Frugivory of *Phyllanthus emblica* at Rajaji National Park, northwest India

Phyllanthus emblica Linn. (Euphorbiaceae, syn *Emblica officinalis* Gærtn, vern. *Amla*, *Nelli*) is a 10–15 m tall tree, common in tropical deciduous forests of South Asia. It flowers during March–April and has an extended fruiting period from October to March. The fruit is globose (15–33 mm), greenish-yellow and drupaceous, encasing a hard stony endocarp that on drying dehisces to release six kidney-shaped seeds (4–6 mm; Figure 1). The *P. emblica* fruit, one of the richest natural sources of vitamin C[1], is edible and is used in pickle, hair-oil and traditional medicine. It is among India's most important non-timber forest produce (NTFP).

The colour and size of *P. emblica* fruit are traits usually associated with mammal-dispersed fruits[2,3]. Fruits of *P. emblica* have been documented as being part of the diet of deer such as chital (*Axis axis* Erxleben), barking deer (*Muntiacus muntjak* Zimmermann) and sambar (*Cervus unicolor* Kerr), and also langur (*Semnopithecus entellus* Dufresne)[4–9]. However, there are no quantitative records of its frugivores and little is known about the fate of *P. emblica* fruit, in the absence of extraction by humans (i.e. dispersal, post-dispersal seed establishment, etc.). The main questions being addressed here are: Who are the frugivores of *P. emblica?* How do these animals handle the *P. emblica* fruit?

Starting from November 2000, we conducted a six-month study within a 2 km^2 intensive study area located in Rajaji National Park (824 km^2), northwest India[10]. Frugivorous mammals that occur here include barking deer, chital, sambar, goral (*Nemorhaedus goral* Hardwicke), nilgai (*Boselaphus tragocamelus* Pallas), langur, rhesus macaque (*Macaca mulatta* Zimmermann), jackal (*Canis aureus* Linnaeus), five-striped palm squirrel (*Funambulus pennanti* Wroughton), porcupine (*Hystrix indica* Kerr) and Indian gerbil (*Tatera indica* Hardwicke). Among these, chital whose density has been estimated to be 53.2–57.2 animals/km^2 for the study area[10], was the most often encountered.

Frugivores of *P. emblica* were identified from direct observations as well as indirect evidences. All our observations were limited to a population of 19 fruiting *P. emblica* trees within the intensive study area. Two of these trees, which could be observed from vantage points (at least 200 m away), were watched between 1400 and 1800 h for a total of 35.5 h using a 7×35 binoculars. This time slot was chosen based on initial monitoring rounds which revealed that frugivore activity was mostly during evening hours, probably due to heavy influx of people during daytime to collect NTFP. Since the study-population was monitored daily (between 6 and 9 h as also 1500 and 1800 h), considerable number of ad hoc frugivory observations were obtained outside of scheduled tree-watches (Table 1). Any animal seen feeding on *P. emblica* fruits, duration of its feeding bout and its foraging behaviour were noted. When such observations lasted longer (> 10 min), scan counts were conducted every 10 min to note the number of animals foraging. Camera traps were set under fruiting *P. emblica* trees for 15 days (143 h) and 21 nights (288 h), using a 35-mm automatic camera with in-built flash. The activating device was designed to trigger the camera only when an animal attempted to feed on the attached *P. emblica* fruits. Droppings of frugivorous mammals and rumen content of two sambar deer carcasses were inspected for remains of fruits and seeds. Location, number and condition of seeds of any animal-handled *P. emblica* fruits seen within the intensive study area were also noted.

Frugivory by small mammals was detected using fruits tied to a string ($n = 6$) set under fruiting trees along with track plots. These stringed fruits were positioned under a log or in a crevice where it was not possible for larger animals such as deer to find them. A rodent which was thus detected to be feeding on *P. emblica* fruit, was trapped (using Sherman traps baited with *P. emblica* fruit) and identified. Since this frugivore could not be observed directly, the rodent was trapped and maintained in captivity for 2 days. It was offered ten *P. emblica* fruits along with leafy vegetables and peanuts.

