Phenological studies of hornbill fruit trees in tropical rainforests: methodologies, problems, and pitfalls

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ABSTRACT

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We describe and discuss, based on our experience with the Great Pied Hornbill *Buceros bicornis* in southwestern India, procedures for designing fruiting phenology studies of tropical flora, especially tree species, with respect to their use by avian frugivores. Topics covered and recommendations made concern the following: size of study area, size and number of sample plots, positioning of sample plots, monitoring of plots and frequency of visits, duration of study, selecting plant taxa, number of plant individuals required per species, minimum size of trees to be included, plant identification and preparation of herbarium voucher specimens.

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INTRODUCTION AND BACKGROUND

There has been a spate of papers in recent years on reproductive phenology or fruit biomass production of forest trees in southwestern India (Patel 1997; Ganesh & Davidar 1997, 1999; Kannan & James 1999), ecology of tropical Asian hornbills (Kinnaird *et al.* 1996; Kannan & James 1997; Mudappa & Kannan 1997; O'Brien 1997; Datta 1998; Kannan & James 1998; Kinnaird & O'Brien 1999; Mudappa 2000; Datta & Rawat 2003, Stauffer & Smith 2004), and the role played by tropical hornbills in seed-dispersal and forest dynamics (Kinnaird 1998; Whitney *et al.* 1998; Holbrook & Smith 2000; Kitamura *et al.* 2004). Given this sharp increase in interest in these topics, we felt the need to write this essay of reflections from a study that we conducted involving these areas of interest.

Monitoring studies of plant phenology have traditionally been of a comprehensive nature, *i.e.* involving almost all plants, with the ultimate goal of a community-wide assessment of fruit production (*e.g.* Frankie *et al.* 1974; Leighton & Leighton 1983). It is preferable, for hornbill conservation and ecology, to have a focal-species approach when designing fruiting phenology studies (Worthington 1982; Wheelwright 1983; Blake *et al.* 1990). In this method, the investigator chooses just the hornbill-preferred plant taxa for monitoring purposes. Such a focused study would not only enable management decisions to be made with relative ease (as one considers just the plant taxa that are of most significance) but would also be less tedious and thus help with logistics and execution of the study. This essay addresses various issues of relevance following a successful 2-year fruiting phenology study in the rainforests of the Anaimalai Hills, Western Ghats, southern India. Our study adopted a focal-species approach to address the conservation needs of the endangered and largely frugivorous Great Pied Hornbill *Buceros bicornis*.

The study resulted in a major chapter in RK's doctoral dissertation (Kannan 1994a), and results of the study were published separately (Kannan & James 1999). The present essay addresses common questions that confront researchers who are about to undertake such a phenological project. How long should the study last? What should be the extent of overall coverage in terms of hectares, and what should be the size of each sampling plot? How does one determine beforehand what taxa of plants to include in the sampling? What should be the minimal sample size per species of plant to get a good picture of the spectrum of fruit available to hornbills and other avian frugivores? What should be the minimum Diameter at Breast Height (DBH, 1.2 m above ground level) of the plants chosen, or should these vary between the various genera? How and where to designate plots for monitoring? How to handle the challenges of rainforest work during the rainy monsoon season? In addition, this essay also discusses specific field-tested methodologies regarding collection and herbarium preparation of plant specimens for recording and identification, problems with confusion in plant taxonomy (especially of the *Ficus* genus), mapping of plots, enlisting of local tribal people for help with plant identification and labor, and productive use of vernacular names.

We conducted our study between 1991 and 1993, based at the settlement of Top Slip (c. 750m) in the Ulandi Range of the Indira Gandhi Wildlife Sanctuary (10° 25'N; 76°50'E). Because the Great Pied Hornbill is principally frugivorous, one of our main tasks was to monitor the production of fruits in its habitat and assess the year-round pattern of fruit availability for the species. A principal goal of the study was to identify any keystone plants (Terborgh 1986; Lambert & Marshall 1991) vital for the sustenance of the species, especial in lean periods of fruit availability. There are significant conservation implications in identifying these pivotal plant species because many frugivores, like hornbills, act as key seed-dispersal agents and thus play critical roles in forest dynamics (Gilbert 1980; Kinnaird 1998; Whitney *et al.* 1998; Kannan & James 1999; Holbrook & Smith 2000; Kitamura *et al.* 2004).

