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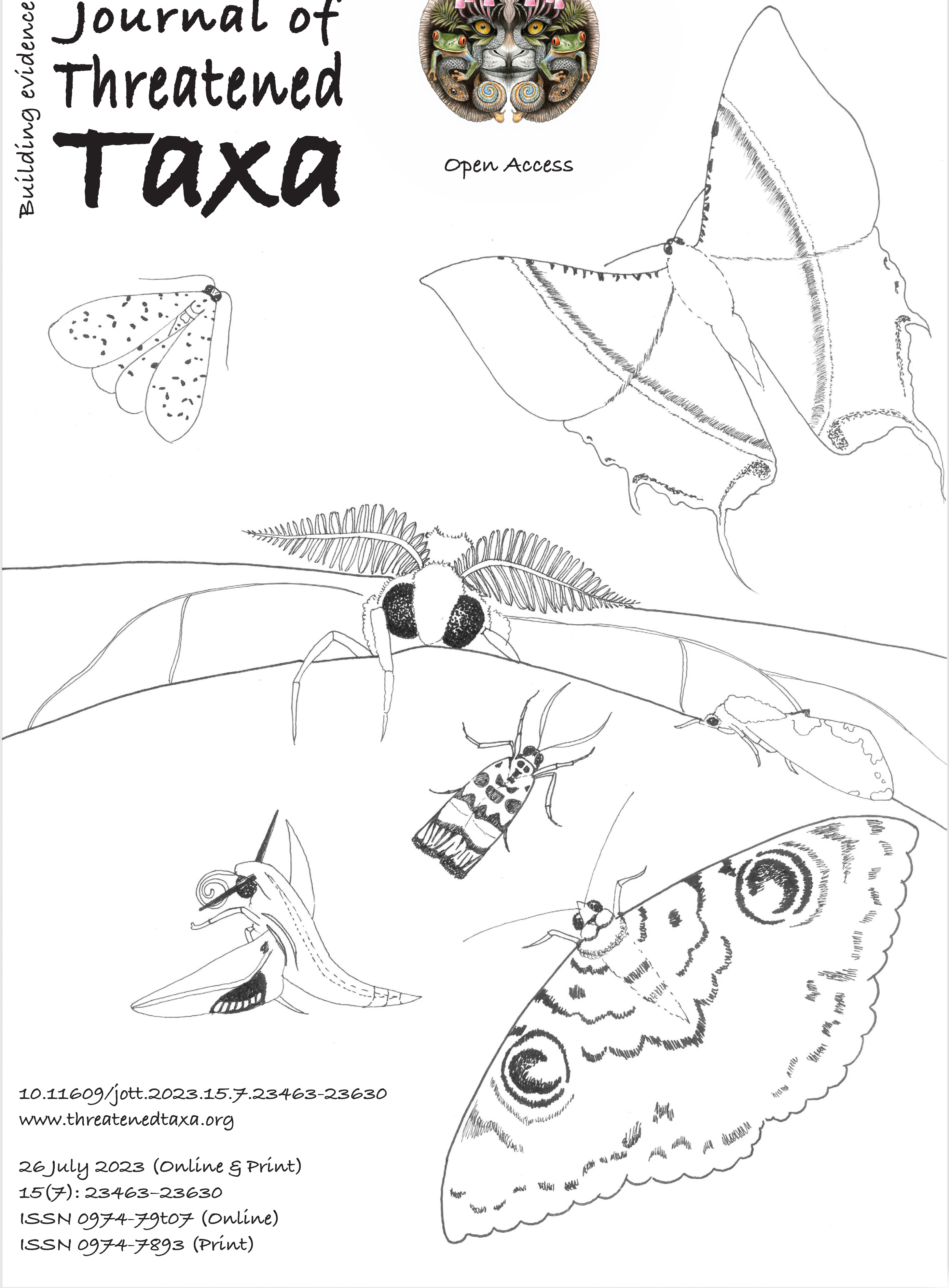

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Cover: Celebrating the unsung heroes—moths, our nocturnal pollinators. © Priyanka Iyer.

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COMMUNICATION

Proximate nutrients of selected forage and the diet composition of adult elephants in Udawalawe National Park, Sri Lanka, a preliminary study

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Abstract: Asian Elephants feed predominantly on grass. The comparative nutritional contribution of grasses and other elephant forage is not known. Therefore, the proximate nutrition of food plants selected by elephants, and the relationship of their diet composition to body condition and gender were examined in this study. Proximate analysis was conducted on 11 plant species recognised upon 66h of opportunistic focal animal sampling. Five species among them were grasses, including the invasive *Megathyrsus maximus*. The micro-histological composition of freshly collected dung from 26 identified elephants was assessed against their body condition and gender. Associations, comparisons, and hypotheses were tested. Dicots were significantly high in dry matter and low in moisture, while monocots were high in moisture and low in dry matter ($p < 0.001$). The average monocot: dicot ratio was 1: 0.73 in elephant diet. However, it was observed that the monocot composition in the male diet was significantly higher than dicots ($p < 0.001$), while there was no significant difference in the female diet composition. Elephant body condition did not show any correlation with the abundance of monocot or dicot plant tissues. The preliminary study implies that dry matter nutrients in dicots and moisture in monocots influence diet selection of elephants. Their diet composition was associated with gender but did not correlate with body condition. *M. maximus* was not outstanding in nutrition from the selected plant species.

Keywords: Asian Elephant, body condition, *Elephas maximus maximus*, food selection, gender, mammals, nutrition.

Abbreviations: UNPSL—Udawalawe National Park of Sri Lanka | DM—Dry matter | BCS—Body condition score.

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Research permission: Permission was obtained for this research from the Department of Wildlife Conservation, Sri Lanka for observation of elephants, collection of elephant dung and plant samples under the Permit No: WL/3/2/55/19.

