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Food and Feeding Patterns of Asian Elephants in Udawalawe National Park, Sri Lanka

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Abstract. Asian elephants feed on a wide variety of vegetation but their preference for particular plant species maybe an important factor in determining seasonal movements. We identified 63 elephant fodder plants in Udawalawe, consisting of 19 trees and 44 herbs and grasses. Elephant fodder species mainly occurred in scrub forest (40%) and grasslands (31%). Elephants in Udawalawe were more grazers than browsers year round. Availability of seasonal vegetation is a possible factor, keeping elephants inside the park during the dry season.

Introduction

Sri Lanka supports a population of Asian elephants (*Elephas maximus*) estimated at 5879 individuals (DWC 2011). Asian elephants are globally threatened by rapid fragmentation and loss of habitat (Leimgruber *et al*. 2003). They prefer scrub forest and areas with grass, low woody plants and forest (Angammana *et al*. 2015). In Sri Lanka, elephants currently inhabit dry evergreen and thorn-scrub forests in the dry zone, having been largely extirpated from the wet zone rainforests by landuse changes over the last century (Fernando 2000).

Availability of food determines the size of home ranges and movement of elephants (Fernando *et al*. 2008). Elephants rarely forage in one area for more than a few days at a stretch (Kumar *et al*. 2010). Requiring a daily intake of about 150 kg, they feed on a wide variety of vegetation (Sukumar 1989). A study conducted on African elephants suggests that their preference for particular plant species is an important factor dictating their movement (Osborn 2002). Acording to Holdo (2003) relatively little is known about the nutritional factors influencing food and habitat selection of African elephants or Asian elephants. Details regarding food choice and seasonal diet composition of Asian elephants remain largely unknown. Relatively few studies have been carried out in Sri Lanka on the food and feeding patterns of elephants (Mueller-Dumbois 1972; McKay 1973; Ishwaran 1983; Santiapillai *et al*. 2003; Santiapillai & Jackson 1990; Samansiri & Weerakoon 2007; Angammana *et al*. 2015).

Methods

Study area

The Udawalawe National Park is located in southern Sri Lanka between latitude 6º 25' N and 6º 35' N and longitude 80º 45' E and 81º 00' E. The 308 km^2 park largely comprises of the catchments of Udawalawe and Mau Ara reservoirs. Since the park is located in the dry zone, conditions are characterized by an annual drought coinciding with the southwest monsoon from May to September. Mean annual rainfall is about 1524 mm received mainly through the northeast monsoon from December to March. Mean day and night temperatures are 29.4ºC and 23.9ºC, respectively (Angammana *et al*. 2015). The Udawalawe National Park supports about 804–1160 Asian elephants, resulting in a high population density (de Silva *et al*. 2011)

The vegetation of Udawalawe National Park is comprised of intermediate zone to dry zone

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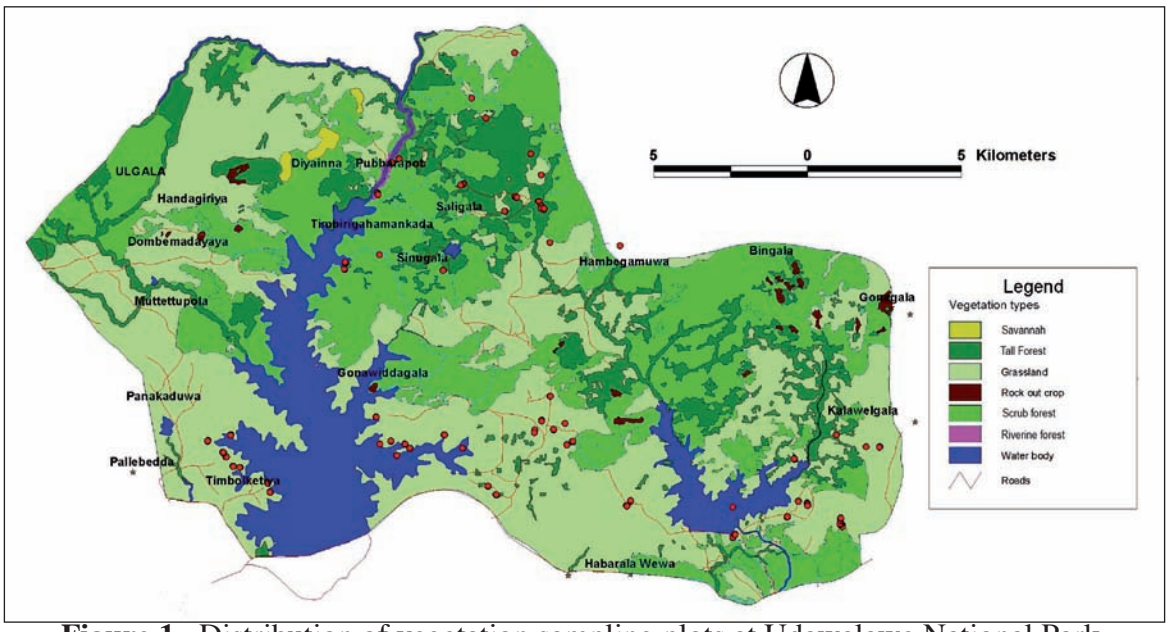

