Research Article *Gajah 40 (2014) 18-25*

Foraging Ecology of the Asian Elephant in Northern West Bengal

Mukti Roy[1]* and Sushant Chowdhury[2]

[1]*Asian Nature Conservation Foundation, Centre for Ecological Sciences, Indian Institute of Science, Banaglore, India*
[2]*Wildlife Institute of India, Chandrabani, Dehradun, India*
**Corresponding author's e-mail: muktiroy@rediffmail.com*

Abstract. Foraging by Asian elephants (*Elephas maximus*) was studied using the lead animal technique at Buxa Tiger Reserve, Jaldapara Wildlife Sanctuary and Gorumara National Park in West Bengal, India. Feeding trials were done in three broad habitat types—Dense-mixed, Open-mixed and Grassland. In total, 3150 bite counts and 67 consumed plant species consisting of 17 grasses, 6 herbs, 13 shrubs, 14 climbers and 17 trees, were recorded. Browse species bites formed 56% of the total sample and 89 %, 57%, and 24 % of the samples in dense-mixed, open-mixed and grassland, respectively. Crude protein in common wild grasses such as *Saccharum spontaneum* and *S. arundinaceum* was lower than cultivated crops like *Eleucine corocana*.

Introduction

Foraging is a major factor in animal movement and habitat selection. The elephant is a mega-herbivore requiring large amounts of food estimated at 1.5–2.5% of its body weight of dry fodder daily (Sukumar 2003). Due to this enormous need for food, the elephant cannot afford to be a selective feeder. Elephant feeding habits have been studied in savannah habitats of Africa and tropical dry forests of Asia, but little documentation exists of feeding in tropical moist forests.

Methods

Study area

Northern West Bengal in north-eastern India is bound by Nepal on the west, Bhutan in the north, Assam in the east, and Bangladesh in the south, covering a total area of 9394 km^2 and a forest area of 3050 km^2. The habitat in northern West Bengal is highly fragmented due to developmental activities such as conversion of forests to tea plantations, settlements and agriculture, and exploitation for timber (Lahiri-Chowdhury 1975; Barua & Bist 1995).

The main study areas were the Buxa Tiger Reserve, Jaldapara Wildlife Sanctuary and Gorumara National Park. Buxa Tiger Reserve is located between E89°25' – E89°52' and N26°33' – N26°50', and encompasses an area of 761 km^2. Buxa was designated as a Project Tiger Reserve in 1983. The Jaldapara Wildlife Sanctuary lies to the west of the Buxa Tiger reserve, between E89°15' – E89° 35' and N26°30' – N26°48', and covers an area of 217 km^2. This sanctuary is popularly known for the one-horned rhinoceros (*Rhinoceros unicornis*). Gorumara National Park is located between E88°47' – E88°53' and N26°42' – N26°52' in the Terai region of the Himalayan foothills and is 80 km^2 in extent with grasslands and forests. It is also primarily known for its population of Indian rhinoceros.

The natural vegetation of the area is primarily tropical moist forest with grasslands along the floodplains of rivers. The habitat types used for the study were:

i) Dense-mixed (Northern tropical semi-evergreen) forest (Fig. 1), which has several sub-types, viz., Eastern alluvial secondary, Sub-Himalayan secondary wet mixed and Eastern submontane forest (Champion & Seth 1968). The most common tree species are *Michilus villosa*,

Figure 1. Elephant foraging in dense-mixed forest (Photo by Jasoprakas).

followed by *Michelia champaca*, *Shorea robusta*, *Amoora wallichii*, *A. rohitica*, *Dysoxylum* sp. and *Elaeocarpus* sp. Common climbers and shrubs are *Cissus adnata*, *Acacia pennata*, *Tinospora cordifolia*, *Ixora undulata*, *Cayratia japonica*, *Millettia pachycarpa*, *Alpinia nigra*, *Laportea crenulata*, *Clerodendrum viscosum*, *Leea indica*, and *Microstegium ciliatum*.

ii) Open-mixed (Moist Sal savannah and Low alluvial savannah woodland): Moist Sal savannah is characterised by the presence of scattered *Shorea robusta* in association with *Careya arborea*, *Emblica officinalis*, *Lagerstroemia parviflora*, and *Bauhinia purpurea*. Predominant grasses are *Saccharum* sp., *Arundo donax*, *Phragmites karka*, *Imperata cylindrica*, and *Themeda villosa* (Fig. 2).

