

Regeneration of *Amla*, an Important Non-Timber Forest Product from Southern India

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Amla fruits collected from *Phyllanthus emblica* and *P. indofischeri* are an important non-timber forest product for the indigenous Soliga community in the Biligiri Rangaswamy Temple Wildlife Sanctuary, India. Seedlings, saplings and trees of these two congeners were monitored over three years in ten 0.1 ha plots each to assess and compare their regeneration status. The densities of seedlings and of adult trees of both species were similar, but the density of saplings of *P. emblica* was lower than that of *P. indofischeri*. The size class distribution of *P. indofischeri*, but not of *P. emblica*, followed the inverse J-shaped curve typically associated with regenerating populations, suggesting a higher mortality of seedlings and saplings of *P. emblica* than of *P. indofischeri*. Furthermore, re-sprouting individuals—presumably a response to damage by fire or grazing—constituted a larger proportion of the population in the case of *P. emblica* and may constitute a future population bottleneck. We suggest that anthropogenic pressures other than harvest could be responsible for differences in population structure between these two species, which are managed under similar harvest intensities and subject to similar disturbance regimes.

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INTRODUCTION

IN INDIA MANY non-timber forest products (NTFP) are important not only in rural and tribal economies, but also in the national economy (Appasamy 1993; Hegde et al. 1996; Kalla 1988; Sekar et al. 1996; Shiva and Mathur 1995). One such NTFP is the fruit of *amla* (also known as *nelli*). *Amla* is highly valued for its medicinal properties, and is the most common ingredient of many medicines and tonics in traditional Indian health practices. *Amla* fruits are also used in the preparation of pickles, jams and juices, in addition to their use in the preparation of cosmetics such as hair dyes and shampoos. Apart from its human consumers, wild animals such as *chital*, barking deer, *sambar*, bear, *gaur*, langur and macaque eat *amla* fruits. In fact, *amla* forms the major food of the *chital* during the summer when other food resources are scarce (John Singh 1981).

Amla collectively refers to two species of *Phyllanthus*, namely, *P. emblica* L. and *P. indofischeri* Bennet. *P. indofischeri* has a distribution that is restricted to the Deccan Plateau of south India, whereas *P. emblica* is more cosmopolitan in its distribution. Where their distributions overlap, the two species tend to be spatially segregated—*P. indofischeri* occurs at lower elevations, in low-statured scrub forests, whereas *P. emblica* occurs at higher elevations in higher-statured dry deciduous forests (Ganesan 2003).

Both species of *amla* occur in the Biligiri Rangaswamy Temple Wildlife Sanctuary (hereafter, BRT) in southern India, where *amla* constitutes one of the three most important NTFPs of the indigenous Soliga community. The Soligas depend on the harvest of NTFP to meet as much as 60 per cent of their cash incomes (Hegde et al. 1996). Given their interchangeable use in trade, both *amla* species are subjected to very similar harvest regimes. A great deal of work has been done in BRT over the last decade to encourage an NTFP-linked, enterprise-based approach to conservation, and to involve the Soligas in participatory resource monitoring and harvest regulation. Harvest typically constitutes about 39–52 per cent of total fruit production annually (Siddappa Setty, unpublished data).