Figure 1. Distribution of vegetation sampling plots at Udawalawe National Park. The sampling plots are indicated in red circles.

transitional high forests in the northern part and interspersed areas of grass, scrub and stages of forest succession in the rest (Fig. 1). The park was originally forested, but anthropogenic activities have resulted in its change to grassland and scrub, which dominated a major part of it during the study period.

Data collection

The study was carried out from December 2005 to January 2007. Firstly, a pilot survey was done by driving through all accessible areas in the park to identify vegetation characteristics. On the basis of the pilot survey, the vegetation was categorised as tall forest, scrub forest, riverine forest, grassland, seasonal vegetation, and savanna land. The natural dry forests were dominated by tall trees with a well-developed canopy (Fig. 2). Vegetation dominated by small trees and shrubs were identified as scrub forests (Fig. 3) and tall buttressed, spreading trees arching over waterways were categorized as riverine foresets (Fig. 4). The grass dominated habitats with less trees were categorized as grasslands (Fig. 5) and grass dominated habitats with a conspicuous scattered tree component were categorized as savannah grasslands (Fig. 6). Seasonal vegetation was located in the reservoir beds, which became available only during the dry season when the reservoir water level receded. During the rainy season this area was under water (Fig. 7). These habitat types were differentiated using recent satellite images covering the park area and the extents of the different habitat types were estimated using ground-verified images. Based on this information, a habitat map was created using Arc GIS software version 9.1.

Observations were performed by vehicle from 6:00 to 18:30 h. Field sampling was carried out for 15 days per month over a period of one

Figure 2. Tall forest.

Figure 3. Scrub forest.

Figure 4. Riverine forest.

year. Driving routes were alternated in a random manner such that all parts of the road network across all habitat types were covered at least three times a month. An effort was made to make the sampling effort in every habitat similar in terms of number of days sampled.

Whenever an individual elephant was encountered, its feeding behavior was observed at 15 min intervals using binoculars. Habitat type, plant species consumed, its life form and part of the plant consumed were recorded. When a herd of elephants was encountered, the feeding behaviour of the entire herd was scanned at 15-minute intervals. The number of elephants feeding in each habitat (including adults, sub adults and calves), the type of feeding plant, its life form and the parts consumed were recorded. All data for individuals and herds were pooled and the relative frequency of feeding on a particular plant was calculated as the number of observations of feeding on a particular plant divided by the total number of observations for all plants observed feeding on.

Once the individual or the herd moved away, a 10 x 10 m plot was examined at the location. All plant species, which had signs of feeding and the parts consumed were recorded. Tree species (dbh > 5 cm), shrubs and saplings found within the quadrat were identified and counted. Grasses and herbs in the plot were identified and their percentages were visually estimated using five 1 x 1 m sub-plots established randomly within the larger plot. Relative cover was calculated and for tree species relative density was calculated from the data obtained. A specimen from each food plant species was collected to confirm identification by comparing with material available at the National Herbarium, Peradeniya. Plant life forms were identified based on Ashton *et al*. (1997).

