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DIET COMPOSITION OF THE BONNET MACAQUE (*Macaca radiata*) IN A TROPICAL DRY EVERGREEN FOREST OF SOUTHERN INDIA

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ABSTRACT

The diet composition of the bonnet macaque (*Macaca radiata*) in a tropical dry evergreen forest was studied. This forest was chosen because is floristically different from other habitats in which bonnet macaques have been studied so far. Fruits formed the most important component of the bonnet macaque diet, followed by foliage and invertebrates. The percent frequency of use of different food items chosen by the monkeys did not vary significantly among age/sex classes. The monkeys were well dispersed as a result of an absence of predation pressure; hence, dominance hierarchy was absent due to a lack of competition over limited resources.

Key Words: age/sex class, bonnet macaque, diet, India, *Macaca radiata*, tropical dry evergreen forest.

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INTRODUCTION

Recent research on primates indicates that our understanding of the interaction of ecology and primate social structure is in a state of transition. Earlier studies explained social structure in primates by classifying primate species in discrete ecological and social categories (Crook and Gartlan, 1966; Eisenberg *et. al.*, 1972). Subsequently, Struhsaker (1969), Clutton-Brock (1974), Altmann (1974), Wilson (1975), and Terborgh and Janson (1986) have all pointed out that social behavior varies widely between species sharing the same ecological niche, challenging the view that interspecific differences are closely related to ecological variations. These studies, in turn, have led to the development of detailed research into adaptive differences in social behaviors such as food selection, ranging behavior, variation in grouping patterns, and antipredator behavior.

Since food selection increases the fitness of an individual, primate social structure, to an extent, depends on this. Only now are we beginning to appreciate the extent to which feeding behavior varies among and within primate species. It has, for example, only recently been realized that dietetic diversity varies among many

sympatric primate species (Hladik and Hladik, 1972; Clutton-Brock, 1975; Struhsaker and Oates, 1975; Crockett and Wilson, 1980); that, in some species, food choice differs systematically between the sexes (e.g., Pollock, 1977; Waser, 1977); and that diurnal variation in food choice may be widespread (Chivers, 1977; Wrangham, 1977). Understanding the extent of intraspecific variation in primate diets is important because of the many insights it can provide into evolutionary and ecological influences on feeding behavior (Clutton-Brock, 1977).

It was in this context that the feeding habits of the bonnet macaque (*Macaca radiata*) were chosen for a short-term study. Before this study was undertaken, bonnet macaques has been studied in most of their habitat range – including deciduous forest (Kurup, 1971), bamboo thickets (Kinloch, 1923), evergreen forests (Sugiyama, 1971), shoal vegetation (Khan, 1977), urban areas (Rahaman and Parthasarathy, 1967), and man-made habitats such as cultivated areas with roadside trees nearby (Simonds, 1965) – with the exception of tropical dry evergreen forests. The aim of this study was to study diet composition of the bonnet macaques in a tropical dry evergreen forest, with special attention given to diet variations among age and sex classes.

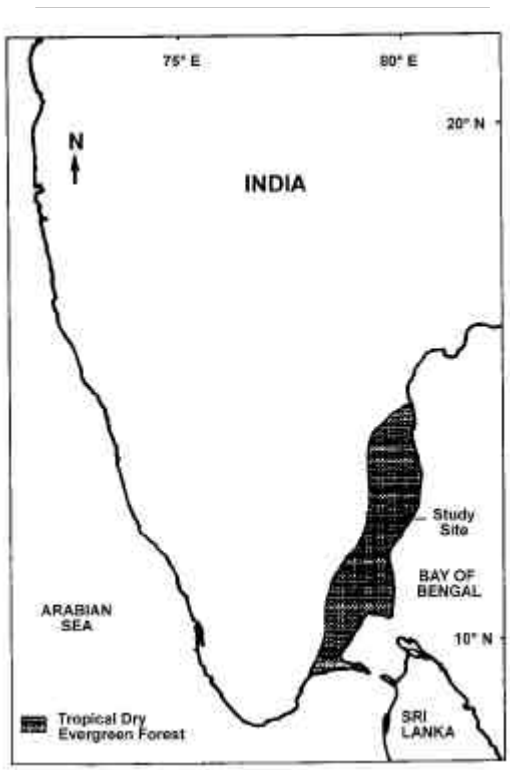

Figure 1. Map of southern India showing the distribution of tropical dry evergreen forests and the location of the study site.

STUDY SITE

The Marakkanam Reserve Forest is situated about 30 km north of Pondicherry in the South Arcot District of Tamil Nadu, southern India (Fig. 1). It lies along the coast at longitude 79°57' E and latitude 12°11' N. Three small dry areas of land occur in this region – Kurumbaram, Agaram, and Marakkanam – comprising areas of 246, 243 and 26 hectares, respectively. Kurumbaram, situated 10km from the sea, is relatively protected; unfortunately, Agaram and Marakkanam have been replaced by plantation of *Casuarina* and *Eucalyptus*. The terrain of the area is more or less a flat plain, with slight depressions formed by soil erosion.

The study was conducted in Kurumbaram. Two troops of *M. radiata* were found in this area. the study concentrated on the troop which occupied the eastern part of this forest. A narrow road, from Marakkanam to Tindivanam, divided the forest into two. On one side of the road was a patch of *Eucalyptus* plantation and the other side contained the relatively pristine tropical dry evergreen forest. Anthropogenic factors, such as the cutting of wood for fuel and the grazing of goats, have greatly reduced the density of the trees which has, in turn, led to severe soil erosion. When protected, however, these forests are dense with trees reaching a height of 20m. This can still be seen in a sacred grove, at Puthupet, which is about 20km from the study site.

