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SEED DISPERSAL BY THE INDIAN GREY HORNBILL *OCYCEROS BIROSTRIS* IN EASTERN GHATS, INDIA

E. Santhoshkumar & P. Balasubramanian*

Division of Landscape Ecology, Salim Ali Centre for Ornithology and Natural History
Anaikatty P.O., Coimbatore - 641 108, Tamil Nadu, India

Abstract. Among the avian frugivores in tropical forests, large birds have an important role in the seed dispersal. The Indian Grey Hornbill *Ocyceros birostris*, one of the few larger avian species in the Eastern Ghats was expected to play a key role in seed dispersal. We studied i. nest middens (i.e. the seeds deposited under the active nest), ii. seed germination trial of hornbill-dispersed seeds and iii. seedling abundance under nest trees, to assess its role in seed dispersal and forest regeneration. Of the 3303 seeds found in the nest middens, *Premna tomentosa* (38.6%), *Drypetes roxburghii* (19.5%) and *Filicium decipiens* (12.7%) formed the predominant species. Seeds found in the nest middens were intact indicating that the Indian Grey Hornbill is a legitimate seed disperser. Germination experiments on hornbill's diet species indicated that the seed germination efficiency of 15 out of 16 species is enhanced after defecation. Indian Grey Hornbill's preferred diet species such as *Syzygium cumini, Premna tomentosa, Diospyros montana* and *Drypetes roxburghii* showed higher percent of germination after defecation. The number of individuals of hornbill diet species (n= 875) was significantly higher in front of the nest cavity than behind (n= 214), confirming the Indian Grey Hornbill's role in seed dispersal. Of the 2082 seedlings recorded under the nests, 55 percent were hornbill's diet species. The dispersal of 26 plant species during the breeding season alone indicates that the Indian Grey Hornbill is a "pivotal" species in the forest ecosystem maintenance.

Key words: Eastern Ghats, Frugivory, Figs, Indian Grey Hornbill, Seed dispersal, Seed germination.

INTRODUCTION

Plant-bird interactions play a pivotal role in maintaining the structural and functional integrity of natural ecosystems. Frugivores disperse the seeds of the majority of the woody plant species in the tropics (Howe & Smallwood 1982). The seed dispersal process is essential for the persistence of plant populations and is the fundamental mechanism for the organization and maintenance of species richness in plant communities (Herrera 1984, Nathan & Muller-Landau 2000). Avian fruit consumption may ensure plant reproductive success by effectively removing fruit pulp and disperse the seeds (Carlo *et al.* 2003). Frugivores affect the germination success of seeds which they either defecate or regurgitate as the gastrointestinal enzymes and acids within the gut of the birds soften the hard seed coat, thus breaking dormancy and enhancing germination in seeds (Fleming & Heithaus 1981, Schupp 1993). The passage of seeds through the digestive tracts of vertebrates, particularly birds, is important in determining their future germination behaviour (Traveset *et al.* 2001).

Hornbills are the principal frugivores in many of the forests which they occupy and their role in seed dispersal, germination and regeneration is notable (Kemp 1995, Whitney *et al.* 1998, Kinnaird and O'Brien 2007). Among the avian frugivores in tropical forests, hornbills owing to their large size have an important role to play in the seed dissemination and regeneration of their food plants. Hornbills can break up and swallow large fruits, may regurgitate seeds undamaged and thus, make them ideal dispersers (Holbrook & Smith 2000). They are known to travel long distances in a day in search of fruits and hence, are capable of moving viable seeds to distant locations. The pattern of hornbill seed dispersal during breeding season is very different from that of the non-breeding season. The breeding habits of hornbills are unique, where the female of most species seals herself into a nest cavity and leaves only a narrow slit through which the male passes her food until the nesting period is completed. The seeds of

* e-mail: balusacon@yahoo.com

the fruits delivered to the nest inmates are squirted out through the narrow slit and are deposited at the base of the tree trunk and these are called seed middens (Kemp 1995). Seed deposition at the nest trees is a useful guide to determine the diet of hornbills in the breeding season (Kitamura *et al.* 2004). Although, studies on seed deposition at nest sites by Asian hornbills have been conducted (Poonswad *et al.* 1987, Kannan and James 1997, Kinnaird 1998, Mudappa 2000, Klop *et al.* 2000, Balasubramanian *et al.* 2004, Kitamura *et al.* 2004), information on Indian Grey Hornbill was scanty.