Twelve 10 x 10 m permanent plots were established in grassland habitat to determine the species occurance in dry and wet seasons. In each plot, five 2 x 2 m sub-plots were laid randomly to observe the grasses and herbs. Sampling was carried out once a month throughout the study period. The types of grass species were identified and their relative cover within the plots was visually estimated.

A Pearson correlation test was performed to measure the relationship between the relative frequency of feeding on a particular plant and its availability in the area, to assess feeding preferences for grasses and herbs.

Results

Tall forests (Fig. 2) had a patchy distribution within the park and covered about 6.4% of the park area. Common tree species in the tall forests included *Diospyros ovalifolia, Chloroxylon swietenia* and *Drypetes sepiaria*. The understorey vegetation was characterised by *Psilanthus wightianus, Mallotus eriocarpus, Polyalthia korinti, Croton officinalis* and *Phyllanthus polyphyllus*.

Scrublands (Fig. 3) covered about 4.2% of the park area and were characterized by tree species such as *Chloroxylon swietenia, Mischodon zeylanicus, Memecylon umbellatum, Acacia leucophloes* and *Mallotus eriocarpus* and shrubs such as *Psilanthus wightianus, Phyllanthus polyphyllus, Carmona retusa, Lantana camara* and *Flueggea leucopyrs*.

Figure 5. Grassland.

Figure 6. Savanna grasslands.

Figure 7. Seasonal vegetation.

Riverine forests (Fig. 4) covered 1.13% of the park area. These forests were found along the banks of the Walawe river. *Dimorphocalyx glabellus, Walsura trifoliolata, Drypetes sepiaria, Diospyros ovalifolia, Hopea cordifolia* and *Pterospermum suberifolium* were common tree species and *Polyalthia korinti, Glycosmis* sp., *Polyalthia cerasoides, Mallotus philippensis, Carmona retusa, Tarenna asiatica,* and *Mallotus eriocarpus* were more abundant in the understory.

The grasslands were identified as a major component (39%) of the park vegetation. *Megathyrsus* grasslands (Fig. 5) with scattered trees were the most extensive grassland type. *Imperata* dominant grasslands were not very extensive and were found in the draw-down area of Seenuggala tank. Several patches of grasslands were also found surrounded by scrublands.

Savanna grasslands (Fig. 6) were located in hilly areas in the northern boundary of the park bordering Kapugala and Kaltota area. These forests were characterized by grasslands with scattered trees, most of which are fire resistant, such as *Anogeissus latifollus, Phyllanthus emblica, Flacourtia indica, Grewia damani* and *Pterocarpus marsupium*.

Seasonal vegetation is a temporary habitat formed during the dry season with the decline of the water level in the major reservoirs in the park (Fig. 7). This habitat was limited to the area between the maximum and minimum water levels of the reservoirs. *Cynodon dactylon, Panicum reptuns, Bracheira mutica, Eragrostis diplachoides, Cyperus paniceus, Kyllinga brevifolis* and *Megathyrsus maximum* were the most abundant grass species in the seasonal vegetation. Herbs such as *Coldenia procumbens, Alysicarpus glunaceus, Mollugo* sp., *Ludwegia* sp., *Xanthium indicum, Evolvulus* sp., and *Clitoria laurifolia* were also seen in the seasonal vegetation.

The data were collected over a period of 201 days. Elephant observation periods ranged from 8.26–123.58 min (mean 78.37 ± 12.54 min) for an individual per day. The number of days spent in each habitat and percent observations are shown in Table 1. Most of the elephant observations (69.7%) were made in grasslands and their feeding activities in *Megathyrsus maximum* grasslands were commonly seen. Comparatively less elephants were observed in other habitats such as natural forest, scrub forest and riverine forests. During the day time elephants were mainly found in the *Megathyrsus* grassland but in the evenings they moved to the seasonal vegetation on the reservoir bed where they gathered in large numbers. During the dry season elephants gathered more commonly in the reservoir bed seasonal vegetation than in other habitats (Fig. 8).