In Low alluvial savannah woodland the common tree species are *Bombax ceiba*, *Albizia procera*, and *Sterculia villosa*. The common shrubs are *Bischofia javanica*, *Trewia nudiflora, Acacia catechu* and *Dalbergia sissoo*. The predominant grasses are *Saccharum* sp., *Arundo donax*, *Phragmites karka*, *Imperata cylindrica*, and *Themeda villosa*.

iii) Grassland habitat (Eastern alluvial grassland) is flooded during the monsoon and becomes completely dry during the summer months making the soil hard and not conducive to the growth of woody species. The predominant grasses are *Saccharum spontaneum*, *Saccharum arundinaceum*, *Saccharum ravennae*, *Themeda villosa*, *Heteropogon contortus*, *Arundo donax, Apluda mutica*, and *Imperata cylindrica*.

Observational data collection

It is difficult to observe foraging by wild elephants in northern West Bengal as the forest is dense. However, captive elephants (Table 1) kept close to forest areas in Buxa Tiger Reserve, Jaldapara Wildlife Sanctuary and Gorumara National Park are allowed to forage in natural habitats. It was assumed that they chose food plants similar to wild elephants, as they have lived in those areas for a long time and depend on natural forage for their sustenance (Bartmann *et al*. 1982; Bartman & Carpenter 1982). Observation of foraging by captive elephants also allows experimental control in sampling of various habitats.

Observations were made by a single observer and the mahout. At a time only one elephant was observed. Elephants go on forest patrols between 5:30 and 8:00 am, and 2:30 and 4:30 pm. Most of the observations were made opportunistically by a researcher following an elephant on patrolling duty. Whenever the elephant ate any plants, the plant names, habit, habitat and parts eaten were recorded in a data sheet. Sometimes the elephant was left in a grazing area (grassland habitat) and the observer and mahout stood 20–25 m away from it and watched it with binoculars without disturbing the animal and observed the plant species eaten by it. A bite was defined as one trunk full of food taken at a time.

Food plant identification and chemical analysis

Herbarium samples of plant species were collected and identified by a local botanist. The samples were collected during the dry season and

Figure 2. Elephant family herd foraging in open-mixed forest (Photo by Jasoprakas).

Table 1. Elephants used for studying feeding habits.

Elephant	Sex	Age [Years]	Location of camp
Anusua	Female	35	CC Line, Jaldapara Wildlife Sanctuary
Champarani	Female	30	South Rydak, Buxa Tiger Reserve
Janardhan	Male	15	Khunia Forest, Jalpaiguri Forest Division
Jatraprasad	Male	50	Gorumara National Park, Wildlife-II Division
Lakhibala	Female	33	Cheko, Buxa Tiger Reserve
Promila	Female	37	North Rydak, Buxa Tiger Reserve
Sambhu	Male	4	Cheko, Buxa Tiger Reserve
Shanti	Female	35	South Jayanti, Buxa Tiger Reserve
Sharmila	Female	40	Moiradanga, Jaladapara Wildlife Sanctuary
Shiprarani	Female	25	Bankdaki, Jaldapara Wildlife Sanctuary
Shree	Female	38	Jaldapara East, Jaldapara Wildlife Sanctuary
Silabati	Female	11	Gorumara National Park, Wildlife II Division
Singhaswari	Female	50	Cheko, Buxa Tiger Reserve
Urbashi	Female	35	Torsa1, Jaldapara Wildlife Sanctuary

250 g of the part of the species of the food plant eaten by the elephants was oven-dried, weighed, ground and sieved through a 1mm mesh and sent for laboratory analysis where 50 g of the dry powder sample was analysed. The analysis was done at the laboratory of the Wildlife Institute of India, Dehradun. One sample of each species was analysed. Thirty-one food plants were analysed for crude protein, acid detergent fibre, lignin, acid-insoluble ash, and tannin content (Harris 1970; Von Soest 1982).