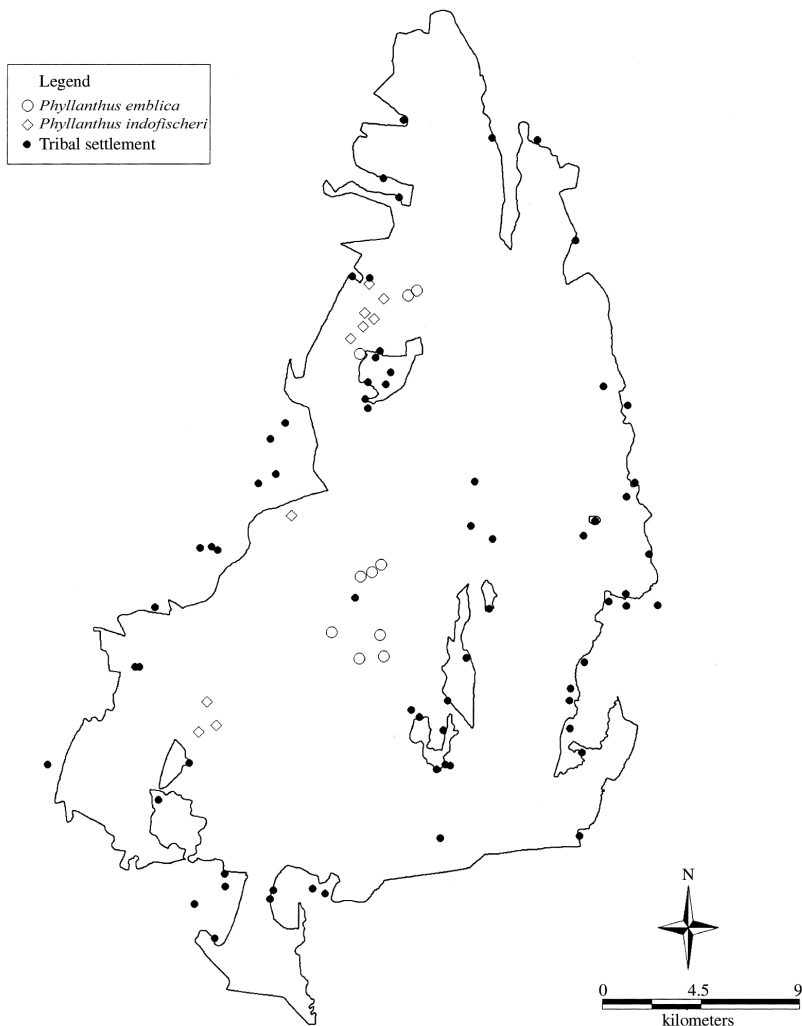
Earlier demographic work on one of these two species of *amla* (*P. emblica*) in BRT demonstrated both temporal and spatial variation in population growth, though populations of the species were stable for the BRT sanctuary as a whole (Sinha 2000). Sinha and Bawa (2002) also demonstrated that infestation of hemiparasitic plants and certain destructive harvest practices (such as lopping of large branches) may have more of a detrimental effect on population growth than harvest per se. The regeneration status of species harvested for NTFP—as inferred from population structure—is a useful indicator of whether NTFP harvest is likely to be detrimental to the target population in the long term (Hall and Bawa 1993). We took the opportunity to compare the regeneration status of populations of these two congeners in BRT under very similar management, which includes harvesting as well as associated anthropogenic disturbances such as fire and livestock grazing.

METHODS

Study Area

Biligiri Rangaswamy Temple Wildlife Sanctuary is in the south Indian state of Karnataka ($11^{\circ}40'-12^{\circ}9'N$ and $77^{\circ}05'-77^{\circ}15'E$; Figure 1). It is a compact hill block of about 540 sq. km, situated between the Eastern and Western Ghats, the

Figure 1
Outline Map of Biligiri Rangaswamy Temple Wildlife Sanctuary
Depicting the Location of Transects and Tribal Settlements



mountain ranges that flank the Indian peninsula. Elevation ranges from about 600 to 1,500 m above sea level. The annual rainfall varies from about 600 mm in the foothills to about 3,000 mm at higher elevation. Mean monthly minimum and maximum temperature ranges from 9–16°C to 20–40°C respectively.

The span of altitude, temperature and rainfall makes the area highly heterogeneous. BRT supports forest types ranging from scrub forests, dry deciduous forest, moist deciduous forest, and evergreen forest in the lower to mid-elevation, to high-elevation *shola* forest and grasslands. Dry deciduous forests and scrub forests are the major forest types and together constitute almost 90 per cent of the total area of BRT. The scrub forest is dominated by *Acacia chundra*, *Diospyros melanoxylon* and *Chloroxylon swietenia*; dry deciduous forest is dominated by *Anogeissus latifolia*, *Terminalia crenulata* and *Terminalia bellirica*.