The regional climate may be classified as "tropical dissymmetric" (Balasubramanyan, 1977), since the peak of the rainy season is toward the year's end (November) rather than toward the middle of the year (July). This area receives both the southwest and the northeast monsoons, but the northeast monsoon (October-December) plays the most active role in shaping the vegetation of this area. Cyclones originating from the Bay of Bengal are common during this period. Total rainfall is around 1400 mm/year. This area is generally warm, but in the months of April-May it is very hot. The average day temperature is around 34°C, and the night temperature is around 24°C.

The lowest mean relative humidity is encountered during May and June (57%) and the highest during October and November (77% and 81%, respectively). Although rainfall is meager during February-April, the nocturnal humidity remains high due to the proximity of the sea. Besides rainfall, temperature, and relative humidity, dew is also one of the important sources of moisture. On average, dew is formed on 44% of the days in a year and is usually seen until 0830 or 0900 h in the morning. Very little is known regarding the geology of this region in spite of the elaborate work of Krishnan (1956) in India and Burma. The soil of this area consists of fluviatile, unconsolidated sediments of clay, sand, and gravel in different proportions (Balasubramanyan, 1977).

According to Champion (1936), "tropical dry evergreen forests" are characterized by the predominance of hard-leaved evergreen trees with a few deciduous (often dense) emergents. The height of the emergents are generally under 12m, although under favorable conditions they may attain a maximum height of about 20m. A marked differentiation between the top canopy and the shrubby undergrowth is lacking. Climbers constitute a good proportion of the vegetation and

the forest is interspersed with many open patches; these patches are mostly due to biotic and anthropogenic factors and facilitate the growth of heliophilous species.

The forest studied resembles very much that of Champion's (1936) "tropical thorn forest," both floristically and in appearance (Balasubramanyan, 1977). However, Meher-Homji (1973) pointed out that the presence of the following six species characterizes the "dry evergreen formations": *Manilkara hexandra, Drypetes sepiaria, Memecylon umbellatum, Pterospermum suberifolium, Carmona macrophylla* and *Garcinia spicata*; the study site fits this characterization. As a result of the climate, this kind of forest is confied to northern Sri Lanka and the Coromandel coast of India. The climate is characterized by rains originating mainly from climatic depressions formed in the Bay of Bengal (some of which may reach the intensity of cyclones) from October through December and through a long dry season from January to June (Balasubramanyan, 1977). Thorny sclerophyllous formations have been recognized that are similar to those on the coasts of West Africa (Boughey, 1957) and Western Australia (Seddon, 1974), and on the islands of tropical America (Loveless and Asprey, 1957).

On vegetation maps, most of these vegetation types have been classified as "scrub woodlands" or "thickets," either dense or discontinuous, and occupy a restricted area in peninsular India. However, a scrutiny of the works published by Champion and Seth (1968), Dabholkar (1962) and Krishnan (1940) reveal that most of these natural thickets found in the Coromandel coast have been equated to "dry evergreen forests." In fact, a diversity exists regarding the physiognomy of these vegetation types (Meher-Homji, 1974). Some of those, known only in northern Sri Lanka, reach almost 15m to 30m in height (Dittus, 1985), while others are moderately tall and dense, with spiny thickets. But all these forests are subjected to constant biotic and anthropogenic pressures. Thanks to its protection by the Forest Department (since the end of the 19th century), the reserve forest in and around Marakkanam still appears as a moderately tall and more or less continuous thicket.

METHODS

To study the feeding patterns and diet composition of *M. radiata*, the frequency different food items were chosen was measured (Struhsaker, 1975; Rudran, 1978). The feeding patterns were observed continuously over 30 minute intervals, each of which was called a 'sample period.' Sampling was carried out from 0545-1900 h (dawn to dusk). Initially, to practice our methods and to enable the macaques to become used to our presence, the monkeys were provisioned and followed without the collection of any data for about 140 'sample periods.' The monkeys were observed using 10 x 50 binoculars. The study was conducted between 1 July and 17 August, 1991.

The monkeys were divided into four age/sex classes, which are listed below along with the numbers per group in the study. Since the dominance hierarchy and lineage of the monkeys were not known, the criteria used in determining an individual's age/sex class are also given. Members of these age/sex class were

observed and 'scored' for feeding using the above mentioned method. Six neonates which were part of the macaque troop were not included in the study.

Adult Male (n=3): Defined as any male that was morphologically bigger than an adult female by at least one-third.

Adult Female (n=6) Defined as any female that was carrying a neonate during the study period.

Subadult (n=4) Defined as any male that was morphologically similar to an adult female, or any female that was bigger than a juvenile but smaller than adult female.

Juvenile (n=4) Defined as any member that was independent of its mother, fed alone, and indulged in playing.

RESULTS

Macaca radiata exploited a wide variety of plant species and plant parts at Kurumbaram. In addition, they actively preyed upon invertebrates, which constituted an appreciable portion of their diet. Vertebrates were not eaten during the observations. During the 'sample period' considered for the study, 287 feeding observations were scored, with the bonnet macaques making use of 39 plant species and 73 specific food items (Appendix 1). Thirty-four of these species were identified, and five remained unidentified. Although the monkeys exploited a wide variety of plant species, they mostly fed on a selected few species. About 54.9% of the feeding observations were recorded from five species, and nearly 71.5% were from ten species (Table1).