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INTRODUCTION

Elephants are bulk feeders with an ability to selectively feed on different forage using their highly specialised trunk (McKay 1973; Eisenberg 1980; Owen-Smith 1988; Dumonceaux 2006). They are generalised mixed feeders (Shoshani & Eisenberg 1982; Fernando & Leimgruber 2011). These monogastric megaherbivores are colonic hindgut fermenters with a very short food retention time due to a relatively short gut (Greene et al. 2019). Studies conducted on the diet of Asian Elephants in the wild include identification of forage plants, their availability and foraging nature, and the study of foraging behaviour (Eisenberg 1980; Steinheim et al. 2004; Chen et al. 2006; Pradhan et al. 2008; Baskaran et al. 2010). Few studies have been carried out on nutrition of their natural diet (Das et al. 2014; Lihong et al. 2007; Borah & Deka 2008; Santra et al. 2008; Koirala et al. 2018). Asian Elephants are observed to prefer and feed more on grasses (Samansiri & Weerakoon 2007; Fernando & Leimgruber 2011; Alahakoon et al. 2017).

It is reported that Sri Lankan elephants spend about 75% of their daily activity budget on feeding, while an adult elephant feeds on about 150 kg and defecates about 80 kg of forage per day (Vancuylenberg 1977; Eisenberg 1980). Feeding behaviour and foraging ecology of elephants, including plant identification and their availability, have also been conducted in Sri Lanka (McKay 1973; Vancuylenberg 1977; Samansiri & Weerakoon 2007; Angammana et al. 2015; Alahakoon et al. 2017). The Sri Lankan Elephant's large diet breadth has been examined. A total number of 116 species of food plants of elephants belonging to 25 families were recorded from northwestern Sri Lanka by Samansiri & Weerakoon (2007), while a diet breadth of 63 food plants was identified by Alahakoon et al. (2017) from Udawalawe National Park of Sri Lanka (UNPSL). Despite, there is a lacuna in the study of nutrition of the natural diet of Sri Lankan elephants.

It has been opined that recently reported observations of elephants with poor body conditions in UNPSL could be due to rapid reduction of the distribution of Guinea Grass (*Megathyrsus maximus*) (Anver 2015; Fernando 2015b; Wijesinghe 2016). *Megathyrsus maximus* is an invasive species introduced as fodder for livestock (Panwar & Wickramasinghe 1997; Wisumperuma 2007). Hence it is important to understand whether the reduced extent of Guinea Grass could affect elephant body condition. Accordingly, this study was conducted with the following primary objectives: (a) Studying the proximate nutrients of selected plant materials in the diet of elephants at UNPSL; (b) Understanding the diet composition in relation to gender and body condition of elephants at UNPSL; and (c) Obtaining an ecological insight into the relationship between diet composition of elephants and the nutritional composition of their feeding materials. Also, the secondary objective of this study was to compare the nutritional value of invasive *M. maximus* with the selected food plants, especially the other grass species.

MATERIALS AND METHODS

Study site

Udawalawe National Park of Sri Lanka (UNPSL) has an extent of 308.2 km^2. It is located between 6.4167^{0}N & 6.5833^{0}N, 80.7500^{0}E & 81.0000^{0}E in the intermediate zone between wet zone and dry zone (Figure 1). The location experiences dry periods between a narrow rainy period (February to April) and a longer rainy season from end of August to December. The mean annual rainfall of UNPSL is about 1,524 mm (Angammana et al. 2015) and Udawalawe and Mau Ara reservoirs are found within it. Major vegetation types of UNPSL are comprised of intermediate zone to dry zone transitional monsoon moist forests in the northern part, dispersed grasslands, scrubs, and different stages of succession (Panwar & Wickramasinghe 1997; Alahakoon et al. 2017).

UNPSL is the third most visited national park of Sri Lanka (Kariyawasam & Sooriyagoda 2017). It is well known for easy sighting of elephants and has been recorded to host 800–1,160 elephants (de Silva et al. 2011).

Permission was obtained from the Department of Wildlife Conservation, Sri Lanka, for observation of elephants, collection of elephant dung and plant samples (Permit No: WL/3/2/55/19).

Determination of nutritional composition in forage

Sample collection

Upon conducting opportunistic focal animal sampling for 66 hours in August 2019, 11 plant species were selected based on the observed foraging behaviour of Sri Lankan elephants *Elephas maximus maximus* inhabiting the site. Selective feeding of mammalian herbivores extends further from plant species to specific plant parts (Owen-Smith & Chafota 2012). Therefore, plant parts varying from complete aerial body, stem, leaves, to fruits, were collected according to the choice of plant varieties by the elephants. Plant parts were selected considering the acceptance of the plant from an observed site, based on the elephant's behaviour, as described in Owen-Smith & Cooper (1987).

