Short communication

Vertebrate assemblage at a fruiting fig (*Ficus caulocarpa*) in Maliau basin, Malaysia

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Abstract

We analyzed the species composition and abundance of birds and mammals at a fruiting hemi-epiphytic fig (*Ficus caulocarpa*) in Maliau Basin, Sabah, Malaysia. Observations were conducted for 32 hours over five days. Forty-four species of birds and three mammal species were recorded. Of these, 28 birds and 2 mammals fed on the figs. In addition, nine species of insectivorous or omnivorous birds that did not feed on the figs were observed foraging in the tree, presumably on the large quantities of fig wasps produced. Inter- and intra-specific aggression was also observed among the species foraging in the tree. Overall the assemblage of large birds, such as hornbills, and mammals was poor, which seems to be due to the small size of the figs (<6 mm diameter) rather than a scarcity of these animals in the area. In contrast, the diversity of smaller bird species, especially the Pycnonotidae (Bulbuls) which comprised 13 species and 68% of visits, was high. Our results suggest fig-frugivore interactions may be more finely structured than reports from other, less pristine sites in Asia have indicated. Moreover, 34% of the birds observed are threatened or more severely endangered. We suggest that planting of hemi-epiphytic fig seedlings could be used to enhance the conservation value of small reserves and degraded forests, and that observations at fruiting figs could be used as an efficient method for assessing how well reserves are protected.

Keywords: Figs, vertebrate assemblage, *Ficus,* frugivore, insectivore, keystone resource

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Introduction

Figs (*Ficus* spp.) are an important source of food for tropical frugivores. Surveys of bird diets in both the New World and Old World show that around 990 bird species feed on *Ficus* species [1]. In Borneo, up to 42% of bird species and 73% of mammal species in a particular forest have been recorded feeding on figs [2]. Moreover, figs have often been referred to as keystone resources in tropical forests because they provide critical fruit resources during periods of scarcity [1, 3-5]. For example, forests in the aseasonal regions of SE Asia are mass flowering and thus produce large crops of flowers and fruits at irregular, often long intervals of up to several years [6]. Between these events fruit production is very low and at these times figs are an important component in the diets of many animals. At Danum Valley in northeast Borneo, during a period of unusually low production of fig fruit, observers recorded starving sun bears *Helarctos malayanus* and bearded pigs *Sus barbartus* [7]. However, not all figs are equally important in the diets of all frugivores [1]. It is particularly the large hemi-epipytic figs (subgenus *Urostigma*) that are eaten by a wide diversity of frugivorous birds and mammals. Even among these figs there is some structure to the plant – frugivore interactions. Species with smaller figs tend to occur lower in the canopy and more frequently attract smaller frugivorous birds and mammals. Conversely, species with larger figs occur higher in the canopy and, in addition to the smaller frugivores which nibble or peck at these fruit, attract large-bodied species, such as hornbills and gibbons [8].

Frugivores are an important group of vertebrates in the tropics, both for the seed dispersal services they provide to a wide diversity of plant species and for their contribution to the diversity of animal assemblages in tropical forests. The diversity of frugivores correlates with the abundance and diversity of fruits, and in Africa frugivore diversity was specifically correlated to the diversity of fig species [9]. Tropical Asian forests are particularly rich in *Ficus* species, with about 60% of known world species, while in Borneo there are over 160 *Ficus* species [10].

In the present study we investigated the assemblage of birds and mammals visiting a fruiting *Ficus caulocarpa* individual over a 5-day period in Maliau Basin, Sabah, Malaysia. Maliau Basin is a remote and relatively undisturbed Bornean forest which still has a full complement of megafauna at (or close to) natural levels of abundance. Frugivores are especially sensitive to hunting pressure [11-12] and therefore this study takes advantage of a rare opportunity to record a plant-frugivore interactions in a forest that still supports a full complement of species.

Methods

This study was conducted in Maliau Basin Study Centre, Sabah, East Borneo from 13-17 July 2009 at a fruiting *Ficus caulocarpa.* The fig was a hemi-epiphyte supported by a *Koompassia excelsa* tree. The fig had a crown volume of approximately 1780 m^3. The fruit of *F. caulocarpa* are small (approximately 5.4 mm wide and 5.9 mm long) and are ramiflorous, being borne along the thicker twigs. Maliau Basin is a pristine hill dipterocarp forest lying 4^0 50' north of the Equator. It has typical aseasonal climate with constant high temperature (around 30^0C), humidity (around 90%), and annual rainfall of approximately 3,800 mm. The study was conducted in a lowland dipterocarp forest, close to a tributary of the Maliau River approximately 500 m from the study centre buildings.