Sampling Method

Linear transects were used to sample the abundance of trees, saplings and seedlings of the two *Phyllanthus* species. For each species ten randomly laid transects were marked in the two forest types where the species occur. Transects were located in forests that have similar kind of management histories for fruit harvesting, grazing, fire, etc. A minimum distance of 500 m was maintained between transects. Transects were 100 m long and 10 m wide.

Transects were sampled once a year during January of 1999, 2000 and 2001. All individuals in the transects were tagged and numbered; in addition, diameter at breast height (DBH; diameter at 1.3 m from the ground) was measured for individuals greater than 1 cm. Stems less than 1 cm diameter were considered seedlings; stems between 1 and 5 cm were considered saplings; and stems >5 cm diameter were considered trees. Adult individuals (>5 cm) were grouped into 5 cm size classes. Sprouting stems (seedlings and saplings that have re-sprouted after being damaged due to fire, grazing, etc.) of both the species were also counted in the plots.

Annual mortality and recruitment were calculated following Hall et al. (1998) and Phillips (1998) such that: (a) annual mortality (as per cent per year), M , is $\ln [(N_o - N_d)/N_o]/t \times 100$, where N_o is initial number of trees, and N_d is number of dead trees in t years; and (b) annual recruitment (per cent per year), R , is $\ln [(N_o - N_d + N_r)/(N_o - N_d)]/t \times 100$, where N_r is the number of newly recruited trees in t years. The Mann-Whitney U-test was used to compare mean values of seedlings, saplings and trees, and mean mortality and recruitment in each of the size classes, between species. The Kruskal-Wallis test was used to assess inter-annual variation in density of individuals in each of the size classes.

RESULTS

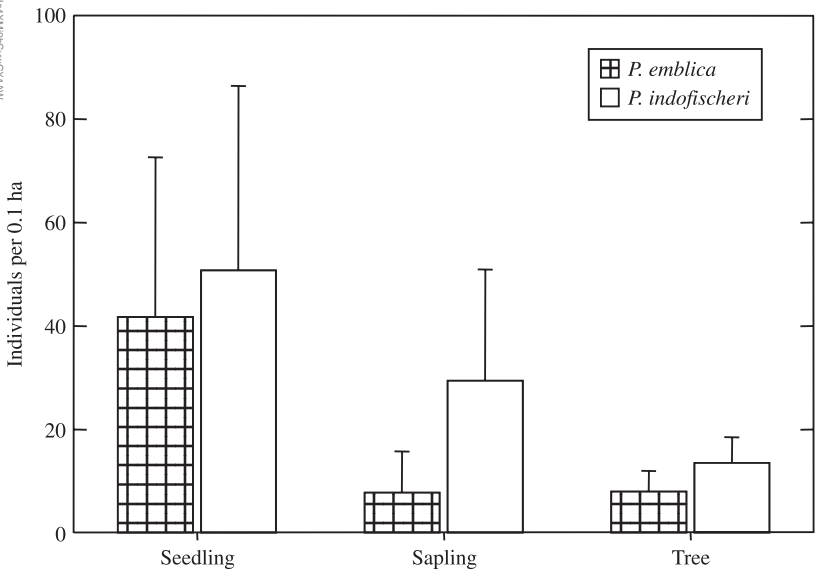
Within species densities of saplings and trees were not significantly different among years (comparison of sapling densities: $KW = 2.462$, $p = 0.292$ and $KW = 2.865$;

$p = 0.239$ for *P. emblica* and *P. indofischeri* respectively; comparison of tree densities: $KW = 1.408$, $p = 0.495$ and $KW = 0.126$, $p = 0.939$ for *P. emblica* and *P. indofischeri* respectively), although there was some *P. emblica* tree mortality (14.3 per cent). Densities of seedlings did, however, vary among years for *P. indofischeri* ($KW = 8.296$, $p = 0.017$), though not for *P. emblica* ($KW = 1.754$, $p = 0.416$).