Indian Grey Hornbill is distributed in India, Pakistan, Nepal & Bangladesh (Ali and Ripley 1987). It is widely distributed in the Eastern Ghats, southern India and found mainly in the low elevation forests and areas of rural cultivation. The major habitats of Indian Grey Hornbill in Eastern Ghats namely dry deciduous forests and low-land riparian forests are severely affected by anthropogenic activities (Balasubramanian *et al.* 2005). In the absence of other large-bodied avian frugivores including other hornbill species in southern Eastern Ghats, the Indian Grey Hornbill appeared to have a major role in seed dispersal. Owing to its predominantly frugivorous habit, the hornbill is expected to consume a wide variety of fruit species, and aid in seed dispersal and forest regeneration. Hence, the present study was made with the objective of assessing its role in seed dispersal and forest regeneration.

MATERIALS AND METHODS

Study site. The study was conducted in Hasanur range (11°40'12" N latitude and 77°07' 87" E longitude) of Sathyamangalam Forest Division, Eastern Ghats, India from June 2006 to December 2008. Elevation of this division varies from 280 to 1698 m above sea level. The study area receives rainfall from both South-west and North-east monsoon, annual rainfall varies from 600 to 850 mm. The temperature is high (40°C) during hot summer and low (20°C) during winter. It has a variety of habitats raging from dry scrub to wet evergreen forest. The study site, Hasanur, is a plateau which extends to 30 km^2 at an elevation of 940 msl. Dry deciduous and riparian fringing semi-evergreen forests are the principal vegetation types here. A total of 22 fleshy-fruited species are common in both riverine and dry deciduous forests. *Vitex altissima, Diospyros montana* and *Capparis grandis* are the dominant species. Thirty seven species of birds are reported to consume fruits in the study area. Notable frugivores include barbets (*Megalaima* spp), bulbuls (*Pycnonotus* spp), pigeons (*Treron* spp), orioles (*Oriolus* spp) and Indian Grey Hornbill (*Ocyceros birostris*).

Study species. The Indian Grey Hornbill measures 50 cm and the mean mass of male bird is 375g. It is a secondary cavity nester which nests in tree cavities formed naturally or excavated by primary cavity nesters. Nesting period starts early in March and ends in June. The nesting period was 87 days in average, with the female sealed in the nest cavity for an average of 76 days and the nestlings emerged out at an average of 13 days after the female emerged (Santhoshkumar and Balasubramanian 2010). Indian Grey Hornbills breed every year, they show high nest-site fidelity, returning to the same nest cavity. In the study area, seventy eight percent of the nest cavities were reused by hornbills in the second year breeding season (Santhoshkumar and Balasubramanian 2010).

Diet. The diet of the Indian Grey Hornbill was determined during the breeding season by direct observations at the nest and by analyzing the seeds deposited under the nest. Due to their specialized breeding habits, male hornbills need to bring loads of food to the nest site to feed the incarcerated female and chicks throughout the nesting period. Seeds of the fruits consumed by the female hornbill and the young ones in the nest cavity are squirted out through the nest slit. These seeds and fruit remains are deposited under the nest cavity and are known as nest midden. In the present study, five different nests per year were selected and 3 x 3 m quadrates were laid at the base of 10 active nest trees for the period of two years (five nests per year) and the seeds were collected once in a week and identified by comparison with seeds collected from fresh fruits. Plant species with minute seeds (<0.2 cm) were not included in the seed midden count as we could not count them in the field. Large and medium sized seeds collected from nest middens were examined for visible physical damage. In addition to nest midden examination for seed identification, extended watches were carried out at active nests, to assess the food, particularly fruits utilized by hornbills during breeding season. In the present case, we observed five nests per year. Even though there was high nest fidelity by Indian Grey hornbills, only two of the nests observed in the first year were observed in the second year. A total of 720 hours (360 hours per year, 72 hours per nest) were spent at the hides made aside the nests for

recording fruit deliveries by males to the nest inmates. Observations were carried out from 0600 to 1800 at 10 nests (five nests per year). Each focal nest selected for observation was situated not less than 1km away from the other nest.