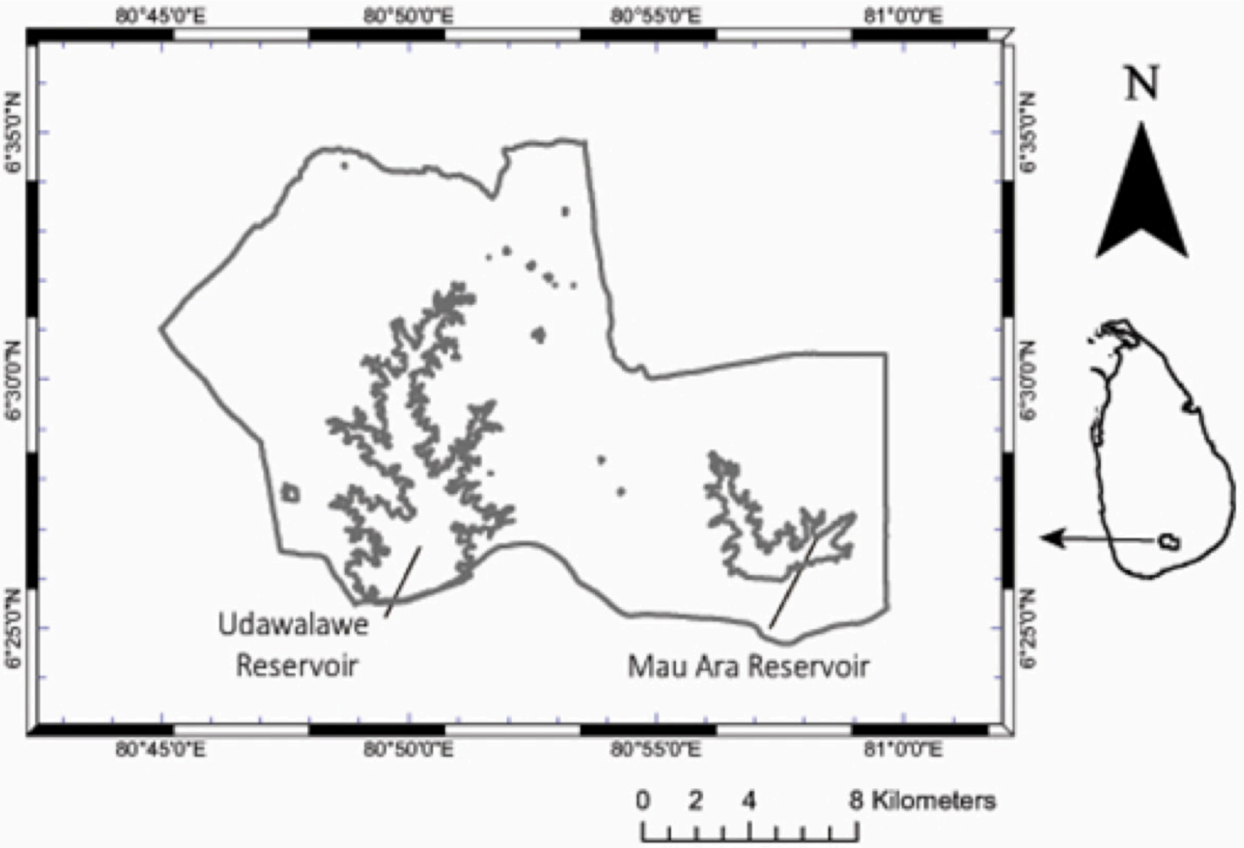

Figure 1. Udawalawe National Park of Sri Lanka (mapped by authors).

The acceptance value was calculated by dividing the utilised number of plants from the available number of plants of a species from the observation site (Owen-Smith & Cooper 1987). Browsed species were counted as individual plants, adapting the method to count grazed species as patches (1x1 m^2) due to their numerous availability and maximum utilisation of their aerial body. It was assumed that the patches of small herbs and grasses were not heavily mixed and represented the nearest randomly missed out/ dropped plants during feeding. The extent of the observation site was determined according to the utilisation area of the focal elephant until it moved out of sight. Plants that had an acceptance rate above 0.5 were selected for sample collection.

Most of the plant species were identified in situ, however, when it was difficult to identify, herbarium samples of the unidentified species were obtained for identification using guides, reference herbarium collections, and through expert assistance. About 200 g of fresh plant matter was collected into re-sealable plastic bags.

The amount of nutrients in plants can differ among habitats, seasons, and maturity of the plant (Rothman et al. 2012; Das et al. 2014; Koirala et al. 2018). Hence the plant parts were selected from the same plants that the elephants were feeding from. For grasses and herbs, samples were collected from the same site as the same plant could not be obtained due to total consumption by the elephants.

Sample preparation

The nature of the consumed plant part, such as maturity, and the exact way in which the plant part was processed by the elephant was also considered during sample preparation (Dierenfeld 2006; Rothman et al. 2012; Ranjeewa et al. 2018). For example, it was observed in the field that elephants feed on thorny *Limonia acidissima* stems only after removing thorns with the aid of their trunks before ingestion. Mature *Bauhinia* legumes were analysed, and the complete legume was used without separating seeds during laboratory analysis. It was presumed that the entire legume was processed in the gut as manual dissection of dung analysis did not reveal any traces of the legume. The digestion of the legumes in elephants is not known, although *Bauhinia* seeds have been found in elephant dung (Chathuranga &

Ranawana 2017).

Collected samples were washed and allowed to dry in the shade before being used in analysis of nutrients. Long twigs and stems were cut to small parts. Prepared plant materials were mixed well before obtaining a subsample for nutritional analysis, to ensure random sampling.

Sample analysis

The amount of moisture, dry matter (DM), ash content, crude protein and crude fats was measured in the plant samples collected from the selected species and quantified amounts were expressed as a percentage of initial mass (w/w). It was assumed that the remaining mass amounts for the total carbohydrates in the sample and it was estimated by substituting the amount of other measured nutrients for the following modified equation adopted from Maclean et al. (2003).

Total carbohydrate % = 100% – ([crude protein + crude fats + water + ash content] %)

All analysed nutrient masses were weighed using an analytical balance BSA223S-CW (max 220 g, least count = 1 mg). The results of analysis were expressed as fed (wet) and dry matter percentages. Analyses were triplicated.

Dry matter/ moisture and ash content

Subsamples of 10 g were measured from each of the collected plant samples and then dried in an air circulating oven at 70–80°C until a constant mass of dry biomass was obtained (Levett et al. 1985). Moisture content was calculated by deducting the dry biomass from the wet biomass.

Oven dried samples were transferred to porcelain crucibles, dried at 550° C for 4 h in a muffle furnace (Model HD-230, Spain) (Richards 1993). The mass of the obtained ash was weighed, to express the percentage wet mass.

Proteins

Proteins were extracted from the samples of 0.5 g of plant material using the salt/ alkaline extraction method with modifications. The prepared plant protein samples were analysed by mixing 1 ml of plant extract with 4.5 ml of Biuret reagent against the blank sample using an UV–Vis spectrophotometer at 545 nm wavelength. The obtained absorbance values were traced to determine the respective concentrations of protein in the samples, using a standard curve obtained for known concentrations of Bovine Serum Albumin (BSA) with Biuret reagent within the range of absorbance (545 nm) at 0.2–0.7.

Crude fats

Fresh samples of 5 g were randomly picked from the collected plant samples. Solvent extraction (AAFCO Lab Methods and Services Committee 2014) with diethyl ether was performed for the plant samples.