Over the study period two observers studied the fruiting *Ficus caulocarpa* continuously from a hide about 20 m above the ground and 10 m from the nearest edge of the fig canopy. We used two pairs of binoculars (10x50 and 8x42) and a camera with a 500 mm zoom lens for documentation. Birds were counted entering and leaving the tree and each of the observers focused on a different area of the crown to avoid double counting. We arrived at the station before 6 a.m. and recorded all the vertebrates that visited the tree over five mornings from 06:00-11:30 and two afternoons from 13:00-15:00. Although the study period is relatively brief, studies elsewhere in Borneo have demonstrated that a substantial proportion of the frugivore assemblage at a particular fig can be

obtained from just three days observation [2]. The birds less than 25 cm were categorized as small birds and the birds greater than or equal to 25 cm were categorized as larger birds. Smythies [13] and MacKinnon and Phillipps [14] were used to identify the birds and obtain details on their body size and biology. Nomenclature follows the checklist of the Oriental Bird Club [15]. Mammals were identified with reference to Payne et al. [16].

Results

During 32 hours of observation, 44 bird species were recorded in the tree with a total of 493 visits (Appendix 1). With respect to guild composition, three raptors, 19 frugivores, 16 ominivores, and 6 insectivores belonging to 20 families either foraged on the tree for fruits and insects or used the fig tree as a vantage to look for food. Of the total bird assemblage observed in the tree, 28 species were seen feeding on figs, including 15 frugivores and 13 omnivores (Appendix 1). Just two species of mammal, both squirrels, were recorded feeding on figs; the pale giant squirrel *Ratufa affinis sandakanensis* and Prevost's squirrel *Callosciurus prevostii pluto.* One other squirrel, the plain pygmy squirrel *Exilisciurus exilis,* was observed on the bole of the tree. Despite the large diversity of species observed feeding on the figs, the species accumulation curve had not flattened off by the end of the five-day observation period, suggesting unseen species remained (Fig. 1).

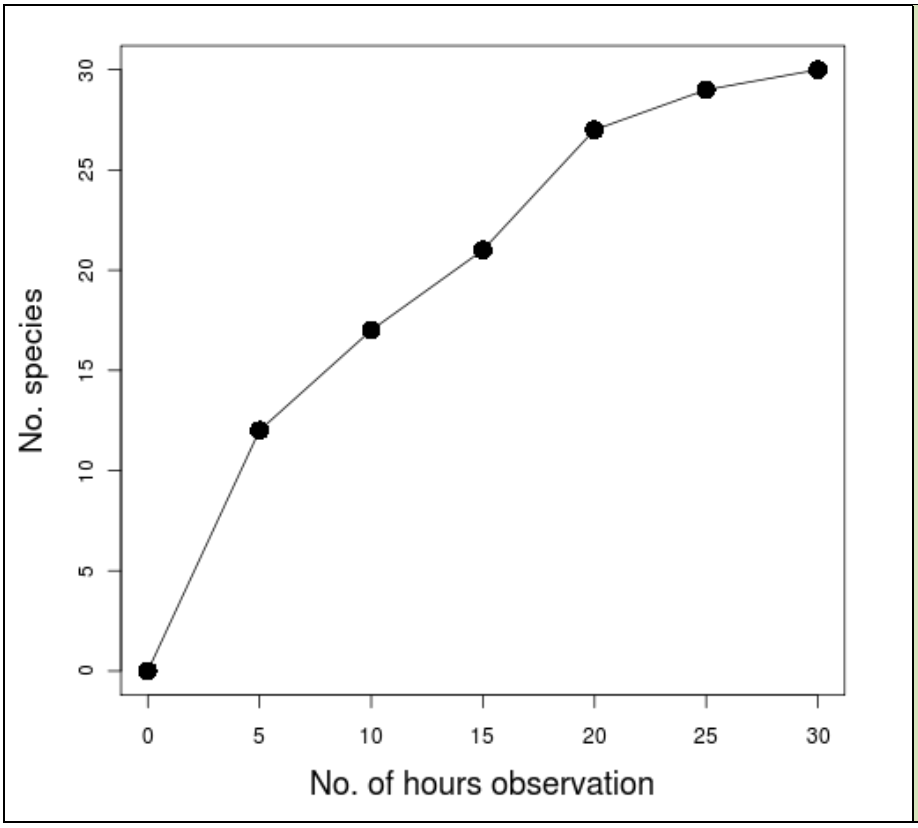

Fig 1. Species accumulation curve for vertebrates feeding on the figs of *Ficus caulocarpa* in Maliau Basin, Sabah.