Germination experiment. Of the seeds of 17 plant species collected from nest middens, seed germination experiments on 16 plant species, excepting *Lantana camara* were conducted to compare the germination percentage of hornbill-defecated seeds with controls. *Lantana camara*, was not included in the experiment, as it is an exotic weed and abundantly occurring in the study area. Control un-ingested seeds were collected from fresh ripe fruits at the study site. Three types of seed treatments were used for germination experiments, i. hornbill-defecated seeds collected from the nest middens, ii. manually depulped seeds and iii. seeds with pulp. For each treatment, 10 seeds were used. Seeds were sown in polythene bags filled with soil sand mixture and placed in enclosures in a nursery. The poly-bags were regularly watered and the height of the seedlings was recorded every week for four months from the date of sowing.

Natural regeneration. The role of the Indian Grey Hornbill in regeneration of its food plants was assessed by sampling the seedling abundance in front and behind the nest trees. We selected 10 nests and laid two 3 x 3 m quadrates (One quadrat each in the front and behind the nest trees) one meter away from the base of the tree. These 10 were not the same nests used for midden examination. Selection of 10 additional nests was aimed to cover the entire spectrum of diet plants of the hornbill. The plot behind the nest tree was used as control. A total of 20 quadrates were laid for sampling seedling abundance. After the rainy season, in the first week of August, all seedlings in the 3 m plots were counted and identified. Here the number of seedlings of diet species and non-diet species recorded under the 10 nest trees were summed up respectively to find out the difference in total number of diet and non-diet seedlings.

Statistical analysis. Differences in the germination percentage of the different treatments (defecated seeds vs depulped seeds vs intact fruits) and plant species were tested for statistical significance with One-way ANOVA. Tamhane's test was used for post-hoc comparison between pairs in the group. To find out the statistical significance of the number of diet seedlings in front of the nest cavities and behind the nest cavities, Paired-Sample T Test was used. The analyses were performed with the software SPSS 10.0 for Windows.

RESULTS

Seeds of 26 fleshy fruited species belonging to 16 families were found in the middens. Of the 26 fruit species, 17 had medium/large seeds (>0.2cm), 9 had minute (<0.2cm) seeds. A total of 3303 large/medium seeds were found. *Premna tomentosa, Drypetes roxburghii, Filicium decipiens, Diospyros montana* and *Santalum album* formed the predominant large/medium seeded species (Table 1). The nine species with minute seeds included Moraceae (seven *Ficus* spp) and Solanaceae (two species). No physical damage was noticed in the seeds dispersed by the hornbills.

Germination Experiment: Of the 16 species subjected to the germination experiment, 15 species in the bird defecated seed sample showed enhanced germination (Fig. 1). Seedling emergence was first recorded for *Syzygium cumini* after one week of sowing. Later in the second and third week, seedling emergence was noted for all the other species except

TABLE 1. Per cent proportion of different seed species recorded in the hornbill nest middens.

