

Food and feeding of captive Asian Elephants (*Elephas maximus*) in the three management facilities at Tamil Nadu, South India

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Abstract

Asian elephants (*Elephas maximus*) in wild feed on diverse spectrum of food plants along with seasonal shift in diet selection. While in captivity, they are often not fed in accordance with their food preference in natural conditions. We evaluated the food, and feeding and health conditions of captive elephants managed by Private, Temple and Forest Department facilities in Tamil Nadu, Southern India. Results on food and feeding reveal that Private and Temple facilities have stall fed their elephants with significantly less food in quantity and quality than the elephants in Forest Department facility that had access to natural feeding apart from supplementary diet. A significant proportion of elephants under the former two facilities were fed with monotonous green fodder (one-two spp.) round the year. The private elephants, especially those owned by keepers were fed less food and put into more work, while the Temple elephants with moderate food supply were kept mostly in chain without much exercise. Data on health assessment show that the body conditions of Private elephants are poorer as compared to the elephants in Temple and Forest facilities. Lack of nutrients including minerals and vitamins due to the inadequate quantity and quality of green fodder and supplementary diet have been attributed to the poor health including deficiency diseases among the Private and Temple elephants. We make recommendations to improve the food and feeding practices for the long term conservation of these captive elephants.

Keywords : captive Asian elephants, food and feeding, southern India

INTRODUCTION

The Asian elephant (*Elephas maximus*) is considered an integral part of culture and mythology in India and elsewhere in Asia. The elephants were first captured probably about 4000 years ago by the people of Indus Valley civilization (Carrington, 1959) and since then, the elephant has become a vital part of Asian cultures and religions. Given that the global population of captive Asian elephants forms one third of total Asian elephant population (Hedges, 2006), attention to and the study of captive elephants may aid conservation effort (Sukumar and Santiapillai, 2006). In India, unlike the wild elephant distribution, captive elephants are found in the non-range states too, as it is linked with the country's culture and religions. Presently, the 23 states and union territories in India including the Andaman and Nicobar Islands have about 3400-3600 captive elephants with major share in the northeastern states (55 %) followed by southern India (25 %) (MoEF, 2004). Tamil Nadu, a southern state of India, manages about 200 elephants in captivity (MoEF, 2004) at Timber camps, Zoo, and in Religious Institutions such as Hindu Temples, Mutts, Trusts, Charities, Mosques and by individual owners, for various purposes. The State Government of Tamil Nadu categorized these elephants into three different captive systems, viz., Forest

Department Captive Elephants, Temple Elephants and Private Elephants.

The Tamil Nadu Forest Department has been managing captive elephants since 1857 mainly in the timber camps of Wildlife Sanctuaries, initially for timber logging purpose (Krishnamurthy and Wemmer, 1995). However, most of the timber camp elephants since the 1994 ban on timber logging are being used for elephant safari (joy ride) for tourists (Bist *et al.*, 2002) for a couple of hours a day and the remaining time left free in the forest. Additionally, there are a few elephants being managed at the Aringar Anna Zoological Park, Chennai for public entertainment and education. The elephants kept in the timber camps and Aringar Anna Zoological Park are categorized and henceforth referred to as "Forest Department Captive Elephants". Detailed descriptions on the management of these elephants are available in Krishnamurthy and Wemmer (1995).

Some of the popular Hindu Temples managed by the Hindu Religious and Charitable Endowments (HR&CE) Board, Government of Tamil Nadu, India, have also been keeping elephants for daily religious rituals in Temples. These are government owned elephants but under the control of HR&CE Department. These elephants are categorized and henceforth referred to as "Temple Elephants" and these are kept in the same Temple year round with relatively less work. Since most of the present

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stocks of the Temple elephants were from Tamil Nadu Forest Department captive population, if any of the Temple elephant becomes unmanageable, they are returned to the Forest Department.

All captive elephants other than that in the Forest Department and Temples are owned by Religious and Charitable institutions other than Temples *i.e.*, Mutts, Mosques, Charities, Missions and Trusts and by individuals such as *mahouts* (elephant keepers), and are categorized and henceforth referred to as "Private Elephants". All these, except the elephants owned by the *mahouts*, are meant for daily rituals in the religious places such as Hindu Temples and Mosques, with limited work and are mostly kept in idle. While the elephants owned by the *mahouts* have been used mostly on contract basis for commercial purposes such as marriage ceremonies, VIP programmes, film shootings and for festivals at temples that does not have the elephants. Such commercial works are mostly seasonal and when there is no commercial demand, these elephants have been used for money collection through begging in nearby markets and residential areas and thus these elephants are more mobile.