Between species there was no significant difference in densities of trees (Mann-Whitney $U = 25.0$, $p = 0.203$) or seedlings ($U = 34.0$, $p = 0.876$). There was, however, a significant difference in densities of saplings (Mann-Whitney $U' = 73.00$, $p = 0.002$) (Figure 2). The number of resprouts, as a proportion of the total number of individuals, in the case of *P. indofischeri* (17 per cent) was more than two-fold greater than in the case of *P. emblica* (7 per cent). Nonetheless, re-sprouts accounted for a much larger proportion of the sapling class in *P. emblica*, than in *P. indofischeri* (Figure 3).

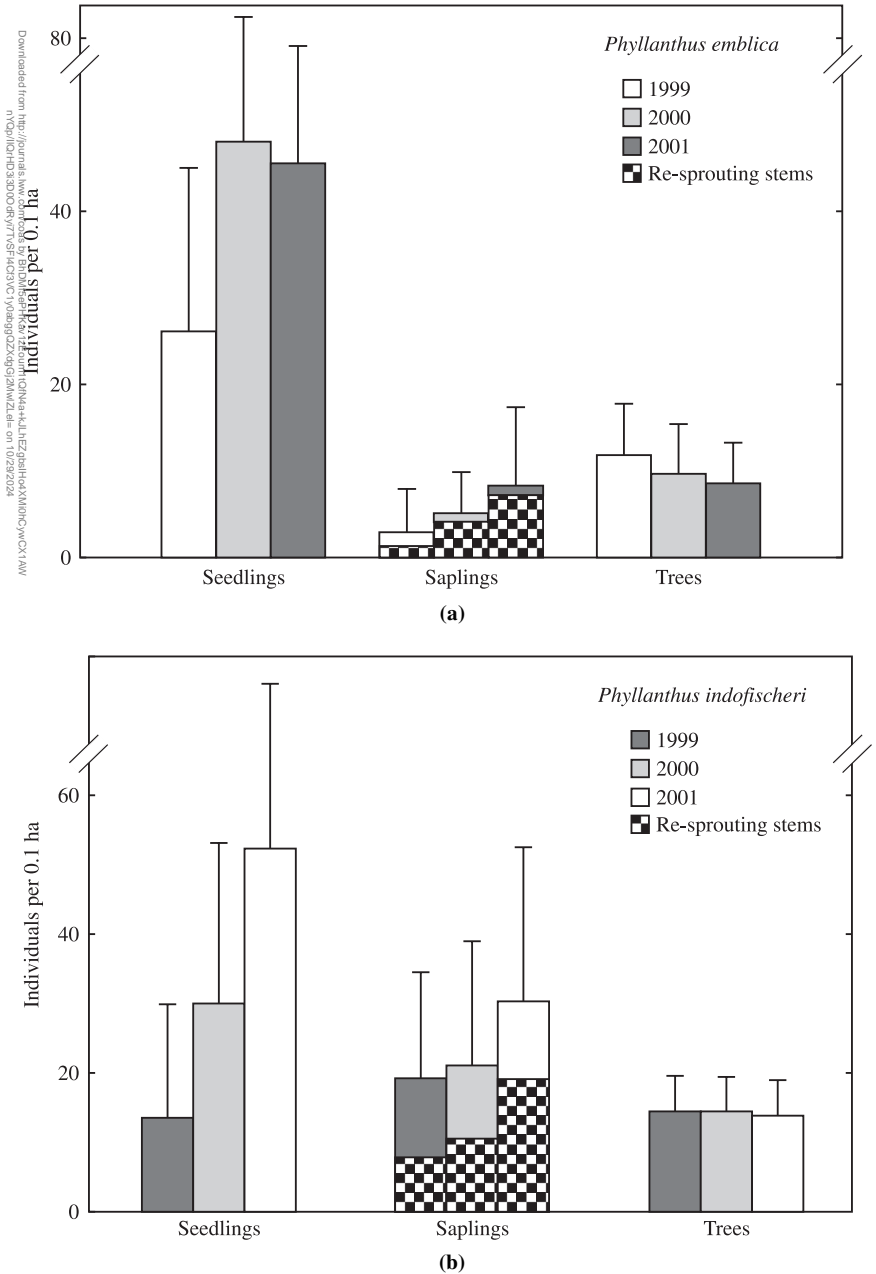
Figure 2

Density of Individuals in Different Life Stages of *P. emblica* and *P. indofischeri*



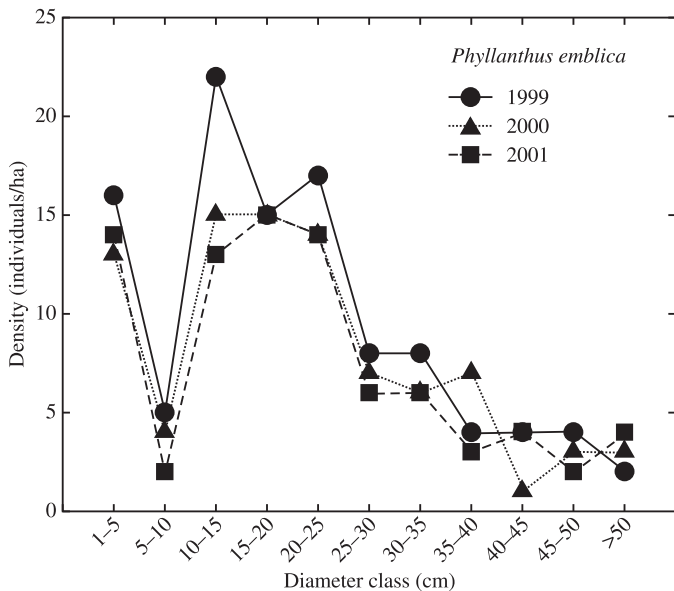
