



Seasonal variation in the diet of the frugivorous bat, *Rousettus leschenaulti*

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ABSTRACT

Seasonal variation in the diet of the frugivorous bat, *Rousettus leschenaulti* of the Lengteng Wildlife Sanctuary was studied from January 2013 to December 2013. The diet of the frugivorous bats, *R. leschenaulti* was evaluated by four methods: analysis of the discarded plant parts like fruits, flowers, leaves, seeds and bolus; analysis of pollens attached to the body of bats; the field observation on feeding behaviour of bats, and the analysis of faecal matter to identify the undigested seeds. These bats consumed the fruits of 34 plant species, leaves of 6 plant species and, flowers, nectars, and pollens of 5 plant species. They consumed fruits exclusively from May to September, but during the remaining months, they supplemented their diet with other plant parts. Leaves, flowers, nectars and pollens were consumed during seven months, i.e., from January to April, and October to December, when the fruit resources were depleted or not available in sufficient quantity in the sanctuary.

Key words: Seasonal variation; diet; *Rousettus leschenaulti*; Lengteng Wildlife Sanctuary.

INTRODUCTION

Diet of the frugivorous bats consists of fruits, floral resources, seeds and leaves.¹ In a given locality, the frugivorous bats prefer certain seasonal fruits having high nutritional value.^{1,2} They exhibit an unambiguous preference for the perennial fruit resources to such an extent that

they eventually become selective feeders. For example, the frugivorous bats, *Rousettus aegyptiacus* preferred to consume a large quantity of figs and each bat consumed about ten figs per night.³ The large frugivorous bats, *Pteropus giganteus*, often fly up to 15 km or more for foraging.⁴ While feeding, these bats swallow small seeds and thereby assist in seed dispersal through their excreta over a vast area since they cover long distances from the roosting trees.^{5,6} Nectar-feeding bats like *Cynopterus sphinx*, *Glossophaga commissaris*, *Glossophaga soricina*, *Anoura caudifer*

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and *Corollia perspicillata* have morphological modification of tongue and mouth that allows them to feed on the nectar and pollens. Few have elongated muzzles with long tongues tipped with papillae to lap up the nectar.⁷ They hover over the flowers or land on them to suck the nectar.⁸ Frugivorous bats are useful for pollination and seed dispersal. A few frugivorous bats like the *Pteropus* species were reported to consume insects, which apparently supplemented the limited protein intake that they received from the plant parts.⁹ This was observed in the captive *Pteropus rodricensis* individuals that consumed mealworms, crickets and other insects.¹⁰ Interestingly, *P. dasymallus* consumed several species of insects in the wild too.¹¹

I have evaluated the seasonal variation in the diet of *Rousettus leschenaulti* from the Lengteng Wildlife Sanctuary ecosystems for one complete year. It should assist in gaining information regarding seed dispersal and pollination by this bat. The plant parts (fruits, flowers, leaves, etc.) included in the diet of the frugivorous bats were identified by four methods: the field observation on feeding habits, collection of the discarded plant parts from the roosts, analysis of pollens attached to body of the bats and the analysis of faecal matter.

MATERIALS AND METHODS

Seasonal variation in dietary items of the frugivorous bat, *Rousettus leschenaulti* of the Lengteng Wildlife Sanctuary (23°50'31.99"N to 93°12'35.39"E) was studied from January 2013 to December 2013, and this period was divided into four seasons: winter (January to February and November to December), summer (March to May), rainy season (June to August) and autumn (September to October). The following methods were employed for data collection.

Field observation on feeding behaviour

Feeding behaviour of *R. leschenaulti* in the field was studied by using night-vision binocu-

lars (D:F = 1:3. No. 6488, Russian) and the night vision mode of a digital video camera (Sony, HDR-XR350V, Japan). At times, important events were video recorded and then viewed with big screen TV. Various components of feeding behaviour of the bats such as landing on the fruits, plucking of the plant parts, hovering near the orchard, sniffing the ripe fruits and plucking of the whole fruit and transporting them to the night roosts or to the day roost, the consumption of plant parts, spitting out the bolus, visiting flowers to drink the nectar, etc. were viewed in a slow motion display or freeze mode on a 74 cm screen of TV for detail analysis.

