

## Fruit Utilization by Five Types of Understory Bird Assemblages in Sarawak, Malaysia

Tamaki Kamoi<sup>1</sup>, Oswald Braken<sup>2</sup>, Kuniyasu Momose<sup>1</sup>

<sup>1</sup> Faculty of Agriculture, Ehime University, Japan

<sup>2</sup> Sarawak Forestry Corporation, Malaysia

### Introduction

In the Oriental Region, highly frugivorous bird species occur in 17 families (of 82), and some degree of frugivory has been reported for 50% of bird families (Corlett 1998). Many frugivorous birds feed on only a portion of the diversity of fleshy fruits produced in any habitat. Fruit selection presumably depends on the behavior, morphology, and nutritional requirements of birds, the abundance of alternative food resources, and fruits characteristics such as temporal availability, habitat, color, abundance, pulp-to-seed ratio and nutrient composition (Corlett 1998, Herrera 1998, Witmer 2001, Alcántara and Rey 2003).

Fruit size may be critical to selection. Sekercioglu (2006) argued that large-seeded plants depend on large frugivores (e.g., hornbills), which account for a relatively small part of the avian fauna, for seed dispersal. Since larger birds have larger gapes, they could potentially eat fruits with a wider range of seed size and a larger number of fruit species. However, it is unlikely that large birds eat small fruits in open spaces and the understory. Therefore, understory birds with gapes of different size should also play some roles in seed dispersal in open spaces and the understory.

The relative abundance of bird groups, based on gape width and frugivory level, was clearly different among forest types (Moran et al. 2004). Also, they discussed potential fruit utilization; however, it is essential to connect gape size with plant species that frugivorous birds actually eat for approach to ecological and conservational subjects. Also, previous studies have investigated how the distribution of understory frugivorous birds changed within a forest (Restrepo et al. 1999; Pearman 2002). However, there has been little research that birds actually feed on how fruits of different plant life forms. By investigating it, the characteristic of fruits utilization of birds within a forest can be expressed.

The purpose of our study was to examine the relationship between smaller birds living in the understory and their fruit utilization in Sarawak, Malaysia. More specifically, we asked three questions: (1) How fruits do understory birds eat on plant life forms? (2) Do understory birds with larger gapes utilize a larger number of fruit species? (3) Do birds with similar gape size overlap about the fruit species they consume?

### Methods

#### *Study site*

This study was conducted in Lambir Hills National Park (4°12'N, 114°02'E), Sarawak, Malaysia. The rain forest in this park is composed of primary mixed dipterocarp (Dipterocarpaceae) forest.

#### *The relationships between birds and fruits*

To clarify the fruit species eaten by understory birds, we conducted three investigations. We referred to

Robson (2000) for the identification of bird species in the field. If the captured bird did not appear in Robson, we referred to MacKinnon and Phillipps (1993).

**Indirect observation** We set sensor cameras near fruiting trees in the canopy and understory for one or more weeks from April 2005 to June 2006, except in November 2005 and from February to April 2006. The camera lens was pointed toward the fruits. Photographed birds were then identified.

**Direct observation** The birds visiting fruiting trees were observed using a field scope and binoculars from April 2005 to January 2006, except in August and November 2005. We recorded the species of birds that ate fruits. We intensively observed trees bearing many fruits or those growing in open spaces where the sensor cameras could not be set.

**Captured birds and excreted seeds** We caught birds with mist nets from March 2005 to June 2006, except in August and November 2005 and from February to April 2006. Two mist nets per day per site were set at a total of five points at the forest edge or in the understory of the forest interior from 07:00 to 17:00. We used four shelf-mist nets that were 6 or 12 m long and 2.5 m high and had a 24- or 36-mm mesh size. The captured birds were carefully removed from the nets and kept for 1 hour in cotton bags where they could not hurt themselves. After the hour, we measured their body mass, wing length, tail length, gape length, and gape width, and released all birds uninjured. We then recorded the number, weight, and size of seeds contained in the excrement found in the cotton bag. The seeds were identified by comparing them with seeds of fruiting plants that had been collected during the field study.