Table 1. Rank order and frequency of use of the 10 most common plant species consumed by *M. radiata*. Species with tied rank order are listed alphabetically.

	Rank order of plant species	number of times used (n)	frequency of use (%)
1)	*Ficus benghalensis*	58	20.4
2)	*Azadirachta indica*	42	14.8
3)	*Tamarindus indica*	21	7.4
4)	*Cassia siamea*	18	6.3
5)	*Dichrostachys cinerea*	17	6.0
6)	*Ehretia macrophylla*	11	3.9
7)	*Maba buxifolia*	11	3.9
8)	*Manihot esculenta*	9	3.2
9)	*Flueggea leucopyrus*	8	2.8
10)	*Syzygium cumini*	8	2.8

Ficus benghalensis was the most frequently consumed plant species (20.4% of all scored feedings), followed by *Azadirachta indica* (14.8%) (Table 1). When specific food items were considered, the fruits of *Ficus benghalensis* and *Azadirachta indica* again occupied the top slots, comprising 19.0% and 13.7%, respectively, of all consumed food items. The top 10 rank orders of specific food items constituted 54.9% of their diet, and the top 20 made up 70.4% of the diet. (Table 2). When the use of food items (regardless of plant species was considered, fruits were the most important food items and constituted 47.9% of the total plant diet. Ali (1986) reported that in his study on bonnet macaques, 53.4% of the *M. radiata* diet consisted of fruits. Field studies on other macaques have also noted predominant frugivory, including studies on *M. mulatta* (65-70%; Lindburg, 1977), *M. fascicularis* (87%; Wheatley, 1980), *M. sylvanus* (33%; Drucker, 1984), *M. nemestrina* (74.2%: Caldecott, 1986), and *M. silenus* (60%; Kumar, 1987).

Table 2. Rank order and frequency of use of the 20 most common food items consumed by *M. radiata*. Food items with tied rank order are listed alphabetically.

	Rank order of food item	number of times used (n)	frequency of use (%)
1)	*Ficus benghalensis*, fruits	54	19.0
2)	*Azadirachta indica*, fruits	39	13.7
3)	*Cassia siamea*, flower buds	9	3.2
4)	*Dichrostachys cinerea*, mature leaves	9	3.2
5)	*Dichrostachys cinerea*, young leaves	8	2.8
6)	*Fluggea leucopyrus*, mature leaves	8	2.8
7)	*Tamarindus indica*, mature leaves	8	2.8
8)	*Cassia siamea*, blossoms	7	2.5
9)	*Ehretia macrophylla*, mature leaves	7	2.5
10)	*Maba buxifolia*, fruits	7	2.5
11)	*Abrus precatorius*, mature leaves	5	1.8
12)	*Carissa carandas*, blossoms	5	1.8
13)	*Manihot esculenta*, young leaves	5	1.8
14)	*Tamarindus indica*, fruits	5	1.8
15)	*Elaeucine coracana*, fruits	4	1.4
16)	*Ficus religiosa*, fruits	4	1.4
17)	*Madhuca longifolia*, fruits	4	1.4
18)	*Oryza sativa*, seeds	4	1.4
19)	*Syzygium cumini*, fruits	4	1.4
20)	*Syzygium cumini*, galls	4	1.4

The importance of foliar food is indicated by the fact that seven food plants were among the top 20 most frequently eaten food items: *Dichrostachys cinerea. Fluggea leucopyrus, Tamarindus indica, Ehretia microphylla, Manihot esculenta*, and *Abrus precatorius* (Table 2). The presence of foliage items in the diet is also reflected in Table 3. Flowers and seeds also constituted a considerable portion of the diet. See Appendices 2, 3, 4 and 5 for a list of all plant parts eaten.

After fruits and leaves, invertebrates formed the third most important food resource. Forty-eight out of a total of 335 feeding observations (14.5%) were for invertebrates (Table 3). In one instance, a juvenile was seen eating mud from a termite mound, which was moist due to the previous day's rain. It scooped the mud from the mound and ate three mouthfuls. One of the other members ate mud during the study period (also see Krishnamani, 1991).

Diet variation by age/sex class

Diet variation was looked at among the age/sex classes. Adult males were dominant in obtaining food doled out by the villagers (pers. observ.). The overall number of plant species and plant parts used was more or less equal among the different classes (Table 4). There were, however, considerable differences in the amount of specific food items eaten when one compares the age/sex classes (Table 3). Adult males and females ate more invertebrates than the subadults and juveniles; subadults and juveniles consumed more fruits than their older counterparts. None of these differences, however, were statistically significant (Table 5).

Table 3. Proportion of different food items consumed by the four age/sex classes of *M. radiata*.

Plant part:	**All**	**AM**	**AF**	**SA**	**Ju**
Fruits (FR)	41.0	49.7	51.8	56.1	59.0
Mature Leaves (mL)	17.2	10.6	15.1	11.6	16.2
Young Leaves (yL)	5.7	7.1	4.2	5.8	2.3
Leaf buds (Lb)	2.1	2.1	-	1.3	1.3
Dry Leaves (dL)	0.6	-	1.2	-	-
Flower Buds (Fb)	3.3	1.4	2.4	2.6	2.3
Blossoms (Bl)	5.4	3.6	4.8	3.9	3.5
Seeds (Sd)	5.1	4.3	4.8	7.1	4.6
Stems (St)	0.2	-	-	-	0.1
Bark (Ba)	0.3	-	0.6	-	-
Galls (Ga)	1.8	0.7	-	2.6	0.6
UPP	3.6	7.1	2.4	2.6	1.7
Invertebrates (Inv)	14.5	13.5	12.1	6.5	8.7

KEY: All=the four age/sex classes combined; AM=Adult Male; AF=Adult Female; SA=Subadult; JU=Juvenile; UPP=Unidentified Plant Part.