Small birds dominated in the tree with 34 species and 465 visits compared to larger bird species (10 species and 28 visits). Birds of the family Pycnonotidae (Bulbuls) were the most abundant, contributing 13 species and 337 visits (68%). However, larger bird species, such as hornbills (Bucerotidae) and pigeons (Columbidae), were sighted around the tree in good numbers but seldom visited the tree, and no recordings were made of these species feeding on the figs. In terms of visits to the tree, the three most important families were Pycnonotidae (68% visits), Chloropseidae (14% visits) and Dicaeidae (4% visits) (Appendix 1).

Birds visited the tree more frequently during the early morning and became less active in the afternoon. During the periods 06:00-08:30, 08:30-11:00, and 13:00-15:00 the mean number of visits was 76±7.93, 36± 6.51, and 19± 6.49, respectively, and the total number of bird species visiting was 37, 25, and 10, respectively, over the five days of observation. Most species fed in the mid to lower region of the crown. Moreover, of the birds that visited the upper part of the tree, most did not feed on figs. They comprised bark gleaners, raptors, and other birds that perched for preening and sunning.

Interspecific aggression was observed between greater green leafbird *Chloropsis sonnerati* and Pycnonotidae species; and lesser green leafbird *Chloropsis cyanopogon* and Dicaeidae species. These involved fast aerial chases and in all cases *Chloropsis* species chased away the smaller birds before feeding on the figs. We also observed a pair of Jerdon's baza *Aviceda jerdoni bornensis* chasing bulbuls (Pycnonotidae) into the bole region of the tree. Intraspecific aggression was observed among Pycnonotidae species, especially among spectacled bulbuls *Pycnonotus erythropthalmos* and hairy-backed bulbuls *Tricholestes criniger*. The birds were commonly sighted in fast aerial chases. Often two or three birds were observed chasing a single bird. We also observed mid-air fights when individuals grasped each other's legs and fell into the understory. When this occurred only one of the two individuals returned to feed on figs.

Discussion

A large number of birds comprising a high diversity of species were recorded at the fruiting *Ficus caulocarpa* individual over the five-day study period. This can be attributed to the large crop size (over 10^6 figs), synchrony of fruit ripening, and accessibility of the fruits [3]. The large size of the assemblage also reflects the undisturbed nature of the forest at Maliau Basin. For example, a three-year study of frugivory at figs in Lambir Hills National Park in Sarawak, Borneo, recorded a maximum of 31 species of frugivore at any one fig species, despite over 800 hours of observation in total [2]. Moreover, the species accumulation curve for frugivores observed at the *F. caulocarpa* individual had not yet reached an ascentope (Fig. 1), whereas all those in the study at Lambir ascentoped after only about 15 hours of observation.

Small birds, with small gapes, such as Pycnonotidae, Chloropseidae and Dicaeidae, with gape sizes 15-36 mm, 23-43 mm and 7-10 mm, respectively [17], dominated the assemblage. This most likely reflects the small size of the *F. caulocarpa* fruit. For larger birds it may not be an efficient investment of energy to feed on such small figs. Large birds, including hornbills and pigeons, were observed nearby and are abundant in the forest at Maliau but were not observed feeding on the *F. caulocarpa* figs. Thus our observations support the findings of previous studies in Peninsular Malaysia and Borneo, which suggested larger birds preferred larger fig fruits [8, 17]. It should be noted that this is a quantitative difference not a qualitative one – one of us (RDH) has observed a helmeted hornbill *Buceros vigil* feeding on *F. cauolcarpa* figs elsewhere in Borneo, and hornbills occasionally fed on smaller figs during the long-term study at Lambir. However, the complete absence of larger frugivores on *F. caulocarpa* in our study does suggest that fig-frugivore interactions may be more finely structured that was previously thought, based on reports from more disturbed sites.

