSAMENSIS*) AND CAPPED LANGUR (*TRACHYPITHECUS PILEATUS*) IN DAMPA TIGER RESERVE IN MIZORAM, INDIA

AN ABSTRACT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

HT. DECEMSON
MZU REGISTRATION NO.: 3095 of 2012
Ph.D. REGISTRATION NO.: MZU/Ph.D./1110 of 03.05.2018

DEPARTMENT OF ZOOLOGY
SCHOOL OF LIFE SCIENCES
AUGUST, 2024

Nutritional Ecology of Assamese Macaque (*Macaca assamensis*) and Capped Langur (*Trachypithecus pileatus*) in Dampa Tiger Reserve, Mizoram, India

BY

HT. DECEMSON

Department of Zoology, Mizoram University

SUPERVISOR

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Submitted

In partial fulfillment of the requirement of the Degree of Doctor of Philosophy in Zoology of Mizoram University, Aizawl

ABSTRACT

Preface and consolidated abstract

Dietary composition and selection of food items are important approaches for the flexibility and adaptability of primate in different natural habitats because diet or selection of food is an important trade in an animal life. Primate food consumption in the wild is largely influenced by seasonality, habitat quality, food abundance and distribution. Adaptation and alteration in dietary patterns account for the major ecological and behavioral differences among primate species especially in wild. 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. Understanding the temporal availability of food to a particular species is crucial when examining the drivers of their feeding strategies. Foraging is the behavior activity in which monkey searches for food or wanders in search for food including eating any substance, licking stone, drinking water and slight movement in search of food. Therefore, the underlying factor is to record primate food intake (*i.e.*, the amount of food consumed by an individual) in the wild which is a crucial measure for studying feeding behavior.

Until recently, the present study site DTR became the center of working field site for wildlife research. Minor work was done on aspects of the distribution, abundance and habitat ecology for DTR primates from previous workers. Nonetheless, no work on nutritional ecology for AM and CL in DTR, for these two animals was aptly carried out.

The topics of this present study are covered broadly under four chapters.

Chapter 1: To study the food plants preference and the composition of the diet.
Chapter 2: To analyze chemical compositions in food plants and fecal matter.
Chapter 3: To study the energy dynamics and digestibility.
Chapter 4: To evaluate the habitat for nutritional status of food.

The study was conducted from September 2018 to August 2020 at DTR (23.38°–23.70°N and 92.27°–92.43°E) located in the western part of Mizoram in Mamit district, northeastern India along the international border to Bangladesh where the reserve core area of 500 km^2 and buffer 488 km^2, covering mountainous terrains, elevation ranging from 250–1100 m and making it the Mizoram’s largest wildlife protected area. In this present work, the first animal study subject in the study area– Assamese Macaque (*Macaca assamensis*) and Capped Langur (*Trachypithecus pileatus*). The study areas were classified under the Cachar Tropical Evergreen and Semi-Evergreen forest types. Habitat and vegetation types at study sites were determined by a stratified sampling method. Sampling was made on foot on a transect line that were previously marked. Three locations at Dampa Watch Tower, Sesih Hnar and New Chikha quadrates were randomly employed measured 20x20 m^2 at elevation of 507–770 m. Vegetation within quadrates was counted and identified to the species level. The DBH (in cm) was measured approximately at 1.37 m above the ground. The Relative Frequency (RF), Relative Density (RDen), Relative Dominance (RDom) of each species within quadrates was calculated and then summing the value and determined the Important Value Index (IVI).

The feeding behavior and dietary composition data of AM and CL were collected by direct and indirect observations in the field. Feeding data was collectively pooled in for two years (September, 2018–August, 2020). Observations via focal individual sampling were noted for adult individuals from the time they were encountered to until out of sight, duration of 0600–1700 hr. carried out for 5–10 consecutive days of every month. The feeding or food plant parts; leaves (both young and mature leaves), flowers, fruits, seeds and shoots consumed were categorically recorded.

Chapter 1: To study the food plants preference and the composition of the diet.