Results

Food plants

In total, 3150 bites were recorded from 14 elephants (Table 1) in the three different habitats. The consumed plants represented 28 families: Acanthaceae (1 species), Alangiaceae (1 species), Anacardiaceae (1 species), Angiospermae (1 species), Apocynaceae (3 species), Areceae (3 species), Asclepiadaceae (1 species), Combretaceae (1 species), Commelinaceae (1 species), Cucurbitaceae (1 species), Dilleniaceae (1 species), Dioscoreaceae (1 species), Dipterocarpaceae (1 species), Euphorbiaceae (5 species), Fabaceae (2 species), Malvaceae (1 species), Menispermaceae (1 species), Mimosaceae (5 species), Moraceae (5 species), Musaceae (1 species), Myrtaceae (1 species), Pandanaceae (1 species), Poaceae (17 species), Sabiaceae (1 species), Smilacaceae (2 species), Urticaceae (1 species), Vitaceae (3 species), and Zingiberaceae (4 species).

Of the 67 species consumed 55 (n=1129) were recorded in dense mixed forest, and 22 each in open mixed forest (n=805), and grassland (n=1216).

Graze Browse ratio

Taking only grasses eaten by elephants as graze and bamboos, trees, shrubs, climbers, and herbs as browse, 56% of all bite counts consisted of browse (Fig. 3). There was no significant variation found in graze and browse in all habitats (browse mean 588 ± 371 SD, graze mean 459 ± 404 SD, t=0.409, P=0.70).

Overall, the elephants consumed 53 species of browse. The browse species most commonly consumed were *Acacia pennata* (5.6%), *Smilax perfoliata* (4.3%), *Cryptolepis buchanani* (4%), *Daemonorops jenkinsiana* (3.7%) and *Laportea crenulata* (3.3%), which together formed 21% of the total bite counts. The remaining 48 species of browse formed 35% of the total bite counts.

Fourteen species of grasses were consumed by the observed elephants. The grass species

most commonly consumed were *Saccharum arundinaceum* (10.6%), *Microstegium ciliatum* (7.2%), *Arundo donax* (6.7%), *Saccharum spontaneum* (5.3%) and *Themeda villosa* (4.6%), which together consisted of 34.6% of the total bite counts. The remaining 9 species together formed 9.4% of the total bite counts.

In dense mixed habitat browse consisted of 89%, in open mixed 57 %, and in grassland 25% of bite counts (Fig. 3).

Habitat types and food plants

In dense mixed habitat, the shrub *Laportea crenulata* (9.1%), climbers *Tinospora cordifolia* (8.8%), *Smilax perfoliata* (8.1%), *Cayratia japonica* (6.1%), and the tree *Mallotus philippensis* (5%) were consumed the most.

In open mixed habitat, the grasses *Microstegium ciliatum* (21.4%) and *Themeda villosa* (6.5%), the climber *Acacia pennata* (16.5%), the shrub *Daemonorops jenkinsiana* (13.7%), and the tree *Ficus hispida* (7.3%) were mostly consumed.

In grassland habitat, grasses *Saccharum arundinaceum* (24.4%), *Saccharum spontaneum* (13.8%), *Arundo donax* (13.4%), *Cryptolepis buchanani* (10.2%), and *Hedychium gracile* (7.9%) were mostly consumed. The details are given in Table 2.

Table 2. Portion from a total of 3150 bite counts (TOT) on 67 food plants in dense mixed (DM, 1129 bites), open mixed (OM, 805 bites) and grassland (GR, 1216 bites).