**Analysis** When excreted seeds could not be identified, the data were not included in the analysis. Birds seen feeding on fruits during direct and indirect observations were included in the analysis along with data from the captured birds.

We showed fruit utilization by the five bird assemblages based on taxonomy and gape width, which were observed feeding on fruits of 28 plant species. The plant species were classified into three groups in terms of life forms: pioneer plants (forest edge and gaps), understory plants (understory of the forest interior), and canopy plants (canopy). Climbing and epiphytic *Ficus* species were categorized as canopy plants.

## Results

Of the 56 species (15 families) that we captured, 19 species (four families) excreted feces containing seeds (Table 1). Captured frugivorous species recorded were divided into five types based on taxonomy and gape width (Table 2). Of seven emerald doves (*Chalcophaps indica*), one excreted intact seeds of *Macaranga bancana* (Euphorbiaceae); however, three doves excreted destroyed seeds. For this reason, we considered that *C. indica* was a seed predator rather than a seed disperser, and *C. indica* was not included in further analysis. Also, a little spiderhunter (*Arachnothera longirostra*) excreted intact seeds, however; *A. longirostra* was not included in further analysis because the seeds were not identified. In contrast, yellow-vented bulbuls (*Pycnonotus goiavier*) and Cream-vented bulbuls (*Pycnonotus simplex*) did not excrete seeds. However, these two bulbuls were included in further analysis because it was recorded that they fed on some fruits in direct observation.

All five types of frugivorous species utilized pioneer plants (Fig. 1). Medium-gaped bulbuls fed on various fruit species (25 of the 28 available species). Moreover, bulbuls with small and medium gapes utilized all three types of habitat for feeding on fruits. Barbets and flowerpeckers did not feed on understory fruits, and sunbirds did not feed on canopy fruits.

Diets of bird types have no overlap in understory plants, except for the overlap between small-gaped and medium-gaped bulbuls (Fig. 2). Barbets fed on fruits of pioneer and canopy plants but did not utilize understory plants. Fruits of *Ficus* accounted for three of seven plants. Fruit diets of flowerpeckers were composed of pioneer plants and *Ficus*. The fruit diet of small-gaped bulbuls was completely included in that of medium-gaped bulbuls. The fruit consumed by sunbirds did not overlap with that of barbets or flowerpeckers. Sunbirds fed only on four fruit species, three of which were pioneer *Macaranga* trees.

## Discussion

Many pioneer trees produce fruits frequently (Davies and Ashton 1999; Sakai et al. 1999; our observations) and attract avian dispersers. At our study site, all understory birds fed on fruits of pioneer plants. Pioneer plants might constantly support understory frugivorous birds. Also, bulbuls fed on a wide range of fruits (Figs. 1, 2). In particular, they fed on a larger number of understory fruit species than the other bird groups. Hence, bulbuls seem to be essential for the seed dispersal of understory trees.

Of the five bird types, it was expected that barbets, which have the largest gapes, could potentially eat the largest number of fruit species. However, medium-gaped bulbuls utilized a greater number of different types of fruit than barbets (Fig. 1). In the same family (Pycnonotidae), small-gaped bulbuls fed on fewer fruit species than medium-gaped bulbuls. There are two possible reasons why medium-gaped bulbuls utilized all kinds of fruits. First, Pycnonotidae birds may not be very selective in feeding on fruits and can therefore utilize a wide variety of fruits. Second, a medium-sized gape might enable them to feed on fruits having a wider range of seed size, making them the most adaptable frugivorous birds in the forest understory.