DISCUSSION

Although *Macaca radiata* exploited a wide variety of food items, they concentrated on a rather small number of select species. Fruits were the most important component of the diet, but leaves and flowers were also significant. Fruits normally contain relatively large amount of simple sugars and are readily usable sources of energy.

The consumption of leaves probably satisfied certain nutrient requirements of *M. radiata*: mature leaves have fairly high concentrations of calcium (Biddulph, 1959), and some young leaves contain a high percentage of crude protein (Struhsaker, 1975).

The folivorous aspect of the bonnet macaque's diet was perhaps adaptive in the context of the lifestyle of this species and the periodic fluctuations in the abundance of various food resources (Ellefson, 1968). Morton (1973) has noted that among frugivorous birds there may be intense selection favoring the ability to exploit a wide variety of foods even if periods of fruit scarcity are relatively improbable. Primates like *M.radiata*, which depend a great deal on fruits, also probably experience the same selection pressure. This affords an explanation for the wide variety of food items used by *M. radiata*. The broad array of foods eaten may be the result of a diverse diet during periods of fruit shortage, as well as the exploitation of small quantities of different items even when fruits are being extensively used.

Table 4. The number of plant species and plant parts consumed by members of the four age/sex classes.

Age/Sex Class	No. of plant species used	No. of plant parts used
Adult males	26	39
Adult females	26	38
Subadults	25	39
Juveniles	25	38

Freeland and Janzen (1974) hypothesize that herbivores must continuously sample a variety of the foods available to them in order to maintain enzymatic pathways for detoxifying secondary compounds. This allows them to ingest large quantities of relatively toxic foods if necessary (i.e., when preferred foods are in short supply) without suffering any ill effects. It is possible that *M. radiata* consumes several foods, especially leafy foods (which usually contain toxic substances), in order to keep periodically-important metabolic pathways open. The use of a wide variety of foods may also be necessary to maximize food intake and to increase total food consumption.

In general, shoots, flowers, and fruit are more commonly eaten than the mature leaves of a given species (Table 4). This is easily explicable in terms of the higher protein content and lower cellulose levels found in these plant parts compared to mature leaves (Hladik, 1977a; 1977b). Difference among plant species concerning the plant parts most often consumed are also probably related to such nutritional differences. In many cases, food choice may be the products of simple differences in energetic value of digestibility. For example, primates such as *Colobus guereza*, which feed largely on mature leaves, tend to select leaves of deciduous tree species (Oates, 1977); such species' leaves often contain lower levels of cellulose and are more easily digested than those of evergreen species.

The leaves and, to a lesser extent, the fruit of different species vary in the specific nutrients they contain. In order to achieve a balanced diet, it may be necessary for both folivores and frugivores (in this case, *M. radiata*) to select particular food species for their chemical content (Westoby, 1974). For example, Oates (1977) found that a two to four-week intervals, *Colobus guereza* groups descended from the trees and traveled to pools of open water in swampy areas to feed on aquatic plants. Subsequent analysis revealed that the leaves of these species contained high levels of sodium, an element which may have been relatively scarce in the rest of the animal's diet. It may even prove to be the case that the extent to which plant species are selected depends on the particular amino acids which they contain. For example, *Pan troglodytes* in Gabon have been shown to select plant and insect species whose amino acids compositions were complementary (Hladik, 1977b).

The seeds and leaves of many tropical tree species contain a variety of secondary compounds, including tannins, alkaloids, and terpenes (Bate-Smith, 1972). Not only do animals eschew plant parts containing especially high levels of toxins, but they may also vary their diet within the span of just several days to avoid acquiring too high a dose of any one toxin (Freeland and Janzen, 1974). However, there is little evidence for the importance of toxin avoidance in determining food choice in primates. While a wide variety of secondary compounds are present in most leaves, their levels are frequently low and small amounts can usually be eaten without danger. For example, *Pan troglodytes*, which possesses a simple digestive system and thus cannot detoxify foods through fermentation preceding absorption, shows little selection against plant species in which alkaloids occur, though it may avoid those carrying high concentrations (Hladik, 1977b).

M. radiata most likely hunts invertebrates for their protein. Invertebrates are ready source of protein, whereas mature leaves contain cellulose and secondary compounds and are thus rather difficult to digest. The monkeys possibly also ate galls in order to obtain protein – sometimes the fruits of this plant contain insect larvae, and in this context fruit-eating can be seen as a form of insectivory (Waser, 1977).

Diet variation by age/sex class

In this study of *M. radiata*, there was no significant variation in the diet with respect to age/sex class. With no predation pressure in the habitat under study, and since natural food sources were abundant, the animals were dispersed and freely chose their feeding sites from among the many unoccupied ones. Here, ecological factors such as population distribution patterns and the volume of available food appeared to be more important than social factors such as kinship or dominance relationships in the animal's choice of food and feeding sites.

