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Harvesting techniques, hemiparasites and fruit production in two non-timber forest tree species in south India

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Abstract

Increasing demands for non-timber forest products and their commercial extractions can result in harvesting methods that maximize short term economic gains with little attention to long term ecological consequences. We assessed the ecological impacts of harvesting techniques used by an indigenous group, the Soligas, on the non-timber forest products they extract from the forests of Biligiri Rangan Hills, south India. Specifically, we examined patterns of resource availability of two non-timber tree species, *Phyllanthus emblica* and *P. indofischeri*, and how the current fruit harvesting techniques influence fruit yields, and susceptibility of trees to infestations by hemiparasitic plants of the Loranthaceae family. We also assessed how hemiparasite infestations affect fruit production and growth rates of *Phyllanthus* trees. There was considerable variation in fruit production in both species of *Phyllanthus* from one fruiting season to the next. The Soligas harvest an average of 86% (±17.72%) of the fruit yield on a per tree basis in *P. emblica* and 94.17% (± 6.9%) in the case of *P. indofischeri*. At the population level, 64.75 and 86.6% of the fruit productivity is harvested in *P. emblica* and *P. indofischeri*, respectively. However, not all individuals or populations are harvested. Harvesting techniques used resulted in cutting of 15% of *P. indofischeri* trees and 5% of *P. emblica* trees. The current harvesting techniques used by the Soligas reduce fruit production in *P. emblica* in the following year ($R^2 = 0.27, p = 0.03$). Furthermore, the Soligas selectively harvest fruits from trees that have larger fruit crop sizes in both species. Individual trees that carried a greater load of hemiparasites produced significantly lower fruit yields (*P. emblica*: $r = -0.32, p < 0.013$; *P. indofischeri*: $r = -0.73, p < 0.001$). The presence of hemiparasites significantly affected the growth rates of trees.

Current harvesting techniques used by the Soligas have negative impacts on trees of *Phyllanthus* spp., as do infestations by hemiparasites. Current fruit harvesting strategies and techniques used by the Soligas focus on maximizing the economic returns by adopting methods of extraction such as lopping of branches and cutting of trees. Such practices can ultimately decrease the rates at which the populations grow, thereby making the extraction of *Phyllanthus* fruits unsustainable. Adopting more sustainable methods of harvesting appears to be one viable solution to the current ecological problem facing the conservation of *Phyllanthus* trees in the forests of Biligiri Rangan Hills.

Keywords: Non-timber forest products; Harvesting techniques; Epiphytic hemiparasites; India; *Phyllanthus emblica*; *Phyllanthus indofischeri*

1. Introduction

The use and extraction of non-timber forest products (NTFPs) have had historical and current importance in local economies and cultures of indigenous people. Today, with increased market demand, NTFPs have

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come to play an important role in large-scale commercial income generation and employment in many parts of the world. For instance, the tagua palm, *Phytelephas aequatoralis*, has been a trade commodity since 1865 in Equador, and is currently being marketed internationally; extractors earn about 40% of their monthly income from tagua collections alone (Runk, 1998). In the state of Madhya Pradesh in India, about 40–63% of the total rural income comes from collection and sale of NTFPs (Tewari and Campbell, 1996). Furthermore, the role of NTFPs in improving rural economies is also well acknowledged (De Beer and McDermott, 1989; Peters et al., 1989a; Sayer, 1990; Bawa, 1992; Nepstad and Schwartzman, 1992; Panayotou and Ashton, 1992; Plotkin and Famolare, 1992; Mendelsohn and Balick, 1995), and in some cases can generate more income than timber (Peters et al., 1989b; Chorpra, 1993; Taylor et al., 1996). Extractions of NTFPs offer great potential for building partnerships with indigenous communities, thereby integrating people's needs and livelihood with conservation (Campbell, 1998; Alcorn, 1993). However, the debate continues about whether indigenous people are stewards of conservation of biodiversity and the extent to which they still follow traditional conservation ethics (Alcorn, 1993; Redford and Stearman, 1993; Chicchón, 2000; Colchester, 2000; Redford and Sanderson, 2000; Schwartzman et al., 2000a,b; Terborgh, 2000).

Human activities, especially harvesting practices, can influence prospects of sustainable use of NTFPs by impacting forests at various levels. Harvesting intensity and techniques may determine the magnitude of these impacts. For instance, if an NTFP becomes commercially valuable, levels of extraction can be determined and driven by market forces. Furthermore, increased demand for products can change the traditional low-impact patterns and techniques of resource extractions. There are many instances where harvesting choices and techniques have affected the extracted species and ultimately led to their depletion (Chambers et al., 1989; Peters et al., 1989a; Vasquez and Gentry, 1989; Sayer, 1990; Reining et al., 1991; Browder, 1992; Nepstad et al., 1992; Clay, 1997; Southgate, 1998; Neumann and Hirsch, 2000 and references therein). At the individual tree level, harvesting of non-timber products, such as fruits, may also lead to changes in flowering and fruiting patterns and lowered yields. These effects may be further exacerbated when harvesting of fruits act together with natural events, such as infestations of trees by hemiparasitic plants. Presence of plant hemiparasites may represent a drain of resources for the plant, the proximate effects of which may be manifested in slower growth rates and lowered levels of fruit yields. Thus, an assessment of sustainability of extractions of NTFPs such as fruits requires an approach that examines the effects of various forces apart from the most obvious, i.e., harvesting intensities.