Captive animals in general are not fed strictly in accordance with their food preference in natural conditions. This is especially true with reference to captive elephants managed in the Zoos (Crandall, 1964) and Temples (Krishnamurthy, 1998; Gokula, 1993; Vanitha, 2007). Some captive facilities feed their elephants with monotonous fodder round the year without any change on a seasonal basis and some do not even feed them adequate quantities (Vanitha, 2007). While on the other hand, the Asian elephants in the wild are known to feed on wide spectrum of food plants (McKay, 1973; Olivier, 1978; Sukumar, 1989; Baskaran, 1998; Roy *et al.*, 2006) with seasonal changes in diet selection according to the variations in nutrient composition of food plants (McKay, 1973; Sukumar, 1989; Sivaganesan and Johnsingh, 1995).

Since captive elephants especially those managed by the Private and Temple facilities are totally dependent upon the food provided by the *mahout* or the management, it is essential to evaluate whether the food and feeding practices prevailed in all the captive facilities are in accordance with their natural food preference and feeding habits? If not, how far has the inadequacy of diet quantity and / or quality affect their health conditions? A study was carried out to address the above questions using food and feeding data collected from the three captive elephant facilities of Tamil Nadu, Southern India between 2003 and 2007 and this paper describes its outcome.

MATERIALS AND METHODS

Study area

The present study was carried out in Tamil Nadu, a southern State of India. Data on food and feeding of captive elephants were collected from (1) The elephant camps of the Tamil Nadu Forest Department at Mudumalai and Anaimalai, (2) Aringar Anna Zoological Park, Chennai, (3) Temples of Tamil Nadu and (4) Private owners of the State.

Evaluation of food and feeding

In order to compare the daily provision of food to the captive elephants with their preference under natural condition and nutritional requirements, quantity of various food items including cooked ration and cut fodder provided to each elephant in the three management facilities were quantified by weighing each item separately using a weighing balance. Additionally, data on age-sex details, verities of fodder and cooked ration (supplementary food) supplied, time and period of supply were obtained from register of records available with the respective captive system and also by enquiring the concerned authorities for all the elephants in the three facilities. Sample of major food items, both green fodder and grains of uncooked rations, were collected for nutrient analyses.

Nutrient analyses

Nutritive components such as crude protein, sodium, magnesium, iron, potassium, copper and zinc which are known to influence the diet selection of elephants in the wild (Sukumar, 1989) were quantified for the major food items provided to the captive elephants. The nitrogen content of food item was estimated by Kjeldahl method and later converted into crude protein using 6.25 as the conversion factor. The mineral contents were analyzed following Harborne (1973 and 1998) using flame photometer.

Assessment of health condition

The health condition of the elephants managed by the three captive systems was assessed by visual assessment method using the variables similar to the one suggested by Wemmer and Krishnamurthy (2006). The variables include (1) Temporal depression, (2) Bucal depression, (3) Prominence of backbone, (4) Prominence of ribs, (5) Prominence of pectoral and (6) Prominence of pelvic regions. The depression or prominence levels of above regions are known to change as health condition change in elephants due to changes in the level of adipose fat deposition. A numeric rating was adopted to record the condition of each region separately to assess the overall health conditions. The method assigned a rating of '0' to represent nil depression/prominence and ratings of '1, 2' and '3' to represent low, medium and high depression/prominence levels, respectively and

these numeric ratings are totalled to give numeric scores ranging from 0-18 with smaller the number better the health condition.

Statistical analyses

To compare the food supply across three systems, all individuals within a given management system belong to various age-sex class were categorized broadly into major age class viz. calf, juvenile, sub-adult and adult using the shoulder height method suggested by Sukumar (1989). The difference in quantity of food supply between the systems was tested using χ^2 test. The quantity of food supplied to Forest Department captive elephants were considered as expected value (because the quantity of food supplied to these elephants are based on veterinarian's prescriptions) and the quantity supplied to the Private and Temple elephants were treated as observed values for the analysis χ^2 . The proportion of elephants with and without change in fodder supply in Private and Temple facilities was tested using Z test.

OBSERVATIONS AND RESULTS

Food and feeding evaluation

Diet variety

The captive elephants in Tamil Nadu were provided with (i) cut fodder of green grass and browse (leaves of trees and shrubs) as stall feeding, (ii) supplementary diets of grains, millets and pulses in cooked form and (iii) natural feeding. The type and quantity of food provided to elephants in the three facilities were not similar (Table 1). For example, most of the elephants (46%) in the Private system are fed with green fodder of coconut leaves (*Cocos nucifera*) followed by *Ficus* spp. (37%) whereas in Temple management, most of the elephants (49%) are fed with grass *Ochlandra* spp. followed by leaves of *C. nucifera* (28%) and *Ficus* spp. (19%). Only few elephants in these two systems (one elephants from each system) had access to natural feeding. Further a significant number of elephants in Private (14% - $Z = 4.23$; $P = 0.05$) and Temple (30% - $Z = 2.59$; $P = 0.05$) are fed with monotonous green fodder, mostly one or two species round the year without considering the seasonal changes in nutrient composition of food plants. In contrast, almost all timber camp elephants managed semi-naturally by Forest Department are let out into adjoining forests for natural feeding and thus they have access to wide varieties of grass and browse. The captive elephants managed at the Zoo although did not have the opportunity to natural feeding are mostly provided with leaves of *C. nucifera*, and *Tectona grandis*, their fodder supply changed seasonally. These results show that the captive elephants in Private and Temple managements by and large were provided with less diverse green fodder than the Forest Department captive elephants.