Scientific name	Family	Habit*	Part eaten	%DM	%OM	%GR	% TOT
Acacia catechu	Mimosaceae	TR	Twig with leaves	0.18	0.00	0.00	0.06
Acacia pennata	Mimosaceae	CL	Twig with leaves	3.63	16.52	0.33	5.65
Alangium begonifolia	Alangiaceae	TR	Twig with leaves	0.09	0.00	0.00	0.03
Albizia lucidor	Mimosaceae	TR	Twig without leaves, branch, bark	1.59	3.73	0.33	1.65
Albizia procera	Mimosaceae	TR	Small branch, large branch	1.06	0.00	0.00	0.38
Alpinia allughas	Zingiberaceae	HB	Stem without (twigs & leaves)	4.87	0.87	2.22	2.83
Artocarpus lakoocha	Moraceae	TR	Twigs with leaves, bark, branch	4.16	0.00	0.00	1.49
Arundo donax	Poaceae	GR	Twigs with leaves	0.00	6.09	13.40	6.73
Bambusa polymorpha	Poaceae	GR	Twigs with leaves	0.00	1.49	0.00	0.38
Bambusa tulda	Poaceae	GR	Twigs, small branch	0.97	0.00	0.00	0.35
Bauhinia purpurea	Fabaceae	TR	Twigs with leaves	0.44	0.00	0.00	0.16
Bombax ceiba	Malvaceae	TR	Bark, branch	0.89	0.00	0.16	0.38
Bridelia scandens	Euphorbiaceae	SH	Twigs with leaves	2.21	0.00	0.00	0.79
Bridelia stipularis	Euphorbiaceae	SH	Twigs with leaves	0.89	0.87	0.00	0.54
Calamus tenuis	Arecaceae	SH	Twigs with leaves	1.06	1.74	0.00	0.83
Carex baccans	Poaceae	GR	Leaves	0.27	0.00	0.00	0.10
Cayratia japonica	Vitaceae	CL	Stem with leaves	6.11	1.49	0.00	2.57
Cissus adnata	Vitaceae	CL	Stem with leaves	0.71	0.00	0.00	0.25
Combretum decandrum	Combretaceae	CL	Twigs with leaves	0.44	0.62	0.00	0.32
Commelina sp.	Commelinaceae	HB	Stem with leaves	0.09	0.00	0.00	0.03
Cryptolepis buchanani	Angiospermae	CL	Stem with leaves	0.00	0.25	10.20	4.00
Daemonorops jenkinsiana	Arecaceae	SH	Twigs with leaves	0.44	13.66	0.00	3.65
Dendrocalamus giganteus	Poaceae	GR	Twigs with leaves	0.89	0.00	0.00	0.32
Digitaria spp.	Poaceae	GR	Leaves	0.00	0.00	0.90	0.35
Dillenia indica	Dilleniaceae	TR	Fruit	1.51	0.00	0.00	0.54
Dioscorea oppositifolia	Dioscoreaceae	CL	Stem with leaves	0.18	0.00	0.58	0.29

Table 2. (continued)

