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Food habits of *Cynopterus brachyotis* (Muller) (Chiroptera: Pteropodidae) in Peninsular Malaysia

K. H. TAN*, A. ZUBAID*[1] *and* T. H. KUNZ†

**Department of Zoology, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia (e-mail: zubaid@ukm.my)*
†Department of Biology, Boston University, Boston, Massachusetts 02215, USA
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ABSTRACT. Information on the feeding habits of the lesser dog-faced fruit bat, *Cynopterus brachyotis*, was obtained by the collection of food remains directly beneath daytime and feeding roosts. The bats were found to feed on the fruits of 54 plant species, the leaves of 14 species and the flower parts of four species. The seasonal phenological differences among congeneric plant species led to a steady production of fruit throughout the year and the data suggest that *Ficus* spp. are a key component in the diet. Judging from its wide selection of fruits, *C. brachyotis*, is considered to be an important seed disperser. Folivory in *C. brachyotis* appears to be more common than previously thought. Of the leaves consumed by the bats, seven species belonged to the family Leguminosae, followed by Myrtaceae, Moraceae, Rhizophoraceae and Euphorbiaceae. Fruits, in general, provide an energy-rich diet for phytophagous bats but most are low in protein. In contrast, leaves consumed by bats have a relatively high protein content. We suggest that folivory (by leaf fractionation) should be energetically more advantageous than the ingestion of large amounts of low protein fruit or the active pursuit of mobile insects.

KEY WORDS: *Cynopterus brachyotis*, *Ficus*, flowers, folivory, fruits, Malaysia, secondary forest

INTRODUCTION

All species of pteropodids are thought to be mainly phytophagous, taking fruit, floral resources (nectar and pollen), or leaves (Fleming 1982, Kitchener *et al.* 1990, Kunz 1996, Kunz & Diaz 1995, Lim 1970; Marshall 1983, 1985; Phua & Corlett 1989) with insects forming a small component (Funakoshi *et al.* 1993,

[1]Corresponding author.

Lim 1970). In the wild, the feeding areas and the composition of their food are largely influenced by the seasonal flowering and fruiting of trees (Lim 1966). Marshall (1983) suggested that phytophagous bats are neither true generalists nor specialists, but rather 'sequential specialists', favouring at any time one or a few plant species amongst potential food plants available at that season.

The lesser dog-faced fruit bat, *Cynopterus brachyotis* (Muller), is a common frugivorous species in Southeast Asia. Throughout its range, this bat occupies a variety of habitats including primary forest, disturbed forest, mangrove, cultivated areas, orchards, gardens and urban areas (Francis 1990, 1994; Lim 1966, Medway 1983, Phua & Corlett 1989; Zubaid 1993, 1994). This species is well adapted to anthropogenic conditions. In an earlier study (Tan *et al*. 1997), we showed that *C. brachyotis* modified the leaves of palm trees to construct tents which were than used as day and/or feeding roosts. Apart from identifying suitable roosting sites, it is also important to know the kinds of food resources that sustain these populations in urban areas. Here we report some preliminary data on the food habits of *C. brachyotis* in an urban environment.

METHODS

Three study sites were selected based upon surveys for evidence of palm tents and tent-roosting bats (Tan *et al*. 1997). Only *C. brachyotis* was found to construct and utilize these tents. These sites were located on the campus of Universiti Kebangsaan Malaysia (UKM) in Bangi, Universiti Pertanian Malaysia (UPM) in Serdang, and Zoo Negara (National Zoological Park) in Hulu Kelang. All of the study sites are extensively landscaped with trees and can be considered as secondary forest habitats. In addition, the eastern and southern sides of the UKM campus are bordered by the Bangi Forest Reserve (disturbed lowland dipterocarp forest), *c*. 100 ha in size. Descriptions of the floristic composition of this forest are given in Latiff (1990).

Observations were made from January to December 1996. Information on the feeding habits of *Cynopterus brachyotis* were obtained by collecting fruit remnants, seeds, leaves and flower parts dropped directly beneath feeding and daytime roosts. Collection of food samples were carried out at least once each week. The utilization and availability of fruits, flowers and leaves were determined on a 'presence/absence' basis (Thomas 1988). All the plant species were identified using Corner (1988), Krempin (1993), Ng (1978, 1989) and Whitmore (1972, 1973), and were further verified using the herbaria at UKM and the Forest Research Institute of Malaysia (FRIM) at Kepong.