Diet quantity

Theoretically, the supplementary food quantity should be based on the age, sex, work nature and reproductive status of elephants as per the veterinarian's prescription (Krishnamurthy and Wemmer, 1995). While this is being strictly followed for all the Forest Department and some Temple elephants; the Private facility especially the elephants managed by the individual owners do not follow the prescription. Thus the mean quantities of supplementary diet provided to Private and Temple elephants were lower than the quantity fed to the Forest Department elephants (Table 2). Similarly, the green fodder supplied to the captive elephants of Forest Department (including fodder consumption during natural feeding) was also higher when compared to quantity supplied to elephants in the other systems.

Total quantity of various supplementary diets provided per elephant in the three captive management systems is shown in Figure 1. It is quite clear from the figure that the quantity of cereals (Ragi, Horse gram and Green gram) fed to Private elephants was less than half the quantity fed to the Temple elephants, although the total quantity of cooked ration supplied/elephant was almost the same in the two systems. A comparison of supplementary diet quantity provided to the elephants in the Forest Department with that of Temple and Private elephants reveal that elephants in the former facility were fed with more finger millets, while the elephants in the latter two systems were fed with more of rice. Further the total supplementary diet fed to each elephant was significantly lower in the Private ($\chi^2 = 6.226$, $df = 2$, $P < 0.04$) and Temple ($\chi^2 = 5.522$, $df = 1$, $P < 0.01$) as compared to the supplementary diet supplied to Forest Department elephants.

Food quantity in relation to age class

Quantity of supplementary food supplied to each age class of elephants among the three managements varied remarkably (Table 3). For example in Private facility, an adult elephant was fed on an average 8 kg of supplementary diet/day, which is lower than the supplementary diet fed to an adult elephant in Forest Department (19 kg/day/elephant) and Temple (10 kg/day/elephant) facilities. For the remaining age classes there were not much differences in the supplementary food supplied in the three captive systems. Interestingly, in the Private facility, the supplementary diet and green fodder provided to the adult class was lesser than that of the quantity fed to the sub-adult class. Comparison of green fodder supplies to elephants in Private and Temple facilities with that of the Forest Department elephants (estimated based on consumption rate of 5 % body weight) show that adult class elephants have fed more in Forest Department system than in the Private and Temple systems. While in sub-adult and juvenile classes,

Table 1. Types of green fodder provided and the percentages of captive elephants receiving each type of food in the three captive management systems in Tamil Nadu

Major cut /green fodder provided		Percentage of elephants		
Scientific Name	Vernacular name	Private (n = 35)	Temple (n = 43)	Forest Department (n = 10*)
<i>Ochlandra</i> sp.	Nannal Grass	22.9	48.8	0
<i>Panicum</i> sp.	Hybrid Grass	0	7.0	0
<i>Cyanodon dactylon</i>	Augampul	0	9.3	0
<i>Cyperus</i> sp.	Koraipul	0	0	0
<i>Saccharum officinarum</i>	Sugarcane	2.9	4.7	100
<i>Sorghum vulgare</i>	Jowar	20.0	9.3	0
<i>Ficus bengalensis</i> and <i>F. religiosa</i>	Banaian & Pupil Trees	37.1	18.6	100
<i>Cocos nucifera</i>	Coconut	45.7	27.9	20.0
<i>Caryota urens</i>	Koonthal Panai	11.4	2.3	0
<i>Bambusa arundinacea</i>	Bamboo	0	2.3	80
<i>Tectona grandis</i>	Thekku	0	0	80
<i>Grewia tiliiaefolia</i>	Thadasu	0	0	80
<i>Lagerstroemia lanceolata</i>	Vellai Thekku	0	0	80

*Represent eight elephants in Mudumalai Timber camp (chained with cut fodder during night) and two elephants in Aringar Anna Zoo, Vandalur that are stall-fed.

Additionally, Forest Department elephants managed at the timber camps have access to varieties of wild grass and browse during their natural feeding that are not listed here.