Scientific name	Family	Habit*	Part eaten	%DM	%OM	%GR	% TOT
Ficus glomerata	Moraceae	TR	Twigs, branch and bark	1.77	0.25	0.00	0.70
Ficus heterophylla	Moraceae	SH	Twigs with leaves	1.51	0.00	0.00	0.54
Ficus hispida	Moraceae	TR	Twigs, branch and bark	0.89	7.33	0.00	2.19
Gouania microcarpa	Apocynaceae	CL	Twigs with leaves	0.00	0.00	0.58	0.22
Hedychium gracile	Zingiberaceae	HB	Stem without (twigs & leaves)	3.28	0.00	0.00	1.17
Hemidesmus indicus	Asclepiadaceae	SH	Twigs with leaves	2.48	0.00	0.00	0.89
Hedychium spp..	Zingiberaceae	HB	Stem without (twigs & leaves)	0.18	0.00	7.89	3.11
Ichnocarpus frutescens	Apocyanaceae)	CL	Stem with Leaves	0.09	0.00	0.00	0.03
Imperata cylindrica	Poaceae	GR	Stem with Leaves	0.00	0.00	6.83	2.63
Holarrhena pubescens	Apocynaceae	SH	Twigs with leaves	0.27	0.00	0.00	0.10
Lannea coromandelica	Anacardiaceae	TR	Twigs with leaves	0.35	0.00	0.41	0.29
Laportea crenulata	Urticaceae.	SH	Root, stem without leaves	9.12	0.00	0.00	3.27
Leea indica	Vitaceae	SH	Stem without leaves	1.68	0.00	0.00	0.60
Macaranga denticulata	Euphorbiaceae	TR	Twigs	0.09	0.00	0.00	0.03
Mallotus philippensis	Euphorbiaceae	TR	Twigs without leaves, bark, branch	5.05	0.25	0.66	2.13
Mallotus roxburghianus	Euphorbiaceae	SH	Twigs without leaves	1.06	0.00	0.00	0.38
Meliosma simplicifolia	Sabiaceae	TR	Twigs with leaves	2.30	0.00	0.00	0.83
Microstegium ciliatum	Poaceae	GR	Stem with leaves	4.96	21.37	0.00	7.24
Microstegium spp.	Poaceae	GR	Stem with leaves	1.06	0.00	0.00	0.38
Millettia pachycarpa	Fabaceae)	CL	Twigs with leaves	3.54	0.00	0.41	1.43
Mimosa pudica	Mimosaceae	HB	Twigs with leaves	0.18	0.00	0.82	0.38
Musa spp.	Musaceae	SH	Stem pith & leaves	0.89	0.00	0.00	0.32
Oplismenus compositus	Poaceae	GR	Leaves	3.45	4.35	0.00	2.35
Pandanus spp	Pandanaceae	SH	Leaves	0.09	0.00	0.00	0.03
Phoenix acaulis	Arecaceae	SH	Stem with leaves	0.71	0.00	0.00	0.25
Phragmites karka	Poaceae	GR	Stem with leaves	0.00	0.00	1.64	0.63
Saccharum arundinaceum	Poaceae	GR	Stem with leaves	0.00	4.72	24.42	10.63
Saccharum spontaneum	Poaceae	GR	Stem with leaves	0.00	0.00	13.82	5.33
Saccharum spp.	Poaceae	GR	Stem with leaves	0.00	0.00	0.74	0.29
Setaria palmifolia	Poaceae	GR	Stem with leaves	0.97	0.00	0.99	0.73
Shorea robusta	Dipterocarpaceae	TR	Bark, branch	0.18	0.00	0.00	0.06
Smilax perfoliata	Smilacaceae	CL	Stem with leaves	8.06	5.59	0.00	4.32
Smilax macrophylla	Smilacaceae	CL	Stem with leaves	0.35	0.00	0.00	0.13
Streblus asper	Moraceae	TR	Twigs with leaves	0.18	0.25	0.00	0.13
Syzygium cumini	Myrtaceae	TR	Twigs with leaves	2.66	0.00	0.00	0.95
Themeda villosa	Poaceae	GR	Stem with Leaves	0.00	6.46	7.73	4.63
Thunbergia coccinea	Acanthaceae	CL	Stem with Leaves	0.00	1.86	0.00	0.48
Thysanolaena maxima	Poaceae	GR	Stem with Leaves	0.18	0.00	4.93	1.97
Tinospora cordifolia	Menispermacea	CL	Stem	8.77	0.25	0.00	3.21
Trichosanthes palmata	Cucurbitaceae	CL	Stem with leaves, fruits	0.62	0.00	0.00	0.22
Zingiber rubens	Zingiberaceae	HB	Stem without leaves	0.35	0.00	0.00	0.13
Total				100	100	100	100

*TR= Tree, SH= Shrub, CL= Climber, HB= Herb, GR- Grass

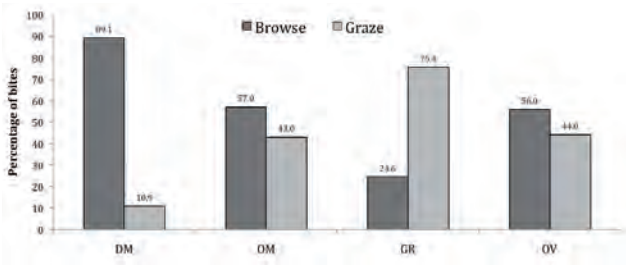

Figure 3. Browse and graze amounts in various habitats of northern West Bengal during the study period. DM = dense mixed, OM = open mixed, GR = grassland, OV = overall.