Micro-histological composition of dung

Dung samples were freshly collected soon after defecation from 26 elephants, out of a total of 509 individual elephants assessed in UNPSL from August to November 2019. The sampling period covered both wet and dry seasons. Two boluses of dung from each elephant's dung pile were collected in a re-sealable plastic bag within a short period upon defecation as soon as the elephants left the study site. Gender and age of the elephants were determined according to Varma et al. (2012). The body condition scoring (BCS) method used in this study replicated the modified Wemmer et al. (2006) method used by Ranjeewa et al. (2018) previously in UNPSL. The visual body condition scoring method which assesses fat deposition in seven prominent areas of the elephant's body considered the appearance of the following body areas: temporal depression at the head, distinction of shoulder blades at the scapular area, prominence of ribs at the thoracic area, the area immediately in front of the pelvic girdle at the flank, the spine between shoulder and pelvic girdle at the thoracic spine, the spine between the pelvic girdle and base of tail at the lumbar spine, and the pelvic girdle at the pelvic area. The recorded body condition scores were normally distributed from a minimum of three (3) to a maximum fourteen (14) within the range of the methodology (0–14). The elephants were identified individually by the morphological features on their body (depigmentation, lumps, wounds, ear tears, ear shape, tail characters, etc.) as described in Fernando et al. (2011) and Vidya et al. (2014).

The ratio of the monocotyledonous and dicotyledonous tissues of dung samples was determined microscopically. A subsample of 20 g of dung was obtained and processed according to Fernando et al. (2016) for the microscopic analysis of plant tissues in elephant dung. A scraping of the final residue was observed under the light microscope at x100 magnification, and the monocotyledonous and dicotyledonous tissues were counted using a Sedgewick rafter counting chamber. Each subsample was observed in triplicates to determine an average count of monocotyledonous and dicotyledonous tissues.

Statistical analysis

To test the hypotheses, the dung analysis and nutrition analysis data were checked for normality and statistically tested using IBM SPSS Statistics version 26 software. The relationship of the visual body condition score and the gender of wild elephants (n = 26), with the monocotyledonous and dicotyledonous tissue count in their dung samples was analysed with Pearson correlation test and chi-square test for association, respectively. The sample means between the monocotyledonous and dicotyledonous tissue counts in each gender group, as well as the sample means of tissue counts of each plant group between the genders was compared by two sample t tests to further understand the relationship between the diet composition and the gender of elephants.

In the nutritional analysis of selected food plants, the mean values and standard errors were calculated for each analysed plant species as well as the plant group (monocotyledonous and dicotyledonous). The composition of moisture, dry matter in the monocotyledonous and dicotyledonous plants was compared by Mann-Whitney test. The 'as fed' and 'dry matter' compositions of each proximate nutrient (ash content, crude protein, crude fats, and total carbohydrates) between the two groups of monocotyledonous and dicotyledonous plant samples were also compared using Mann-Whitney test or two sample t tests according to the normality of data distribution.

To examine whether *Megathyrsus maximus* had a significantly different nutritional contribution from other selected grasses, the nutrition composition of grasses was compared using the Kruskal-Wallis test and post hoc pairwise comparison.

RESULTS

Plant sample collection

Five monocotyledonous plants which were all grasses (Family Poaceae) and six key dicotyledonous plants were selected for the nutritional analysis based on observation of elephant foraging behaviour and are shown in Table 1.

Forage nutrition

The nutritional composition of analysed plant materials was expressed in mass percentages in both wet basis and dry basis (DM) as given in Table 2. Figure 2 presents the moisture content, total dry matter, and other nutrients (ash content, crude proteins, crude fats, total carbohydrates) in wet basis, while Figure 3 presents the dry basis of the nutrients in the studied plant samples.

It was observed that monocotyledonous plants (Mean±SE: 74.76±0.96) had a significantly higher amount of moisture over dicotyledonous plant parts (42.4±3.30) consumed by elephants. DM in dicotyledonous plants was significantly higher compared to monocotyledonous plants ($P < 0.001$). The as fed composition of ash content (7.80±1.40) and total carbohydrates (29.50±4.00) in the dicotyledonous plants was significantly higher than the as fed ash content (3.10±0.20) and total carbohydrates (14.17±0.90) in monocotyledonous plants ($P < 0.001$). There were no significant differences in the dry matter compositions of nutrition between monocotyledonous and dicotyledonous samples.

Megathyrsus maximus was similar to several other grasses assessed in this study for each proximate nutrient either in as fed or dry matter composition.

Table 1. Selected plants and different parts used for the analysis.

Group	Plant (Scientific name and Common name)	Analysed part	Foraging method by elephant	Acceptance value
Monocotyledonous	*Megathyrsus maximus* (Guinea Grass)	Total aerial body	Grazed grass	0.67
	Lepturus radicans	Total aerial body	Grazed grass	0.79
	Cyrtococcum spp.	Total aerial body	Grazed grass	0.88
	Bouteloua dactyloides (Buffalo grass)	Total aerial body	Grazed grass	0.72
	Garnotia fergusoni	Total aerial body	Grazed grass	0.71
Dicotyledonous	*Phyllanthus polyphyllus*	Leaves	Grazed shrub	0.85
	Achyranthes aspera (Devil's horsewhip)	Total aerial body	Grazed herb	0.67
	Cryptolepis buchananii	Leaves from a young climber	Browsed climber	0.73
	Bauhinia racemosa	Mature dried fruit (legume)	Browsed/ Picked from ground	0.62
	Ziziphus oenoplia (Jackal Jujube)	Leaves from young tree	Browsed shrub	0.58
	Limonia acidissima (Woodapple)	Leaves and stem from young tree	Browsed tree	0.55

Table 2. Mass percentage of nutritional composition of analysed plant samples (sample size: 3).