Table 2. Mean quantity of food supplied to the captive elephants in the three captive management systems at Tamil Nadu

Management system	Mean quantity of food (kg) / day / elephant			
	Green fodder	Natural feeding	Supplementary diet	Total food
Private (n = 35)	124.7 ± 48.24	Nil	8.1 ± 4.63	133
Temple (n = 43)	132.8 ± 63.31	Nil	9.4 ± 4.16	142
Forest Department Zoo (n = 2)	153 ± 0.70	Nil	7.50 ± 2.12	161
Forest Department Timber Camp (n = 46)	13.7 ± 34.75 ^a	173.6 ^b	17.88 ± 5.95	191

^aGreen fodder supply to forest department elephants was calculated based on cut fodder supply to eight adult males in MWLS that were stall fed during night, but during day they were left free in forest for natural feeding.

^bFodder consumption is arrived using consumption rate of 5% of body weight based on the findings from an experimental study at Aringar Anna Zoo, Vandalur (Natarajan, 1986). From the estimated fodder consumption, quantity of green fodder supplied is subtracted.

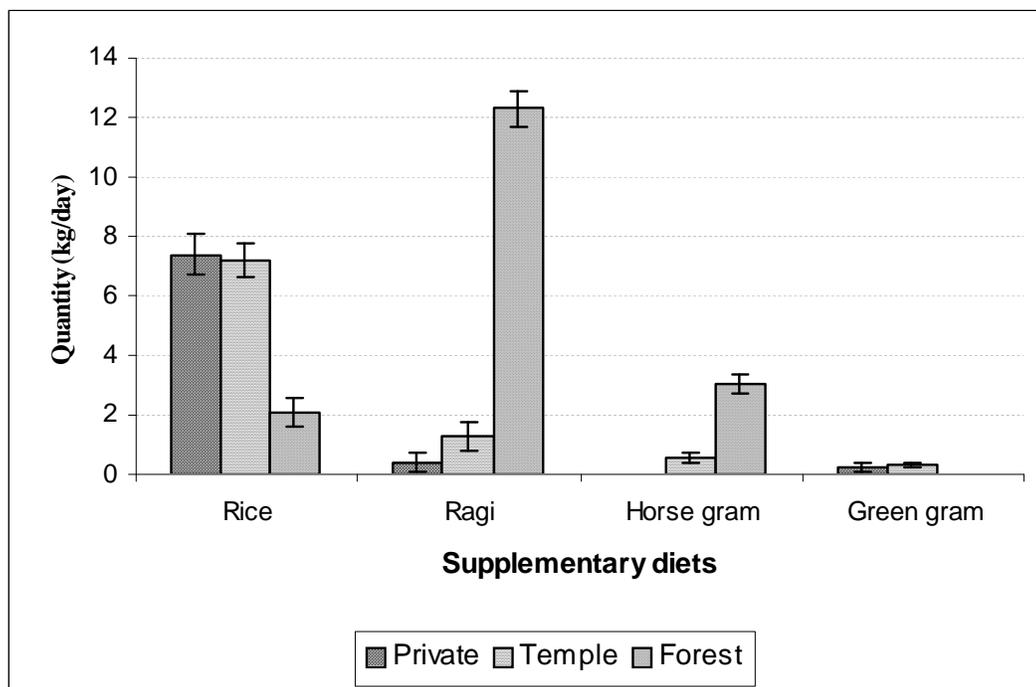
Table 3. Quantity of diet provided to different age classes of elephants in the three captive management systems at Tamil Nadu

Management systems	Age class (n)	Quantity of food provided (kg) / elephant		
		Green fodder	Supplementary diet	Total food
		Mean \pm S.D.	Mean \pm S.D.	Mean \pm S.D.
Private	Adult (30)	126.9 \pm 50.57	8.27 \pm 4.01	135.2 \pm 51.49
	Sub-adult (3)	135.0 \pm 30.41	10.5 \pm 9.96	145.5 \pm 36.01
	Juvenile (1)	152.5	3	155.5
	Calf (1)	-	0.6	0.6
Temple	Adult (31)	141.6 \pm 68.61	10.3 \pm 4.34	151.0 \pm 69.59
	Sub-adult (12)	109.9 \pm 40.96	6.9 \pm 2.36	116.8 \pm 40.23
	Juvenile (0)	-	-	-
	Calf (0)	-	-	-
Forest Department	Adult (40)	168.8* \pm 31.01	19.1 \pm 7.69	188.1 \pm 30.44
	Sub-adult (6)	71.8* \pm 17.36	10.9 \pm 3.07	82.7 \pm 17.38
	Juvenile (2)	23.8* \pm 5.30	3.5 \pm 2.12	27.3 \pm 7.42
	Calf (0)	-	-	-

All the timber camp elephants except the adult males at Mudumalai Wildlife Sanctuary during nighttime were left out for natural feeding both during day and night

*Fodder consumption is arrived using consumption rate of 5% of body weight based on the findings from an experimental study at Aringar Anna Zoo, Vandalur (Natarajan, 1986)

Figure 1. Mean quantity (kg/day) of various supplementary diets provided to the captive elephants in the three management systems. (Bars represent mean values and the vertical lines \pm one Standard Error)



Private and Temple systems have supplied more than the consumption rate by the Forest Department. As nearly 30-50% of the fodder supplied is discarded (not fed by elephants), fodder consumption by the elephants in the Private and the Temple systems is likely to be less than the Forest Department captive elephants. Further the mean quantity of total food supplied to each elephant was significantly lower in the Private ($\chi^2 = 64.58$, $df = 2$, $P < 0.01$) and Temple facilities ($\chi^2 = 21.37$, $df = 1$, $P < 0.01$) as compared to the quantity supplied to the Forest Department elephants.

