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SHORT COMMUNICATION

Frugivores and fruit removal of *Antiaris toxicaria* (Moraceae) at Bia Biosphere Reserve, Ghana

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In tropical forests, most individual fruit-bearing trees depend on frugivores for seed dispersal (Howe & Smallwood 1982, Wilson 1992). Seed dispersal enhances germination potential, provides an opportunity for seeds to escape predation under the parent plants, and reduces seedling numbers under parent trees (Şekercioğlu *et al.* 2004). The way frugivores handle seeds and process them may influence the seed fate of many plants (Janzen 1971). The quantity of seeds dispersed and the quality of dispersal provided by frugivores impact plant fitness (Herrera & Jordano 1981). Schupp (1993) defined the effectiveness of seed dispersal by frugivores as an empirical measure of quantity of seeds dispersed and quality of dispersal from the parent plant to a suitable microsite. Seed dispersal by frugivores increases the chances for seedling survival away from the vicinity of the parent plant because in tropical forests seed predation is concentrated under adult trees that prevent seedlings from establishing near parent trees (Howe & Miriti 2004).

This study contributes to our understanding of the role of frugivores in the natural regeneration of tropical forests by focusing on *Antiaris toxicaria* seed removal. This tree is one of the most heavily exploited timber species in Ghana (FAO 2007). In 2001, the total stock volume of merchantable *A. toxicaria* above 70 cm diameter at breast height (dbh) in Ghana was 166 m^3 km^{-2} (Bosu & Krampah 2005). We hypothesized that the proportion of fruits removed and how they are processed would differ between frugivores. Here we used fruit removal and fruit handling as a proxy to compare frugivore seed-dispersal quantity and quality.

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The study was carried out in the Bia Biosphere Reserve (7700 ha, grid reference: 6°32′–6°37′N, 3°02′–3°08′W) in Ghana. Temperature in the area ranges from 20.5–34 °C. The dry season lasts from December to March and rainfall peaks are in June and October, the vegetation is primary tropical rain forest and there is a variety of wildlife (Short 1983).

Antiaris toxicaria Leschenault (Moraceae) is a species of medium to large deciduous tree, usually with a maximum height of about 47 m and 2.5 m girth. The seeds are elliptical (Hall & Swaine 1981, Taylor 1960) but sometimes round in shape. The seed has a mean weight of 25.4 ± 0.65 g (N = 400) (this study). The flowering and fruiting time is 1 mo (Ewusie 1992), and mostly from December to January (Irvine 1961, Taylor 1960). Antelopes and monkeys are reported to eat the fruit in Ghana (Irvine 1961).

To determine rates of visitation and fruit consumption by vertebrates, we observed six focal *A. toxicaria* trees for 1200 h (200 h per tree). The focal trees were randomly chosen but we made sure that any one individual was at least 250 m away from the nearest adult tree used in this research. Observation began at the initiation of flower formation and continued until the cessation of visits by frugivores because the flowering and fruiting stages take place almost simultaneously (Ewusie 1992) and could not readily be distinguished. During the day, we watched a single tree for 1–4 h in the morning beginning at 06h00 or in the afternoon beginning at 13h00. At night, each focal tree was watched using a hand-held light with luminance of 80 000 cd m^{-2} with a red lens on. The light was thrown on visiting animals in order to identify their feeding habits. We watched for 1.5–2 h between 18h30 and 20h30, a peak feeding time for most nocturnal mammals (B. O. Kankam *pers. obs.*). We recorded the time of arrival of