In dense mixed habitat out of the 55 species of food plants recorded, 16 were trees, 11 climbers, 13 shrubs, 6 herbs, and 9 grasses. Of these, 10 tree species (*Acacia catechu*, *Alangium begonifolia*, *Albizia procera*, *Artocarpus lakoocha*, *Bauhinia purpurea*, *Dillenia indica*, *Ficus glomerata*, *Macaranga denticulata*, *Meliosma simplicifolia*, *Shorea robusta*, *Syzygium cumini*), five climbers (*Cissus adnata*, *Dioscorea oppositifolia*, *Ichnocarpus frutescens*, *Smilax macrophylla*, *Trichosanthes palmata*), 10 shrubs (*Bridelia scandens*, *Ficus heterophylla*, *Hemidesmus indicus*, *Holarrhena pubescens*, *Laportea crenulata*, *Leea indica*, *Mallotus roxburghianus*, *Musa* spp., *Pandanus* spp, *Phoenix acaulis*),three herbs (*Commelina* sp., *Hedychium gracile*, *Zingiber rubens*), and four grasses (*Bambusa tulda*, *Carex baccans*, *Dendrocalamus giganteus*, *Microstegium* sp.) were unique to this habitat.

In open mixed habitat, out of the 22 species of food plants, 5 trees, 7 climbers, 3 shrubs, 1 herb, and 6 grasses were recorded. Of these, the climber *Thunbergia coccinea* and grass *Bambusa polymorpha* were unique to this habitat.

In grassland habitat out of the 22 species recorded, *Digitaria* sp., *Imperata cylindrica*, *Phragmites karka*, *Saccharum spontaneum,* and *Saccharum* sp. (madhua) were unique to this habitat.

Some food plants were found in more than one habitat: Dense mixed (1), open mixed (2) and grassland (3). They consisted of climbers *Acacia pennata* (1,2,3), *Cayratia japonica* (1,2), *Combretum decandrum* (1,2) *Cryptolepis buchanani* (2,3), *Dioscorea oppositifolia* (1,3), *Millettia pachycarpa* (1,2), *Smilax perfoliata* (1,2), *Tinospora cordifolia* (1,2) and grasses like Arundo donax (2,3), *Microstegium ciliatum* (1,2), *Oplismenus composites* (1,2), *Setaria palmifolia* (1,3), *Themeda villosa* (2.3), *Thysanolaena maxima* (1,3), *Alpinia allughas* (1,2,3) and shrubs like *Bridelia stipularis* (1,2), *Calamus tenuis* (1,2), *Daemonorops jenkinsiana* (1,2) and trees like *Albizia lucidor* (1,2,3), *Bombax ceiba* (1,3), *Ficus glomerata* (1,2), *Ficus hispida* (1,2), *Lannea coromandelica* (1,3), *Mallotus philippensis* (1,2,3), and *Streblus asper* (1,2)

Nutritional analysis of elephant food plants

Thirty-one species of food plants were analysed for energy and crude protein content, acid detergent fibre (ADF), lignin, acid soluble ash (AIA) and tannin (Table 3). Average percentage of crude protein in browse was 11.01±0.71, and in graze 8.70±0.80. Lignin in browse was 11.63±1.12, and in graze 4.31±0.94. Tannin/g in browse was 0.51±0.11, and in graze 0.15±0.07. Crude protein in cultivated crops marua (*Elucine corcona*) was higher at 9% compared to common wild grasses (*Saccharum spontaneum* 6% and *S. arundinaceum* 7%).

Discussion

The analysis of forage consumed by elephants, showed exploitation of a large variety of species in the study area. A higher number of food plant species were found in dense mixed habitat than in open mixed or grassland habitat. The analysis of grass:browse ratio showed browse consumption to be somewhat higher than grass in our study area. Browse dominates the diet of elephants in rainforests of Malaysia (Olivier 1978) as the habitat is mostly dominated by browse and grass is very rare. Grass dominates the diet of elephants in grass-dominated habitats of Sri Lanka (McKay 1973) and deciduous forests of Mudumalai Wildlife Sanctuary [Browse 12%, grass 88% (Sivaganesan & Johnsingh 1995); browse16%, and grass 84% (Baskaran *et al*. 2010)].