Nutrient quality

The analysis of nutrient content of the major diet items revealed that the protein contents in the supplementary diets like green gram (20.6%) and horse gram (20.5%) were more; but they were supplied in lower quantities, while rice (7.1%) and ragi (6%) with lesser protein contents are supplied more. Since the total quantity of these diet items fed per elephant in each system and their percentage values of crude protein levels are known, the total quantity of crude protein consumption per elephant in each system is estimated. The results showed that crude protein consumption was highest per elephant in the Forest Department management (1.5 kg out of 17 kg of total supplementary diet) followed by the Temple elephants (0.8 kg out of 9 kg of total supplementary diet) and lowest in the Private elephants (0.6 kg out of 8 kg of total supplementary diet). Important minerals like sodium (Na), iron (Fe), and zinc (Zn) are more in ragi (Table 4), the major supplementary diet provided to Forest Department elephants than in rice, the major supplementary diet fed to Private and Temple elephants.

Although the actual quantities of various green fodders provided to each elephant is known, the lack of data on actual consumption of various green fodders (as elephants are known to discard a significant amount of green fodder) does not permit such calculations for the cut fodder provided to Temple and Private elephants. However from the results of the analysis of nutrient contents in the present study, it can be inferred that among the 11 species of green fodder supplied to the captive elephants, *Sorghum vulgare* (17%), *Cyanodon dactylon* (16.5%), *Bambusa arundinacea* (11%), *Ficus religiosa* (10.9%) and *Panicum* spp. (10%) which are rich in crude protein should be considered as important fodder to the captive elephants in Tamil Nadu (Table 4). Similarly, sodium an essential microelement is found high in *B. arundinacea* (201.6 ppm) and magnesium, iron and zinc in *Caryota urens*, a frequently fed green fodder in south Tamil Nadu bordering Kerala. Notably, the widely supplied leaves of *C. nucifera* (among 46% of the Private elephants) and grass of *Ochlandra* spp. (among 49% the Temple elephants) have relatively lower levels of most nutrients as compared to most of

the other green fodders.

Health assessment

The health conditions assessed by the numeric rating method for the 128 elephants managed in the three captive facilities revealed that the mean health rating was poorest (3.11) for the elephants managed by the Private facility among the three systems (Fig. 2). Further, the proportion of elephants with health rating >5 was also highest in the Private facility (24%) followed by Temples (16%) and lowest in the Forest Department (6%). In the Forest Department, among the three elephants that showed health ratings >5 , two were adult males of over 50 yrs with health ratings of 6 & 7 and the third one, with a health rating of 10 was an adult female of 37 yrs old that was returned from a Temple due to a dental problem (fourth molar has not fallen, although fifth one has erupted). She was unable to feed fodder and was surviving only with supplementary diet. The week body condition in the case of two adult males in the Forest Department could also be due to musth (*i.e.*, they might have come out of musth just before the health assessment) as bulls are known to be in poor body condition after musth (Desai and Johnsingh, 1995) or might also be due to old age. Excluding these few cases, all other elephants in Forest Department facility were with health ratings <5 , indicating a uniform and moderate health condition maintained by the Forest Department facility.