To this end, we established a system of 1-ha phenology study plots in the rainforest, and monitored hundreds of rainforest plants producing fruits utilized by the Great Pied Hornbill (Table 1). In this essay of reflections from that study, we have addressed some of the hurdles and dilemmas we faced in the course of the project. We have also re-examined the data and performed some additional analyses that may help future investigators. This essay is not intended as a blueprint for such studies in the future, but merely as a guide to address common questions and help avoid potential problems. If we had had access to such an article prior to our study, we could have avoided learning a lot of these tips the hard way. We faced numerous challenges from the onset of the project, not the least of which was the paucity of adequate funding. Most of the work was conducted on a shoestring budget. This forced us to consider methodologies that would be most cost-effective. This account would, therefore, be of particular help in situations where financial constraints limit the hiring of long-term field-assistants, as was the case in this project.

Table 1. List of plants monitored for two years within ten 1-ha phenology plots (from Kannan & James 1999). All plant and family names were crosschecked with the International Plant Names Index (2004).

Family	Scientific name	Vernacular (Tamil) name	No. of trees
Moraceae	*Ficus**	*Kallichi, Aal*	24
	F. beddomei	*Aal*	2
	Artocarpus	*Selai*	26
Flacourtiaceae	*Scolopia*	*Kodali*	6
Meliaceae	*Dysoxylum*	*Vellaigil*	24
Myrtaceae	*Eugenia*	*Naval*	140
Lauraceae	*Cinnamomum*	*Lavangam*	80
	Beilschmiedia		15
	Alseodaphne	*Mammarudhu*	16
	Litsea (?)		2
	Persea	*Kolamaavu*	19
Myristicaceae	*Myristica*	*Sadhipatri*	56
	Knema	*Sadhikai*	15
Annonaceae	*Polyalthia*	*Nedunari*	92
Sapotaceae	*Palaquium*	*Pali*	18
Burseraceae	*Canarium strictum*	*Karung Kungiliam*	2
Ebenaceae	*Diospyros microphylla*	*Chinna Thuvarai*	5
	D. ovalifolia	*Thuvarai*	1
Euphorbiaceae	*Bischofia javanica*	*Solai Vengai*	7
Elaegnaceae	*Elaeagnus conferta*		2
Lamiaceae+	*Vitex altissima*	*Myladi*	26
		Total	578

*several bird-dispersed species
+*Vitex* placed in Verbenaceae according to Ramachandran and Nair (1988).

DESIGNING THE STUDY

WHY CHOOSE AN AREA-BASED PHENOLOGICAL SAMPLING METHOD AND HOW TO SAMPLE FRUITS?