RESULTS

Cynopterus brachyotis was observed to feed upon the fruits of 54 plant species, the leaves of 14 species and the stamens of four species (Tables 1 and 2). The fruit bearing families that dominated the list are: Sapotaceae (nine species),

Table 1. Fruit remnants collected beneath feeding and day-time roosts of *Cynopterus brachyotis*.

Plant species	Family*	Location†	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Piper aducum	1	a	+	+	+	+	+	+	+	+	+	+	+	+
Terminalia catappa	2	ab	+	+	+	+	+	+	+	+	+	+	+	+
Muntingia calabura	3	ab	+	+	+	+	+	+	+	+	+	+	+	+
Calophyllum inophyllum	4	abc	+	+	+	+	+	+	+	+	+	+	+	+
Ficus fistulosa	5	ac	+	+	+	+	+	+	+	+	+	+	+	+
Elaeocarpus stipularis	3	c	+	+	+	+	+						+	+
Eugenia grandis	6	abc	+	+	+	+	+							+
Elaeocarpus sp.	3	c	+	+	+									+
Eugenia sp. (2)	6	c	+	+						+	+			
Musa sp.	7	a		+	+		+	+		+		+		
Fragrae fragrans	9	b		+	+	+				+	+	+		
Achras zapota	8	b		+	+	+				+	+			
Psidium guajava	6	ab		+		+	+				+			
Eugenia aquea	6	abc			+	+	+	+			+	+	+	+
Polyalthia longifolia	10	ac			+	+	+	+	+	+	+			
Pellacalyx saccardianus	11	c			+			+	+		+	+	+	+
Ficus roxburgii	5	c			+	+		+			+			
Flacourtia inermis	12	b			+	+	+							
Mimusops elengi	8	bc				+	+	+			+	+	+	+
Ficus sp. (1)	5	a				+	+							
Eugenia malaccensis	6	c					+	+	+				+	+
Livistona rotundifolia	14	ac						+	+		+	+	+	
Nephelium malaccensis	13	c						+	+	+				
Licuala grandis	14	c						+	+			+	+	
Grewia tomentosa	16	a						+	+			+		
Pternandra echinata	15	d						+						
Ficus benjamina	5	ac						+	+		+			
Mangifera indica	10	b						+	+					
Ficus religiosa	5	b						+	+					
Chrysalindocarpus lutescens	14	c						+	+					
Livistona chinensis	14	bc						+	+					
Ptycosperma macarthurii	14	c						+						
Annona squamosa	10	b						+				+		
Roystonea regia	14	c						+				+		
Eugenia jambos	6	bc							+	+	+			
Artocarpus maingayi	5	c							+	+	+			
Palaquium obovatum	8	c							+	+	+			
Payena maingayi	8	c							+	+	+			
Pouteria malaccensis	8	c							+	+	+			
Eugenia sp. (1)	6	c							+	+				
Diospyros sp.	17	c							+	+				
Palaquium gutta	8	c							+	+				
Palaquium clarkeanum	8	c							+	+				
Payena lucida	8	c								+	+			
Madhuca selangorica	8	c								+	+			
Ficus sp. (2)	5	c								+	+			
Ficus sp. (3)	5	c								+	+			
Eugenia sp. (3)	6	c										+		
Unidentified seeds (1)	?	a		+	+	+								
(2)	?	a					+	+						
(3)	?	c							+	+				
(4)	?	c							+					
(5)	?	c							+	+				
(6)	?	c										+		

* 1 = Piperaceae, 2 = Combretaceae, 3 = Elaeocarpaceae, 4 = Guttiferae, 5 = Moraceae, 6 = Myrtaceae, 7 = Musaceae, 8 = Sapotaceae, 9 = Loganiaceae, 10 = Anacardiaceae, 11 = Rhizophoraceae, 12 = Flacourtiaceae, 13 = Sapindaceae, 14 = Palmae, 15 = Melastomaceae, 16 = Tiliceae, 17 = Ebenaceae

† a = Zoo Negara, b = Universiti Pertanian Malaysia, c = Universiti Kebangsaan Malaysia

Table 2. Chewed leaves and flowers collected beneath feeding and day-time roosts of *Cynopterus brachyotis*.