Table 1. Elephant feeding observations (EFO) in different habitats and sampling effort (SE).

Habitat	# days	% SE	% EFO
Tall forest	28	13.9	0.1
Scrubland	34	16.9	12.7
Riverine forest	27	13.4	0.2
Grassland	49	24.4	69.7
Seasonal veg.	35	17.4	17.2
Savannah	28	13.9	0.1

Altogether 63 elephant food plants belonging to 19 families were identified (Appendix I). Of these 44 were identified through direct observations of feeding and 19 from feeding signs. Elephants were found to feed more frequently on grasses such as *Megathyrsus maximus* (28.9%), *Cyrtococcum trigonum* (5.1%), and *Heteropogon contortus* (12.2%). Of the trees *Bauhinia racemosa* (7.1%)

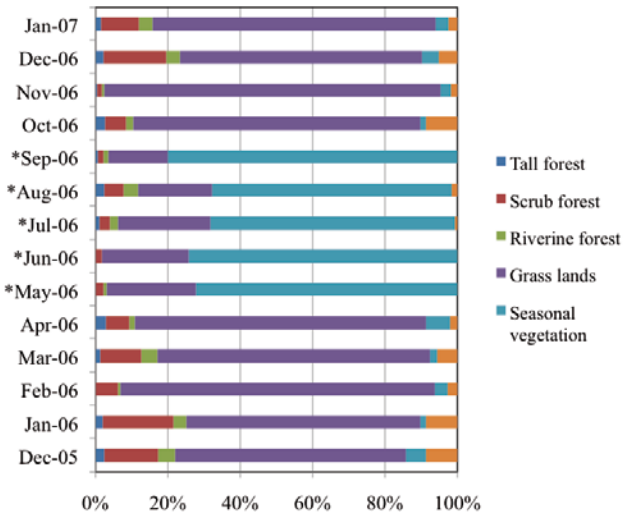

Figure 8. Observations of elephants feeding in different habitats. Dry months are indicated by *.

Table 2. Percentage of plant parts consumed by elephants in each life form category.

Life form	Trees	Shrubs	Herbs	Grass	Liana	Woody climber
All parts	-	-	72	58	-	-
Bark	35	-	-	-	-	-
Leaves, flowers	-	-	-	33	-	-
Stem	30	-	7	-	-	-
Bark, stem	20	-	-	-	-	67
Leaves, stem	5	-	21	-	100	-
Leaves	-	100	-	9	-	33
Bark, stem, leaves	5	-	-	-	-	-
Stem, fruits	5	-	-	-	-	-

and *Tectona grandis* (5.1%) had a higher feeding frequency (Fig. 9). Elephants were observed to feed more frequently on grasses (33%), trees (29%) and herbs (24%). Other plant forms such as lianas (3%), climbers (2%) and small trees (6%) were represented in small quantities in elephants' diet.

Elephants consumed different parts of different life forms of vegetation (Table 2). When feeding on trees they mostly consumed bark or stem (35% of observations for each) or both bark and stem (20% of observations). The bark of tree species such as *Bauhinia racemosa*, *Tectona grandis*, *Cassia fistula*, and *Grewea damani* was consumed regularly. Certain grasses (57%) such as *Megathyrsus maximus*, *Panicum repens* and herbs (35%) such as *Achyranthes aspera*, *Aerva javanica* were consumed whole. Elephants seemed to prefer leaves and flowers (33%) in grass species such as *Cyperaceae exaltatus*, *Cyperus procerus*, *Digitaria bicornis*, *Eragrostis tenella*, *Eriochloa procera* and *Heteropogon contortus*.

Most elephant fodder species were available in grassland and scrub forest habitats, where species such as *Megathyrsus maximum*, *Heteropogon contortus* and *Bauhinia racemosa* are abundant (Fig. 10). Availability of fodder species of elephants varied seasonally. Many species were available both in the dry season and in the wet season while a few species were confined to the seasonal vegetation in the reservoir bed and were available only in the dry period (Appendix I).