Collection of discarded plant parts

The plant parts like fruits, leaves, flowers, etc. included in their diet were identified by collecting their discarded bits and pieces on the floor of the night roosts in the orchards and the day roost in the cave, at the first week of every month. These bats extract juice of several fruits like figs, mangoes, guavas, etc. and spit out the fibrous remnants known as bolus. By the colour and smell of fresh bolus, the consumed fruits were identified, since the bolus of each of the above mentioned fruits has a characteristic colour and smell. Moreover, the bolus of figs could be identified with great ease owing to small grain like seeds covering its surface.

Removal of attached pollens from the body

The flowers from which the bats collected the pollens were identified by wiping the facial region and the body of the captured bat with a fresh tissue paper. Then the pollens adhering to the tissue paper were transferred to a petridish containing saline. They were observed under a dissecting binocular microscope (40 X) and compared with specimen pollens of the local flowers.

Analysis of faecal matter

Analysis of the faecal matter was carried out to identify the undigested seeds or seed-

fragments of the dietary fruits of these bats. Faecal droppings were collected in the first week of each month as follows. Soon after the bats left the roosting site at dusk, a plastic sheet (6 x 6 m) was spread on the floor of the roost and left undisturbed for 24 h. The faecal matter was collected, weighed and analysed by dissolving it in distilled water. The fragments of the seeds or intact seeds were separated by using a strainer, air dried and observed under a dissecting binocular microscope. They were compared with reference to the specimen seeds collected locally.¹² Data were presented as the weight of seeds (g) of a particular fruit type per 1,000 g of faecal matter. Chi-square test was performed to compare the diet of *R. leschenaulti* across the seasons and one sample *t*-test was used to analyse the significant test on faecal analysis.

RESULTS

The *R. leschenaulti* bats from the Lengteng Wildlife Sanctuary fed on fruits, leaves, flowers, nectars, and pollens of 40 plant species as revealed by four methods: identification of undigested seeds or seed fragments in the faecal matter, identification of plant parts discarded beneath the day and night roosts, collection of pollens attached to the body of bats and the field observation on feeding behaviour (Table 1). They consumed fruits of 34 plant species, leaves of 6 plant species, and flowers, nectars and pollens of 5 plant species. They used to circle around the fruit bearing branch of a tree and then land directly on big fruits like jackfruit, mango, papaya, etc. These were consumed without plucking as such fruits were too heavy to carry. An individual bat usually bit off a fragment of such fruits and carried it to their night or day roosts. A small fruit like figs, palms, berries, etc. were plucked off at once while hovering and carried to their night or day roosts. This behaviour was repeated several times throughout the night.

Seasonal variation in the dietary fruits of *R. leschenaulti* bats were determined by identifying the undigested seeds or seeds fragments in 1000g

of faecal matter collected in each month of the year 2013 (Figure 1). The seasonal variation in the consumption of *Ficus* spp. ($t = 4.83331$, $df = 3$, $p < 0.05$), *Carica papaya* ($t = 4.9752$, $df = 3$, $p < 0.05$), and *Musa* spp. ($t = 6.92294$, $df = 3$, $p < 0.05$) is significantly different despite their availability throughout the year. For example, the highest consumption of figs occurred during the rainy season while the least consumption occurred during summer. *R. leschenaulti* diet varied significantly among the four seasons ($\chi^2 = 585.200$, $df = 525$, $p < 0.05$) (Figure 1). The summer and rainy season were characterized by a total of 8 fruit types in their diet but only 7 and 6 fruit types in the winter and autumn. These bats also consumed 15 other fruits like mangoes, jackfruits, willughbeia, berries, etc., however, their big seeds were not ingested and therefore they were not detected in their faecal matter. Such fruits were identified by other methods.