Size class distributions (stems >1 cm diameter) of neither species varied over the three years monitored, as is to be expected. Nonetheless, a comparison of species' size class distributions showed a striking difference between the two species. *P. indofischeri* had the inverse J-shaped distribution associated with regenerating populations (Hall and Bawa 1993), but *P. emblica* did not. On the contrary, the size class distribution of *P. emblica* was depauperate in the sapling (1–5 cm diameter) and the small adult (5.1–10 cm diameter) size classes (Figure 4).

Figure 3

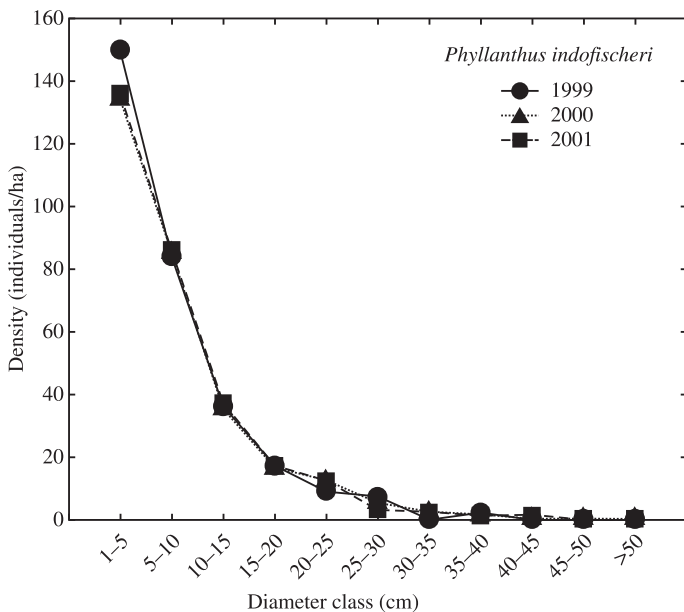
Population Structure of Stems (>1 cm DBH) of (a) *P. emblica* and (b) *P. indofischeri*

Note: Note the proportion of re-sprouting stems in the sapling class for both species.