During the dry season, most fodder species in the park dry up and die, except for the grasses on the reservoir bed (Figs. 11 & 12) which elephants used extensively. A larger number of elephants were seen in the reservoir beds than in the grasslands or other habitats during the dry season. Common food plants such as *Cynodon dactylon, Eragrostis tenella,* and *Panicum repens* were found mostly in the seasonal vegetation during the dry season. Therefore, seasonal vegetation serves as the major dry season feeding ground for elephants.

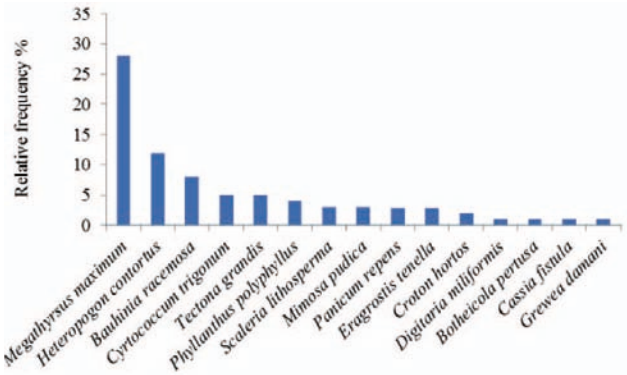

Figure 9. Relative frequency of food plant consumption based on observations.

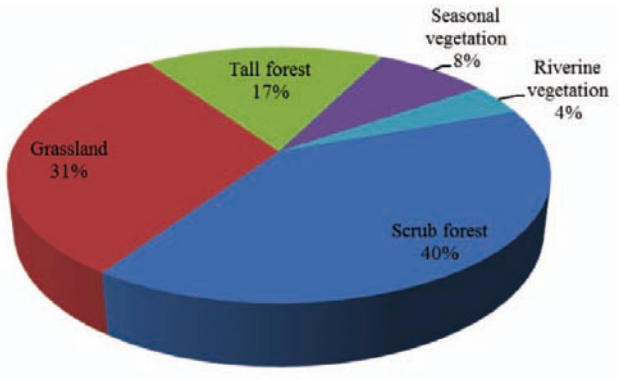

Figure 10. Availability of elephant fodder plants in different habitats.

Table 3. Availability of grasses and herbs in the seasonal vegetation (* = species consumed by elephants).

Family	Species	Life form	% cover
Poaceae	*Cynodon dactylon**	Grass	28.51
Poaceae	*Brachiaria mutica**	Grass	11.70
Poaceae	*Eragrostis diplachoides**	Grass	9.34
Poaceae	*Panicum repens**	Grass	9.24
Boraginaceae	*Coldenia procumbens*	Herb	7.73
Fabaceae	*Alysicarpus glunaceus*	Herb	5.97
Poaceae	*Megathyrsus maximus**	Grass	1.41
Cyperaceae	*Cyperus paniceus**	Grass	1.31
Molluginaceae	*Mollugo* sp.	Herb	1.20
Convolvulaceae	*Evolvulus* sp.	Herb	1.10
Asteraceae	*Xanthium indicum*	Herb	1.05
28 species with < 1% coverage each			8.58
Dry grass			4.37
Open space			8.48

The percent cover and availability of grasses and herbs in the seasonal vegetation are given in Table 3. Thirtyseven plant species in 14 families were recorded from the seasonal vegetation. These included 11 species of grasses, 25 herbs, two shrubs and one liana (Appendix I). *Cynodon dactylon, Panicum repens, Brachiaria mutica, Eragrostis diplachoides, Panicum repens, Megathyrsus maximus* and *Cyperus paniceus* were the most abundant grasses in the seasonal vegetation (Table 3). *Coldenia procumbens, Alysicarpus glunaceus, Mollugo* sp., *Evolvulus* sp. and *Xanthium indicum* were the most abundant herbs in this habitat (Table 3).