each visitor, its identity, duration of visit, amount of fruit consumed, and feeding behaviour, especially fruit handling of mammalian frugivores (Chapman *et al.* 1992) such as monkeys. We grouped species to three consumer categories as: (1) 'dispersers through seed swallowing', when they swallow the entire fruit with pulp and seeds intact. For these consumers, most seeds are deposited away from parent trees and are more likely to germinate; (2) 'dispersers through seed spitting/dropping', where seeds are deposited under the parent tree singly. For cercopithecine monkeys, some seeds may be stored in the cheek-pouch at the time when the monkey moves out of the tree. The seeds are spat out without destroying them; (3) 'predators', where seeds are broken and their contents destroyed by the animal during feeding, whether the remains are spat out, eliminated in faeces, or rotted whole in a food hoard (Lambert 1999, Lambert & Chapman 2004). Observing fruit removal by fruit bats was challenging, however, we took advantage of the moonlight to record bat visits and estimated the number of fruits removed by fruit bats. Fruit bats usually carried fruit away from the tree (B. O. Kankam *pers. obs.*), so fruit removal was taken to have occurred when a visiting bat flew away from the focal tree. We fed captive duikers (*Cerphalophus maxwelli* and *C. dorsalis*) and bushbuck (*Tragelaphus scriptus*) at the Kumasi Zoological Garden with *A. toxicaria* fruits to better observe how these species processed *A. toxicaria* fruits in their mouth. Nomenclature for mammal and bird species follows Wilson & Reeder (1993) and Clements (2000) respectively.

We used percentages to estimate the number of visits, number of groups per visit, number of fruits taken per visit, and per cent of fruits removed or dropped under the parent tree. Seed dispersal was calculated by this procedure: (1) the number of visits by frugivores was multiplied by the number of individual species (bird or mammal) per visit. (2) The product of step one was multiplied by the number of fruits detached per visit and the percentage of fruits removed by each species. All reported values are presented as mean ± SE unless otherwise stated.

Fruit ripening and dispersal occurred over the period of 10 wk (range = 6–8 wk) (Table 1). The number of fruits detached from each tree by frugivores varied considerably (Table 1); for example trees 5 and 6 which had greater diameter at breast height (dbh) and crown volume, produced more fruits than the other focal trees. Trees 5 and 6 received the most visitors during the fruiting season.

A total of 10 species of mammal and nine species of bird were observed to visit *A. toxicaria* at Bia Biosphere Reserve (Table 1); however, data on number of fruits removed or eaten were estimated for only potential seed dispersers. Mammals were responsible for 76.3% of fruits dispersed as compared with birds (23.7%). The western plantain-eater (*Crinifer piscator*) and the monkeys (*Cercopithecus campbelli* and *C. petaurista*) were the major seed dispersers among the birds and mammals respectively (Table 1). Fruit bats, especially *Eidolon helvum* removed more than 400 fruits in each night they visited the focal trees for 3 d.

The fruits of *A. toxicaria* were processed differently by different frugivores; for example, *Pycnonotus barbatus* and *Gymnobucco calvus* picked off the pulp and dropped every seed under the parent tree. *Musophaga violacea* and *Crinifer piscator* kept fruits in the bill, pressed them and ingested the pulp, dropping the seeds under the parent tree. In one out of every four observations they swallowed the fruits whole and were likely to disperse the seeds.

Cercopithecus campbelli and *C. petaurista* dropped or knocked down as many fruits as they consumed. Fruits were often packed in their cheek-pouches as they moved away from the parent tree to consume only the fleshy exo- and mesocarp. The monkeys did not swallow the whole seed intact. They spat out seeds as single units rather than ingesting and defecating them, often spitting out large piles of seeds in one place as observed in other primates (Howe 1980, Russo & Augspurger 2004). The seed-processing pattern in the mouth by *C. campbelli* and *C. petaurista* is similar to that observed by Lambert (2001) in red-tailed monkeys (*C. ascanius*) in Kibale National Park, Uganda. Seeds deposited just outside the tree crown area (near the parent tree) by primates and birds can be beneficial, at least in the early recruitment of some tropical tree species (Howe 1977). The squirrels *Funisciurus pyrropus*, *Protoxerus aubinnii* and *Protoxerus strangeri* ate only the fruit pulp and dropped the seeds under parent trees. *Paraxerus poensis* was seen transporting fruits away from the parent tree. The feeding trials at the Kumasi Zoological Garden revealed that *Cerphalophus maxwelli* and *C. dorsalis*, and *Tragelaphus scriptus* crushed the fruits in their mouths destroying the seeds completely. During our observation on *Eidolon helvum*, we observed that fruit bats moved seeds from focal trees to feeding roosts usually located within 100 m from the focal trees. During this seed-dispersal process some seeds are dropped under the parent tree while flying back and forth from feeding trees to roosting trees (Muscarella & Fleming 2007). Most seeds also had fruit pulp attached to them.