Vegetation in DTR study sites was determined through vegetative sampling and collection of ecological based data of various quadrates. The RF, RDen, RDom and IVI (%) was determined for the 148 plant species in DTR study sites. Among the plant studied the highest RF value was observed for *Artocarpus lakoocha* (1.81%) and lowest value (0.36%) was observed in other 68 plants species. The highest RDen was recorded for *Acrocarpus fraxinifolius* (2.11%) and the lowest value 0.26% for *Bombax ceiba*. The highest RDom was recorded value of 2.34% for *Acrocarpus fraxinifolius* and the lowest of 0.29% both for *Bombax ceiba* and *Calamus acanthospathus*. The highest IVI value of 5.17% observed was for *Acrocarpus fraxinifolius* and the lowest value of 0.62% both for *Eriobotrya benghalensis* and *Hardina cordiflora*.

In the study, 203 days of the survey resulted in 2,233 scans and 16,381 behavioural records AM troop were observed to forage on 57 plant species under 46 genera belongs to 30 families. Food plants belonging to 13 species contributed for >1% feeding times. Among the feeding plant species, trees accounted for 91%, herbs 7% and climbers/vines 2%. The major top ten feeding plants of AM were identified and the time recorded for feeding were *Artocarpus lakoocha* (15.65%), *Albizia procera* (12.03%), *Glochidion hyneanum* (10.53%), *Diospyros glandulosa* (9.49%), *Albizia lebbeck* (7.28%), *Cephalotaxus graffithii* (4.53%), *Ficus auriculata* (4.20%), *Protium serratum* (3.04%), *Albizia chinensis* (1.57%) and *Bombax insigne* (1.44%). The number of food plant species consumed in each observation month ranges from 20 to 43 (32.42 ±6.56).

The diversity of the family contributed the feeding plants of AM diet family consists as follows, Moraceae with 9 species, Meliaceae with 5 species, Mimosaceae and Euphorbiaceae both 4 species, Combretaceae with 3 species, Bombacaceae, Poaceae, Caesalpiniaceae, Magnoliaceae, Fabaceae, Verbenaceae and Anacardiaceae were 2 species each and Ebenaceae, Cephalotaxaceae, Burseraceae, Rosaceae, Clusaceae, Musaceae, Gnetaceae, Myrtaceae, Dilleniaceae, Malvaceae, Lauraceae, Flacourtiaceae, Heliconiaceae, Sonnertiaceae, Theaceae, Sapotaceae, Fagaceaea and Phyllantaceae with 1 species each.

Significant variation was not observed both for time spent on feeding leaves in different months of the seasons (H=3.429, df=2, p>0.05) and in different year (H=19.46, df=11, p>0.05). Fruits were most abundant during monsoon/summer (June to August) constituting the major food item. Maximum feeding of fruits was in the month of August (44.62% of the total food items) and the lowest consumption recorded in February (3.48% of the total food items). The time spent feeding of fruits did not show significant variation in different months (H=15.87, df=11, p>0.05) and seasons (H=4.571, df=2, p>0.05).

The highest consumption of flowers was observed in the month of February (28.05%), but, no significant variation was observed monthly and seasonally for time spent on feeding of flowers. The highest seed consumption was recorded in January (12.4%) and it was observed mainly during winters when there was scarcity of fleshy fruits. Bamboo shoots of species such as; *Melocana baccifera* and *Dendrocalamus longispathus* were fed only in monsoon (June to October) and the total time spent on feeding of shoots during the observation period was 2.14% only. 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%). The average diurnal feeding time spent for AM is 44% and observed highest in January (59.03%) and lowest in July (35.19%).

In this study, 196 days of the survey resulted in 2,156 feeding scans and 16,060 behavioral records for CL were observed to forage on 66 different plant species under 54 genera from 33 families. Among the feeding plant trees species in CL accounted for 86.36%, herbs 7.58%, shrubs and climbers 3.03%, respectively. The top ten major feeding plants of CL identified and the time spent for consuming these plants were as follows, *Albizia chinensis* (7.28%), *Alstonia scholaris* (5.61%), *Albizia richardiana* (4.77%), *Albizia lebbeck* (4.48%), *Bischofia javanica* (4.41%), *Castanopsis tribuloides* (4.14%), *Aglaia edulis* (3.86%), *Cephalotaxus graffithii* (2.86%), *Diospyros glandulosa* (3.64%) and *Albizia procera* (2.82%). The number of food plant species consumed in each observation month ranges from 34 to 57 (42.42 ±6.35).