Figure 4
Variation in Densities of Different Life Stages of (a) *P. emblica* and (b) *P. indofischeri* Over the Three-year Period of the Study



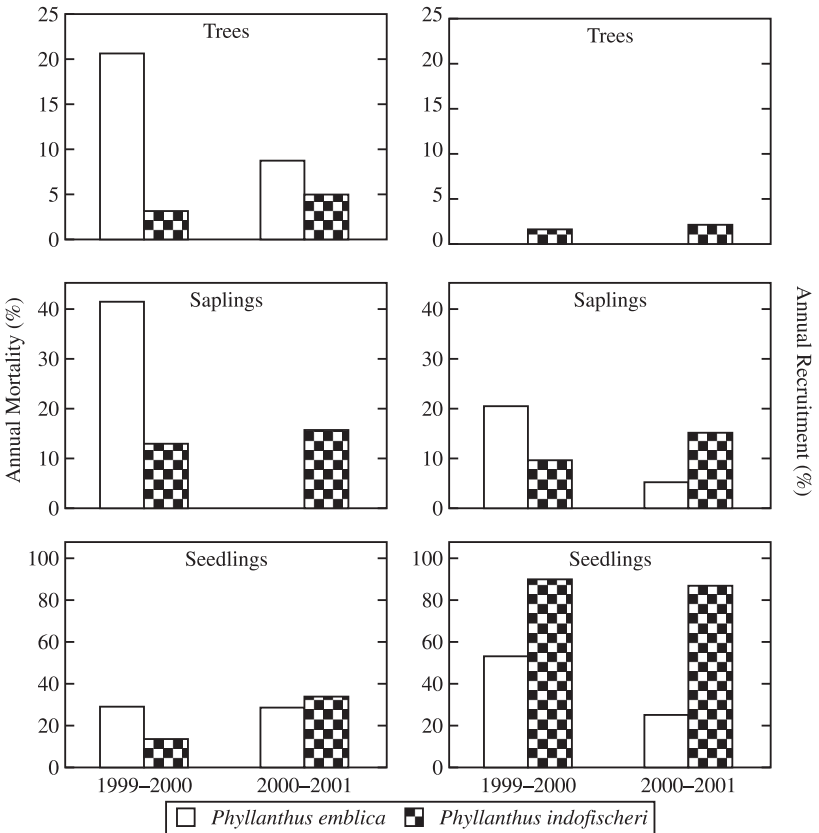
(a)



(b)

The annual rate of recruitment and mortality of trees, saplings and seedlings of *P. emblica* and *P. indofischeri* varied between species, among size classes and among the three years monitored (Figure 5). Annual mortality rate of *P. emblica* trees (14.3 per cent) was more than three times higher than that of *P. indofischeri* (3.9 per cent). This pattern was compounded by the lack of tree recruitment in the case of *P. emblica* during the three years monitored, while *P. indofischeri* had an annual recruitment rate of 1.8 per cent. In the sapling size class the mortality rate in the case of *P. emblica* (20.7 per cent) was high compared to *P. indofischeri* (14.2 per cent), but the annual recruitment rates of saplings of both species were almost the same (12.8 per cent and 12.1 per cent for *P. emblica* and *P. indofischeri* respectively). Seedling mortality rates of both species were similar (28 per cent and 23 per cent for *P. emblica* and *P. indofischeri* respectively), but the seedling recruitment rate for *P. emblica* (40 per cent) was low compared to *P. indofischeri* (89 per cent).