The seasonal variation in dietary plant parts was qualitatively analyzed by identifying the plant parts discarded beneath their roosts, the field observation on feeding behaviour and by identifying pollens attached to the body of bats. Fruits, leaves, nectars and pollens of 40 plant species were consumed by these bats and their seasonal variation is shown in Table 2. These bats fed exclusively on fruits for five months, i.e., from May to September, but during the remaining 7 months, they supplemented their diet with other plant parts like leaves, flowers, nectars, and pollens too. This lean period of 7 months was divided into two phases: the first phase from January to April, and the second phase from October to December.

DISCUSSION

Most frugivorous bats basically prefer to consume fruits because of their high energy carbohydrate contents; nonetheless, other plant parts like leaves, flowers, nectar and pollens are also consumed during the lean period when the fruit resources are depleted.¹³ The present study on the *R. leschenaulti* bats from the Lengteng Wildlife Sanctuary extends this confirmation. These

Table 1. The dietary habit of *R. leschenaulti* at the Lengteng Wildlife Sanctuary were identified by analysis of faecal matter, collection of discarded plant parts beneath the day and night roosts, collection of pollens attached to the body of bats, and the field observation on feeding behaviour.) The plant species were identified by the undigested seeds/seed fragment (S) in the faecal matter, the discarded fruit parts (DFP), leaves (L), flowers (Fl), nectars (N), and pollens (P) which were collected from January 2013 to December 2013.