The diversity of plants were mainly observed and contributed greatest of feeding plants of CL diet from the family, Moraceae consisting of 8 species, 6 species from Malvaceae, 5 species for both Euphorbiaceae and Mimosaceae, 4 species for Combretaceae, 3 species for Anarcadiaceae, and 2 species each for Apocynaceae, Bombacaceae, Caesalpiniaceae, Clusiaceae, Fabaceae, Lauraceae, Poaceae, Sapotaceae, Verbenaceae and 1 species each under Burseraceae, Cephalotaxaceae, Dilliniaceae, Dioscoreaceae, Ebenaceae, Flacourtiaceae, Gnetaceae, Heliconiaceae, Magnoliaceae, Musaceae, Myrtaceae, Phyllanthaceae, Rosaceae, Sapindaceae, Sapotaceae, Sonnertaceae, Theaceae and Ulmaceae.

In the present observation for CL, no significant variations were observed on time spent on feeding leaves in different seasons (H=4.86, df=2, p=0.08) and in different months of the year (H=18.66, df=11, p=0.06). Fruits were abundant during monsoon/summer constituting the major food item during June to August (22.90% to 33.42%). CL were observed to feed maximum fruits in July (33.42% of the total food items), and the lowest consumption recorded in the month of March (22% of the total food items). Time spent on feeding of fruits did not show significant variation in different months (H=18.22, df=11, p=0.07) and seasons (H=3.18, df=2, p=0.20).

The highest consumption of flowers was observed in May (27.78%), there was no significant variation in the time spent on feeding of flowers observed monthly (H=19.27, df=11, p=0.05), but a significant variation was observed seasonally (H=7.28, df=2, p=<0.05). Seeds were consumed mainly in winters (H=16.09, df=2, p<0.01), when there was a scarcity of fleshy fruits, and the highest seed consumption recorded in January (33.71%) with a monthly significance (H=21.37, df=11, p<0.05) of seeds consumption and seasonally variation (H=16.09, df=2, p<0.01). Shoots of bamboo species were fed only in monsoon (June to September) with highest consumption of shoots during July (8.68%), while the lowest consumption observed in September (5.34%) with a seasonally significant variation (H=9.20, df=2, p<0.05) and the monthly significant variation (H=22.120, df=11, p<0.05). The total time spent on feeding of shoots during the whole observation periods was 2.39% only. Leaves formed the highest bulk of CL diet (46.24%), due to availability throughout the year and it is followed by fruits (21.66%), flowers (18.19%), seeds (11.52%) and shoots (2.39%). The diurnal time invested on feeding (>38.70% on average) and observed highest in January (40.77%) and lowest in July (35.29%).

Seasonal variation in the diet of AM and CL was clearly linked to seasonal fluctuations in food availability and influenced by a number of environmental factors which is a common observation across home ranges. Their diet was primarily folivorous which was consistent with the results in this study. This agrees and similar to other observations and findings of earlier works.

Chapter 2: To analyze chemical compositions in food plants and fecal matter.

In the present work, the proximate content value of DM(%) for AM was observed lowest to highest for *Artocarpus lakoocha* (13.67±1.18) and *Albizia procera* (40.99±0.61), while the proximate content of moisture (%) was observed lowest for *Albizia procera* (59.01 ±0.61) and highest for *Artocarpus lakoocha* (86.33±1.18%). For CL, the proximate content of DM (%) was observed lowest for *Castanopsis tribuloides* (14.73±2.96) and highest for *Albizia lebbeck* (38.39±0.99), while lowest to highest proximate content of moisture (%) was observed for *Albizia lebbeck* (61.61±0.99) and *Aglaia edulis* (86.37±0.74), respectively.