There was a strong positive correlataion (r = 0.9461; P < 0.05) between the relative feeding frequency and the percent cover of grasses and herbs (Fig. 13). Therefore, the most commonly consumed grasses and herbs were the most common plants in the area. The relationship between the relative feeding frequency and the relative density of tree species also showed a positive correlation (r = 0.5371; P < 0.05) (Fig. 14), but there seemed to be a preference for certain tree species as their consumption was not in proportion to their availability.

Discussion

Asian elephants are well adapted to living in diverse habitats by exploiting a wide spectrum of plant species (Baskaran *et al*. 2010). In Uda-

Figure 11. Grassland during the dry season.

Figure 12. Seasonal vegetation in the dry season.

walawe we found a higher presence of elephant food plants in grasslands and scrub forests. Elephants were also observed mostly in these habitats. Weerakoon *et al*. (2003) state that the preffered habitats of Asian elephants are grassland and scrublands, which is supported by the findings of the current study. Elephants also seemed to feed more frequently on seasonal vegetation in the reservoir bed in the driest periods of the year, making it an important resource during the dry period. Natumi *et al*. (2005) state that habitat use of elephants is mostly influenced by vegetation biomass, vegetation cover and water availability. All these needs seem to be fulfiiled within the park throughout the year, hence elephants are seen year round in Udawalawe.

Elephants have evolved to be generalist herbivores consuming a wide variety of vegetation of well over a hundred species (Vancuylenberg 1977; Sukumar 1989; Samansiri & Weerakoon 2007). Samansiri and Weerakoon (2007) recorded 116 plant species belonging to 35 families in northwest Sri Lanka, which included around 30 cultivated crops. Comparatively, Udawalawe elephants eat a less diverse diet, as they consumed only 63 plant species. The lower diversity of plants in Udawalawe maybe attributed to the regional availability of particular plants and their distribution. Samansiri and Weerakoon (2007) indicate a diet dominated by plants of families Fabaceae and Poaceae (50%) in northwest Sri Lanka, which was also the case in Udawalawe (28.6% Poaceae, 22.2% Fabaceae). However, these two plant families also dominate the natural vegetation in Udawalawe.

There seem to be a preference for particular plant parts by elephants. A higher feeding frequency was observed on entire plants in grasses and herbs, but for certain tree species only the bark was consumed. Elephant consumption of plants is positively correlated with their nutrient content, especially calcium, magnesium, potassium and protein (Holdo 2003; Angammana *et al*. 2005). Therefore, preference for certain plant parts might be attributed to their nutrient levels.

Results of the current study indicate that elephants feed on grass species in proportion to their occurence and that they do not have preference for particular grass species. But for the trees, elephants seem to show a degree of preference irrelevant to their availability. Asian elephants are mixed feeders, and there is seasonal variation in their food selection (Sukumar 1989). They feed on a wide variety of browse species when the availability of grasses decrease (Chen *et al*. 2006). Elephants tend to shift towards seasonal vegetation in the dry season to obtain crude protein, which is in short supply in old grass during the dry season. Previous studies have indicated that during the wet season elephants' diet is dominated by grasses while browse

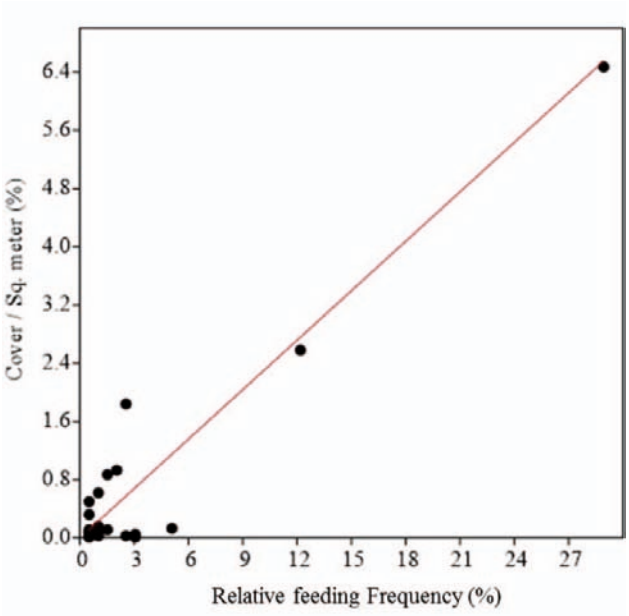

Figure 13. Correlation between relative feeding frequency and cover of grass and herb species.

