Short Communications for Integrative Zoology

Title: **A short note on seed dispersal by colobines: The case of the proboscis monkey**

Running title: **Seed dispersal by the proboscis monkey**

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Abstract

The role of primates in seed dispersal is well recognized, except in colobines, which are widely distributed in Asian and African tropical forests. Colobines consume leaves, seeds and fruits, usually unripe. A group of proboscis monkeys (Colobinae, *Nasalis larvatus*) consisting of an alpha-male, six adult females, and several immatures, was observed from May 2005–2006. A total of 400 fecal samples from focal group members covering 13 months were examined with over 3,500 hr of focal observation data on the group members in a forest along the Menanggul River, Sabah, Malaysia. Intact small seeds were only found in 23 of 71 samples in November 2005, 15 of 38 in December 2005, and 5 of 21 in March 2006. Seeds of *Ficus* (all < 1.5 mm in length) were found in all three months and seeds from *Antidesma thwaitesianum* (all < 3 mm) and *Nauclea subdita* (all < 2 mm) only in November and December, which was consistent with members of the study group consuming fruits of these species mostly at this time. To our knowledge, these are the first records of seeds in the fecal samples of colobines. Even if colobines pass relatively few seeds intact, their high abundance and biomass could make them quantitatively significant in seed dispersal. The potential role of colobines as seed dispersers should be considered by Colobine researchers.

Key words: Borneo; biomass; leaf-monkey; *Nasalis larvatus*; primate

INTRODCUTION

The role of primates in seed dispersal is well recognized (Chapman 1995; Russo & Chapman 2011), with the exception of the colobines, a subfamily of Old World monkeys (Cercopithecidae, Colobinae) that includes the colobus monkeys of Africa and the leaf monkeys of Asia. Colobine monkeys account for approximately one-sixth of all primate species (Groves 2002) and are usually at least as high in biomass in the tropical forests of Asia and Africa as the fruit-eating cercopithecine monkeys (Cercopithecidae, Cercopithecinae) and more so than the apes (Table 1). Colobines are known as feeders of 'difficult' plant materials, including leaves, seeds and unripe fruits, which they process in their complex, multi-chambered stomachs, where bacteria detoxify defensive chemicals and digest cellulose (Chivers 1994). It has therefore been assumed that any seeds ingested are destroyed (e.g., Sun *et al.* 2007). However, colobine diets are extremely varied (Fashing 2011; Kirkpatrick 2011) and tropical forest ungulates with similar diets and digestive systems are known to disperse some seeds intact (Bodmer 1991; Corlett 1998). In view of their abundance in Old World tropical forests, the assumption that colobines do not disperse seeds deserves re-examination.

The proboscis monkey (*Nasalis larvatus*) is the largest colobine, with a diet consisting of various proportions of leaves and fruit (Yeager 1989; Matsuda *et al.* 2009). They are endemic to the island of Borneo where they inhabit mangroves, freshwater swamps and riverine forests. Although seed dispersal by proboscis monkeys has not been previously investigated, no whole seeds were found in 76 and over 50 fecal samples collected for parasitological analyses (Ranglack & Yeager 1986) and for genetic analyses (Salgo-Lynn *et al.* 2010; Munshi-South & Bernard 2011), respectively.

Here, we report the presence of small, intact seeds in the feces of proboscis monkeys: to our knowledge, the first record of this for a colobine monkey.

MATERIALS AND METHODS

Between May 2005 and May 2006, we observed a well-habituated, one-male group (one adult male, six adult females, nine immatures) along a tributary of the Kinabatangan River, Sabah, Malaysia (118º 30′ E, 5º 30′ N). We collected 3,507 h of behavioural and feeding data on the adult monkeys through focal animal sampling (Altmann 1974). During the study period, continuous observations facilitated calculation of time budgets of adult monkeys, including the proportion of the day spent feeding, and time spent feeding on individual food items. Young leaves (65.9%) and fruits (25.9%) accounted for the majority of their feeding time. Over 90% of fruit feeding involved the consumption of unripe fruits and in the majority of case both the fruit flesh and seeds were eaten. Although fruit eating was rare in some months, during other times of the year fruit feeding exceeded the time devoted to young leaves. A total of 188 plant species were consumed by the focal monkeys: the number of plant species providing young leaves, fruits, and flowers were 182, 49, and 28, respectively (see Matsuda *et al.* 2009 for details).