In addition to the frugivores, six species of insectivore and three species of omnivore that did not feed on figs were observed visiting the tree. It seems likely that these birds were foraging on the fig insects. Each fig fruit produces several tens to hundreds of pollinating and non-pollinating wasps (Chalcidoidea), depending on the size of the fig fruit, just before ripening [10]. Thus as many as 100 million fig wasps may be produced when a large fig tree fruits. Swifts and swallows (Apodidae and Hirundinidae) can often be seen swooping back and forth above a fruiting fig, presumably feeding on the fig wasps, and the diets of swifts investigated in the Neotropics comprised up to 80% fig wasps [18]. Hence, these figs are probably very important resources for the smaller insectivorous birds, as well as those that feed on the fruit.

Our study is also remarkable for the very poor mammal assemblage recorded. Maliau Basin has a complete fauna and, for example, gibbons which eat large numbers of figs [19], were heard nearby every morning. Again this may reflect the small size of the figs, as gibbons and most other canopy-feeding frugivorous mammals, such as macaques (*Macaca* spp.), binturong *Arctictis binturong,* and sun bear *Helarctos malayanus,* are relatively large animals. However, we also did not observe any tree shrews, which are much smaller and occasionally feed on figs [20]. It is possible that our presence near the tree affected the behavior of these animals, but our vantage point was well concealed and so we think this unlikely. Moreover, hornbills which are often very shy were observed frequently in neighboring trees and even landed in the upper canopy of the *F. caulocarpa* tree but did not feed on the figs.

Some hemi-epiphytic figs with large fruit are known to depend on large vertebrates like hornbills and gibbons to disperse their seeds [10, 21-22], which in turn provides a high-quality seed dispersal service, as they move large distances and directly between the crowns of large trees [23]. However, such figs also lose a large proportion of their crops to seed predators, such as pigeons in the genus *Treron* [1]. Thus, figs with smaller fruit may escape seed predators to a greater extent but are more dependent on smaller birds, which are likely to disperse the seeds shorter distances and perhaps also more to unfavorable sites in the understory.

The abundance of birds in the early morning can be explained by the production of new ripe fruit at this time, which is a typical pattern for these figs. The frugivorous species may have preferred the middle and lower canopy for the additional protection it affords from raptors. We occasionally saw raptors perching at the top of the canopy and once observed a pair of Jerdon's Baza chasing bulbuls into the bole region of the crown.

The inter- and intra-specific aggression observed indicates that the fig fruits are a resource worth protecting for these smaller frugivorous birds. However, more detailed behavioral interpretations would require mapping of the movements of individual birds, which in turn would be possible only with marked birds. Nevertheless, we suggest that such a study would furnish very interesting information both on the habits of the birds and their contributions to seed dispersal.

In conclusion, over a brief study period of just five days we recorded 44 bird species and three mammals in the crown of a fruiting *F. caulocarpa* individual. Of these, 28 birds and two mammals were observed feeding on the figs. The frugivore community was dominated by small species, which presumably reflects the small size of the figs. Large species of both bird and mammal were abundant in the area but did not feed on the *F. caulocarpa* figs. However, the abundance and behavior of smaller birds, in particular bulbuls, indicated that *F. caulocarpa* is an important resource for these species. In addition, to the frugivorous birds several species of insectivore regularly visited the tree presumably to feed on the fig insects.

Implications for conservation

As noted earlier, hemi-epiphytic figs are often regarded as keystone resources in tropical forests. In this study, we observed a large diversity of frugivorous and insectivorous birds in a single fruiting fig in just five days. Moreover, 15 bird species, that is 34% of the birds that visited this fig tree, are listed under the IUCN Red Book as near threatened or more severely at risk (Appendix 1). This suggests that not only are hemi-epiphytic figs important resources for wildlife, but that they support a disproportionate number of threatened species. This is perhaps not surprising since frugivores are particularly sensitive to hunting pressure [11-12] and hence tend to dominate threatened species lists in tropical forests. However, it does underline the potential importance of considering fig resources in reserve management plans.