Sl. No.	Family	Plant species	English name	Local name	Day and night roosts	Field observation	Faecal analysis
1.	Moraceae	<i>Ficus benjamina</i>	Weeping fig	Zamanhmawng	DFP,S	-	S
2.	Moraceae	<i>Ficus benghalensis</i>	Banyan	Bung	DFP,S	DFP	S
3.	Moraceae	<i>Ficus religiosa</i>	Peepal	Hmawng	DFP	L	S
4.	Moraceae	<i>Ficus racemosa</i>	Cluster Fig tree	Theichek	S	-	S
5.	Moraceae	<i>Ficus elastica</i>	Rubber Fig	Theiret	DFP,S	-	S
6.	Moraceae	<i>Ficus altissima</i>	Council Tree	Bung	S	-	S
7.	Moraceae	<i>Ficus drupacea</i>	Mysore Fig	Bung	DFP,S	DFP	S
8.	Moraceae	<i>Ficus hirta</i>	Hairy Fig	Sazu theipui	DFP,S	-	S
9.	Moraceae	<i>Ficus semicordata</i>	Drooping Fig	Theipui	S	-	S
10.	Moraceae	<i>Artocarpus lakoocha</i>	Monkey fruit	Theitat	DFP	DFP	-
11.	Moraceae	<i>Artocarpus chaplasha</i>	Chaplash	Tat-kawng	DFP	DFP	-
12.	Moraceae	<i>Artocarpus heterophyllus</i>	Jack fruit	Lamkhuang	DFP	DFP	-
13.	Moraceae	<i>Morus australis</i>	Indian Mulberry	Thingtheihmu	S,DFP	DFP	S
14.	Caesalpiniaceae	<i>Bauhinia variegata</i>	Orchid Tree	Vaube	P,FL	P,N,FI	-
15.	Bombacaceae	<i>Bombax ceiba</i>	Silk cotton Tree	Phunchawng	P,FL	P,FI,N	-
16.	Bombacaceae	<i>Bombax insigna</i>	Silk cotton Tree	Pang	P,FL	P,FL,N	-
17.	Clusiaceae	<i>Calophyllum polyanthum</i>	Poonspar tree	Sentezel	S,DFP	L,	S
18.	Euphorbiaceae	<i>Bridelia retusa</i>	Kasi	Phaktel	S,DFP	DFP	-
19.	Euphorbiaceae	<i>Bischofia javanica</i>	Bishop wood	Khuangthli	L	DFP-	S
20.	Fabaceae	<i>Erythrina variegata</i>	Coral Tree	Fartuah	FI	FI,P,N	-
21.	Fabaceae	<i>Tamarindus indica</i>	Tamarind	Tengtere	L	L	-
22.	Fabaceae	<i>Erythrina stricta</i>	Tiger claw	Fartuah	FL, P	FL,P,N	-
23.	Flacourtiaceae	<i>Flacourtia jangomas</i>	Coffee plum	Sakhi thei	S,DFP	DFP	-
24.	Rubiaceae	<i>Meyna spinosa</i>		Thingruahsur	S,DFP	-	S
25.	Rosaceae	<i>Prunus domestica</i>	Plum Tree	Zapan theite	DFP	S,DFP	-
26.	Rosaceae	<i>Rubus ellipticus</i>	Raspberry	Hmutau	S,DFP	S DFP	S
27.	Rosaceae	<i>Prunus persica</i>	Peach	Theitehmul	DFP	DFP	-
28.	Myrtaceae	<i>Syzygium cumini</i>	Blackberry	Lenhmu	DFP	DFP	-
29.	Myrtaceae	<i>Syzygium grande</i>		Theichhawl	DFP,S	DFP	-
30.	Myrtaceae	<i>Syzygium claviflorum</i>	Grey Satinash	Hmuifarial	DFP,S	DFP	-
31.	Myrtaceae	<i>Psidium guajava</i>	Guava	Kawlthei	DFP,S	DFP	S
32.	Caricaceae	<i>Carica papaya</i>	Papaya	Thingfanghma	DFP,S	DFP	S
33.	Musaceae	<i>Musa sp.</i>	Banana	Balhla	DFP,S	DFP	S
34.	Rhamnaceae	<i>Zizyphus jujube</i>	Indian plum	Bawrai	DFP, S	DFP	-
35.	Anacardiaceae	<i>Mangifera indica</i>	Mango	Theihai	L, S	DFP	-
36.	Oxalidaceae	<i>Averrhoa carambola</i>	Starfruit	Theiherawt	DFP,S	DFP	S
37.	Myricaceae	<i>Myrica esculenta</i>	Bayberry	Keifang	S	DFP	S
38.	Apocynaceae	<i>Willughbeia edulis</i>	Willughbeia	Vuakdup	DFP	DFP	-
39.	Rhizophoraceae	<i>Carallia brachiata</i>	Corkwood	Theiria	DFP,L	DFP,S	-
40.	Sapindaceae	<i>Litchi chinensis</i>	Litchi	Theifeihmung	DFP,S	DFP	-

Seasonal variation in the diet of the frugivorous bat, *Rousettus leschenaultia*

Table 2. Seasonal variation in the diet of *R. leschenaulti* as identified from the discarded plant parts on the floor of the night and day roosts, field observation on feeding behaviour and collecting pollens attached to the body of bats. These plant parts were fruits (F), leaves (L), flowers (Fl), nectars (N) and pollens (P) of 40 plant species. Nine *Ficus* species are combined under the genus *Ficus* for ease of presentation.