S. No.	Plant species	Family	% of seeds
1.	*Atalantia monophylla*	Rutaceae	1.36
2.	*Capparis grandis*	Capparidaceae	1.67
3.	*Celtis tetrandra*	Ulmaceae	0.36
4.	*Cordia monoica*	Boraginaceae	0.64
5.	*Cordia obliqua*	Boraginaceae	0.70
6.	*Diospyros montana*	Ebenaceae	9.87
7.	*Drypetes roxburghii*	Euphorbiaceae	19.59
8.	*Filicium decipiens*	Sapindaceae	12.75
9.	*Lantana camara*	Verbenaceae	1.33
10.	*Mimusops elengi*	Sapotaceae	1.54
11.	*Pithecellobium dulce*	Caesalpiniaceae	0.27
12.	*Premna tomentosa*	Verbenaceae	38.66
13.	*Santalum album*	Santalaceae	6.81
14.	*Strychnos potatorum*	Loganiaceae	1.15
15.	*Syzygium cumini*	Myrtaceae	1.36
16.	*Vitex altissima*	Verbenaceae	1.21
17.	*Zizyphus mauritiana*	Rhamnaceae	0.73

Santalum album, in which seedlings emerged only after the fourth week. In the bird defecated seeds treatment, four species showed 100 percent germination. Nine species in the pulp removed seed treatment and four species of intact fruit treatment alone germinated, that too in lower numbers when compared to bird defecated seeds (Fig. 1).

According to One-Way ANOVA, significant differences were observed in the case of germination percentage of three categories of seeds experimented ($F_{2,9}$ = 6.142, P < 0.05). Tamhane's post-hoc comparison mean difference values between pairs for bird defecated seeds and pulp removed seeds = 30.0, bird defecated seeds and seeds with pulp = 60.0 and pulp removed seeds and seeds with pulp = 30.0. The mean percentage of seed germinated for the three treatments are follows: seeds with pulp 32.5%, pulp removed seeds 62.5%, bird defecated seeds 92.5%.

Natural regeneration. Seedlings of 24 food plant species were recorded beneath the nests of the Indian Grey Hornbill. Dominant diet species found in front of the nest trees were *Diospyros montana* (23.9%), *Drypetes roxburghii*, (17.4%), *Capparis grandis* (5.4%) *Premna tomentosa* (5.4%) and *Filicium decipiens* (5.1%). While the number of seedlings of hornbill's food plant species was higher in front of the nests (i.e. nearly four times than the behind), the non-diet species was higher behind the nest, indicating that the nest inmates squirt out their droppings through the nest hole, which falls in front of the nest tree (Fig. 2). The number of seedlings of the diet species in front of the nest was significantly higher than the one behind the nests (Paired-Sample T Test t = 3.630, df = 38 P < 0.01). There was no significant difference for non-diet species in front and behind the nest (Paired-Sample T Test t = 0.412, df = 24 P > 0.05).

DISCUSSION

The present study indicates that the Indian Grey Hornbill is a legitimate seed disperser which aids in the seed dispersal of a large number of plant species