We found that *P. emblica* fruits were consumed by two species of deer (chital and barking deer), a colobine monkey (langur) and a rodent (Indian gerbil). Chital was the most frequently observed frugivore of *P. emblica*, followed by barking deer and langur, both from direct observations as well as camera-trapping (Tables 1 and 2). Chital and barking deer usually visited fruiting *P. emblica* trees in pairs or singly for short durations (chital 7.3 ($\pm$ 5.6) min, $n = 12$; barking deer 7.8 ($\pm$ 6.6) min, $n = 4$). However, when langur troops were on a tree, chital aggregated in large numbers (2–18 at a single tree) and spent hours feeding on fruits dropped by the langurs (Table 2). Chital and barking deer searched intensively for fruits under trees and swallowed whole fruits after chewing for a short while. On one occasion, we were able to count the number of fruits just before and after a chital doe had visited a *P. emblica* tree.

Figure 1. Fruits of *Phyllanthus emblica.*

Table 1. Observations on frugivory of *Phyllanthus emblica*

Method	Chital	Barking deer	Langur	Indian gerbil
Direct observation				
Tree watches	9 (55 min)	3 (21 min)	–	–
Ad hoc sightings	3 (32 min)	1 (10 min)	2 (10 min)	–
Indirect observation				
Camera traps	2	–	–	(1 unidentified rodent)
Fruits tied to string	–	–	–	All were dragged into Indian gerbil burrows

Results are the number of observations. Figures in parentheses are sum total of duration of observations. See text for details of methods employed.

Table 2. Number of animals seen at two fruiting *P. emblica* trees during extended feeding sessions by langur troops

		Mean ± SD	Maximum	Duration (h)
29 December 2000, Rest-house tree (n = 23)	Chital	7.4 ± 3.2	14	4.5
	Langur	2.4 ± 1.6	5	4.5
3 January 2000, Sampawali tree (n = 8)	Chital	10.7 ± 5.7	18	1.5
	Barking deer	0.3 ± 0.8	2	< 0.17
	Langur	6.6 ± 3.2	10	1.5

Figures in parantheses are number of scan counts conducted once every 10 min.

In 16 min, the animal consumed 30 of 33 fruits beneath the tree. At chital bedding sites within the intensive study area, regurgitated *P. emblica* cocci (seeds enclosed in endocarps) were found in dense clusters (4–193 cocci per group; median = 15; n = 23) along with cocci of other species such as *Terminalia bellerica*, *Zizyphus mauritiana* and *Zizyphus xylopyra*.

Langur troops were observed to spend hours on fruiting *P. emblica* trees. Such extended feeding sessions by langur troops were sporadic events within the study population[11]. During the study period, we documented two extended (lasting 4.5 and 1.5 h) and two shorter durations of langur feeding on *P. emblica* fruits (Tables 1 and 2). Langurs took a few bites and dropped the remaining fruit under the parent tree itself. Unlike the deer, they were never observed to swallow whole fruits. Langur-handled *P. emblica* fruits were found mostly under or close to fruiting *P. emblica* trees and signs of seed damage were rare among them (< 0.05%; n = 137). Besides dropping the fruits that they feed on, langurs also brought down substantial quantities of the fruit-crop while moving and feeding in the tree. There was little fruit left on the tree after an extended visit by langur troops.

The rodent which dragged stringed fruits into its burrow was identified as the Indian gerbil. This rodent hoarded fruits in burrows, often under the fruiting trees themselves. We found one such cache, in which none of the *P. emblica* (n = 12) and 98% of the *Z. mauritiana* fruits (n = 178) bore signs of seed damage. The Indian gerbil maintained in captivity fed on pulp only and left cocci and seeds of *P. emblica* intact.

Though other frugivorous mammals were seen under or close to the fruiting *P. emblica* trees (elephants – twice, jackal – once, wild pig – twice, nilgai – twice and sambar – six times), we did not observe them eating or searching for *P. emblica* fruits. Nor did the rumen content of two sambar carcasses and the droppings of jackal, porcupine and wild pig (at least 10 of each) examined during the fruiting season contain *P. emblica* fruit or seed remains.

Chital and barking deer were the most frequently observed frugivores of *P. emblica* during the present study. These deer swallowed whole fruits and regurgitated seeds in their bedding sites. They appear to have a crucial role in the dispersal of *P. emblica*, since they help transport seeds away from the parent plant. Further, chital are known to consume large quantities of fruit. Fruits, including *P. emblica*, have been reported to constitute 2–70% of their rumen content[5,7,12]. There is limited information on frugivory by barking deer[9]. Though not observed by us, sambar have been noted to feed on *P. emblica* fruits[6,7].