Hemi-epiphytic figs make poor timber and in the Old World are often protected for their spiritual significance [24]. Hence they are rarely deliberately exploited. However, the diversity and abundance of hemi-epiphytic figs may decline in logged or otherwise degraded forests as a result of the simplified canopy structure and a reduced number of suitable large host trees [21-22]. As the abundance of hemi-epiphytic figs is most probably dispersal limited [21,25], planting seedlings could be an effective strategy to increase fruit resources in smaller reserves and degraded forests [21-22].

Our results suggest that fig-frugivore interactions may be more finely structured than previously thought based on studies from more disturbed sites. This is consistent with the idea that when symbionts are lost, not only are the specific interactions with these symbionts lost but the whole structure of the interaction network is affected [26]. This in turn underlines the importance of trying to protect all the component species in a habitat, rather than just the vegetation or certain charismatic animals.

Finally, our approach illustrates a potential method for evaluating the degree to which reserves are protected. Frugivores are especially sensitive to hunting pressure [11-12], and hemi-epiphytic figs provide a comparable resource for frugivores throughout tropical forests and are available year-round. Moreover, all frugivores in tropical forests feed on figs [1], and a substantial proportion of the frugivore assemblage at any particular fig can be observed within a few days [2]. Hence, brief observations at a small number of hemi-epiphytic figs, preferrably across a range of fruit sizes, could be used to assess how intact the frugivore community is at a site and by extension how well the site is protected.

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Appendix 1. Composition of birds, number of visits recorded, whether observed feeding on figs (x), feeding guild, size (S= <25 cm, L= ≥25 cm), IUCN Red Data book status (threatened or above).

Species	# visits	Feeding on figs	Guild	Size	IUCN
Aviceda jerdoni	2	-	Raptor	L	-
Hieraaetus kienerii	1	-	Raptor	L	-
Spilornis cheela	1	-	Raptor	L	-
Treron capellei	8	-	Frugivore	L	*
Psittinus cyanurus	3	-	Frugivore	S	-
Phaenicophaeus javanicus	1	-	Insectivore	L	-
Anthracoceros malayanus	8	-	Frugivore	L	*
Buceros vigil	1	-	Frugivore	L	*
Megalaima australis	7	x	Frugivore	S	-
Megalaima mystacophanos	1	x	Frugivore	S	-
Meiglyptes sp.	5	-	Insectivore	S	-
Mulleripicus pulverulentus	1	-	Insectivore	L	-
Calyptomena viridis	1	x	Omnivore	S	*
Eurylaimus ochromalus	1	x	Omnivore	S	*
Pycnonotus melanoleucos	2	x	Frugivore	S	*
Pycnonotus atriceps	3	x	Omnivore	S	*
Pycnonotus squamatus	5	x	Frugivore	S	*
Pycnonotus cyaniventris	11	x	Frugivore	S	*
Pycnonotus simplex	58	x	Omnivore	S	-
Pycnonotus eutilotus	10	x	Frugivore	S	-
Pycnonotus brunneus	49	x	Frugivore	S	-
Pycnonotus erythropthalmos	113	x	Frugivore	S	-
Alophoixus phaeocephalus	4	x	Omnivore	S	-
Iole olivacea	75	x	Frugivore	S	*
Ixos malaccensis	4	x	Frugivore	S	*
Tricholestes criniger	1	x	Omnivore	S	-
Alophoixus finschii	2	x	Frugivore	S	*
Aegithina tiphia	1	-	Omnivore	S	-
Aegithina viridissima	1	x	Omnivore	S	*
Chloropsis cyanopogon	50	x	Omnivore	S	*

Appendix 1 continued

Species	# visits	Feeding on figs	Guild	Size	IUCN
Chloropsis sonnerati	19	x	Omnivore	S	-
Irena puella	2	x	Omnivore	L	-
Muscicapinae sp.	6	-	Insectivore	S	-
Hypothymis azurea	2	-	Insectivore	S	-
Sitta frontalis	3	-	Insectivore	S	-
Prionochilus percussus	9	x	Frugivore	S	-
Dicaeum chrysorrheum	5	x	Frugivore	S	-
Dicaeum trigonostigma	6	x	Frugivore	S	-
Nectarinia sp.	2	x	Omnivore	S	-
Anthreptes rhodolaema	1	x	Omnivore	S	*
Arachnothera sp.	2	x	Omnivore	S	-
Zosterops sp.	2	x	Frugivore	S	-
Dicrurus aeneus	1	-	Omnivore	S	-
Platysmurus leucopterus	3	-	Omnivore	L	-