Group	Plant sample	Percentage (%) (Mean±SE)									
		Moisture content	Dry matter (DM)	Ash content		Crude protein		Crude fats		Total carbohydrates	
				As fed	DM	As fed	DM	As fed	DM	As fed	DM
Monocotyledonous	*Megathyrsus maximus*	73.90 ±1.21	26.10 ±1.21	3.36 ±0.70	13.20 ±3.30	5.84 ±1.69	22.01 ±6.02	0.35 ±0.04	1.31 ±0.11	16.55 ±1.29	63.48 ±4.49
	Lepturus radicans	75.87 ±0.91	24.13 ±0.91	3.50 ±0.15	14.5 ±0.12	4.87 ±0.67	20.04 ±1.98	0.35 ±0.02	1.44 ±0.06	15.41 ±0.17	64.02 ±2.00
	Cyrtococcum sp.	79.51 ±0.04	20.49 ±0.04	3.64 ±0.21	17.76 ±0.98	5.56 ±0.66	27.11 ±3.19	2.83 ±0.15	13.79 ±0.71	8.46 ±0.97	41.34 ±4.82
	Bouteloua dactyloides	75.57 ±1.19	24.43 ±1.19	2.75 ±0.41	11.16 ±1.29	8.31 ±0.85	33.86 ±2.36	0.05 ±0.00	0.20 ±0.02	13.32 ±0.48	54.78 ±3.62
	Garnotia fergusoni	68.96 ±0.39	31.04 ±0.39	2.25 ±0.18	7.24 ±0.61	11.06 ±0.60	35.7 ±2.38	0.61 ±0.06	1.98 ±0.22	17.11 ±1.03	55.08 ±2.64
Dicotyledonous	*Phyllanthus polyphyllus*	60.07 ±0.56	39.93 ±0.56	2.97 ±0.29	7.45 ±0.79	25.33 ±0.37	63.44 ±0.63	1.64 ±0.40	4.08 ±0.93	9.99 ±0.03	25.02 ±0.27
	Achyranthes aspera	48.20 ±0.05	51.80 ±0.05	7.84 ±0.14	15.13 ±0.28	3.45 ±0.40	6.67 ±0.78	23.72 ±0.68	45.78 ±1.27	16.79 ±0.99	32.42 ±1.95
	Cryptolepis buchananii	61.23 ±0.08	38.77 ±0.08	2.89 ±0.13	7.45 ±0.35	22.51 ±1.72	58.05 ±4.35	0.85 ±0.09	2.18 ±0.23	12.52 ±1.52	32.31 ±3.97
	Bauhinia racemosa mature legume	19.40 ±0.49	80.60 ±0.49	5.43 ±0.79	6.74 ±1.16	45.75 ±3.58	56.79 ±2.60	0.29 ±0.03	0.36 ±0.22	29.13 ±3.30	36.11 ±3.87
	Ziziphus oenoplia leaves	38.00 ±0.31	62.00 ±0.31	20.47 ±2.83	32.97 ±4.42	5.46 ±1.04	8.80 ±1.66	0.30 ±0.04	0.49 ±0.06	35.77 ±3.06	57.74 ±5.25
	Limonia acidissima leaves	34.27 ±0.82	65.73 ±0.82	9.10 ±0.62	13.82 ±0.78	11.39 ±1.61	17.39 ±2.66	3.54 ±0.11	5.39 ±0.17	41.71 ±1.80	63.41 ±1.94
	Limonia acidissima stem	27.79 ±0.73	73.21 ±0.73	5.14 ±0.17	7.12 ±0.28	6.26 ±0.81	8.70 ±1.21	0.22 ±0.01	0.31 ±0.02	60.59 ±1.61	83.88 ±1.47

Micro-histological analysis of elephant dung

Among the 26 individual elephants, 10 were males and 16 females, and 24 were adult elephants while two were subadult males. The average ratio of monocotyledonous (grasses): dicotyledonous tissues in dung was 1: 0.73 (57.95: 42.04±3.78 %) in average. The relative abundance of monocotyledonous tissues (0.58±0.03) was significantly higher than that of dicotyledonous tissues (0.42±0.03) ($p < 0.001$) in the examined dung samples. There was no significant difference between the abundance of monocots ($p = 0.877$) or dicots ($p = 0.815$) between the wet and dry seasons.

There was an association between the gender of the elephants and the type of tissues (monocotyledonous, dicotyledonous) found in their dung ($p = 0.041$, Pearson chi square = 4.196). The relative abundance of monocotyledonous tissues (64±4.8%) was significantly higher than dicotyledonous tissues (36±5.0%) in dung samples obtained from males ($P < 0.001$). However, based on the dung analysis, there was no significant difference between the abundance of monocotyledonous and dicotyledonous tissues detected in dung samples of female elephants.

There was no significant difference ($p = 0.065$) between the relative abundance of monocotyledonous tissues detected in the dung samples of male and female elephants. Also, a significant difference was not observed ($p = 0.132$) between the relative abundance of dicotyledonous tissues detected in the dung samples of male and female elephants.

The average body condition of the focal elephants was 8.15±1.73. The lowest BCS recorded was three (3) while the highest was fourteen (14). The body condition score of the elephants had no significant correlation with the abundance of monocotyledonous tissues or the abundance of dicotyledonous tissues. Neither did the relative abundance of monocotyledonous or dicotyledonous tissues correlate with the body condition score of the elephants. This result was consistent when each gender group (male and female) was considered separately. There was no correlation between the body condition and the abundance of monocots or dicots within either gender group.

DISCUSSION

This study is the first comparative analysis of nutrition between the grasses and other forage of wild elephants in Sri Lanka. Although many studies have reported the