The average percentage of crude protein, lignin and tannin was higher in wild browse than in graze species. In the present study, the crude protein in cultivated crops was found

Table 3. Summary for nutritional analysis of elephant food plants.

Name	Kcal/g	ADF	Lignin	AIA	Tannin/g	C.Protein	%Org ma	%Silica	ADL
Acacia pennata	4.99	46.63	12.21	5.82	0.42	11.05	96.26	3.74	0.19
Albizia lucidor	5.31	36.21	9.91	0.58	0.48	20.17	96.90	4.10	0.29
Alpinia allughas	4.07	34.46	8.36	0.54	0.36	13.44	91.16	8.84	0.26
Arundo donax	4.96	49.50	0.12	12.20	0.01	10.51	98.29	1.71	0.19
Bridelia stipularis	4.99	48.36	22.63	2.74	0.62	10.89	86.36	13.64	0.20
Cayratia japonica	4.65	28.91	10.83	0.66	0.52	13.21	92.58	7.42	0.18
Combretum decandrum	4.66	29.71	11.42	0.30	0.81	12.40	92.43	7.57	0.18
Cryptolepis buchanani	4.79	45.10	7.62	10.94	0.45	8.77	93.34	6.66	0.20
Daemonorops jenkinsiana	4.51	49.84	14.03	2.50	2.35	7.11	94.63	5.37	0.33
Dendrocalamus giganteus	4.36	46.63	9.57	8.24	0.00	13.11	89.33	10.67	0.29
Dioscorea oppositifolia	4.89	37.58	2.43	18.70	1.68	8.35	95.59	4.41	0.21
Ficus hispida	3.74	37.94	6.66	4.07	0.39	14.95	85.53	14.47	0.29
Ficus religiosa	4.12	49.66	20.35	5.23	0.14	9.07	90.46	9.54	0.24
Herdicium gracile	4.41	49.89	11.03	8.53	0.35	7.22	90.89	9.11	0.32
Ichnocarpus frutescens	5.14	43.58	17.18	0.98	0.50	8.12	94.75	5.25	0.26
Lannea coromandelica	4.96	29.01	14.66	10.10	1.17	10.23	96.56	3.44	0.25
Laportea crenulata	4.24	41.62	2.73	3.63	0.02	8.75	90.65	9.36	0.24
Lagerstrimea spp	3.36	42.80	10.08	0.53	0.43	4.42	91.16	8.85	0.34
Mallotus philippinensis	4.88	32.04	8.13	1.67	0.13	14.24	94.25	5.75	0.23
Elucine-Corcona	4.52	29.15	4.44	0.76	0.12	8.93	91.92	80.08	0.24
Microstegium ciliatum	4.86	46.91	5.64	8.94	0.27	8.52	93.52	6.48	0.32
Millettia pachycarpa	5.02	41.86	9.17	11.98	0.46	11.76	93.60	6.40	0.26
Musa spp.	5.08	37.64	9.33	10.80	0.00	12.23	84.91	15.09	0.20
Oplismenus compositus	4.40	32.43	5.43	2.18	0.42	8.86	89.26	10.74	0.25
Pothos Scandens	4.79	38.96	9.93	0.69	0.29	13.60	92.78	7.22	0.29
Saccharum arundinaceum	4.61	41.27	6.68	2.19	0.22	7.01	92.48	7.54	0.32
Saccharum spontaneum	4.82	28.81	4.12	13.60	0.00	6.08	94.08	5.92	0.19
Setaria palmifolia	4.52	40.35	3.88	6.73	0.09	11.21	87.62	12.38	0.30
Smilax perfoliata	5.26	53.60	21.18	55.00	0.38	15.58	97.78	2.22	0.31
Tinospora cordifolia	3.88	33.24	10.79	0.18	0.02	7.60	94.24	5.76	0.23
Zinziber rubens	4.38	39.02	18.97	9.60	0.18	8.00	93.16	6.84	0.29