The range of proximate content of nutrients value (%) from lowest to highest for AM were as follows; carbohydrate content was observed for *Diospyros glandulosa* (6.42 ±0.57) and for *Albizia chinensis* (13.71±1.55). Protein content was observed for *Protium serratum* (2.15 ±1.48) and *Bombax insigne* (8.98 ±1.23). The ash content was observed for *Bombax insigne* (2.55 ±0.28) and *Cephalotaxus graffithii* (11.70 ±1.24). Fat content was observed for *Albizia lebbeck* (0.58 ±0.47) and *Glochidion hyneanum* (5.70 ±0.46). The fiber content was recorded for *Protium serratum* (3.06 ± 0.87) and *Artocarpus lakoocha* (38.06 ±0.87). AM devoted maximum time for feeding (15.65%) on *Artocarpus lakoocha* that contains protein (6.75%) with fiber content 38.06% and Protein: fiber is 0.18. The protein: fiber is highest (0.70) for *Protium serratum* and minimal (0.14) for *Ficus auriculata* with feeding time spent 3.04% and 4.20%, respectively. Similarly, for CL the range of proximate content of nutrients value (%) from lowest to highest of carbohydrate was found for *Diospyros glandulosa* (6.42 ±0.57) and *Albizia chinensis* (13.71 ±1.55). Protein content was observed for *Albizia richardiana* (2.15 ±1.48) and *Albizia chinensis* (8.72 ±2.53). The content of ash was observed for *Bischofia javanica* (4.80 ±0.40) and *Cephalotaxus graffithii* (11.70 ±1.24). Fat content observed for *Albizia lebbeck* (0.58 ±0.47) and *Alstonia scholaris* (3.39 ±1.06). Fiber content recorded for *Albizia richardiana* (0.78 ±0.48) and *Albizia chinensis* (27.47 ±0.83).

The protein: fiber was observed highest for *Aglaia edulis* (3.84) and lowest for *Diospyros glandulosa* (0.22) with feeding time spent more or less the same, 3.86% and 3.64%, respectively. CL spent highest time for feeding (7.28%) on *Albizia chinensis* that contains protein (8.72%) with fiber content 27.47% and protein: fiber is 0.32. This agreed to observations made byvarious earlier workers. Amongst the nutritional factors influencing food choice, protein and fiber have been considered vital determinants. The statistical correlation among the different nutrient values showed that none of the tested parameters showed zero correlation between them (r>0.0), and the correlation coefficient signified that there is moderate positive correlation between protein and fiber (r=0.439), as also observed between higher protein and higher crude fiber contents in Western hoolock gibbon food plants (r=0.48) reported from Assam, India. In addition to studies concerning the protein–fiber ratio for folivore, three key concepts needs consideration when evaluating how food resources act as selection pressures to influence species conservation potential which is ideal free distribution, ecological sinks and fallback foods.

The assessment of the combined preferred food plant species of AM and CL (n=15) revealed no statistically significant correlations across all the different nutrient values (p>0.05). But, none of the tested parameters showed zero correlation between them (r>0.0), and the correlation coefficient signified a moderate positive correlation between protein and fiber (r=0.439); weak positive correlations between carbohydrate and protein (r=0.359), between fiber and fat (r=0.204), between fiber and ash (r=0.211); very weak positive correlation between protein and fat (r=0.174), between carbohydrate and ash (r=0.145) and also, weak negative correlations was observed between fat and ash (r=-0.303), between carbohydrate and fiber (r=-0.261); and very weak negative correlations between protein and ash (r=-0.035), between carbohydrate and fat (r=-0.010).

In this work, the fruit epicarp of *Protium serratum* was recovered from fecal matter for AM, however absent in CL. The remnants of fruit fibers in *Artocarpus lakoocha* and leave fibers of *Glochidion hyneanum* are present in both fecal matters of AM and CL. In addition to it for CL, leave fibers of *Diospyros glandulosa*, *Alstonia scholaris* and *Bishchofia javanica* were extracted from fecal matters which were the most exploited food species. Moreover, seeds part of *Albizia procera* and *Ficus auriculata* in the formed of fine granules were observed for AM fecal sample. Fecal specimens analysis such as tiny items of undigested matter recovered from the study sites contained number of food plants identified with fibers for 5 species followed by seeds for 2 species and fruit epicarp for 1 species. Some fecal remnants present in the fecal matter could not be identified. The analysis of fecal samples provided a useful complementary approach to the understanding of the composition of primate diet. Furthermore, the data presented suggests that the main application of the fecal analysis is to access the composition of the diet of study subjects complementarily to the data collected through behavioral monitoring, especially for undigested food items.

Chapter 3: To study the energy dynamics and digestibility.