Sl. No.	Plant species	Winter		Summer			Rainy			Autumn		Winter	
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.	<i>Ficus</i> spp.	F, L	F, L	F	F	F	F	F	F	F	F, L	F, L	F, L
2.	<i>A. lakoocha</i>	-	-	-	-	-	F	F	F	F	-	-	-
3.	<i>A. chaplasha</i>	-	-	-	-	-	F	F	F	F	-	-	-
4.	<i>A. heterophyllus</i>	-	-	-	-	-	F	F	F	F	-	-	-
5.	<i>M. australis</i>	-	-	-	F	F	F	F	-	-	-	-	-
6.	<i>B. variegata</i>	-	Fl, P, N	P, N	-	-	-	-	-	-	-	-	-
7.	<i>B. ceiba</i>	Fl, P	P, N	P, N	-	-	-	-	-	-	-	-	-
8.	<i>B. insignia</i>	-	-	-	-	-	-	-	-	-	-	Fl, P, N	P, N
9.	<i>C. polyanthum</i>	L	L	-	F	F	F	-	-	-	-	-	-
10.	<i>B. retusa</i>	F	F	-	-	-	-	-	-	-	-	F	F
11.	<i>B. javanica</i>	F	-	L	L	-	-	-	-	-	-	F	F
12.	<i>E. variegata</i>	-	-	Fl, P	P, N	-	-	-	-	-	-	-	-
13.	<i>T. indica</i>	L	L	L	L	-	-	-	-	-	L	L	L
14.	<i>E. stricta</i>	-	Fl, N	P, N	Fl, P	-	-	-	-	-	-	-	-
15.	<i>F. jangomas</i>	-	-	-	-	-	-	-	-	F	F	F	-
16.	<i>M. spinosa</i>	-	-	-	-	-	-	-	F	F	F	-	-
17.	<i>R. ellipticus</i>	-	-	-	F	F	F	-	-	-	-	-	-
18.	<i>P. persica</i>	-	-	-	-	F	F	F	F	-	-	-	-
19.	<i>P. domestica</i>	-	-	-	-	F	F	F	-	-	-	-	-
20.	<i>S. cumini</i>	-	-	-	-	-	F	F	F	-	-	-	-
21.	<i>S. grande</i>	-	-	-	-	-	F	F	F	-	-	-	-
22.	<i>S. claviflorum</i>	-	-	-	-	F	F	F	-	-	-	-	-
23.	<i>P. guajava</i>	-	-	-	-	-	-	F	F	F	F	F	-
24.	<i>C. papaya</i>	-	-	-	-	F	F	F	F	F	-	-	-
25.	<i>M. species</i>	F	F	F	F	F	F	F	F	F	F	F	F
26.	<i>Z. jujube</i>	-	F	F	F	-	-	-	-	-	-	-	-
27.	<i>M. indica</i>	L	L	L	-	-	F	F	F	F	-	-	-
28.	<i>A. carambola</i>	F	-	-	-	-	-	-	-	-	-	F	F
29.	<i>M. esculenata</i>	-	-	-	F	F	F	F	-	-	-	-	-
30.	<i>W. edulis</i>	-	-	-	-	-	F	F	F	-	-	-	-
31.	<i>C. brachiata</i>	L	L	-	-	F	F	-	-	-	-	-	-
32.	<i>L. chinensis</i>	-	-	-	-	-	F	F	F	F	-	-	-

bats fed on one particular part (for example, fruit) or several parts (for example, fruits, leaves, flowers, etc.) of 40 plant species (Table 1). They consumed fruits of 34 plant species whereas the leaves, flowers, nectars and pollens of 11 plant species which were grown in the wild or cultivated in the orchards of the Sanctuary and nearby villages. These results are akin to those on the other frugivorous bat species from the tropics and sub-tropics.^{11,13-15} These bats always favoured the ripe fruits and routinely ignored the raw ones.^{8,16}

Analysis of the bat guano is a quantitative method to identify the dietary fruits of frugivorous bats.⁶ It helps us to understand their habitat preference and role in seed dispersal.^{17,18} Moreover, such information assists us to develop appropriate strategies for conservation of their

habitat.^{18,19} Analysis of guano of *R. leschenaulti* bats in the present study revealed that they consumed fruits of 19 plant species in which nine species of figs predominated their diet throughout the year (Fig. 1). It should be noted that the faecal analysis is a reliable method to identify the dietary fruits of bats, but all fruits in their diet are not covered by this method as it is solely based on the identification of undigested seeds or seed fragments in the faecal matter. These bats also consumed several other fruits without swallowing their seeds, for example, they ate the pulp or sucked the juice of mango, litchi, jack-fruit, India plum, etc. Such dietary fruits could be identified by other methods as such the field observation, collection of fruit fragments, etc.