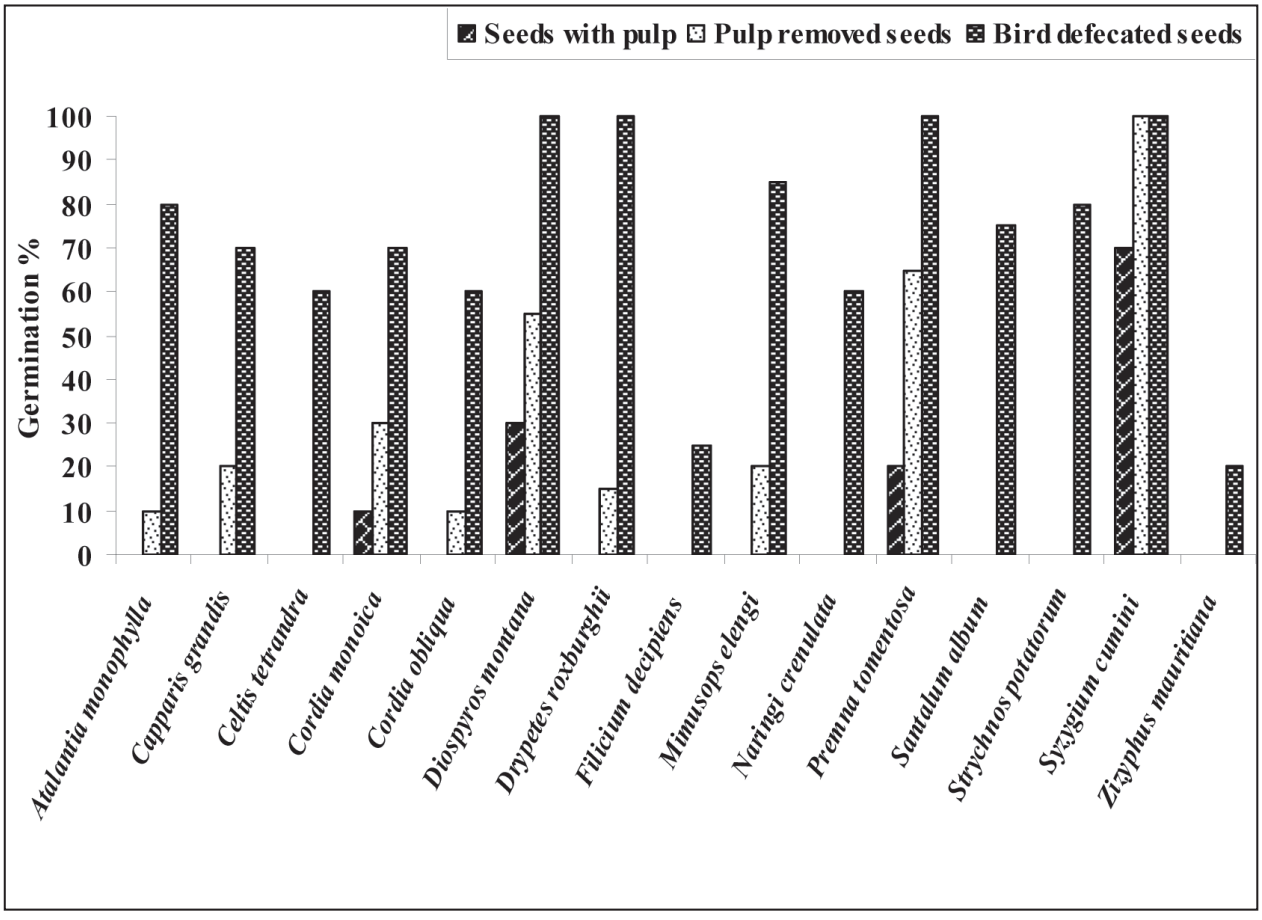

FIG. 1. Germination percentage of different types of seeds subjected to germination experiment.