Plant species	Family*	Location†	Food type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Erythrina orientalis	1	a	Leaf	+	+	+	+	+	+	+	+	+	+	+	+
Erythrina subumbrans	1	a	Leaf	+		+	+	+	+	+	+		+	+	
Eugenia grandis	2	bc	Leaf	+				+	+		+		+	+	
Artocarpus fulvicortex	3	c	Leaf		+		+	+	+	+	+	+	+		+
Cassia spectabilis	1	b	Leaf		+		+	+	+	+	+				+
Cassia spectabilis	1	b	Flower		+		+	+	+	+	+				+
Peltophorum pterocarpum	1	c	Flower			+	+	+	+		+			+	
Ficus religiosa	3	b	Leaf			+		+			+				
Pellacalyx saccardianus	4	c	Leaf				+	+	+		+		+	+	
Cassia fistula	1	b	Leaf				+		+			+		+	
Cassia fistula	1	b	Flower				+		+			+		+	
Bauhinia purpurea	1	c	Flower						+			+	+		
Erythrina sp.	1	b	Leaf					+				+	+		
Erythrina glauca	1	c	Leaf					+			+				
Eugenia aquea	2	c	Leaf						+	+					
Erythrina variegata	1	bc	Leaf						+		+	+			
Hevea brasiliensis	5	c	Leaf						+			+	+		
Eugenia sp. (1)	2	c	Leaf								+	+			

* 1 = Leguminosae, 2 = Myrtaceae, 3 = Moraceae, 4 = Rhizophoraceae, 5 = Euphorbiaceae
† a = Zoo Negara, b = UPM, c = UKM (as Table 1)

Moraceae (eight species), Myrtaceae (eight species), and Palmae (six species). Of the leaves consumed by the bats, seven species belonged to the family Leguminosae. This was followed by Myrtaceae, Moraceae, Rhizophoraceae and Euphorbiaceae. All the flowers belonged to the family Leguminosae.

Fruits of five species were found throughout the year, namely *Terminalia catappa, Muntingia calabura, Piper aduncum*, *Calophyllum inophyllum* and *Ficus fistulosa* (Table 1). Other plant species that had a long fruiting season were *Elaeocarpus stipularis, Eugenia grandis* and *Polyalthia longifolia*. Although fruits of the above-mentioned species (except *Muntingia calabura*) are found in abundance in the UKM campus, *C. brachyotis* there preferred to feed on various kinds of fruits from the Bangi Forest Reserve during the fruiting season (from July to September) (Table 1). In the Bangi Forest Reserve, most of the fruiting trees were *c*. 20 m in height. These included *Palaquium* spp, *Payena* spp., and *Pouteria malaccensis*. Ornamental palms provide an important food source for *C. brachyotis* in the months of June, early July and October, just before and after the forest fruiting season. Soft fruits were either totally or partially consumed. However, it was quite common for some fruits to be dropped undamaged under the feeding roosts or day-time roosts. In the Bangi Forest Reserve, uneaten fruits with bat tooth marks were often observed on the forest floor.

The leaves and flowers upon which *C. brachyotis* feeds are available throughout the year and their consumption was non-seasonal (Table 2). *Cynopterus brachyotis* appeared to feed extensively on the leaves of *Erythrina orientalis, E. subumbrans, Eugenia grandis, Cassia spectabilis, Pellacalyx saccardianus* and *Artocarpus fulvicortex*. In the case of the *Eugenia* spp., *Artocarpus fulvicortex* and *Ficus religiosa*, only the young leaves were eaten. The flowers of *Peltophorum pterocarpum, Bauhinia purpurea, Cassia spectabilis* and *Cassia fistula* were frequently visited by *C. brachyotis*.

All of the leaf pellets were collected under the daytime roosts and feeding roosts. The leaves were chewed and the soluble contents extracted by the bats. The fibrous contents were discarded as fibrous pellets. Petioles and veins were common in the leaf pellets. Different plant species may produce differently shaped leaf pellets. The leaf pellets of *Erythrina orientalis* were usually 'kidney' or 'm' in shape (Figure 1), with the average length and width measurements (n = 60) of 1.18 ± 0.11 cm and 0.70 ± 0.23 cm, respectively. On the other hand, the leaf pellets of *Artocarpus fulvicortex* were mostly round or ovoid in shape, 1.08 ± 0.17 cm and 0.84 ± 0.15 (n = 60).