The digestibility expressed in % and values from the minimum to maximum of AM top ten plant species are as follows; *Artocarpus lakoocha* (56.284±3.47), *Albizia procera* (65.887±3.54), *Albizia chinensis* (67.933±4.16), *Albizia lebbeck* (70.034±3.14), *Diospyros glandulosa* (71.354±5.16), *Bombax insigne* (80.473±2.51), *Glochidion hyneanum* (83.982±4.15), *Cephalotaxus graffithii* (85.577±3.47), *Ficus auriculata* (88.438±2.64) and *Protium serratum* (94.784±3.68). For CL, expressed in % with values are as follows; *Albizia chinensis* (67.93±4.10), *Albizia lebbeck* (70.03±4.67), *Diospyros glandulosa* (71.35±5.26), *Alstonia scholaris* (82.43±3.47), *Albizia procera* (83.98±4.54), *Cephalotaxus graffithii* (85.57±2.98), *Bischofia javanica* (91.24±3.54), *Castanopsis tribuloides* (91.78±3.28), *Aglaia edulis* (96.67±3.28) and *Albizia richardiana* (97.29±4.21).

From the study, the digestibility % of top ten preferred plants by AM ranges from *Artocarpus lakoocha* (56.284±3.47) to *Protium serratum* (94.784±3.68), whereas CL preferred the digestibility % ranged between 67.93±4.10 (*Albizia chinensis*) and 97.29±4.21 (*Albizia richardiana*). It can be reported that, the digestibility of food plants are also within the range of digestibility reported by Davies et al. The present work study suggests that due to medium (56.28%) to highest (97.29%) digestibility the of top food plants, both study subject preferred these plants for food. Since digestibility is an important factor of forage quality, in which an animal's relative performance when fed forages for consumption and nutrient concentration, intake, digestibility and metabolic efficiency all contribute to animal performance.

The lowest to highest proximate energy content (kcal/g of DM) of top ten plants fed by AM were as follows; *Albizia chinensis* (2.058±0.210), *Albizia procera* (2.180±0.340), *Albizia lebbeck* (2.245±0.140), *Artocarpus lakoocha* (2.358±0.150), *Diospyros glandulosa* (2.714±0.270), *Cephalotaxus graffithii* (2.795±0.640), *Glochidion hyneanum* (2.942±0.120), *Bombax insigne* (3.122±0.590), *Ficus auriculata* (3.405±0.134) and *Protium serratum* (3.485±0.124). The energy content for CL, top ten plants were; *Albizia chinensis* (2.05±0.21), *Albizia procera* (2.18±0.34), *Albizia lebbeck* (2.24±0.14), *Alstonia scholaris* (2.24±0.21), *Diospyros glandulosa* (2.74±0.27), *Cephalotaxus graffithii* (2.79±0.64), *Bischofia javanica* (2.79±0.10), *Castanopsis tribuloides* (2.96±0.05), *Aglaia edulis* (3.48±0.08) and *Albizia richardiana* (3.58±0.11). In this study, AM consumed food plants with energy contents ranging from 2.06±0.21 kcal/g (*Albizia chinensis*) to 3.49±0.12 kcal/g (*Protium serratum*), whereas CL fed on food plants with energy contents range from 2.06±0.21 kcal/g (*Albizia chinensis)* 3.58±0.11 kcal/g (*Albizia richardiana*). These findings showed that the energy content of top ten plants consumed by AM and CL are moderately higher which might be one of the reason they inhabited in the DTR forest. The estimated energy requirement for AM (718.75±22.85 kcal/day) and CL (826.03±12.19 kcal/day) was reasonable. The amount of energy available to primates from ingested diets is determined by the composition of the food as well as the extent to which various ingredients, particularly fiber fractions, are digested. The availability of energy content in the food plants were mostly influenced by the seasonal changes. Other researchers have found that energy expenditure is similar across wild groups.

The expected energy expenditure (TEE kcal/day) from the top plant species was expressed in kcal/g. For AM was estimated value of 718.75±22.85 kcal/day and then energy required per day was found to be 266.21±12.31 g of top preferred food plants. However, for CL it was estimated 826.03±12.19 kcal/day and the required amount of energy per day was 305.93±8.22 g. The TEE, in addition to BMR and physical activity, may influence metabolic variations amongst primates. However, BMR of physical activity does not explain the substantial fall in TEE in primates. Thus, to acquire sufficient quantity of the energy required per day will be obtained from top preferred food plants which are achievable from availability of food plants sources throughout the year.