DISCUSSION

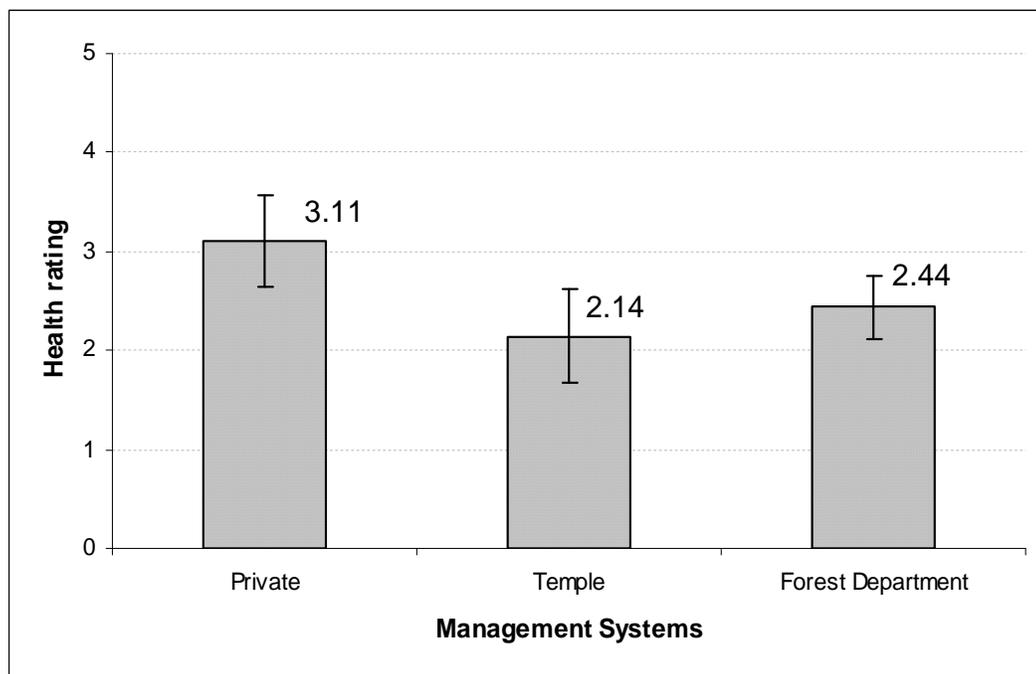
Asian elephants in the wild feed on wide varieties of food plants ranging from 54 to 390 species (McKay, 1973; Olivier, 1978; Sukumar, 1989; Baskaran, 1998; Roy *et al.*, 2006). Their natural diet includes leaves, twigs, stems, barks, fruits, and roots from herbs, shrubs and trees, although their major food items are grass species (McKay, 1973; Sivaganesan and Johnsingh, 1995; Baskaran, 1998). The elephants are also well known to change their diet species and parts according to season with an increase in browse consumption ratio during dry season as compared to wet season. (McKay, 1973; Sukumar, 1989; Sivaganesan and Johnsingh, 1995; Baskaran, 1998). Such changes have been related to seasonal variation in nutrient quantity of food plants and their parts (Sukumar, 1989; Sivaganesan and Johnsingh, 1995). However, the captive elephants managed by the Private and Temple facilities did not have access to such wide varieties food plants, as all these elephants (except two) are stall-fed. A given elephant in either facility was provided with a maximum of three to five species of green fodder round the year. More over a significant number of elephants in the Temple (30%) and Private (14%) managements are fed with monotonous green fodder of one or two species round the year. Such restricted or monotonous green fodder supply without much of change could have reduced the consumption

Table 4. Composition of protein and some important microelements in the food items provided to the captive elephants in the three management systems at Tamil Nadu

Botanical name	Vernacular name / English name	Crude protein (%)	Micro elements (ppm)						
			Na	Mg	Fe	K	Cu	Zn	Mn
Grain									
<i>Oryza sativa</i>	Paddy	7.1	64.5	8.5	0	55.5	0	3.2	0
<i>Eleusine coracana</i>	Ragi (Finger millet)	6	-	450.6	20.4	134	0	351.7	5.9
<i>Vigna unguiculata</i>	Horse Gram	20.5	34.8	45.1	0	268.8	0.6	2.7	0
<i>Vigna radiata</i>	Green Gram	20.6	24.6	56.3	0	322.4	0	1.7	0
Green fodder									
<i>Ochlandra</i> sp.	Nannal	3.3	24	50.7	4.7	316.3	0	1.6	3.1
<i>Cyperus</i> sp.	Koraipul	3.6	76.5	76.1	20.5	396.5	0.4	2	10.1
<i>Panicum</i> sp.	Hybrid Grass	10.1	62.6	81.1	7	416.3	4	2.7	0
<i>Cyanodon dactylon</i>	Common Grass	16.5	11.6	32	1.8	240	1.2	2.8	0
<i>Saccharum officinarum</i>	Sugarcane	3.6	23.1	69.8	15.3	342	3.4	2.8	0
<i>Sorghum vulgare</i>	Jowar	17	14.8	99.7	3.9	367.6	0.5	2.6	0
<i>Ficus bengalensis</i>	Banyan Tree	8.5	12.5	174.6	0.2	294.7	4.2	1.8	0
<i>Ficus religiosa</i>	Peepul Tree	10.9	12.2	40.3	0	158	1.9	1.6	0
<i>Cocos nucifera</i>	Coconut Tree	8.8	35.4	133.5	10.9	285.9	2	2.1	0
<i>Bambusa arundinacea</i>	Bamboo Tree	11.1	201.6	123.6	14.7	337.7	1.2	2.4	0
<i>Caryota urens</i>	Kunthal Panai Tree	6.5	-	1199	26	294.1	1.5	409.6	9.2
Herbal medicine	Astasooranam	11.3	241	81.9	12.8	309.7	0.6	6	2.5

- indicates that analysis was not carried out

Figure 2. Mean health rating of elephants in the three management systems of Tamil Nadu (n = 128). (Bars represent mean values and the vertical lines ± one Standard Error)