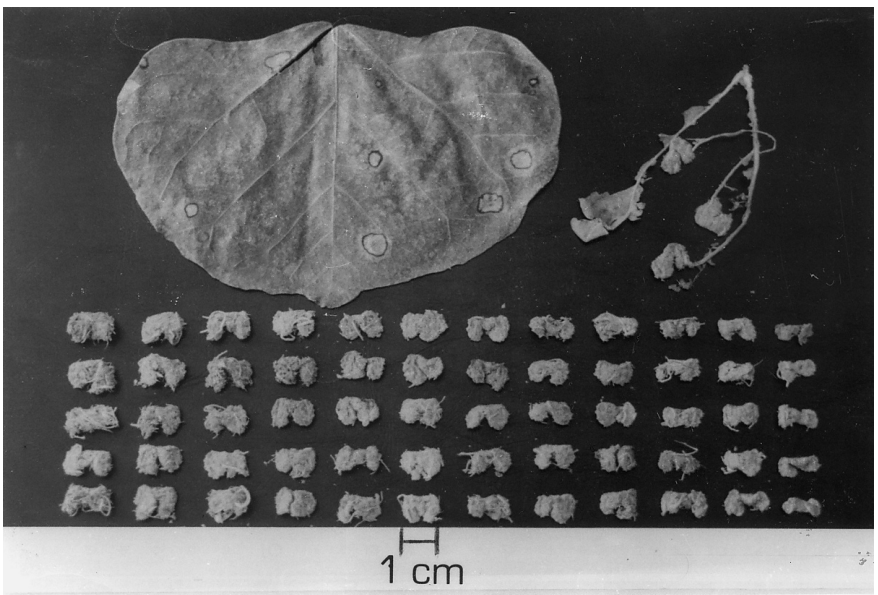

Figure 1. Partially chewed leaves and rejected leaf pellets of *Erythrina orientalis* collected beneath feeding and day-time roosts of *Cynopterus brachyotis*.

DISCUSSION

Fruits that are available throughout the year or with a long fruiting season are presumably a major factor in maintaining the population of *C. brachyotis*. In

addition, the seasonal phenological differences among congeneric plant species (e.g. *Ficus* spp. and *Eugenia* spp.) led to a steady production of fruit throughout the year. The present data indicates that *Ficus* spp. may be an important component in the diets of *C. brachyotis*. Previous studies have shown that pteropodid bats have a great predilection for *Ficus* spp. (Bhat 1994, Marshall 1985, Phua & Corlett 1989). Similarly, some phyllostomid bats are also known to forage largely on *Ficus* spp. (Fleming & Heithaus 1981, Handley *et al*. 1991; Morrison 1978, 1980). During the forest fruiting season, *C. brachyotis* preferred to forage in the forest rather than in urban areas. This indicates that *C. brachyotis* shows distinct food preferences at any one place and time if a choice is available. Most of the bat fruits in the forest were located at the canopy level which may explain why pteropodid bats are more readily captured there than in the understorey (Francis 1990, 1994; Zubaid 1994).

In this study, *C. brachyotis* was observed to visit flowers of four legume species. Lim (1970) and Kitchener *et al.* 1990 found considerable quantities of pollen in the faecal samples of *C. brachyotis*. Phyllostomid bats have been observed feeding on the flowers of *Bauhinia* spp. (Fischer 1992, Heithaus *et al*. 1974). It is generally agreed that bats visit flowers for nectar, pollen and floral parts (Baker & Harris 1957, Marshall 1985). Rasweiler (1977) suggested that pollen may provide an important source of dietary protein for plant-visiting bats.

In addition to fruits and flowers, *C. brachyotis* also fed regularly on the leaves of 14 plant species (Table 2) and is the first published report of the importance of this component for this species. Lim (1970) stated that leaves represented a minor component of the diet whereas Kitchener *et al.* (1990) noted the presence of plant epidermis in their analyses. Phua & Corlett (1989) who collected plant remains under feeding roosts only reported the presence of fruits and seeds. Of these, the most important were *Erythrina* spp., *Cassia* spp., *Eugenia* spp. and *Artocarpus fulvicortex*. Bhat (1994) reported that *C. sphinx* fed on leaves of *Cassia fistula* and *Erythrina indica*. *Erythrina* spp. are also commonly eaten by other phytophagous bats (Kunz & Diaz 1995, Marshall 1985, Zortea & Mendes 1993).