Both the taxonomy and gape width of sunbirds were similar to those of flowerpeckers (Table 2); however, the fruit species eaten by sunbirds did not completely overlap with those eaten by flowerpeckers (Fig. 2). In general, frugivores select fruits in terms of fruit color, fruit size, seed size, and nutrient composition of the fresh pulp (Stiles 1993; Bollen et al. 2004). Both sunbirds and flowerpeckers utilize fruits; however, sunbirds mainly feed on nectar and insects and flowerpeckers mainly feed on the fruits (Corlett 1998). Sugar preferences also differ between nectar- and fruit-eating birds (Lotz 2006), and fruits eaten by these two bird types might be distinguished by the nutrient composition of the pulp.

All understory birds fed on fruits of pioneer plants. Pioneer plants might constantly support understory frugivorous birds. Also, Taxonomy rather than gape size might explain fruit utilization of understory birds.

## Acknowledgments

The authors thank Daisuke Fukuda and Shoko Sakai, Kyoto University, for their great help in getting the permits to research and catch the birds; Takahito Yamamoto, Ehime Pref. Science Museum, for teaching us to use mist nets and to handle captured birds and for giving useful advice; Yumi Aihara, Ehime University,

for field assistance and advice; and Ikuo Ninomiya and his students, Ehime University, for their valuable advice. This research was carried out as a part of project #2 of the Research Institute of Humanity and Nature organized by Tohru Nakashizuka and Masahiro Ichikawa. We thank the organizers of these projects and their Malaysian counterparts, Lucy Chong, Sarawak Forest Corporation, and Josef J. Kendawang, Sarawak Forestry Department, as well as other project members.

## References

- Alcántara JM, Rey PJ (2003) Conflicting selection pressures on seed size: evolutionary ecology of fruit size in a bird-dispersed tree, *Olea europaea*. *J. Evol. Biol.* 16:1168–1176.
- Bollen A, Van Elsacker L, Ganzhorn JU (2004) Relations between fruits and disperser assemblages in a Malagasy littoral forest: a community-level approach. *J. Trop. Ecol.* 20:599–612.
- Corlett RT (1998) Frugivory and seed dispersal by vertebrates in the Oriental (Indomalayan) Region. *Biol. Rev.* 73:413–448.
- Davies SJ, Ashton PS (1999) Phenology and fecundity in 11 sympatric pioneer species of *Macaranga* (Euphorbiaceae) in Borneo. *Am. J. Bot.* 86:1786–1795.
- Herrera CM (1998) Long-term dynamics of Mediterranean frugivorous birds and fleshy fruits: a 12-year study. *Ecol. Monogr.* 68:511–538.
- Lotz CN (2006) Sugar preferences in nectar- and fruit-eating birds: behavioral patterns and physiological causes. *BIOTROPICA* 38:3–15.
- MacKinnon J, Phillipps K (1993) *A Field Guide to The Birds of Borneo, Sumatra, Java and Bali*. Oxford University Press.
- Moran C, Catterall CP, Green RJ, Olsen MF (2004) Functional variation among frugivorous birds: implications for rainforest seed dispersal in a fragmented subtropical landscape. *Oecologia* 141:584–595.
- Pearman PB (2002) The scale of community structure: habitat variation and avian guilds in tropical forest understory. *Ecol. Monogr.* 72:19–39.
- Restrepo C, Gomez N, Heredia S (1999) Anthropogenic edges, treefall gaps, and fruit-frugivore interactions in a neotropical montane forest. *Ecology* 80:668–685.
- Robson C (2000) *A Field Guide To The Birds of South-East Asia*. New Holland Publishers (UK).
- Sakai S, Momose K, Yumoto T, Nagamitsu T, Nagamasu H, Hamid AA, Nakashizuka T, Inoue T (1999) Plant reproductive phenology over four years including an episode of general flowering in a lowland dipterocarp forest, Sarawak, Malaysia. *Am. J. Bot.* 86:1414–1436.
- Sekercioglu CH (2006) Increasing awareness of avian ecological function. *Trends Ecol. Evol.* 21:464–471.
- Stiles EW (1993) The influence of pulp lipids on fruit preference by birds. *Vegetatio* 107/108:227–235.
- Witmer MC (2001) Nutritional interactions and fruit removal: Cedar Waxwing consumption of *Viburnum opulus* fruits in spring. *Ecology* 82:3120–3130.