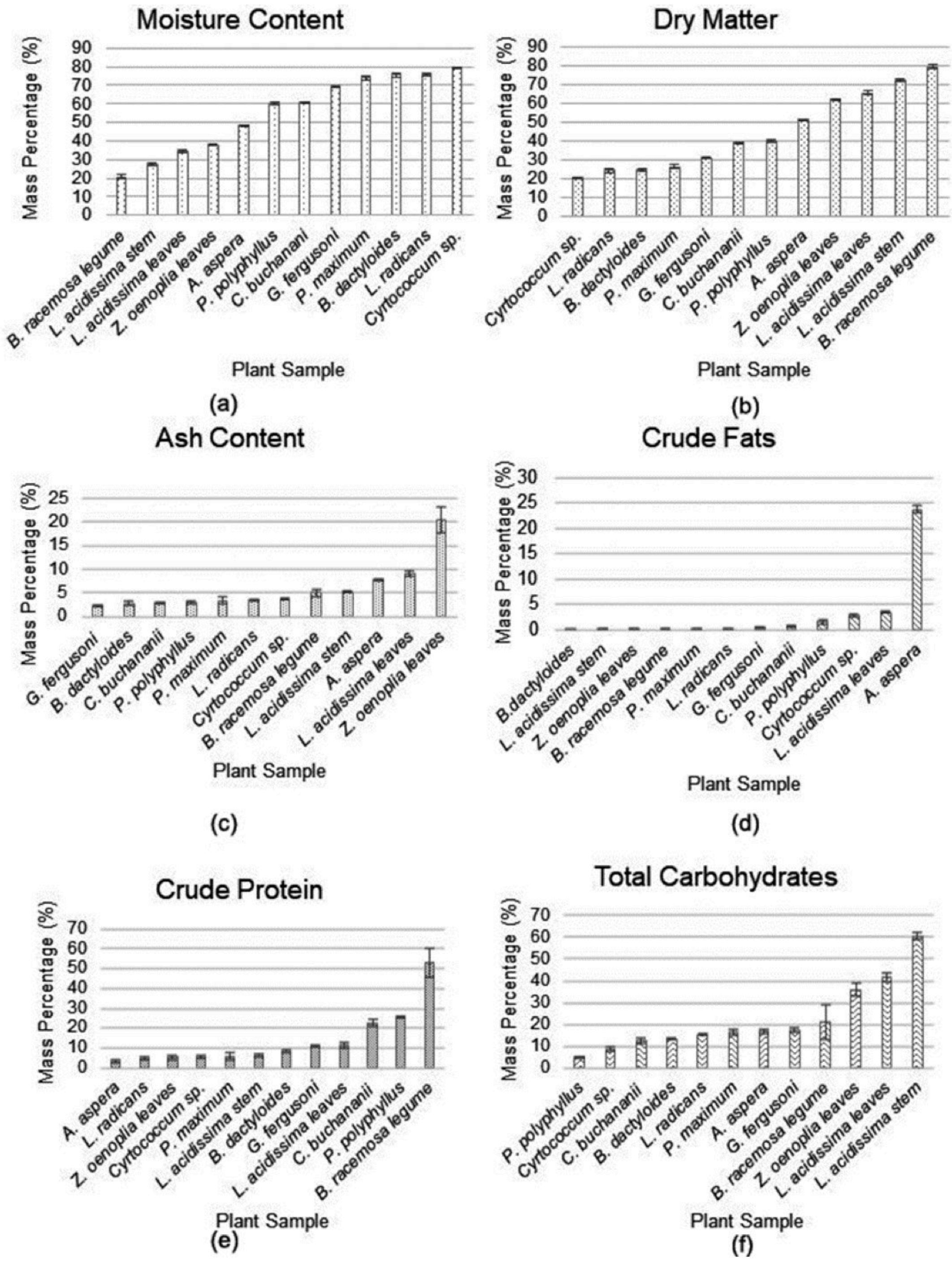

Figure 2. Percentage (w/w) (%) in as fed basis: a—Moisture content | b—Dry matter | c—Ash content | d—Crude fats | e—Crude protein | f—Total carbohydrates.

ratio of monocotyledonous to dicotyledonous tissues in elephant dung (Steinheim et al. 2005; Samansiri & Weerakoon 2007; Koirala et al. 2016), this is also the first study to report dung composition of identified adult wild elephants from Sri Lanka, enabling the comparison of their body condition and gender with their diet composition revealing important novel findings. According to the dung analysis results, the diet preference of elephants in UNPSL is dominated by monocotyledonous plants, represented mainly by grasses. However, the results suggest a difference in the diet composition of the males and females. There was no relationship between the body condition of elephants and the plant type. The proximate analysis revealed that dicotyledonous food plants are more nutritious than monocotyledonous grasses as expected. But the moisture content of grasses was unexpectedly high, suggesting that the preference for grasses may be influenced by the feed moisture as well. *Megathyrsus maximus* was similar to other selected grass species in nutrition. Altogether, these results suggest that the disappearance of invasive *Megathyrsus maximus* from UNPSL could not affect the body condition of the elephants.

Proportions of Monocot and Dicot Tissues

The results are consistent with previous research that suggests that the Asian Elephant is adapted to a natural diet high in grass. Samansiri & Weerakoon (2007) had also reported that monocotyledonous tissues were dominant in the dung collected from elephants in northwestern areas of Sri Lanka. Alahakoon et al. (2017) observed that elephants in UNPSL show a higher behavioural frequency in feeding grasses. The same has been observed in Assam, India (Borah & Deka 2008). Grasses are accessible to elephants of all age groups (Baskaran et al. 2010). Juveniles predominantly forage on grasses (Samansiri & Weerakoon 2007). The diet composition of elephants has been observed to change among seasons in other countries (Steinheim et al. 2005; Chen et al. 2006; Lihong et al. 2007; Pradhan et al. 2008; Baskaran et al. 2010; Koirala et al. 2018). Generally, the Asian Elephant foraging is considered to be dominated by grazing during the wet season and browsing during the dry season (Sukumar 1990; Baskaran 2010). In Nepal, it has been observed that while browsing is dominant during dry season, both browsing and grazing are equally important during the wet season (Koirala 2016). However, in Sri Lanka, especially UNPSL, it has been reported that grasses have remained dominant in the diet constantly as they regenerate during each season, as usual during wet season and as a special occurrence on exposed tank beds of the main two reservoirs within UNPSL during the dry season (Alahakoon et al. 2017; Ranjeewa et al. 2018; Sampson et al. 2018). Hence, the absence of a significant difference in monocots or dicots between the wet and dry seasons is possibly due to the influence of climatic factors and geographic features at UNPSL.