In a study of female vervet monkeys (*Cercopithecus aethiops*), Whitten (1983) found that dominance-biased differences in food intake appeared only where food items were clumped in their distribution, and that there was no significant relationship between supplant rates and and food distribution. This may be because

subordinates avoided clumped food sources at which dominants were feeding. In other studies of group-living primates, it was found that when food was clumped in its distribution, dominants had priority of access to the food (*Macaca fuscata*: Iwamoto, 1974; *Cercopithecus aethiops*: Wrangham, 1981). Dominance relationships probably influence an animal's choice when food sources are clumped. Similar results have been obtained for *Macaca fuscata* on Koshima Islet (Mori, 1977; Furuichi, 1983; Ihobe, 1989). Malik and Southwick (1987) have reported that for *M. mulatta*, dominance relationships become evident and fighting occurs when preferred food sources are either scarce or clumped.

Table 5. Summary of the χ^2 statistic comparisons between different pair combinations of age/sex classes. No pairings revealed significant differences among age/sex classes regarding variations in diet.

	Pair combinations:					
	AM/AF	AM/SA	AM/JU	AF/SA	AF/JU	SA/JU
c^2	4.670	7.479	9.215	4.352	1.948	4.654
df	9	9	9	9	9	9
p	0.8621	0.5874	0.4177	0.8867	0.9923	0.8633

KEY: AM=adult male; AF=adult female; SA=subadult; JU=juvenile.

Other researchers have reported age/sex differences in the diets of many species. Ali (1986) reported that in a group of *M. radiata*, subadult males spent the maximum amount of time feeding among all age/sex classes, while this dropped to the minimum amount of time when they became the dominant males. Dittus (1980) observed that the adult males of *M. sinica* "consumed the greatest proportion of foods that are high in proteins and calories" than any other members of the group. In *Indri indri* (Pollock, 1977), males may eat more fruit and less foliage than females. In addition, *Cercocebus albigena* Waser (1977) found that males spent proportionately (though not absolutely) more time feeding on fruit and less time foraging for insects than females and immature animals, whereas immatures spent more time feeding on flowers and stems of leaves. Conversely, *Pongo pygmaeus* males may eat less fruit and more bark than females, particularly when food is scarce (Rodman, 1977).

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Appendix 1. Frequency of use (%) of specific food items consumed by *M. radiata* (all sex/age classes combined) during the study period. '*' indicates a cultivated species.

Species	**Lb**	**yL**	**mL**	**dL**	**St**	**Fb**	**Bl**	**Fr**	**Sd**	**Ga**	**Ba**	**UPP**	**(n)**	**(%)**
Ficus bengalensis	-	-	-	0.7	-	-	-	19.0	-	0.4	-	0.4	58	20.4
Azadirachta indica	0.7	-	0.4	-	-	-	-	13.8	-	-	-	-	42	14.8
Tamarindus indica	0.4	0.4	2.8	-	-	-	1.1	1.8	1.1	-	-	-	21	7.4
Cassia siamea	-	-	0.4	-	-	3.2	2.5	-	0.4	-	-	-	18	6.3
Dichrostachys cinerea	-	2.8	3.2	-	-	-	-	-	-	-	-	-	17	6.0
Maba buxifolia	-	-	0.4	-	-	-	-	2.5	1.1	-	-	-	11	3.9
Ehretia microphylla	-	-	2.5	-	-	-	0.4	1.1	-	-	-	-	11	3.9
Manihot esculenta *	-	1.8	0.7	-	-	-	-	-	-	-	-	0.7	9	3.2
Fluggea leucopyrus	-	-	2.8	-	-	-	-	-	-	-	-	-	8	2.8
Syzygium cumini	-	-	-	-	-	-	-	1.4	-	1.4		-	8	2.8
Carissa carandas	-	-	0.7	-	-	-	1.8	-	-	-	-	-	7	2.5
Cassia auriculata	0.4	0.7	0.7	-	0.4	-	-	-	-	-	-	-	6	2.1
Ficus religiosa	-	-	-	-	-	-	-	1.4	-	-	0.4	-	5	1.8
Mangifera indica	-	-	-	-	-	-	-	1.1	0.7	-	-	-	5	1.8
Abrus precatorius	-	-	1.8	-	-	-	-	-	-	-	-	-	5	1.8
Dalbergia paniculata	0.4	-	0.4	-	-	0.4	-	-	0.7	-	-	-	5	1.8
Oryza sativa *	-	-	-	-	-	-	-	-	1.4	-	-	-	4	1.4
Madhu longifolia	-	-	-	-	-	-	-	1.4	-	-	-	-	4	1.4
Jasminum angustifolium	-	-	-	-	-	0.4	-	1.1	-	-	-	-	4	1.4
Tephrosia villosa	0.4	0.4	0.7	-	-	-	-	-	-	-	-	-	4	1.4
Pterolobium hexapetalum	-	0.7	0.7	-	-	-	-	-	-	-	-	-	4	1.4
Eleusine coracana *	-	-	-	-	-	-	-	1.4	-	-	-	-	4	1.4
Jatropha gossyiifolia	-	-	-	-	-	-	0.4	-	0.7	-	-	-	3	1.1
Carissa spinarum	-	-	0.7	-	-	-	0.4	-	-	-	-	-	3	1.1
Pongamia pinnata	-	-	-	-	-	-	-	-	-	0.4	-	0.7	3	1.1
Psidium guajava *	-	-	-	-	-	-	-	0.7	-	-	-	-	2	0.7
Zizyphus oenoplia	0.4	-	0.4	-	-	-	-	-	-	-	-	-	2	0.7
Solanum melongena *	-	-	-	-	-	-	-	0.4	-	-	-	-	1	0.4
Prosopis juliflora	-	-	0.4	-	-	-	-	-	-	-	-	-	1	0.4
Aristida sp.	-	-	-	-	-	-	-	0.4	-	-	-	-	1	0.4
Borassus flabellifer	-	-	-	-	-	-	-	0.4	-	-	-	-	1	0.4
Grass 1	-	-	0.4	-	-	-	-	-	-	-	-	-	1	0.4
Opuntia stricta var. *dillenii*	-	-	-	-	-	-	-	0.4	-	-	-	-	1	0.4
Albizia amara	-	-	0.4	-	-	-	-	-	-	-	-	-	1	0.4
Uniden. plant spp. (5)	-	-	-	-	-	-	-	-	-	-	-	2.5	7	2.5
No. of food items	6	6	19	1	1	3	6	16	7	3	1	4	287	
Freq. of use (%)	2.5	6.7	20.0	0.7	0.4	3.9	6.3	47.9	6.0	2.1	0.4	4.2		