While we were designing the study we were in a dilemma whether to quantify fruit production in terms of fruit biomass per unit area and time (kg/ha/month) or to simply assess seasonal phenological patterns of hornbill trees. We adopted a phenological approach by establishing 10 1-ha plots, plus a fig tree trail, in which the number of hornbill-fruit patches per month per hectare were counted, a patch being a fruiting tree. Our ultimate decision was driven by an excellent comparative review of the various methodologies by Blake *et al.* (1990). We considered and decided against making fruit biomass estimates because of its associated problems. Estimates of fruit production could be notoriously unreliable. For example, we were not comfortable with estimating, with any degree of confidence, the number of fruits per cubic meter from a hundred feet below the canopy, especially in a rainforest with its poor visibility. Some studies have used subjective indices to characterize fruit abundance (Frankie *et al.* 1974; Opler *et al.* 1980) but such indices are less likely to be useful for comparative analyses (Blake *et al.* 1990). We did not use fruit-fall traps to estimate fruit abundance in the canopy: such traps, by their very nature, are unreliable because they only reflect what was not available for the arboreal frugivores. Besides, they tend to sample a very tiny proportion of the study area so that in some cases the extent of the total area sampled may be nebulous (Blake *et al.* 1990). The logistical difficulties would have been hard to overcome: it would have entailed hundreds of baskets and many man-hours of effort. It would also have led to the inevitable problem of marauding rodents, bears, deer, elephants, and even people. It did not take long for us to realize that baskets left lying around on the forest floor are likely to disappear, because tribal people often follow a 'finding is keeping' philosophy - some of the bright orange ribbons we used to mark the edge of the plots appeared as part of the hair-do of local tribal girls! A recent study in the neotropics (Parrado-Rosselli *et al.* 2006) compared fruit traps with other methods, and the results supported our misgivings on the reliability of fruit-fall traps. We also decided against direct counting of the large numbers of fruits per individual tree and extrapolating that data community-wide because of the time and effort such a method would entail. Besides, we figured that, for our purposes of gauging fruit availability for the Great Pied Hornbill in the area, knowing that approximately 12% of the fig trees in the area fruited in one particular month was better than knowing that a total, of say 20,948 fig fruits, was borne that month. Therefore, we directly counted the actual number of fruit patches (fruiting trees) per month per hectare of forest. Our choice of an area-based, focal-species method gave a better picture of fruit availability from a 'hornbill's eye' viewpoint because, after all it is of direct relevance for a hornbill to assess how many trees come into fruit in the habitat every month of the year

HOW MUCH AREA TO COVER?

Clearly, the answer to this is "as much as possible". Ideally, phenological studies are best done with a team of researchers and field-assistants covering a wide area. But we were under-funded and understaffed for much of the duration of the project. Therefore, practical and financial limitations forced us to consider the minimum possible coverage that would still provide a fairly reliable reflection of what is happening phenologically over a wider swath of habitat. We could cover ten 1-ha plots in this study, in addition to a system of fig trails. We are confident that this spatial coverage provided an adequate idea of the fruiting phenology of hornbill-fruits in the area because the gist of our findings (year-round pattern of figs and other sugar-rich fruit, highly seasonal availability of non-figs and lipid-rich fruits) was supported by other studies from similar habitats (Leighton & Leighton 1983; Lambert & Marshall 1991; Patel 1997).

One major reason to extend coverage to a maximum possible area is the markedly clumped spatial distributions of many rainforest plants, as was the case with the genera of hornbill-favored fruit trees in our study area (Table 2). We used variance to mean ratios (VMR) to characterize plant distribution. Distribution was random if VMR was equal to 1.0. Clumped distributions would result in VMR being greater than one, and even or uniform distributions would yield VMRs less than one. These characteristics of VMRs stem from the fundamental property of the Poisson distribution that the variance and the mean are equal. As shown in Table 2, the various genera of hornbill-preferred fruit plants in our study (with the exception of *Ficus*) showed VMRs greater than one, indicating clumped distributions.

Plants in the same genus were not represented in some plots but showed up in considerable numbers in others. *Polyalthia* was absent in two of the plots but numbered as high as 15 in each of two other plots. Of the 19 individuals of *Persea*, an important species of the fruit-producing family Lauraceae, 12 (63%) occurred in just one of the plots. Similarly, *Eugenia* numbers ranged from as little as one up to as high as 34 inside individual plots. Therefore, covering a small area may potentially under- or over-represent the taxa that are clumped in distribution. It would also entail the risk of overlooking locally rare taxa like *Canarium* (see Kannan 1994b) and *Elaeagnus*, both of which were represented by just two individuals in all of the 10 ha of

Table 2. Pattern of distribution of various hornbill-preferred fruit-producing genera of trees in the Anaimalai Hills, southern India, using the method described by Cox (1980) and Grieg-Smith (1983).