The dung composition and the gender biased access to resources

No reported information was found on the diet composition and gender of elephants in literature and an interesting difference between the genders was observed in the present study. Adult male and female elephants indicate distinct gender roles in the wild. Generally, female elephants live in family units while adult male elephants are solitary animals (McKay 1973; Schulte 2006). The same social arrangement was observed in the UNPSL during this study. Sri Lankan elephants avoid competition for food (Yapa & Rathnavira 2013). McKay (1973) reported that Sri Lankan elephant herds stay separated from other herds in the same area and the female movement rates are significantly slower when moving, while feeding, owing to needs to nurture and care for the young. Accordingly, the amounts and flexibility of food choice available for female elephants in herds are limited in comparison to solitary males. Male elephants are also accused of raiding crops which mainly involve monocotyledonous plants such as paddy *Oryza sativa*, maize *Zea mays* of family Poaceae, and palms (Arecaceae) such as coconut *Cocos nucifera* and kitul *Caryota urens* that are generally found associated with human settlements (Samansiri & Weerakoon 2007; Fernando 2015a).

The nutritional needs of animals change with their stage of life. The young and juvenile need nutrition for weight gain, bone and muscle development, while lactating and expectant animals require additional nutrition for nourishing the young (Birnie-Gauvin et al. 2017; Bechert et al. 2019). In Argali *Ovis ammon*, males have been identified to select abundant forage of lower quality (grasses and forbs) and females to select higher quality forage (forbs and shrubs) to achieve energy requirements for nursing and gestation (Li et al. 2018). Consuming more and different types of food plants that are high in nutritional quality minimizes the animal's effort for finding nutritious food (Owen-Smith 1988; Shannon et al. 2006). Moisture also assists digestion and lactation of females to nurse calves (Beede 2005; Van Weyenberg 2006). Accordingly, it could be inferred from the results that both monocotyledonous grasses and diverse dicotyledonous plants are equally important in the diet composition of an adult female elephant due to their behavioural role. Therefore, the difference in dung composition results in males and females is suggested to be due to behavioural differences affecting food selection of the two genders.

Nutritional composition

The dicotyledonous plants were significantly higher in dry matter nutrition than the monocotyledonous grasses, although the diet composition of the Asian elephants is dominated by monocotyledonous plants. This finding is consistent with previous reported studies

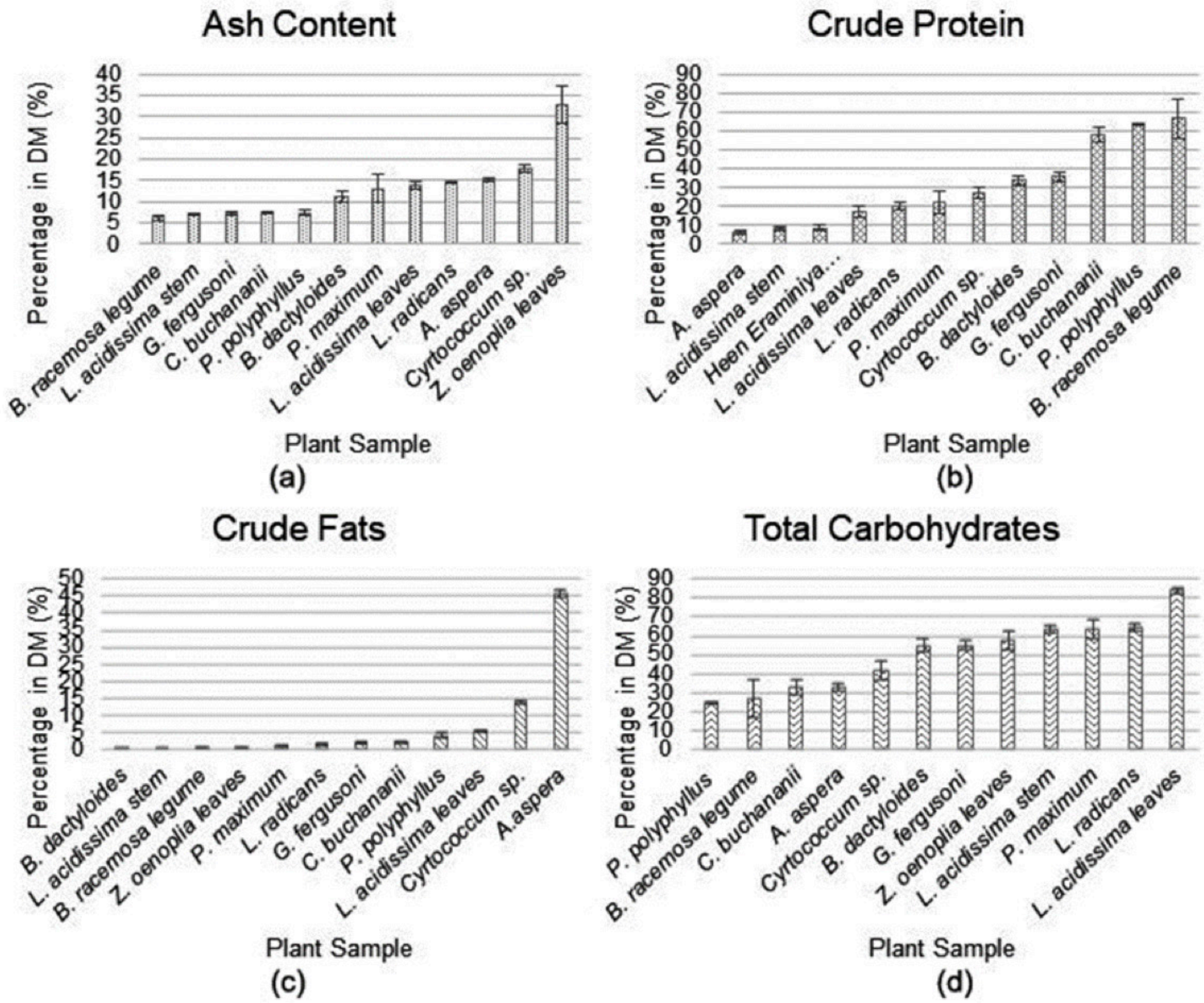

Figure 3. Percentages (w/w) (%) in dry matter basis: a—Ash content | b—Crude protein | c— Crude fats | d—Total carbohydrates.

on elephant nutrition with dicotyledonous plants occupying the highest values for various nutrients (Chen et al. 2006; Lihong et al. 2007; Das et al. 2008; Santra et al. 2008; Borah & Deka 2014). In contrast, the grasses indicated an unanticipated significantly high moisture content (about 70% w/w).