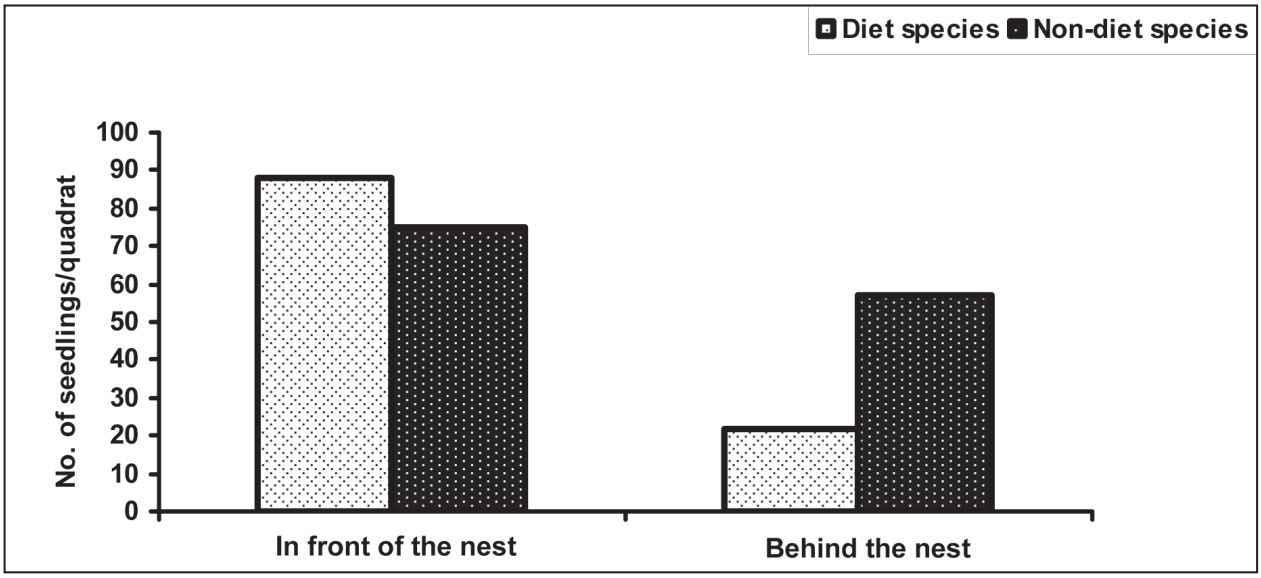

FIG. 2. Mean number of seedlings recorded per quadrat in front and behind the hornbill nest trees (n = 10).

in the study area, enhances the germination potential of seeds of their food plant species, and ultimately plays a major role in forest regeneration in the Eastern Ghats, southern India.

The Indian Grey Hornbill has some of the general features of a legitimate seed disperser. It's diet consisted of mostly fruits, and in the nest middens, regurgitated/defecated seeds were found uninjured. Seeds of 26 plant species were dispersed by the Indian Grey Hornbill during the breeding season. Studies by Whitney *et al.* (1998) on *Ceratogymna* hornbills in Cameroon and Kinnaird and O'Brien (2007) on Red-knobbed Hornbill in Indonesia provide supporting evidences of hornbill's role in seed dispersal. The higher rate of germination observed in the case of hornbill-dispersed seeds, when compared with the control seeds indicates that the Indian Grey Hornbill enhances the germination potential of seeds of their food plants. Our findings of enhanced germination of seeds passing through avian gut are in confirmation with that of Whitney et al (1998) on *Ceratogymna* hornbills and Balasubramanian & Maheswaran (2002) on Malabar Grey Hornbill *Ocyceros griseus* and other birds (Ridley (1936), Mishra *et al.* (1987), Midya and Brahmachary (1991), Naranjo *et al.* (2003), Nogales *et al.* (2005) and Robertson *et al.* (2006).

The occurrence of greater number of seedlings of hornbill's diet species in front of the nests than at behind the nest in the study area indicate the Indian Grey Hornbill's role in aiding forest regeneration. Kinnaird (1998) and Kitamura *et al.* (2004) have reported that greater numbers of diet seedlings germinated in front of the nest cavities of Sulawesi Red-knobbed Hornbill and Wreathed Hornbill respectively. Further evidences of hornbills' role in seed dispersal are available from the findings of Kitamura *et al.* (2008) who observed significantly higher densities of hornbill diet species in the quadrates located beneath the crown of the roosting trees than in the quadrates located beyond the crown. These studies establish the fact that the Asian hornbills are important seed dispersers in the tropical forest ecosystem.

Regeneration of hornbill's food plants was noticed in all the hornbill nest sites in the study area. Seed dispersal of 26 plant species including the large seeded species such as *Diospyros montana* and *Mimusops elengi* which have only a fewer seed dispersing species highlights that the hornbill is an important seed disperser. Hornbills (*Buceros bicornis, Anthracoceros malabaricus, Tockus griseus* and *Ocyceros birostris*) along with bulbuls (*Pynonotus* spp), barbets (*Megalaima* spp), mynas (*Acridotheres tristis*, *Gracula religiosa*), and Koel (*Eudynamys scolopacea*) are regarded as major frugivores that are likely to play a major role in seed dispersal and forest regeneration in southern India (Balasubramanian and Maheswaran 2002). Therefore, protection of bird-dispersed trees and bird nesting sites are suggested in order to sustain the frugivore population and enhance the natural regeneration of forests.

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