Despite the limitation of faecal analysis method, the seasonal variation in the dietary

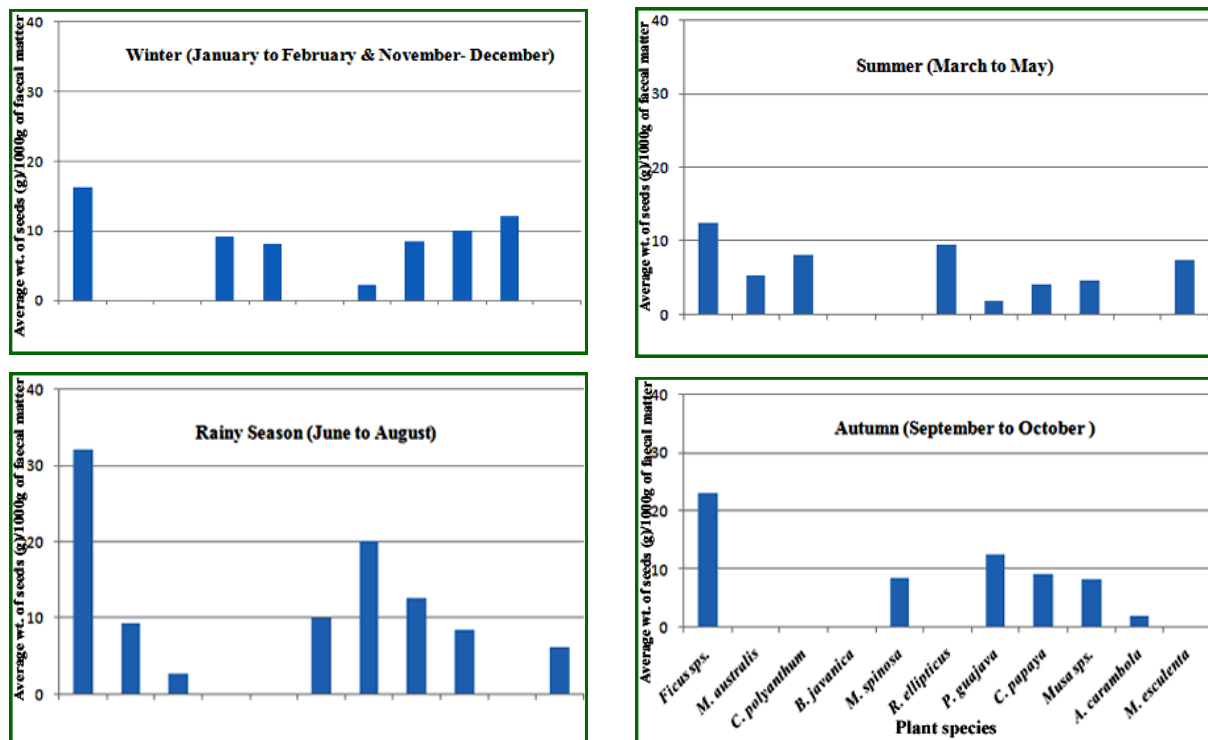


Figure 1. Seasonal variation in the dietary habit of *R. leschenaulti* was determined by identifying the undigested seeds or seed-fragments in 1000 g of faecal matter collected in each month of the year 2013. The seasonal variation is evident in consumption of *Ficus* sp., *C. papaya*, and *Musa* sp. despite their availability throughout the year. Consumption of other fruits depends mainly on their seasonality. *Ficus* includes nine species.

fruits of *R. leschenaulti* is evident. These bats consumed 8 fruit types in the summer and rainy season but only 7 and 6 fruit types in winter and autumn. Unequivocal seasonal variation was observed in the consumption of all 19 fruit types (Fig. 1) which was partly attributed to seasonality in their fruiting or cultivation by the orchard growers. For example, *B. javanica* were available only during the winter and accordingly these fruits were consumed by the bats. Although, three fruit types: *Ficus* sp., *C. papaya* and *Musa* sp. were available throughout the year, their consumption varied over the seasons. Bananas were devoured maximally during the winter season but least during the summer which may be ascribed to the availability of nine other fruit types in the sanctuary, as the sub-tropical summer is noted for abundance in cultivated and wild fruits.²⁰