Plant Genus	Mean no. of trees/ha	Variance	Variance:Mean ratio (VMR)	*t*-value	Distribution	*P* (d.f.=9)
Eugenia	14	119.55	85.39	179.55	Clumped	0.001
Polyalthia	9.2	39.06	4.24	80.97	Clumped	0.001
Cinnamomum	8	83.33	10.41	20.02	Clumped	0.001
Myristica	5.6	28.99	5.17	59.55	Clumped	0.001
Vitex	2.6	4.48	1.72	7.4	Clumped	0.001
Dysoxylum	2.4	8.04	3.35	5.0	Clumped	0.001
Ficus	2.4	1.6	0.66	1.27	Uniform	0.001

sampling (Table 1). *Ficus* was the only genus with a significantly uniform spatial distribution (Table 2). *Ficus* too, may be under-represented, even with sizeable coverage. Our 10-ha of plots had only 26 individuals of the genus. In order to augment *Ficus* sample size, we had to establish a system of three fig trails with a total length of approximately 5 km. All fig plants greater than 20 cm DBH were marked. These plants were also monitored at least once a month, like the plot samples. Lambert & Marshall (1991) also reported poor sample sizes of *Ficus* at the species level in their study transects in Malaysian rainforests.

HOW LONG SHOULD THE STUDY LAST?

Ideally, the longer the better. Fruiting patterns could differ markedly between years (Leighton & Leighton 1983; Blake *et al.* 1990), as was evident in the present study and in others (e.g. Leighton & Leighton 1983; Lambert & Marshall 1991). Fruiting patterns could be seasonal in some plant taxa (e.g. Lauraceae) but sporadic and capricious in others (e.g. *Ficus*). In order to account for these vagaries, it is important to have a broad temporal coverage. When this study was planned we considered a one-year study but eventually, after perusal of the literature, decided on doubling that to two years. In retrospect, we realize how inadequate and misleading a 1-yr study would have been. Many plants in our study (e.g. *Eugenia* and *Polyalthia*) did not fruit or fruited weakly in one of the two years. Moreover, we obtained a better picture of fruiting patterns, especially for the fruiting of lipid-rich fruits, only by looking at two years of data. Our experience leads us to believe that data taken over a short time frame may deceptively suggest patterns of fruiting that do not exist in reality, and that may be 'ironed out' by analysis of longer-term data. Chapman *et al.* (1999) also emphasized that the trends suggested from one year of data were not supported when additional years were considered. In fact, studies extending longer than two years are preferable. It is encouraging that recent studies on plant reproductive phenology in the tropics have been conducted over three or more years (Sakai e*t al.* 1999; Hamann 2004; Stauffer & Smith 2004; Anderson *et al.* 2005; Bollen & Donati 2005).

HOW TO CHOOSE HORNBILL PLANTS BEFOREHAND?

Starting a project of this kind generates a classic dilemma: one may not know what hornbills eat before the study, and one may not know what plants to monitor before knowing what the birds eat. The general rule we adopted was to be liberal in the choice of the plants included in the sample, i.e. what to mark and monitor. Plants that showed even remote signs of producing bird-fruits, based on fruit color, location on tree, and texture (McKey 1975; Blake *et al.* 1990), were included. Also, there was a sufficient amount of information on hornbill fruits from previously published studies (*e.g.* Poonswad *et al.* 1988; Kemp 1995).

We knew that any of the Lauraceae should be included, even if they looked unsuitable for hornbills (*e.g.* some *Alseodaphne* fruits were uncharacteristically green, but turned out to be preferred by Great Pied Hornbill). But the best source of information on what fruit plants to include came from the local tribal people. One of our best tribal guides, Natarajan, during RK's initial interviews with him, was able to describe in detail how the Great Pied Hornbill opens the undehisced husks of the capsular *Dysoxylum* and Nutmeg (*Myristica* and *Knema*) fruits and gobbles up the edible portions within. This was and is still a surprise to us because in the two years of study we were not able to make even one observation of the Great Pied Hornbill feeding on these large capsular fruits. Great Pied Hornbill occurs at low densities, and the large-seeded capsular fruit plants in the community fruit in a synchronous and widely scattered manner within a species, making bird congregations unnecessary and thus the Great Pied Hornbill hard to find. This, coupled with the dense nature of the habitat they inhabit, makes one really appreciate Natarajan's field knowledge of the bird's feeding behavior. Clearly, he could not have derived that knowledge from the literature because he could not read English. The local tribal people knew most of the hornbill fruits, but not all - some were surprised to hear that the toxic *Strychnos* fruits were preferred by the Great Pied Hornbill.