Previous studies conducted on the nutrition of elephant forage have focused on dry matter as that accounts for providing energy to the animal (Chen et al. 2006; Borah & Deka 2007; Lihong et al. 2007; Santra et al. 2008; Rothman et al. 2012; Das et al. 2014; Koirala et al. 2018). Although Santra et al. (2008) present moisture composition, the selected plant parts are limited to browsed plant parts identified from signs of plant damage. This is the first report on the moisture content of both grazed and browsed plant species of elephants.

Feeding large quantities of grass of low nutritional quality and their rapid passing through the gut by large herbivores is recognised as a mechanism of gaining more energy from low quality feed abundant in the environment (Bell 1971; Owen-Smith 1988; McArthur 2014). However, elephants are known to select food from their environment despite their availability (Koirala et al. 2016; Birnie-Gauvin et al. 2017). Therefore, the high moisture in the grass could be an additional incentive for the Sri Lankan elephant that mostly inhabits the dry zone, to select more grasses from their environment. Moisture contributes to the palatability of forage which is a factor in selection and rejection by elephants (Lihong et al. 2007; Santra et al. 2008; Das et al. 2014). Elephants have a high utility rate of water with limited ability to concentrate urine and water loss occurring from frequent urination and defecation (Ratnasooriya et al. 1994; Cheeke & Dierenfeld 2010). Freshly defecated elephant dung has been reported to hold 45–75% (w/w) water content (McKay 1973). The amount of moisture and water holding capacity in feed intake assists digestibility, passage of materials through the gut, and defecation as well (Van Weyenberg et al. 2006). African Elephants have been reported to increase woody parts in their diet during the dry season as the stem and pith of woody plants contain more water content (Owen-Smith 1988; Rothman et al. 2012; Greene et al. 2019). Horses are considered to be closest to elephants in the digestion physiology (Bechert et al. 2019; Greene et al. 2019). Captive horses have also been reported to select hay samples with more moisture and hay wetting behaviour (Müller & Udén 2007; Muhonen et al. 2009; Harris et al. 2016; Müller 2018). Hence, the high moisture content in grass influences preference and selection by elephants.

As elephants are hindgut fermenters, it is considered that they are benefitted from more fermentable feed due to limited digestion of fibre in their gut. The fibre in grass could draw water which is important for the fermentation process required for digestion in the hindgut (Sneddon & Argenzio 1998; Muhonen et al. 2009; Bechert et al. 2019).

Body Condition Score

The relationship of the elephant body condition with their diet composition has not been described previously. The results of this study do not support previous inferences that the availability of grass in the environment supports better body condition of elephants (Ranjeewa et al. 2018). According to Ranjeewa et al. (2018) the average body condition scores of elephants are higher during the dry seasons as more grass grows on the exposed tank bed due to receding water levels. However, according to this study, the relative abundance of monocotyledonous tissues (grasses) in their diet does not correlate with their body condition. Hence the availability of more grasses, especially a single grass species such as *Megathyrsus maximus* in the environment could not be considered as a contributing factor to the elephant body condition.

***Megathyrsus maximus* at UNPSL**

Megathyrsus maximus was not outstanding in nutrition from the other selected plants. Pairwise comparison between the five selected grass species revealed that *Megathyrsus maximus* was nutritionally similar to one or few of the other four grasses (*Bouteloua dactyloides, Cyrtococcum* sp., *Garnotia fergusoni*, *Lepturus radicans*) for the different proximate nutrients analysed, both in as fed and dry matter basis. A study conducted from December 2005 to January 2007 states that 67% of elephant sightings and feeding behaviour (28.9%) observations at UNPSL were made in *Megathyrsus maximus* grasslands that had occupied 39% of the land area of UNPSL (Alahakoon et al. 2017) unlike today where it is limited to a small patch of 0.13 km^2 near the entrance (less than 1% of the area). *Megathyrsus maximus* is a tall grass while other studied grasses were short. Its large size and biomass compared to other smaller ground hugging grasses is the reason for elephants' preference and choice (Fernando 2015b). Elephants are generalists with a large diet breadth. They are bulk feeders and do not linger at one plant species but move ahead through available choices giving it more access to choose food from the environment (McKay 1973). It is reported that they spend more time feeding on short grasses than long grasses (McKay 1973). It had been observed that elephants avoid areas of high *M. maximus* abundance while indicating a positive correlation with short grasses (Sampson et al. 2018). Thus, it could be presumed that Guinea grass does not have an effective nutritional influence for elephant diet in UNPSL.

The dung analysis did not identify *M. maximus* separately, even though the monocotyledonous and dicotyledonous tissues could be distinguished. Presuming that the monocotyledonous tissues in elephant diet are mainly represented by grass according to the vegetation in the UNPSL (DWC 2008), as there was no linear relationship between the abundance of either tissue type with body condition, although there was a significantly high abundance of monocots, it could be concluded that the amount of grass in the diet has no effect on body condition of elephants. Hence, the findings of this study challenge the notion that the reduced distribution of invasive Guinea Grass (*M. maximus*) was the reason for poor body condition of elephants at UNPSL.

Information on dietary choice and differences in elephants are essential for informed decision making in their conservation and management. The elephants in UNPSL preferred grasses, but demonstrated a difference in the food plant selection between the genders which could be attributed to their gender biased behaviour. As generalist megaherbivores with a large diet breadth (Fernando & Leimgruber 2011), elephants are allowed for greater flexibility in food choice as preferred and required. Therefore, a single type of food plant such as grass or a single species such as *Megathyrsus maximus* could not influence their body condition. The most preferred grasses exhibited lower nutritional quality than other preferred food plants, but the high water content in grass suggest that the moisture could influence the diet selection of the hindgut fermenting megaherbivore. While this preliminary study provides information on the diet composition of Sri Lankan elephants, further research should be conducted on the nutrition and food plants of the Sri Lankan elephant expanding across their large diet breadth, the varying seasons, and different localities of the elephant within the island. Additionally larger sample sizes and more in-depth analysis are needed to fully understand the nutritional contribution of different forage types and their implication for elephant health and well-being.

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Articles

Communications

Short Communications

Notes

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