Seasonal variation in consumption of diverse plant parts was qualitatively studied by three methods: collection of discarded plant parts, field observation on feeding behaviour and collection of pollens attached to the body of bats (Table 2). The period of five months, i.e. from May to September was characterized by the consumption of fruits only, it appears that other plant parts were not consumed at all during this period. However, the period of 7 months (January-April, October-December) was noted for the consumption of all plant parts: fruits, leaves, flowers, nectars and pollens as the fruits were in short supply in the sanctuary. Three species of nectarivorous bats, *Glossophaga soricina*, *Anoura caudifera* and *A. geoffroyi* from the Brazilian Cerrado also exhibited significant differences in their diet; both, fruits and arthropods predominated in the dry season while only fruits predominated in the rainy season.²¹ The Egyptian fruit-bat, *R. aegyptiacus* consumed leaves mainly during the winter, when they faced times of severe shortage of fruits in the field, while fruits and pollens were consumed during the summer.¹⁸ The short-nosed fruit-bat, *C. sphinx* also exhibited pronounced seasonal variation in dietary fruits.^{22,23}

Nine species of figs (Table 2) comprises the

largest proportion of their diet as figs are abundant throughout the year in the sanctuary. These results are consistent with those on the frugivorous bat species from the tropical Old World and the New World.²⁴⁻²⁷ Frugivorous bats appear to derive all nutrients if they feed on several fig species, for example, *R. aegyptiacus* bats from Panama consume several species of figs in the field that supply them with all the required nutrients.²⁸ If there are several species of figs in the foraging area, the bats prefer to consume the sweetest figs having highest concentration of soluble sugars as a potential source of energy.²⁹ Most frugivorous bats swallow soft, juicy and sugary pulp of the fruits and spit out seeds and fibrous part known as the bolus.^{6,8,30} Such fruits with high fibre contents are consumed by frugivorous bats when the juicy and soft fruits are not available in the foraging areas, and invariably they have to expend more energy to masticate the fibrous fruits to extract nutrients.³ Field observations revealed that the fibrous ripe fruits like figs, willughbeia, guava, etc. from the orchards in the Lengteng Wildlife Sanctuary were selected by *R. leschenaulti* bats by sniffing. These bats extracted the juice from these fruits by chewing them for 3-6 min and spat out the bolus. Such feeding behaviour was also observed in *Artibeus jamaicensis*.³¹ Rejecting the fibrous part of fruits by spitting out the bolus apparently allows these bats to separate sugar rich fluid from fibre of the fruits. Thus, energy of the bat is conserved in further mastication of the fibrous part of the fruit and its passage through the gut.^{9,32} Seeds of several fruits are usually rejected despite their small size as they are rich in lipid contents, have a hard covering and are therefore difficult to digest.³ Despite spitting out the bolus, seeds of 19 fruit types were swallowed by *R. leschenaulti* in the present study which were excreted out in the faecal matter.

The *R. leschenaulti* bats in the present study supplemented their diet with leaves, flowers, nectars, and pollens during the lean period which is characterized by depletion of fruit resources in the sanctuary (Table 2.3). Frugivorous bats are reported to feed on leaves, flowers,

nectars and pollens of a variety of plant species.^{11,14,15,21,33,34} Consumption of leaves might be owing to their relatively higher nitrogen contents than that in fruits.³⁵ Nevertheless, the studies on nitrogen budgets of the frugivorous bats have revealed that their nitrogen requirements could be satisfied by fruit consumption alone.^{18,36,37} Apart from fruits and leaves, the *R. leschenaulti* bats consumed flowers, nectars and pollens of several plants (Table 2) which complement previous studies.³⁶ Both of these are known to be an important source of proteins and minerals.^{38,39}

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