Figure 5

Annual Recruitment and Mortality of Different Life Stages of *P. emblica* and *P. indofischeri*

DISCUSSION

Over the three years monitored, populations of both species were relatively stable in the sapling and adult size classes, though there was significant variation in the seedling size class among years, especially in the case of *P. indofischeri*. This fluctuation in seedling abundance may be a reflection of variation in fruit production. Fruit production varied between 84 and 117 tons (in 812 ha of forest monitored for production and extraction; Siddappa Setty, unpublished data) over the study period; fruit harvest varied between 39 and 52 per cent of total production over the same period.

The density of *P. emblica* trees we observed (9.5 trees/ha) is higher than reported from other dry forests in India (for example, 2 trees/ha in Rajaji National Park [Prasad 2001]; 4 trees/ha in Mudumalai wildlife sanctuary [Sukumar et al. 1992]), including past reports from BRT (Murali et al. 1996). The lower density of *P. emblica* reported by Murali et al. (ibid.), also from BRT, could be due to their having worked in a part of the sanctuary (Kanneri colony) where the forest is largely woodland savanna. Our transects are representative of both dry deciduous forest and woodland savanna, the two habitats in which *P. emblica* occurs. Density of *P. indofischeri* has not been reported from other sites; in fact past studies on amla have not distinguished between these two *Phyllanthus* species (for example, Murali et al. 1996; Uma Shankar et al. 1998).

A high abundance of individuals in smaller size classes, leading to an inverse J-shaped size class distribution, is generally regarded as an indicator of adequate regeneration and population maintenance (Condit et al. 1998; Lieberman 1996; Zagt and Werger 1998). The abundance of seedlings is a manifestation of successful seed germination and establishment, and is affected by a suite of biotic and abiotic factors that includes amounts of fruit produced and harvested. Similarly, the abundance of saplings is a manifestation of successful recruitment of seedlings into the sapling size class. In the case of the two congeners we studied, though seedling densities were similar, *P. emblica* populations had significantly fewer saplings.

Given the similarities in seedling abundances between the two species, their differences in sapling abundances implies lower recruitment into the sapling size class, or greater mortality of the sapling size class (or some combination of the two) in the case of *P. emblica*. We observed greater sapling mortality for *P. emblica* compared with *P. indofischeri*. Moreover, a higher proportion of resprouts in the sapling size class of *P. emblica*—presumably a response to damage or disturbance—points to a greater susceptibility of *P. emblica* to agents of damage compared with *P. indofischeri* or, possibly, greater intensity of disturbance in *P. emblica* habitats compared with *P. indofischeri* habitats. Either or both of these factors may also be linked to higher sapling mortality in *P. emblica*.

In the BRT forests, NTFP harvest by people is accompanied by a suite of associated anthropogenic disturbances such as livestock grazing and fire. These disturbances may be responsible for the high sapling mortality and the large numbers of re-sprouts we observed. Further support for this comes from reports by

others (for example, Sukumar et al. 1992) who found very similar size class distributions of *P. emblica* in nearby Mudumalai, where NTFP extraction is non-existent or minimal. Furthermore, grazing is absent in the Mudumalai site, leaving fire as the main common factor between the two sites, and suggesting that regeneration of *Phyllanthus* spp. in the BRT forest may be determined largely by fire.

In our study, differences between the two *Phyllanthus* species are confounded by differences in the types of forests in which they occur. Thus, it is impossible to say whether the species differ in their response to anthropogenic disturbances such as fire, or whether fires have varying effects in the different forest types (for example, due to differences in fuel loads). Nonetheless, our observations highlight the depauperate sapling size class in the case of *P. emblica*, which could constitute a population bottleneck in future. This serves to underscore the need to consider other associated anthropogenic disturbances—not NTFP harvest alone—when assessing the ecological impacts of managing forests for NTFP.

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