A total of 400 feces samples from focal group members were examined over 13 months, ranging from 19 samples in September to 71 in November (mean ± SD = 27.5 ± 10.0 samples per month). Fecal samples were examined manually with foreceps and magnifying glass for the presence of seeds. To verify that fruit-eating resulted in the seeds being defecated, some feces from focal individuals were examined *in situ*. For identification, we compared the seeds found in the feces with

the ones in the fruits eaten by the focal individuals.

RESULTS AND DISCUSSION

Intact seeds were only found in 23 of the 71 November samples, 15 of the 38 December samples, and 5 of the 21 March samples. Seeds of *Ficus* (all < 1.5 mm in length; each sample contained from 3-18 seeds) were found in all three months and seeds from *Antidesma thwaitesianum* (Euphorbiaceae; all < 5 mm; 1-3 seeds) and *Nauclea subdita* (Rubiaceae; all < 2 mm; 1-23 seeds) only in November and December (Figure 1A), which was consistent with members of the study group consuming fruits of these species mostly at this time (Figure 1B). Although the monkeys targeted unripe fruits of *A. thwaitesianum*, ripe fruits were sometimes ingested at the same time, presumably accidentally. Fruits of *N. subdita* were usually consumed ripe, and the monkeys fed mostly on the seed-rich interior of the fruits.

Within the identified 21 fig species eaten by focal members (Matsuda *et al.* 2009), two species of fig, *F. binnendijkii* and *F. globosa*, were relatively abundant in the study area and their fruits were positively preferred by proboscis monkeys (Matsuda 2008). Although *F. binnendijkii* fruited throughout the study period, the monkeys consumed only the immature figs and no seeds were detected in the feces, suggesting that they were digested in the forestomach. *F. globosa* fruited from September to May and the monkeys consumed both unripe and ripe figs, usually eating only the seed-rich interior of each fig. Comparing their feature with the eaten figs at that time, most of the fig seeds in the feces were probably from *F. globosa* (their seed size was slightly larger than other fig species). While there was a good match between the observation of feeding on *A.*

thwaitesianum and presence of its seeds in the feces, the seeds of *N. subdita* and *Ficus* spp. were not detected in the feces in all months when feeding on these fruits was observed (Fig. 1). This mismatch is most likely due to the difference in feces sampling effort between the months.

To our knowledge, these are the first records of seeds in colobine fecal samples. Proboscis monkeys are generally seed-predatory primates as the consumed seeds are mostly digested; the monkeys prefer to feed on the immature seeds that are possibly easy to digest in their forestomach. However, there is potential for proboscis monkeys to disperse small seeded plants when they consume their ripe fruits: the likelihood of small seeds passing through intact is higher when they consume a lot of these fruits at once because small seeds may be pre-adapted to surviving ingestion and perhaps digestion by ruminant guts as emphasized in Janzen (1984). Similar to our study, Norconk *et al.* (1998) also reported small seeds in the feces of white-faced and bearded sakis, which are seed-predatory New World primates. Although most feces samples examined in this study contained no seeds and the seeds of most species consumed during the study period were not found in feces, the broad distribution and high biomass of colobines in tropical regions of Asia and Africa suggests that they could be quantitatively significant in seed dispersal. Considering the relevance of colobine biomass in various ecosystems (Table 1), it is timely that colobine researchers examine this possibility in other colobine species.