Having been liberal in the inclusion of plants in the beginning, we had to delete 59 plants of *Artocarpus, Palaquium, Bischofia, Diospyros ovalifolia, D. microphylla*, and *Ficus beddomei* from our sample, and not consider their fruiting episodes in the data analyses at the end of the study because we did not find any evidence that those plants produced fruits chosen by the Great Pied Hornbill. Obviously, the aforementioned methodology worked well because almost all the taxa of plants represented in the Great Pied Hornbill seed middens below nests were represented in the phenological plots (see Kannan & James 1997).

HOW MANY INDIVIDUALS PER SPECIES OF PLANT TO INCLUDE?

Although the obvious answer to this is as many as possible, our experience indicates that it may take an enormous area of coverage to obtain an adequate sample size per species of plant. This is supported from other studies in tropical Asian forests (Leighton & Leighton 1983; Blake *et al.* 1990). Although Frankie et al. (1974) have suggested that the minimum number of individuals per species should be at least five for phenological studies, we think it is still too small to obtain reliable results at the species level. Perhaps an ideal sample size would be that adopted by Hamann (2004) who monitored phenological patterns of 5,800 trees in a Philippine submontane forest community during a 4-year period to evaluate reproductive phenology at the community level.

Rainforest trees occur at notoriously low densities at the species level. An indirect reflection of this may be obtained when one considers the sheer number of species per genus in any given area of rainforest. There are, for example, 12 species of *Cinnamomum* (Lauraceae) in the altitudinal range of 600-1000 m a.s.l. where the Great Pied Hornbill is found in India (Pascal & Ramesh 1987). Identifying them to the species level was difficult (see below) but it is safe to assume that most of those species occurred in our study area (c. 750 m a.s.l.). There were a total of 80 individuals of *Cinnamomum* in our 10-ha of plots. Even assuming that each species was represented with similar numbers in the area, this comes to just 6-7 individuals per species of *Cinnamomum*. Not a statistically comfortable number for a phenological study at the species level. Similarly, the 100 *Ficus* trees in our sample could have belonged to as many as 20 species. But, fortunately for hornbills, it may not really matter because tight species-to-species plant-vertebrate interactions are rare in nature (see Gilbert 1980). We have not found any strong evidence in the literature, or during the course of our study, of Great Pied Hornbill or any other rainforest hornbill showing strong interactions with any particular species of *Ficus* or any other fruit genus. For a hornbill, a **fig** is a *fig* is a fig, as long as it is of the bird-dispersed kind. An analysis at the genus level may be sufficient and that is what we did.

When our paper was offered for publication to *Biotropica*, one of the anonymous reviewers asked for a species-wise analysis of fruiting phenology and fruit consumption, suggesting that even within a species, some may be more important than others for a particular frugivore. The editor added a note saying this should be carefully complied with in the revision. We wrote a strong rebuttal arguing why it could not be done with our data, and why such an analysis may not really be of much significance. The editor (Dr. Ted Fleming, a noted expert on plant-vertebrate interactions) agreed.

HOW BIG SHOULD EACH PLANT BE?

The minimum diameters at which trees produce fruits vary with tree species. For convenience, a minimum DBH of 20 cm was chosen for all trees. While this may seem too small, this is the approximate diameter at which a woody liana creeper *Elaeagnus conferta*, a hornbill fruit plant, produced fruit. Another hornbill fruit tree, *Vitex altissima*, showed wide variation in the diameters of fruiting trees (Table 3). Similarly, there were reproductive individuals with strikingly small diameters in five other genera (Table 3). Had we chosen a larger minimum diameter, we would have overlooked these individuals as potential fruiting trees and thus underestimated the fruit patches generated.