KEY: Lb=leaf buds; yL=young leaves; mL=mature leaves; dL=dry leaves; St=stems; Fb=flower buds; Bl=blossoms; Fr=fruits; Sd=seeds; Ga=galls; Ba=bark; UPP=unidentified plant part; (n)=total nimber of times a species used; (%)=total frequency that species was used.

Appendix 2. Frequency of use (%) of specific food items consumed by adult male *M. radiata* during the study period. '*' indicates a cultivated species.

Species	**Lb**	**yL**	**mL**	**dL**	**St**	**Fb**	**Bl**	**Fr**	**Sd**	**Ga**	**Ba**	**UPP**	**(n)**	**(%)**
Ficus bengalensis	-	-	-	-	-	-	-	25.4	-	-	-	0.8	32	26.2
Azadirachta indica	0.8	-	-	-	-	-	-	14.8	-	-	-	-	19	15.6
Dichrostachys cinerea	-	3.3	3.3	-	-	-	-	-	-	-	-	-	8	6.6
Manihot esculenta *	-	3.3	1.6	-	-	-	-	-	-	-	-	0.8	7	5.7
Maba buxifolia	-	-	-	-	-	-	-	2.5	0.8	-	-	-	4	3.3
Cassia siamea	-	-	-	-	-	-	0.8	0.8	0.8	-	-	-	3	2.5
Mangifera indica	-	-	-	-	-	-	-	1.6	0.8	-	-	-	3	2.5
Syzygium cumini	-	-	-	-	-	-	-	2.5	-	-	-	-	3	2.5
Oryza sativa *	-	-	-	-	-	-	-	-	2.5	-	-	-	3	2.5
Eleusine coracana *	-	-	-	-	-	-	-	2.5	-	-	-	-	3	2.5
Pterolobium hexapetalum	-	0.8	1.6	-	-	-	-	-	-	-	-	-	3	2.5
Tamarindus indica	-	-	-	-	-	-	0.8	1.6	-	-	-	-	3	2.5
Ehretia microphylla	-	-	0.8	-	-	-	0.8	0.8	-	-	-	-	3	2.5
Pongamia pinnata	-	-	-	-	-	-	-	-	-	0.8	-	0.8	2	1.6
Psidium guajava *	-	-	-	-	-	-	-	1.6	-	-	-	-	2	1.6
Jasminum angustifolium	-	-	-	-	-	-	-	1.6	-	-	-	-	2	1.6
Fluggea leucopyrus	-	-	1.6	-	-	-	-	-	-	-	-	-	2	1.6
Madhu longifolia	-	-	-	-	-	-	-	1.6	-	-	-	-	2	1.6
Carissa carandas	-	-	0.8	-	-	-	0.8	-	-	-	-	-	2	1.6
Abrus precatorius	-	-	1.6	-	-	-	-	-	-	-	-	-	2	1.6
Tephrosia villosa	0.8	0.8	-	-	-	-	-	-	-	-	-	-	2	1.6
Opuntia stricta var. *dillenii*	-	-	-	-	-	-	-	0.8	-	-	-	-	1	0.8
Dalbergia paniculata	-	-	-	-	-	0.8	-	-	-	-	-	-	1	0.8
Jatropha gossypiifolia	-	-	-	-	-	-	0.8	-	-	-	-	-	1	0.8
Grass 1	-	-	0.8	-	-	-	-	-	-	-	-	-	1	0.8
Zizyphus oenoplia	0.8	-	-	-	-	-	-	-	-	-	-	-	1	0.8
Uniden. plant spp.	-	-	-	-	-	-	-	-	-	-	-	5.7	7	5.7
No. of food items	3	4	8	-	-	1	5	13	4	1	-	4	122	
Freq. of use (%)	2.5	8.2	12.3	-	-	0.8	4.1	58.1	4.9	0.8	-	~~0.8~~ 8.1		

KEY: Lb=leaf buds; yL=young leaves; mL=mature leaves; dL=dry leaves; St=stems; Fb=flower buds; Bl=blossoms; Fr=fruits; Sd=seeds; Ga=galls; Ba=bark; UPP=unidentified plant part; (n)=total nimber of times a species used; (%)=total frequency that species was used.

Appendix 3. Frequency of use (%) of specific food items consumed by adult female *M. radiata* during the study period. '*' indicates a cultivated species.