Table 1. List of captured birds, the number and the proportion of the bird excreting seeds.

Faimly	Species	Common name	The number of captured birds	The number of the bird excreting seeds	The proportion of the bird excreting seeds
Apodidae	<i>Collocalia esculenta</i>	Glossy Swiftlet	2	0	0.00
Columbidae	<i>Chalcophaps indica</i>	Emerald Dove	7	1	0.14
Alcedinidae	<i>Alcedo meninting</i>	Blue-eared Kingfisher	9	0	0.00
	<i>Ceyx rufidorsu</i>	Rufous-backed Kingfisher	3	0	0.00
Halcyonidae	<i>Iacedo pulchella</i>	Banded Kingfisher	1	0	0.00
Cuculidae	<i>Cuculus micropterus</i>	Indian Cuckoo	2	0	0.00
	<i>Surniculus lugubris</i>	Drongo Cuckoo	1	0	0.00
Megalaimidae	<i>Megalaima mystacophanus</i>	Red-throated Barbet	3	3	1.00
Picidae	<i>Blythipicus rubiginosus</i>	Maroon Woodpecker	1	0	0.00
	<i>Meiglyptes tukki</i>	Buff-necked Woodpecker	7	0	0.00
	<i>Sasia abnormis</i>	Rufous Piculet	6	0	0.00
Cisticolidae	<i>Prinia flaviventris</i>	Yellow-bellied Prinia	2	0	0.00
Corvidae	<i>Hypothymis azurea</i>	Black-naped Monarch	7	0	0.00
	<i>Rhipidura javanica</i>	Pied Fantail	1	0	0.00
	<i>Rhipidura perlata</i>	Spotted Fantail	1	0	0.00
	<i>Philentoma pyropteron</i>	Rufous-winged Philentoma	2	0	0.00
Eurylaimidae	<i>Cymbirhynchus macrorhyncho</i>	Black-and-red Broadbill	1	0	0.00
Muscicapidae	<i>Copsychus malabaricus</i>	White-rumped Shama	14	0	0.00
	<i>Cyornis caeruleus</i>	Large-billed Blue-Flycatcher	1	0	0.00
	<i>Cyornis turcosus</i>	Malaysian Blue-Flycatcher	2	0	0.00
	<i>Cyornis spp.</i>	Blue-Flycatcher	3	0	0.00
	<i>Rhinomyias umbratilis</i>	Grey-chested Jungle-Flycatcher	2	0	0.00
Nectariniidae	<i>Dicaeum trigonostigma</i>	Orange-bellied Flowerpecker	1	0	0.00
	<i>Prionochilus muculatus</i>	Yellow-breasted Flowerpecker	11	9	0.82
	<i>Prionochilus xanthopygius</i>	Yellow-rumped Flowerpecker	5	3	0.60
	<i>Aethopyga siparaja</i>	Crimson Sunbird	3	0	0.00
	<i>Anthreptes malacensis</i>	Plain-throated Sunbird	2	1	0.50
	<i>Anthreptes rhodolaem</i>	Red-throated Sunbird	1	1	1.00
	<i>Anthreptes simplex</i>	Plain Sunbird	7	5	0.71
	<i>Anthreptes spp.</i>	Sunbird	8	4	0.50
	<i>Anthreptes singalensis</i>	Ruby-cheeked Sunbird	3	0	0.00
	<i>Arachnothera longirostra</i>	Little Spiderhunter	96	1	0.01
	<i>Hypogramma hypogrammicum</i>	Purple-raped Sunbird	13	7	0.54
	<i>unidentified</i>	Sunbird	1	0	0.00
Passeridae	<i>Lonchura fuscans</i>	Dusky Munia	36	0	0.00
Pycnonotidae	<i>Alphoixus bras</i>	Grey-cheeked Bulbul	6	5	0.83
	<i>Alphoixus phaeocephalus</i>	Yellow-bellied Bulbul	15	8	0.53
	<i>Iole olivacea</i>	Buff-vented Bulbul	1	1	1.00
	<i>Pycnonotus atriceps</i>	Black-headed Bulbul	24	19	0.79
	<i>Pycnonotus brunneus</i>	Red-cyed Bulbul	12	11	0.92
	<i>Pycnonotus erythropthalmos</i>	Spectacled Bulbul	25	22	0.88
	<i>Pycnonotus eutilohus</i>	Puff-backed Bulbul	13	11	0.85
	<i>Pycnonotus goiavier</i>	Yellow-vented Bulbul	1	0	0.00
	<i>Pycnonotus plumosus</i>	Olive-winged Bulbul	10	6	0.60
	<i>Pycnonotus simplex</i>	Cream-vented Bulbul	1	0	0.00
	<i>Tricholestes criniger</i>	Hairy-backed Bulbul	3	2	0.67
Sylviidae	<i>Orthotomus atrogularis</i>	Dark-necked Tailorbird	4	0	0.00
	<i>Orthotomus sericeus</i>	Rufous-tailed Tailorbird	10	0	0.00
	<i>Alcippe brunneicauda</i>	Brown Fulvetta	1	0	0.00
	<i>Macronous ptilosus</i>	Fluffy-backed Tit-Babbler	3	0	0.00
	<i>Mulucocincla muluccensis</i>	Short-tailed Babbler	3	0	0.00
	<i>Malacocincla sepiarium</i>	Horsfield's Babbler	1	0	0.00
	<i>Malacopteron affine</i>	Sooty-capped Babbler	1	0	0.00
	<i>Malacopteron cinereum</i>	Scaly-crowned Babbler	2	0	0.00
	<i>Pellorneum capistratum</i>	Black-capped Babbler	1	0	0.00
	<i>Stachyris erythroptera</i>	Chestnut-winged Babbler	8	0	0.00
	<i>Stachyris maculata</i>	Chestnut-rumped Babbler	6	0	0.00
	<i>Stachyris nigricollis</i>	Black-throated Babbler	2	0	0.00
	<i>Trichastoma rostratum</i>	White-chested Babbler	1	0	0.00
Total			419	120	0.29