Measuring the DBH of trees with buttresses posed a problem because buttresses tended to inflate diameter values. There is no clear solution to this problem. Measuring the diameter of the trunk above the buttresses will be difficult in most cases. Since many rainforest trees were buttressed, we decided to measure the diameters at breast height for all trees, with or without buttresses. We used this procedure in this and other related studies (Kannan 1994a; Mudappa & Kannan 1997; Kannan & James 1998).

In order to aid future investigators, we have included DBH statistics for the reproductive individuals of the major genera of hornbill-preferred trees in our study plots, plus the trail samples for fig trees (Table 3). This may enable one to decide minimum DBH thresholds for each taxon, and thus possibly save time and resources from not tracking non-reproductive individuals.

Table 3. Mean Diameter at Breast Height (DBH) of the flowering or fruiting reproductive individuals of the various genera of hornbill-preferred fruit trees in the Anaimalai Hills of southwestern India.

Genus	Mean DBH, cm	Standard Deviation, cm	Range, cm	Sample size (Number of trees)
*Ficus**	129.5	39.5	50-215	68
Persea	73.1	24.0	45-105	8
Beilschmiedia	71.8	15.4	46-93	8
Vitex	69.4	22.3	23-105	11
Cinnamomum	65.4	26.9	23-105	20
Alseodaphne	65.3	14.0	53-85	3
Polyalthia	54.6	14.7	31-90	38
Eugenia	51.5	19.6	23-105	53
Dysoxylum	45.2	16.8	23-77	10
Myristica	40.3	16.8	17-98	39
Knema	34.4	8.6	19-46	11

*bird-dispersed kind only

CONDUCTING THE STUDY

CHOOSING THE LOCATIONS OF EACH PLOT

Plots have to be chosen at random across the study area for an unbiased sample. We realized that this was challenging in many ways. Trails that were already established provided easy access to the study area and one may be tempted to locate the plots off such trails for the sheer convenience and accessibility they afford. However, this may lead to bias because trails themselves are usually not randomly laid. In our study area, the main trail followed a now-defunct pipeline that was established to bring water from a waterhole inside the forest to the settlement of Top Slip. Other trails were either game trails or those that were established by tribal people in their forays into the forest for honey collection and other reasons. Obviously these trails followed paths that were simply the easiest to negotiate topographically. To avoid the possibility of such non-random sampling, we located plots some distance off the trails by using a random number of paces derived from a random numbers table, but this led to other problems. We had to ignore some potential plot locations because the area was simply not conducive for phenology study: they were in topographically challenging areas, too open, too dense with thickets, or had few forest fruit trees and were thus of little value to the Great Pied Hornbill. Consequently, one of our plots had to assume a rectangular shape (133 x 75 m) in order to avoid an open area full of *Eupatorium* and *Lantana* underbrush that was so dense that we would have had to use a machete to cut through it. The other nine plots were 100 x 100 m squares.

MAPPING OF PLOTS

We mapped the plots using a compass, a 100-m tape, and strips of bright orange ribbons to mark the borders. Once the perimeter was established, we walked about inside the plots and marked the approximate locations of all hornbill fruit trees within a grid of ten 10 x 10 m subplots. Since our knowledge of the botany of the area was weak when we started the study and established the plots, we relied almost exclusively on the local vernacular Tamil names of the plants as used by the tribal guides. RK wrote these names in Tamil on the maps of the plots. The botanical names were obtained progressively in later periods by painstaking identification work (Table 1).

On the maps we indicated a suite of useful information in addition to the locations and names of the hornbill trees: compass bearings of trees that were difficult to locate in dense stands of vegetation, locations of harmful nettles and deep pits dug to trap wild elephants in the distant past, prominent landmarks such as dead stumps or boulders, swamps, steep drop-offs and ravines, impenetrable thickets, game trails, forest roads and a single Great Pied Hornbill nest site stumbled upon by chance. We marked each hornbill fruit tree with a small metal tag with its number painted on and noted the number by its location on the maps. To facilitate the finding of focal trees, color painting on the tree trunk is also a useful method. The compass bearings of trees were particularly helpful in the monsoon when some of the metal tags faded away completely, were obscured by vegetation or were lost. Eventually we marked 578 trees belonging to 19 genera inside the plots (Table 1). Considering the overwhelming importance of the local vernacular names of the plants for researchers, we included in the paper (Kannan & James 1999) an appendix of the Tamil names of the various hornbill fruit trees in the phenology plots (Table 1). The entire phenological sample, combining plots and trails, included 652 individual trees.