Note : The higher the health rating value the poorer the health condition

rate as shown by earlier study on captive elephants (Natarajan, 1986), apart from insufficiency to meet the nutrient requirements of the elephants. On the other hand, the natural feeding provided to the captive elephants in the Forest Department timber camps offer them access to varieties of palatable food plants available in the forest areas. Although the present study did not collect data on feeding by timber camp elephant in natural habitats earlier short term studies carried out on the captive elephants at Mudumalai timber camp identified a diverse browse species (27 spp.) being eaten by elephants in addition to a variety of grass species (Bouwmeester, 1986) including seasonal shift in diet selection (Maranko, 1987). The number of browse species consumed could still be more than the above report, if observations carried out round the year, because the Forest Department timber camp elephants from the base camps have access to dry deciduous and moist deciduous habitats and thus they can feed on a diverse food plants available in these habitats. A study by Baskaran (1998) on the wild elephants feeding in the dry and moist deciduous habitats of Mudumalai has shown that a minimum of 38 species of grass and browse constituted the diet of elephants in these habitats. Therefore, the Forest Department timber camp elephants with their natural feeding in the vast natural habitats did enjoy diverse food plants in accordance with seasonal variation in nutrient quality similar to wild elephants.

Intake rate of food quantity had been estimated to vary in different wild populations of elephants. African elephants in the wild feed on an average amount of food that equal to 5% of their body weight on wet matter basis (1.25% on dry matter basis) (Laws *et al.*, 1975), while the Asian elephants have been shown to consume slightly more (*i.e.*, 1.7% of body weight on dry matter basis) (Sukumar, 1989). In Tamil Nadu Forest Department the dry matter allotment to timber camp elephants had been fixed to be about 1.5 to 2% (Krishnamurthy and Wemmer, 1995). An experimental study with unlimited fodder supply to six different age classes of captive elephants in Aringer Anna Zoo, Tamil Nadu showed a mean consumption of 5.07% of body weight on wet matter basis (Natarajan, 1986). On an average, to consume food equaling 5% of body weight (on wet matter basis), a cow elephant requires as much as 150-175 kg of fodder and bull needs 200-275 kg of fodder per day (Natarajan, 1986). Nevertheless, the present study has estimated the mean amount of total food supplied to an adult class elephant was remarkably lower in Private (135 kg) and Temple (151 kg) managements than the quantity fed by an adult elephant in Forest Department (188 kg). In Forest Department system, the higher proportion adult males in the population could result in higher estimate of total food consumption to some extent compared to the other two systems, where adult male proportion is very low. Therefore a direct comparison of Private and Temple

elephant food quantity with that of Forest Department elephant may not be appropriate. Thus we estimated the food requirement per elephant per system based on 5% of body weight (mean body weight 3141 kg) and this worked out to 157 kgs/elephant in Private system and 164 kgs/elephant in the Temple facility (mean body weight 3279 kgs). Although elephants in the Private and Temple facilities would feed another 5 to 10 kg of food items at the time of begging and blessing (respectively by the Private and Temple elephants), the total quantity food supplied to these elephants could still be lower than the 5% of body weight prescribed. Further, the study also showed that in Private facility adult class elephants are fed with lesser quantity of food as compared to sub-adult class in the same facility. Such disproportionate food supply between systems and between age-classes (adult and sub-adult) within the Private system was mainly due to the reason that majority (70% out of 30 individuals) of adults in the Private facility were individually owned by *mahouts* (*mahout* - owners) who do not feed their elephants sufficiently perhaps due to inadequate earning by their elephants, while the two out of three elephants in the sub-adult class were owned by the Private agencies (Institutions) which supply more food to these elephants. In fact most of the elephants owned by the Private agencies (excluding the *mahouts* owned elephants) were fed with higher quantity of nutritive food. However, since larger proportion of elephants under Private management are owned by mahouts their insufficient food supply might have resulted in lower food supply among the Private elephants when compared to elephants in the Temple and Forest Department facilities.

Since grains, millets and cereals (provided as supplementary to captive elephants) are known to have higher nutrients than the wild plants eaten by the elephants in their natural habitats (Sukumar, 1989), the lower food supply in the case of Private and Temple elephants could have been compensated by higher quantities of supplementary diets. In contrast, the actual amount of supplementary diet fed to the Private elephants was also far lower than quantity of food fed to Forest Department elephants. In the case of Temple elephants also, the amount of supplementary diet was lower than the quantity supplied to Forest Department captive elephants. But their higher consumption of coconut (a protein rich diet fed to the elephants by the devotees) and relatively higher quantity of grams (with rich protein content of as high as 21 ppm) in their diet along with lower workload as compared to the Private elephants and absence of energy loss in breeding might probably, offset their lower food supply. Thus the Temple elephants are likely to upkeep their body condition better than the Private elephants as shown by health assessment data. The absence of breeding in Private

elephants (Vanitha, 2007) could offset the short supply of food to some extent. However, the workload imposed on them is so high that they could not keep up health conditions as shown by health assessment data.