Species	**Lb**	**yL**	**mL**	**dL**	**St**	**Fb**	**Bl**	**Fr**	**Sd**	**Ga**	**Ba**	**UPI**	**(n)**	**(%)**
Ficus bengalensis	-	-	-	1.4	-	-	-	27.4	-	-	-	0.7	43	29.5
Azadirachta indica	-	-	0.7	-	-	-	-	17.1	-	-	-	-	26	17.8
Dichrostachys cinerea	-	3.4	4.1	-	-	-	-	-	-	-	-	-	11	7.5
Cassia siamea	-	-	0.7	-	-	2.7	2.7	-	0.7	-	-	-	10	6.9
Manihot esculenta *	-	1.4	1.4	-	-	-	-	-	-	-	-	1.4	6	4.1
Tamarindus indica	-	-	-	-	-	-	1.4	2.1	-	-	-	-	5	3.4
Oryza sativa *	-	-	-	-	-	-	-	-	2.7	-	-	-	4	2.7
Ehretia microphylla	-	-	2.1	-	-	-	-	0.7	-	-	-	-	4	2.7
Maba buxifolia	-	-	-	-	-	-	-	2.7	-	-	-	-	4	2.7
Carissa spinarum	-	-	1.4	-	-	-	0.7	-	-	-	-	-	3	2.1
Mangifera indica	-	-	-	-	-	-	-	1.4	0.7	-	-	-	3	2.1
Fluggea leucopyrus	-	-	2.1	-	-	-	-	-	-	-	-	-	3	2.1
Madhu longifolia	-	-	-	-	-	-	-	2.1	-	-	-	-	3	2.1
Ficus religiosa	-	-	-	-	-	-	-	1.4	-	-	0.7	-	3	2.1
Abrus precatorius	-	-	2.1	-	-	-	-	-	-	-	-	-	3	2.1
Syzygium cumini	-	-	-	-	-	-	-	0.7	0.7	-	-	-	2	1.4
Psidium guajava *	-	-	-	-	-	-	-	1.4	-	-	-	-	2	1.4
Solanum melongena *	-	-	-	-	-	-	-	0.7	-	-	-	-	1	0.7
Tephrosia villosa	-	-	0.7	-	-	-	-	-	-	-	-	-	1	0.7
Jatropha gossyiifolia	-	-	-	-	-	-	-	-	0.7	-	-	-	1	0.7
Prosopis juliflora	-	-	0.7	-	-	-	-	-	-	-	-	-	1	0.7
Borassus flabellifer	-	-	-	-	-	-	-	0.7	-	-	-	-	1	0.7
Jasminum angustifolium	-	-	-	-	-	-	-	0.7	-	-	-	-	1	0.7
Pterolobium hexapetalum	-	-	0.7	-	-	-	-	-	-	-	-	-	1	0.7
Carissa carandas	-	-	-	-	-	-	0.7	-	-	-	-	-	1	0.7
Cassia auriculata	-	-	0.7	-	-	-	-	-	-	-	-	-	1	0.7
Uniden. plant spp.	-	-	-	-	-	-	-	-	-	-	-	1.4	2	1.4
No. of food items	-	2	12	1	-	1	4	13	5	1	1	3	146	
Freq. of use (%)	-	4.8	17.0	1.4	-	2.7	5.5	58.9	5.5	-	0.7	3.4		

KEY: Lb=leaf buds; yL=young leaves; mL=mature leaves; dL=dry leaves; St=stems; Fb=flower buds; Bl=blossoms; Fr=fruits; Sd=seeds; Ga=galls; Ba=bark; UPP=unidentified plant part; (n)=total nimber of times a species used; (%)=total frequency that species was used.

Appendix 4. Frequency of use (%) of specific food items consumed by subadult *M. radiata* during the study period. '*' indicates a cultivated species.

Species	**Lb**	**yL**	**mL**	**dL**	**St**	**Fb**	**Bl**	**Fr**	**Sd**	**Ga**	**Ba**	**UPI**	**(n)**	**(%)**
Ficus bengalensis	-	-	-	-	-	-	-	31.0	-	0.7	-	-	46	31.7
Azadirachta indica	0.7	-	-	-	-	-	-	13.8	-	-	-	-	21	14.5
Tamarindus indica	0.7	0.7	0.7	-	-	-	1.4	3.5	2.1	-	-	-	13	9.0
Dichrostachys cinerea	-	3.5	4.1	-	-	-	-	-	-	-	-	-	11	7.6
Cassia siamea	-	-	-	-	-	2.1	2.1	-	0.7	-	-	-	7	4.8
Syzygium cumini	-	-	-	-	-	-	-	2.1	-	2.1	-	-	6	4.1
Manihot esculenta *	-	2.1	1.4	-	-	-	-	-	-	-	-	-	5	3.5
Ehretia microphylla	-	-	2.1	-	-	-	-	1.4	-	-	-	-	5	3.5
Eleusine coracana *	-	-	-	-	-	-	-	2.8	-	-	-	-	4	2.8
Oryza sativa *	-	-	-	-	-	-	-	-	2.1	-	-	-	3	2.1
Dalbergia paniculata	-	-	0.7	-	-	-	-	-	1.4	-	-	-	3	2.1
Mangifera indica	-	-	-	-	-	-	-	0.7	0.7	-	-	-	2	1.4
Ficus religiosa	-	-	-	-	-	-	-	1.4	-	-	-	-	2	1.4
Psidium guajava *	-	-	-	-	-	-	-	1.4	-	-	-	-	2	1.4
Fluggea leucopyrus	-	-	1.4	-	-	-	-	-	-	-	-	-	2	1.4
Carissa carandas	-	-	-	-	-	-	0.7	-	-	-	-	-	1	0.7
Opuntia stricta var. *dillenii*	-	-	-	-	-	-	-	0.7	-	-	-	-	1	0.7
Jatropha gossypiifolia	-	-	-	-	-	-	-	-	0.7	-	-	-	1	0.7
Jasminum angustifolium	-	-	-	-	-	0.7	-	-	-	-	-	-	1	0.7
Pterolobium hexapetalum	-	-	0.7	-	-	-	-	-	-	-	-	-	1	0.7
Carissa spinarum	-	-	0.7	-	-	-	-	-	-	-	-	-	1	0.7
Aristida sp.	-	-	-	-	-	-	-	0.7	-	-	-	-	1	0.7
Pongamia pinnata	-	-	-	-	-	-	-	-	-	-	-	0.7	1	0.7
Cassia auriculata	-	-	0.7	-	-	-	-	-	-	-	-	-	1	0.7
Madhu longifolia	-	-	-	-	-	-	-	0.7	-	-	-	-	1	0.7
Uniden. plant spp.	-	-	-	-	-	-	-	-	-	-	-	2.1	3	2.1
No. of food items	2	3	9	-	-	2	3	12	6	2	-	2	145	
Freq. of use (%)	1.4	6.2	12.4	-	-	2.8	4.1	60.0	7.6	2.8	-	2.8		