Langurs were the only arboreal frugivores of *P. emblica*. Unlike the deer, langurs did not swallow whole fruits and instead dropped fruits under the parent tree after taking a few bites of the pulp. In the context of dispersal, there is no advantage to the plant if seeds remain under the parent itself. However, langurs, by bringing down large quantities of fruit, facilitated use of *P. emblica* fruits by terrestrial frugivores like chital. Previous research done at Kanha reveals that langurs drop a mean of 4.0 kg vegetation fresh weight per day and that chital gleaned forage in 38.2% of langur–chital associations lasting 66 (± 87.5) min on an average[13]. Such langur–chital associations have been noted for fruits of 15 species and leaves of 20 species[13,14]. This overlap in diet may be partly explained by the fact that the digestive physiology of colobine monkeys such as langurs is similar to that of ruminants[15]. In the absence of langur activity, *P. emblica* fruit-fall rates were slow, being less than 1% of the fruit-crop per day[11]. Mature fruits persisted up to five months on the branches, drying up on the tree itself (Soumya Prasad, pers. obs.). Thus the langur–chital association appears to have a key role in the dispersal of *P. emblica* by making large quantities of fruit available to chital.

Rodents are generally considered to be seed-predators[16]. From our limited observations on the Indian gerbil, we did not find any evidence that it predated upon *P. emblica* seeds though it was observed to damage seeds of *Z. mauritiana*.

P. emblica appears to be dispersed mainly by deer aided by langur. Further research into this plant–animal interaction is needed to evaluate the effectiveness of these frugivores as dispersers of *P. emblica*. This could be done by quantifying the proportion of fruit-crop removed by each frugivore species and examining the fate of seeds swallowed by deer and hoarded by rodents.

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ACKNOWLEDGEMENTS. We thank the Director, Wildlife Institute of India; K. Ullas Karanth and Wildlife Conservation Society – India Programme for funds and Wildlife Institute of India and Uttaranchal Forest Department for providing facilities for this supported this work. We thank Ajith Kumar, Aparajita Dutta, Divya Mudappa, Jayashree Prasad, A. J. T. Johnsingh, Meherban, Meghraj Saini, H. N. A. Prasad, Raman Kumar, Ramsharan, Renee Borges, Richard Corlett, Roopali Raghavan, Salvador Manjadano, Shomen Mukherjee and Smitha Badrinarayan for help, information and ideas.

Received 18 March 2004; revised accepted 15 June 2004

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Conserving the breeding habitat of the near threatened Oriental White ibis *Threskiornis melanocephalus*

The nesting colonies of Ciconiiform and Pelecaniform waterbirds, popularly known as heronries or egretries[1], are spatio-temporal aggregation of nests at favourable locations during the breeding season. A wide variety of waterbirds breed during monsoon, when food resources are abundant[1,2]. Nesting colonies could be of multi-species composition and varying size. Waterbirds in their nesting colonies defend type-C territories, which are small defended areas around the nest containing no resource other than the breeding site[3]. These biologically active regimes are important due to the presence of a great number of nests and individuals in a limited space and many rare as well as IUCN-listed species. Failure to protect at-risk species is likely to result in an accelerated loss of biodiversity[4] at a regional perspective. Knowledge on the distribution of at-risk species should be a key factor in selecting sites for species conservation[5]. Colonial waterbirds may choose a nesting site after careful assessment of the prevailing safety conditions at the site[6]. Extensive foraging areas are required for breeding Ciconiiforms[7]. In unmanned areas, the nesting colonies are severely attacked by natural predators and late nesters are more susceptible to predatory loss of nestlings[8], the birds thus tend to form nesting colonies near human habitations[2]. The vulnerability of small feeding habitats to anthropogenic alterations and their management problems[9], and availability of quality feeding habitat in proximity are important aspects governing the general health of the waterbird colonies. Local populations are critically vulnerable to the loss of breeding habitat and nomadic species pose special management and conservation challenges due to the large area they occupy and their unique population dynamics[10].

Oriental White ibis (*Threskiornis melanocephalus*) is a near-threatened[11] resident, uncommon and nomadic Ciconiiform waterbird of the Indian subcontinent[12], gregariously frequenting shallow wetland, habitats. It roosts and nests in colonies situated in and around wetlands, often in association with other Ciconiiform as well as Pelecaniform waterbirds[13] (Figure 1). The nest of Oriental White ibis is a platform of twigs and sticks, usually unlined and built on tops of bamboo, trees and emergent shrubs. In mixed species colonies, Oriental White ibis tends to form a separate core group[13] and avoids the interspersed nesting pattern of other species of waterbirds. An attempt was made to understand the species composition and conservation priorities of a nesting col-