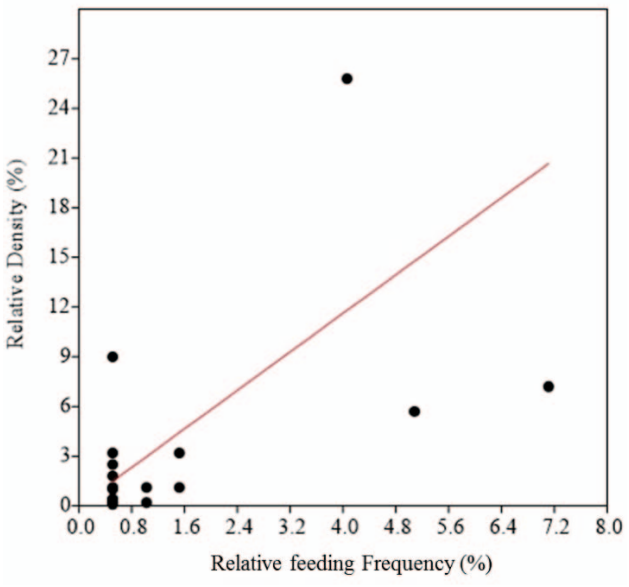

Figure 14. Correlation between relative feeding frequency and relative density of tree species.

dominates it in the dry season only if new grass is unavailable (Hettiarachchi *et al*. 2005; Prathan *et al*. 2008; Baskaran *et al*. 2010). A marked shift from graze to browse was not observed in Udawalawe, probably since new grass in seasonal vegetation were available during the dry season. McKay (1973) stated that grass dominates the diet of elephants in grass-dominated habitats of Sri Lanka, which is in accordance with our findings. Presence of higher amounts of grasses and herbs in the diet throughout the year observed by us, indicates that Udawalawe elephants graze more than they browse. The availability of seasonal vegetation may attract elephants to those habitats during the dry period since they remain the only lush areas.

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Appendix I. List of plants consumed by elephants and their seasonal availability during the dry (D) and wet (W) season in different habitats (GL = grassland; TF = tall forest; SF = scrub forest; RF = riverine forest; S = savvanah; SV = sesonal vegetation).

Family	Species	Life form	Part consumed	GL	TF	SF	RF	S	SV
Amaranthaceae	*Achyranthes aspera*	Herb	All	W	WD	WD			D
Amaranthaceae	*Aerva javanica*	Herb	All			W			
Apocynaceae	*Ichnocarpus frutescens*	Liana	Leaves, stem	WD	WD	WD			
Arecaceae	*Phoenix* sp.	Small tree	Leaves			WD			
Caprifoliaceae	*Crateva adansonii*	Small tree	Leaves, stem	WD					
Convolvulaceae	*Ipomia* sp.	Liana	Leaves, stem			W			
Cyperaceae	*Cyperaceae exaltatus*	Grass	Leaves, flowers						D
Cyperaceae	*Scleria lithosperma*	Grass	All		WD	W			
Euphorbiaceae	*Phyllanthus polyphyllus*	Small tree	Stem	WD	WD	WD	WD		
Euphorbiaceae	*Croton hirtus*	Herb	All	W		W			
Fabaceae	*Acacia leucophloea*	Tree	Bark			WD			
Fabaceae	*Alysicarpus glunaceus*	Herb	All			W			D
Fabaceae	*Bauhinia racemosa*	Tree	Bark, stem, leaves	WD	WD	WD			
Fabaceae	*Cassia fistula*	Tree	Bark	WD	WD	WD			
Fabaceae	*Cassia mimosoides*	Herb	All	W		W			
Fabaceae	*Cassia tora*	Herb	All	W		W			D
Fabaceae	*Clitoria laurifolia*	Herb	Leaves, stem	W					D
Fabaceae	*Derris scandens*	Woody liana	Leaves	WD	WD	WD	WD		

Appendix I. Continued.