Several hypotheses have been proposed to explain why phytophagous bats feed on leaves. Fruits are typically high in carbohydrates and poor in protein (Rasweiler 1977, Thomas 1984a). Phyllostomid bats which have the ability to echolocate can consume insects in order to partially fulfil their protein requirements. Unlike phyllostomid bats, pteropodids do not echolocate, hence, it is very difficult for them to hunt for insects. Thomas (1984) and Stellar (1986) suggested that pteropodids may over-consume and then excrete carbohydrates in order to meet their protein requirements from otherwise protein-poor fruits.

Alternatively, leaves could provide an important source of dietary protein for phytophagous bats (Kunz 1996, Kunz & Diaz 1995, Kunz & Ingalls 1994, Lowry 1989, Rasweiler 1977, Thomas 1984a). Lowry (1989) reported that *Pteropus electo* fed extensively on *Albizia lebbek* leaves (36% protein on dry matter basis) by

extracting the protein-rich soluble fraction and rejecting the protein-poor fibrous pellets. Similarly, *Artibeus jamaicensis* is known to consume leaves of *Erythrina poeppigiana* which are relatively high in protein (19% dry matter content) (Kunz & Diaz 1995). Besides bats, Choo *et al*. (1981) noted that *Erythrina excelsa* (17% protein on dry matter basis) served as an important protein source for some neotropical primates. In this study, leaves of *Erythrina* spp. and *Cassia* spp. were preferred by *C. brachyotis*. The protein content of *Erythrina variegata* and *Cassia spectabilis* has been estimated as 21.7 and 30.7% of dry matter, respectively (Telek & Martin 1983). Some phyllostomid bats may prefer to consume protein-rich leaves (Kunz & Diaz 1995, Zortea & Mendes 1993), because leaves are abundant, and predictable in space and time (Kunz & Diaz 1995). Bats need less energy to pursue leaves as compared to insects. Hence, bats can reduce their daily energy expenditure especially during late pregnancy and lactation when energy and nutrient demands are expected to be highest. Kunz & Diaz (1995) concluded that the consumption of leaves by bats provides a higher yield of protein per unit foraging effort.

The leaves could also be an important source of minerals and vitamins. Leaves of some plant species are rich in calcium and phosphorus as compared to fruits (Herrera 1987, Rasweiler 1977). Rasweiler (1977) reported a high mortality of captive pteropodids maintained for extended periods on fruits due to calcium deficiency. Females bear almost the entire nutrient cost of producing the skeleton of their offspring (Barclay 1994, Papadimitriou *et al.* 1996). Recent evidence suggests that there is a high demand for calcium and a scarcity causes significant structural changes in the bones of lactating bats (Kwiecinski 1987 *et al*.).

Leaves may also contain several metabolites important for reproduction in bats (Cunningham van Someran 1972, Kunz & Diaz 1995). These metabolites include steroidal sapogenins and alkaloids (reviewed by Kunz & Diaz 1995). Since steroids are essential for hormone synthesis, the oral intake of these compounds by phytophagous bats may influence their reproductive activity (Wickler & Seibt 1976). On the other hand, it is well documented that secondary metabolites especially phenolic compounds (e.g. condensed tannins) can act as inhibitors of protein digestion (Telek & Martin 1983). Since pteropodids have short digestive tracts and rapid transit-times (Forman 1990, Richardson *et al*. 1987, Tedman & Hall 1985), a high concentration of phenolic compounds could limit the effectiveness of protein digestion. However, leaves consumed by bats, such as *Erythrina* spp. and *Albizia* spp. are relatively low in condensed tannins and total phenols (Lowry 1989, Telek & Martin 1983). Moreover, young leaves contain higher protein content and lower secondary metabolites than mature leaves (Telek & Martin 1983). The latter may explain why *C. brachyotis* prefers to consume young leaves of *Eugenia* spp., *Ficus religiosa* and *Artocarpus fulvicortex*.

We suggest that folivory (by leaf fractionation) may reflect high protein and

low phenolic content of leaves. In general, fruits provide an energy source (carbohydrates) to phytophagous bats, and leaves may be an important source of protein, minerals, and steroids. Pollen is also a protein-rich food and perhaps leaves are consumed to a greater extent when pollen is unavailable. Future studies should investigate the nutritional composition of the fruits, leaves and flowers eaten by these bats.

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