Chapter 4: To evaluate the habitat for nutritional status of food.

To evaluate the nutritional status of the food plants for DTR habitat, different ecological parameters such as; the IVI, RDom, RDen and RF of tree plants were determined. 148 plant species was documented within the habitat, the habitat status was evaluated by testing whether there are significant differences between the overall plants consumed and non–consumed based on the various ecological parameters. The present study indicates the total 57 food plant species of AM comprised 135.27 for IVI, 46.09% for RF, 44.23% for RDen and 44.95% for RDom. Likewise, for CL the total 66 food plant species comprised 146.86 for IVI, 49.69% for RF, 48.44% RDen and 48.73% for RDom.

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In AM, assessment on the ecological parameters between the consumed plants (n=57) and non–consumed plants (n=91) reveals higher mean values across all the habitat parameters in the consumed plants, and the differences are also statistically significant in all the ecological parameters at the alpha level of 0.05; such as IVI (Mean=2.38±1.2 for consumed plants and 1.81±0.87 for non–consumed plants; U=1875.0), RDen (Mean=0.78±0.39 for consumed plants and 0.61±0.34 for non–consumed plants; U=1945.0; $p<0.05$), RDom (Mean=0.79±0.48 for consumed plants and 0.38±0.00 for non–consumed plants; U=2017.0; $p<0.05$) and RF (Mean=0.81±0.4 for consumed plants and 0.59±0.28 for non–consumed plants; U=1800.5; $p<0.05$).

In CL, the current assessment on the ecological parameters between the consumed plants (n=66) and non–consumed plants (n=82) revealed higher mean values across all the habitat parameters in the consumed plants, and the differences are also statistically significant in RDen and RF at the alpha level of 0.05; IVI (Mean=2.26±1.18 for consumed plants and 1.84±0.88 for non–consumed plants; U=2209.5; $p<0.05$) RDen (Mean=0.74±0.39 for consumed plants and 0.34±0.26 for non–consumed plants; U=2208.0; $p<0.05$), RDom (Mean=0.75±0.47 for consumed plants and 0.61±0.39 for non–consumed plants; U=2302.5; $p>0.05$) and RF (Mean=0.76±0.40 for consumed plants and 0.60±0.28 for non–consumed plants; U=2135.5; $p<0.05$).

Among the fifteen food plants, the highest RF value observed in both AM and CL was highest for *Artocarpus lakoocha* (65.08) and lowest for *Albizia richardiana* (15.78). The proximate nutrient values of the combined top preferred food plant species for AM and CL (n=15) showed statistically significant positive correlations with respect to all the habitat ecological parameters. The proximate nutrient values of the combined top preferred food plant species for AM and CL (n=15) showed statistically significant positive correlations with respect to IVI ($p<0.05$, r=0.692), RDom ($p<0.05$, r=0.610), RDen ($p<0.05$, r=0.603) and RF ($p<0.05$, r=0.627) at alpha level 0.05. The scatter plots for 15 nutrients in AM and CL between IVI and proximate nutrient values (R^2 Linear=0.480), (B) RDom and proximate nutrient values (R^2 Linear=0.372), (C) RDen and proximate nutrient values (R^2 Linear=0.364) and (D) RF and proximate nutrient values (R^2 Linear=0.394), respectively.

The results clearly showed that the habitats in the selected study sites at DTR forest is flourished with high quality of food plants diversity in relation to the nutrition value which is sufficient and important for the studied primates. This agrees with other reports in which vegetation correlated with primate abundance to basal area of tree, density, species diversity and shrub covers, since such availability of food resources is the key indicator for habitat quality. Spending more time resting in high quality habitats may be the result of having plenty of food and requiring less time spent foraging and feeding.

In conclusion it is determined that tropical evergreen DTR forest harbors high food plant species diversity that contained adequate nutrients for both the primates throughout the year, where vegetation associates with primate abundance to density, species diversity and shrub covers. The availability of food resources is a main indicator for habitat quality. Changes in food availability are a driving force of changes in primate populations.