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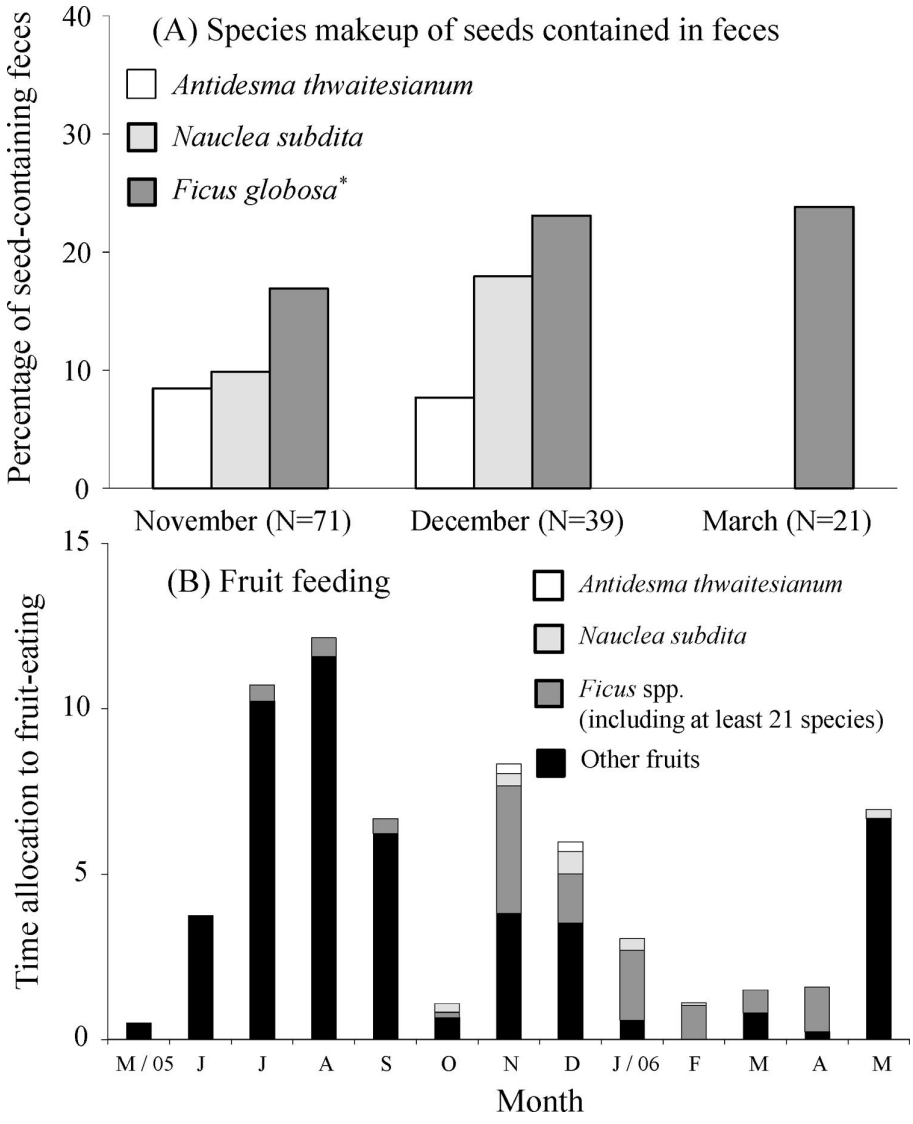

Figure 1. Species makeup of seeds contained in feces (A) and seasonal trends of time allocation to fruit feeding (B). Whereas a total of 400 feces were examined during 13 months, fruit seeds of only three species were found in 43 feces examined in November, December, and March. * Comparing their feature with the eaten figs at that time, most of the fig seeds in the feces were probably from *F. globosa*.

Table 1
Comparison of the primate biomass (kg km-2) among study sites.

	Asian Study Sites				African Study Sites								
	Kuala Lumpat Malaysia[1]	Ketambe Indonesia[1]	Siberut Indonesia[2]	Barito Ulu Indonesia[3]	Lope Gabon[1]	Douala-Edea Cameroon[1]	Budongo Uganda[1]	Ituri Congo[1]	Tai Cote d'Ivoire[1]	Tiwai Island Sierra Leone[1]	Kibale Uganda[1]	Lomako Congo[4]	Kalinzu Uganda[5]
Colobinae	704	144	535	44	91	198	284	308	704	785	2077	57	83
Hominoidea	83	400	6	37	68	25	89	28	59	25	85	70	115
Cercopithecinae	179	344	341	6	161	239	354	248	534	907	416	569	375
Others	7	6	0	0	0	0	0	0	15	0	0	0	0

Fleagle, et al., 1991[1]; Quinten et al., 2009[2]; McConkey and Chivers, 2004[3]; McGraw, 1994[4]; Tashiro, 2001[5]