to be higher at 9% compared to common wild grasses at 6–7%. Roy (2010) also found higher crude protein (same study area) in crops like paddy, *Oryza sativa* (5.6%), maize, *Zea mays* (11%) and wheat (9.1%), than in wild grasses like *Saccharum arundinaceum* (5.2%) and *S. spontaneum* (5.8%). Osborn (2004) found that crops were significantly higher in crude protein than either browse or grass in Africa. A similar result was found by Sukumar (1989) in southern India. The lignin values for the browse samples were significantly higher than for grass or crops in the study area similar to what was found by Osborn (2004) in Africa.

Acknowledgements

We thank the West Bengal Forest Department for logistic help to carry out the field work, the mahouts and patawallas of the 14 captive elephants for help in data collection in the field, and the field assistants Dilip Roy, Biplab Singh and driver Dinesh Roy for their support.

References

Bartmann RM, Alldredge AW & Neil PH (1982) Evaluation of winter food choices by tame deer. *Journal of Wildlife Management* **46:** 807-812.

Bartmann RM & Carpenter LH (1982) Effects of foraging experience on food selectivity of tame mule deer. *J. Wildlife Management* **46:** 813-818.

Barua P & Bist SS (1995) Changing pattern in the distribution and movement of wild elephants in Northern Bengal. In: *A Week with Elephants*. Daniel JC & Datye HS (eds) Bombay Natural History Society, Oxford University Press, Bombay. pp 66-83.

Baskaran N, Balasubrmanian M, Swaminathan S & Desai AA (2010) Feeding ecology of the Asian elephant (*Elephas maximus*, Linnaeus) in the Nilgiri biosphere reserve, southern India, *J. Bombay Natural History Society* **107:** 3-13.

Champion HG & Seth SK (1968) *A Revised Survey of Forest Types of India*. Government of India Publication, New Delhi.

Harris EL (1970) *Nutrition Research Techniques for Domestic and Wild Animals*. Pub. 1408, Highland Drive, Logan, Utah.

Lahiri Choudhury DK (1975) *Report on Elephant Movement and Depredation in Jalpaiguri Division and Part of Madarihat Range of Cooch Behar Division in June–July, 1975*. Submitted to West Bengal Government.

McKay GM (1973) Behaviour and ecology of the Asiatic elephant in South-eastern Ceylon. In: *Smithsonian Contribution to Zoology*. Smithsonian Inst., Washington. DC. 125: 1-113.

Olivier RCD (1978) *On the Ecology of the Asian Elephant*. Ph.D. thesis, Cambridge University, UK.

Osborn FV (2004) Seasonal variation of feeding patterns and food selection by crop raiding elephants in Zimbabwe. *African Journal of Ecology* **42:** 322-327.

Roy M (2010) *Habitat Use and Foraging Ecology of the Asian Elephant (Elephas maximus) in Buxa Tiger Reserve and Adjoining Areas of Northern West Bengal*. Ph.D. thesis, Vidyasagar University, Paschim Medinipur, West Bengal.

Sivaganesan N & Johnsingh AJT (1995) Food resources crucial to the wild elephants in Mudumalai Wildlife Sanctuary, Tamil Nadu, India. In: *A Week with Elephants. Proceedings of the International Seminar on the Conservation of Asian Elephant*. Daniel JC & Datye HS (eds) Bombay Natural History Society, Oxford University Press, Bombay, India. pp 405-423.

Sukumar R (1989) *The Asian Elephant Ecology and Management*. Cambridge University Press, Cambridge, UK.

Sukumar R (2003) *The Living Elephants: Evolutionary Ecology, Behavior and Conservation*. Oxford University Press, New York.

Von Soest PJ (1982) Nutritional ecology of the ruminant. Comstock Pub. Assoc. Cornell University Press, Ithaca, USA.

Figure 4. Tusker elephant foraging in the forest (Photo by Jasoprakas).