KEY: Lb=leaf buds; yL=young leaves; mL=mature leaves; dL=dry leaves; St=stems; Fb=flower buds; Bl=blossoms; Fr=fruits; Sd=seeds; Ga=galls; Ba=bark; UPP=unidentified plant part; (n)=total nimber of times a species used; (%)=total frequency that species was used.

Appendix 5. Frequency of use (%) of specific food items consumed by juvenile *M. radiata* during the study period. '*' indicates a cultivated species.

Species	**Lb**	**yL**	**mL**	**dL**	**St**	**Fb**	**Bl**	**Fr**	**Sd**	**Ga**	**Ba**	**UPI**	**(n)**	**(%)**
Ficus bengalensis	-	-	-	-	-	-	-	31.0	-	-	-	-	49	31.0
Azadirachta indica	-	-	-	-	-	-	-	18.4	-	-	-	-	29	18.4
Tamarindus indica	-	-	5.1	-	-	-	1.3	1.9	0.6	-	-	-	14	8.9
Cassia siamea	-	-	-	-	0.6	2.5	1.9	-	0.6	-	-	-	9	5.7
Dichrostachys cinerea	-	1.9	2.5	-	-	-	-	-	-	-	-	-	7	4.4
Manihot esculenta *	-	-	1.9	-	-	-	-	-	-	-	-	1.3	5	3.2
Maba buxifolia	-	-	0.6	-	-	-	-	1.3	1.3	-	-	-	5	3.2
Syzygium cumini	-	-	-	-	-	-	-	1.9	-	0.6	-	-	4	2.5
Eleusine coracana *	-	-	-	-	-	-	-	2.5	-	-	-	-	4	2.5
Ehretia microphylla	-	-	2.5	-	-	-	-	-	-	-	-	-	4	2.5
Oryza sativa *	-	-	-	-	-	-	-	-	1.9	-	-	-	3	1.9
Cassia auriculata	0.6	0.6	0.6	-	-	-	-	-	-	-	-	-	3	1.9
Fluggea leucopyrus	-	-	1.9	-	-	-	-	-	-	-	-	-	3	1.9
Mangifera indica	-	-	-	-	-	-	-	1.3	0.6	-	-	-	3	1.9
Carissa carandas	-	-	0.6	-	-	-	0.6	-	-	-	-	-	2	1.3
Madhu longifolia	-	-	-	-	-	-	-	1.3	-	-	-	-	2	1.3
Psidium guajava *	-	-	-	-	-	-	-	1.3	-	-	-	-	2	1.3
Ficus religiosa	-	-	-	-	-	-	-	1.3	-	-	-	-	2	1.3
Jasminum angustifolium	-	-	-	-	-	-	-	0.6	-	-	-	-	1	0.6
Albizia amara	-	-	0.6	-	-	-	-	-	-	-	-	-	1	0.6
Aristida sp.	-	-	-	-	-	-	-	0.6	-	-	-	-	1	0.6
Zizyphus oenoplia	-	-	0.6	-	-	-	-	-	-	-	-	-	1	0.6
Solanum melongena *	-	-	-	-	-	-	-	0.6	-	-	-	-	1	0.6
Abrus precatorius	-	-	0.6	-	-	-	-	-	-	-	-	-	1	0.6
Dalbergia paniculata	0.6	-	-	-	-	-	-	-	-	-	-	-	1	0.6
Uniden. plant spp.	-	-	-	-	-	-	-	-	-	-	-	1.3	2	1.3
No. of food items	2	2	11	-	1	1	3	13	5	1	-	12	159	
Freq. of use (%)	1.3	2.5	17.7	-	0.6	2.5	3.8	64.6	5.1	0.6	-	2.5		

KEY: Lb=leaf buds; yL=young leaves; mL=mature leaves; dL=dry leaves; St=stems; Fb=flower buds; Bl=blossoms; Fr=fruits; Sd=seeds; Ga=galls; Ba=bark; UPP=unidentified plant part; (n)=total nimber of times a species used; (%)=total frequency that species was used.