Cricetomys gambianus is more of a seed predator (Emmons 1983) than a seed disperser (Guedje *et al.* 2003), although other squirrels (e.g. *Heliosciurus rufobrachium* and *Paraxerus palliates*; Gathua 2000) are known to disperse seeds in tropical forest. *Atherurus africanus* carries fruits to eat under fallen logs, sometimes dozens of metres from the source (Schupp 1993).

Our results suggest that *A. toxicaria* fruits were eaten and dispersed by multiple frugivores (Bakker *et al.* 1996). However, not all observed frugivores provide the same quality of seed-dispersal service in terms of seeds handling or feeding behaviour (Clark *et al.* 2001, Dennis & Westcott 2007, Loiselle *et al.* 2007, Schupp 1993). By treating seeds in the mouth and depositing them away from the

Table 1. Frugivores observed visiting *Antiaris toxicaria* trees at Bia Biosphere Reserve in Ghana. No. of fruits moved refers to the number of fruits moved away from parent tree; dispersed seeds reflects the estimated number of seeds moved by frugivores away from the focal trees.

Frugivore	No. of fruits detached per tree						No. of visits	No. of individuals per visit (± SD)	No. of fruits detached per visit	No. of fruits moved (%)	Dispersed seeds (%)
	1	2	3	4	5	6					
Mammals											
Cercopithecus campbelli	700	800	720	743	1100	2500	12	8.3 ± 1.9	67.9	65.0	4396 (45.6)
Cercopithecus petaurista	310	365	200	150	735	1000	9	7.0 ± 1.5	43.8	70.0	1932 (20.0)
Funisciurus pyrropus	0	0	0	0	0	4	1	1.0 ± 0.0	4.0	0.0	0 (0.0)
Paraxerus poensis	0	0	0	0	0	4	2	1.0 ± 0.0	2.0	100.0	4 (<0.1)
Protoxerus aubinnii	1	0	0	0	1	4	2	1.0 ± 0.0	3.0	0.0	0 (0.0)
Protoxerus stangeri	0	0	0	1	2	3	2	1.0 ± 0.0	3.0	0.0	0 (0.0)
Anomalurus pelii	x	x	x	x	x	x	16	x	x	x	x
Atherurus africanus	x	x	x	x	x	x	6	x	x	x	x
Cricetomys gambianus	x	x	x	x	x	x	12	x	x	x	x
Eidolon helvum	90	70	40	70	310	620	3	8.3 ± 1.7	48.2	85.0	1020 (10.6)
Birds											
Pycnonotus barbatus	300	250	200	150	1100	2185	75	3.1 ± 0.9	18.0	0.0	0 (0.0)
Tauraco macrorhynchus	33	37	21	9	55	95	16	1.3 ± 0.5	12.0	29.5	74 (0.8)
Musophaga violacea	35	55	45	61	182	365	45	1.1 ± 0.4	15.0	25.0	186 (1.9)
Crinifer piscator	156	210	78	95	510	1780	52	3.2 ± 0.9	17.0	32.5	919 (9.5)
Gymnobucco calvus	28	90	70	40	435	1965	55	3.1 ± 0.8	16.0	0.0	0 (0.0)
Ceratogymna atrata	120	34	150	330	120	880	43	2.0 ± 0.3	19.0	24.3	397 (4.1)
Tockus fasciatus	99	40	44	76	542	772	37	2.5 ± 0.7	17.0	35.0	550 (5.7)
Tropicranus albocristatus	220	188	62	37	984	1984	27	1.3 ± 0.5	16.0	22.6	127 (1.3)
Treron calva	215	151	198	210	847	1854	31	5.9 ± 0.0	19.0	1.0	35 (0.4)

parent tree, *Cercopithecus campbelli* and *C. petaurista* are quite likely among the best seed dispersers for *A. toxicaria*. Other species such as hornbills, turacos, plantain-eaters and fruit bats may contribute effectively to the distribution of *A. toxicaria* seeds in Bia Biosphere Reserve because they are mobile foragers (Fleming & Heithaus 1981). A population reduction of dispersers can affect seedling recruitment and possibly the genetic structure of tropical trees (Chapman & Onderdonk 1998, Cordeiro & Howe 2001), therefore the conservation of important frugivore seed dispersers should be part of sustainable management of *A. toxicaria*.

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