Family	Species	Life form	Part consumed	GL	TF	SF	RF	S	SV
Fabaceae	*Desmodium heterophyllum*	Herb	All	W		W			D
Fabaceae	*Desmodium triflorum*	Herb	All	W		WD			D
Fabaceae	*Leucaena leucocephala*	Tree	Bark, stem, leaves	W		W			
Fabaceae	*Mimosa pudica*	Herb	All	W		W	D		D
Fabaceae	*Tephrosia villosa*	Herb	Stem	W		W			D
Fabaceae	*Vigna trifolia*	Herb	All			W			WD
Lamiaceae	*Tectona grandis*	Tree	Bark, stem	WD					
Lamiaceae	*Premna tomentosa*	Tree	Bark	WD		WD	WD		
Malvaceae	*Abutilon indicum*	Herb	Leaves, stem	W		W			
Malvaceae	*Abutilon pannosum*	Herb	Leaves, stem			W			
Malvaceae	*Grewia orientalis*	Woody climber	Bark, stem			WD			
Malvaceae	*Sida cordifolia*	Herb	All			W			D
Meliaceae	*Azadirachta indica*	Tree	Bark, stem	WD		WD			
Meliaceae	*Chukrasia tabularis*	Tree	Bark			WD	WD		
Moraceae	*Ficus mollis*	Tree	Bark, stem	WD	WD				
Moraceae	*Ficus* sp.	Tree	Bark	WD	WD				
Moraceae	*Streblus asper*	Tree	Stem			WD			
Poaceae	*Bothriochloa pertusa*	Grass	All	W					
Poaceae	*Brachiaria mutica*	Grass	All					WD	
Poaceae	*Brachiaria* sp.	Grass	All	W		W			
Poaceae	*Cymbopogon nardus*	Grass	Leaves					WD	
Poaceae	*Cynodon dactylon*	Grass	All	W		W			D
Poaceae	*Cyrtococcum trigonum*	Grass	All		WD	W	WD		
Poaceae	*Dactyloctenium aegyptium*	Grass	All	W		W			
Poaceae	*Digitaria bicornis*	Grass	Leaves, flowers	W					
Poaceae	*Eragrostis* sp.	Grass	Leaves, flowers	W		W			
Poaceae	*Eragrostis tenella*	Grass	Leaves, flowers	W		W			D
Poaceae	*Eriochloa procera*	Grass	Leaves, flowers			W			
Poaceae	*Heteropogon contortus*	Grass	Leaves, flowers	WD		WD	WD		
Poaceae	*Imperata cylindrica*	Grass	Leaves	WD		WD			
Poaceae	*Megathyrsus maximus*	Grass	All	WD		WD	WD		
Poaceae	*Panicum repens*	Grass	All			WD			D
Poaceae	*Paspalidium flavidum*	Grass	All			W			D
Poaceae	*Paspalidium punctatum*	Grass	All						WD
Poaceae	*Setaria* sp.	Grass	All			W			
Rhamnaceae	*Ziziphus oenoplia*	Woody liana	Bark, stem	WD	WD	WD	WD		
Rubiaceae	*Mitragyna tubulosa*	Tree	Stem	WD		WD			
Rutaceae	*Chloroxylon swietenia*	Tree	Bark	WD	WD	WD			
Rutaceae	*Limonia acidissma*	Tree	Stem, fruits	WD		WD			
Rutaceae	*Murraya koenigii*	Small tree	Stem			WD			
Sapindaceae	*Sapindus emarginatus*	Tree	Stem	WD	WD	WD			
Sapotaceae	*Manilkara hexandra*	Tree	Bark	WD		WD			
Sapotaceae	*Schleichera oleosa*	Tree	Stem	WD	WD		WD		
Tiliaceae	*Grewia damine*	Tree	Bark, stem	WD		WD			