Unlike the elephants in Private and Temple facilities, captive elephants managed by the Forest Department are well known for regular breeding (Krishnamurthy, 1995; Sukumar *et al.*, 1997; Vanitha, 2007). Thus in spite of their energy loss/expenditure in breeding, the Forest Department captive elephants showed better health condition than the Private and Temple elephants that did not spent energy in breeding. The possible reason for such condition could be their better management by the Forest Department in terms of food and feeding practices, as shown by the nutrient analysis results that the captive elephants managed by the Forest Department, with higher quantities of supplementary diets especially cereals, acquired a larger quantity of crude protein as compared to the Private and Temple elephants. Further, the opportunity for natural feeding available to the Forest Department timber camp elephants might also have increased their protein intake rate, as they had option to shift their diet selection according to season (Maranko, 1987) with which the protein content of food plants reported to vary (Sukumar, 1989; Sivaganesan and Johnsingh, 1995). Such an option was not available to the Private and Temple elephants, as their cut fodder supply were not changed according to seasonal variations in the nutrient contents of the food plants. Furthermore, important minerals like sodium (Na), iron (Fe), zinc (Zn) are higher in ragi, the major supplementary diet provided to Forest Department elephants, than in rice, the major supplementary diet of Private and Temple elephants. The insufficient supply of minerals and vitamins due to inadequate quality and quantity of green fodder and the supplementary diet in the case of Private and Temple elephants could affect the health conditions, as reported elsewhere on captive elephants (Ashraf *et al.*, 2001). A considerable number of elephants in the Temple facility with health problems like arthritis, blindness and overweight (Vanitha, 2007) could also be the result of inadequate nutrition and exercise (Vanitha, 2007). Thus it is essential for the management to ensure appropriate quantity and quality of food as prescribed by the veterinarian's to upkeep the captive elephants that belong to Private and Temple facilities.

CONCLUSIONS AND RECOMMENDATIONS

In summary, the captive elephants managed by the Forest Department unlike the elephants in the Private and Temple facilities, enjoyed a wide variety of food and showed better health condition in spite of their energy loss/expenditure in regular breeding, suggesting that the food and feeding practices are sufficient to meet the nutritive requirements in terms of quantity as well as

quality. On the other hand, though the Temple management provided green fodder of poor variety and quality to their elephants, they supplied the supplementary diet to their elephants, which was higher both in quantity and quality as compared to that of the Private facility. Although the food supply to Temple elephants was lower than the Forest Department captive elephants, their lower workload (limited to performing pooja and blessing the devotees) without much of physical work, coupled with absence of energy loss in reproduction (Vanitha, 2007) could easily offset the short supply of food and thus likely to upkeep the health condition as shown by the results of health assessment. Nevertheless, the insufficient supply of minerals and vitamins due to inadequate quality and quantity of green fodder would still have its adverse effect on the health conditions of these Temple elephants, as reported elsewhere on captive elephants (Ashraf *et al.*, 2001). A considerable number of elephants in the Temple facility with health problems like arthritis, blindness and overweight (Vanitha, 2007) could also be the result of inadequate or inappropriate nutrition and insufficient exercise (Vanitha, 2007). Similarly, in the case of the Private elephants (especially those owned by keepers) the poor health condition recorded could be due to the lower food supply and higher workload. Therefore with regards to food and feeding, we make the following recommendations to improve the health conditions of captive elephants.

- ◆ The captive elephants in Private and Temple facilities need to be provided with adequate quantity (5% of body weight) and quality (diverse) of green fodder with more of grass during rainy season and more browse during summer.
- ◆ Among the green fodders supplied to the captive elephants, *Sorghum vulgare*, *Cyanodon dactylon*, *Bambusa arundinacea*, *Ficus religiosa* and *Panicum* spp. with higher crude protein are of high importance to captive elephants in Tamil Nadu.
- ◆ Important microelement like sodium is found high in *B. arundinacea* and magnesium, iron and zinc in *Caryota urens* a frequently fed green fodder in southern Tamil Nadu bordering the Kerala. Such green fodders should be supplied wherever they are available locally.
- ◆ Similarly the quantity of supplementary food given to Temple and Private elephants should be based on the Veterinarian's prescription as per the age, sex, workload and reproductive status of elephants, as practiced for captive elephant in the Tamil Nadu Forest Department. However, some of the Temple and the Private (especially individually owned) facilities do not strictly follow the prescriptions. Steps must be taken to ensure that all elephants are provided with prescribed supplementary diets viz., Ragi, Rice, Horse

gram and Green gram with the last two items consisting of at least one third of the total quantity of supplementary diet in cooked form in order to meet the protein and other nutritional requirements of elephants.

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