COLLECTION AND PREPARATION OF HERBARIUM PLANT SPECIMENS

This was one of the most challenging aspects of the project, but also one of the most important. For reliable identifications, botanists require a specimen with the inflorescence or fruits intact. We were not adept at tree climbing and thus had to rely on the local tribal people to climb trees and obtain specimens. Often a specimen had to be taken within the narrow flowering window and the task of finding someone willing and able to do the climbing was a challenge. But we used some other methods to get specimens, with varying degrees of success. Animal activity in tall fruiting trees often dislodged branches that we could collect from the ground. Similarly, we hastened to visit fruiting or flowering trees after a storm because of the wealth of specimens knocked down by wind and rain. Many trees remained unidentified to the species-level because we were unable to get an appropriate specimen at the right time. When obtained, specimens for identification were dipped in mercuric chloride solution, dried, pressed and then mounted on large white sheets of paper.

IDENTIFICATION OF RAINFOREST PLANTS
Appropriate botanical keys must be found that cover the flora of the study site in question. We used Gamble (1967), Pascal & Ramesh (1987), and Ramachandran & Nair (1988) to identify some of the plants, down to at least the generic level. We often sought the help of plant taxonomists specializing in the local rainforest vegetation. We took some herbarium specimens to the Botanical Survey of India in Coimbatore to compare with their extensive collections. But identifying specimens up to the species level, especially of *Ficus*, proved a daunting task, largely because of the confusion prevailing in rainforest taxonomy. On some occasions, two experts disagreed on the species identification of the same specimen. The Lauraceae, especially *Cinnamomum*, were also particularly frustrating. This is one of the reasons why we analyzed the phenology data at the genus and not the species level.

Once the specimen is identified, a standard herbarium label must be affixed to the herbarium sheet giving scientific name of species, place and date of collection, and name of collector(s). The specimens should then be deposited in an appropriate herbarium collection and the location of these voucher specimens should be noted in all publications concerning the project.

MONITORING THE PLOTS
Each month we used a simple code to note the fruiting status of each plant: 'ripe' (several ripe fruits present), 'unripe' (all fruits unripe) or 'unripe/ripe' (fruits unripe but apparently on the verge of ripening). Individuals in the last category were then revisited weekly to monitor them for any change in status. All trees were checked at least once a month by scanning the canopy, usually with binoculars. At least 10 days were spent each month on phenological monitoring (each plot took a day to survey). Animal activity in the canopy was often a good indication of fruiting activity, and this was particularly helpful in trees with tall crowns. Rainy season monitoring was arduous, with all the associated problems of leeches, tree falls, lost or faded tags and poor visibility, but fortunately the rainy season was also a lean period for fruit production, and so the plots could often be surveyed during rapid walks.

CONCLUSIONS

A project of this nature and scope would be nearly impossible without the expert assistance of the local people. People like Natarajan were invaluable, not just for their ability to spot birds, lead us safely past elephants, sloth bears and gaur herds, but they were also indispensable for their incredible knowledge of the local natural history.

As we indicated in the Introduction, these are some reflections from our study that could help a potential researcher about to embark on a similar venture. We do not imply that the methods used can be used elsewhere with equal success. Indeed one has to consider a suite of options and choose the one that is most practicable, and the one that best fits the budget and other constraints. Our essay simply provides investigators with some overall guidelines and experiences for use in adopting or modifying their designs for new projects. Our focus was on studying fruiting phenologies with respect to the feeding ecology of hornbills and other frugivores.

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