Table 2. List of the analyzed 19 bird species and their body mass and gape width.

Bird type	Family	Tribe	Species	Body mass (g)	Gape width (mm)	Gape size class
Barbets	Megalaimidae		<i>Megalaima mystacophanos</i>	75.2	21.59	l
Flowerpeckers	Nectariniidae	Dicaeini	<i>Dicaeum trigonostigma</i>	6.4	5.99	s
			<i>Prionochilus maculatus</i>	8.6	6.74	s
			<i>Prionochilus xanthopygius</i>	7.7	6.37	s
Sunbirds	Nectariniidae	Nectariniini	<i>Anthreptes malacensis</i>	11.4	7.08	s
			<i>Anthreptes rhodolaem</i>	NA	7.28	s
			<i>Anthreptes simplex</i>	8.4	6.73	s
			<i>Hypogramma hypogrammicum</i>	11.9	8.67	s
Medium-gaped bulbuls	Pycnonotidae		<i>Alophoixus bres</i>	42.0	14.16	m
		<i>Alophoixus phaeocephalus</i>	31.4	12.58	m	
		<i>Iole olivacea</i>	24.4	10.74	m	
		<i>Pycnonotus brunneus</i>	25.6	10.66	m	
		<i>Pycnonotus eutilotus</i>	35.8	12.50	m	
		<i>Pycnonotus goiavier</i>	28.0	12.79	m	
		<i>Pycnonotus plumosus</i>	30.3	11.75	m	
Small-gaped bulbuls	Pycnonotidae		<i>Pycnonotus atriceps</i>	22.0	9.88	s
		<i>Pycnonotus erythrophthalmos</i>	17.7	9.61	s	
		<i>Pycnonotus simplex</i>	23.0	9.27	s	
		<i>Tricholestes criniger</i>	16.2	9.37	s	

NA: not available, s: small-gaped (<10 mm), m: medium-gaped (10-15 mm), l: large-gaped (>15 mm).

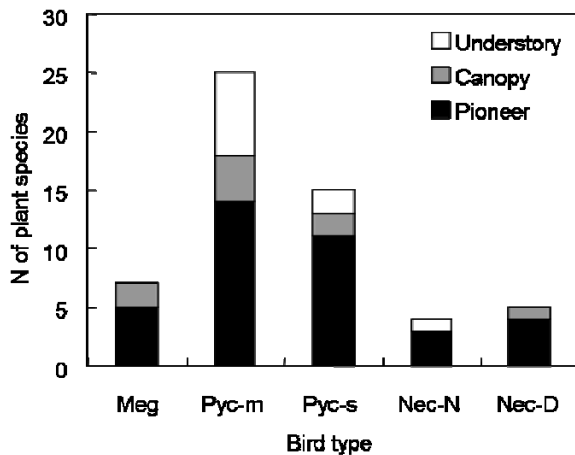


Fig. 1. The fruit utilization by five bird types: barbets (Meg), medium-gaped bulbuls (Pyc-m), small-gaped bulbuls (Pyc-s), sunbirds (Nec-N) and flowerpeckers (Nec-D).

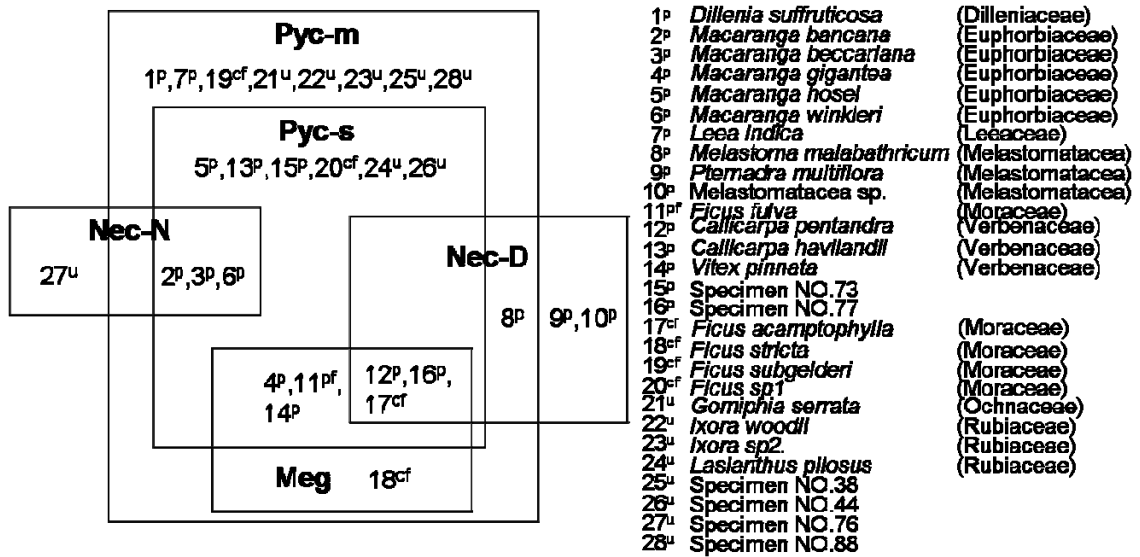


Fig. 2. The fruit diet information was classified into five bird types: barbets (Meg), medium-gaped bulbuls (Pyc-m), small-gaped bulbuls (Pyc-s), sunbirds (Nec-N) and flowerpeckers (Nec-D). In addition, the fruit species was classified into three groups: pioneer plants (p), understory plants (u), canopy plants (c). Climber/epiphyte plants of genus *Ficus* (f) were included in canopy plants.