In India, millions of people living in and around forests subsist on collections of NTFPs; local and indigenous people usually have usufruct rights to extract NTFPs from protected areas, such as wildlife sanctuaries. A significant percent (over 50%) of the revenue of the Forest Department comes from NTFP extractions and 75–80% of forest export income comes from NTFP exports, and these numbers have been rising as have the quantities of NTFPs exported (Tewari, 1998 and references therein). Extraction patterns of certain NTFPs such as honey, soapnut, and Indian gooseberry, the focal NTFP of this study, have gone from subsistence-collections to large-scale commercial extractions over the last few years. The NTFPs extracted are contracted to traders or to cooperative societies and these products, either in raw or processed form, eventually reach the local, regional and, in some cases, international markets.

Although the collection of NTFPs is an age-old practice in India and many other parts of the world, there is little empirical knowledge of the spatial and temporal patterns of variations in resource availability, how NTFP species are used and managed by local people, and the changes in resource use and extractions that follow commercialization of an NTFP. Such information is required by foresters, non-government organizations, and the local people themselves to understand how wild plant resources are being manipulated and its ecological impacts, and to foster sustainable use of the very resources that support them.

An indigenous people, the Soligas, live within the forests of Biligiri Rangan Hills, Karnataka, India where this research was conducted. They make a living by extracting a wide variety of NTFPs such as fruits, soapnut, honey, and lichens. The Soligas use a wide variety of techniques to harvest fruits of *Phyllanthus emblica* and *P. indofischeri*, the two focal species. These can range from methods such as

beating of branches or lopping of small branches and subsequent collection of fruits from the ground to lopping of large branches, cutting of the entire canopy or even the tree. Harvesting techniques that involve lopping and cutting are likely to have effects on levels of fruit yields, patterns of fruit production and growth rates of trees. Accompanying this pressure of harvesting and its ancillary disturbances, trees of *P. emblica* and *P. indofischeri*, the two focal species, are heavily infested by epiphytic hemiparasitic plants of the Loranthaceae family. The hemiparasites are more prevalent on the trees of *Phyllanthus* spp. than other species (Sinha, pers. obs.). The Soligas believe that increased loads of hemiparasites lead to mortality of adult trees. It has been suggested by the Soligas that the downward trend in fruit yields of *Phyllanthus* spp. in the past might be due to the high levels of hemiparasite infestation. It has also been speculated by the forest department that lopping of branches during fruit harvesting may increase incidences of hemiparasite infestations; lopped branches may provide a landing and, subsequently, a germination site for the seeds of the hemiparasites.

The broad objective of this study was to examine the ecological impacts of the current fruit harvesting techniques and hemiparasite infestations in two non-timber tree species, *P. emblica* and *P. indofischeri*, in the forests of Biligiri Rangan Hills, south India. We addressed the following questions: (i) what are the patterns of inter-annual variation in fruit production? (ii) what factors influence the Soligas' decisions regarding fruit choice and the extent of collections? (iii) what are the direct impacts of harvesting techniques currently used by the Soligas on fruit production? (iv) do the harvesting techniques, specifically lopping, increase the susceptibility to infestations by hemiparasites? (v) how does the presence of hemiparasites on *Phyllanthus* trees influence levels of fruit production and growth rates of trees? and (vi) how can the current harvesting techniques be improved to foster sustainable use of *Phyllanthus* fruits?

2. Study site, indigenous people and species description

The study was conducted in the scrub and deciduous forest of the Biligiri Rangaswamy Temple Wildlife Sanctuary in the Biligiri Rangan Hills (hereafter referred to as BR Hills) in south India. BR Hills is part of the Western Ghats, one of the biodiversity hotspots in India. The wildlife sanctuary covers 540 km^2 and lies at an elevation of 600–1800 m above sea level. It extends from 11°40′ to 12°09′N latitudes and 77°05′ to 77°15′E longitudes. The area receives most of its rainfall from June to November from the southwest monsoons, and in December from the northeast monsoons. Rainfall varies with topography and altitude and ranges from 941 to 1800 mm. Typically, the eastern slopes receive lower amounts of rainfall than the western slopes. The dry season extends from February to April.

Scrub forest commonly occur along the periphery on the eastern slopes and the northern parts of the wildlife sanctuary at elevations of 700–900 m but may extend up to 1200 m. The deciduous forest is found at higher altitudes from 900 to 1400 m. The scrub forest covers about 28.2% and the deciduous forest about 61% of the area within the wildlife sanctuary. Based on importance index values and dominant forest associations, the scrub forest is classified under *Anogeissus–Chloroxylon–Albizzia* spp. type series and the deciduous forest as *Anogeissus–Pterocarpus–Terminalia* spp. type series (Ramesh, 1989).

The two focal species, *P. emblica* L. and *P. indofischeri* Bennet. (Euphorbiaceae), commonly called Indian gooseberry or Amla, occur in the deciduous and scrub forests of BR Hills, respectively. *Phyllanthus* trees usually attain a height of about 5–10 m. The fruits of both species are identical in appearance; they are fleshy, 6-seeded, globose berries. The fruits of *P. emblica* measure about 1.7–3 cm in diameter and those of *P. indofischeri*, 2–3.6 cm. The fruits turn greenish-yellow when ripe, and begin to disperse around November. Mammals such as Sambar (*Cervus unicolor*), Barking Deer (*Muntiacus muntjak*), Mouse Deer (*Tragulus meminna*) and Chittal or Spotted Deer (*Axis axis*) eat the fleshy fruits that fall to the ground and regurgitate the hard fruits containing the seeds. The regurgitated fruits are less susceptible to fungal attacks and also dehisce sooner than the fruits not eaten by animals (Sinha, pers. obs.). Species of epiphytic hemiparasites such as *Taxillus tomentosus* (Roth.) Var. Tiegh. and *Dendropthoe falcata* (L.f) Etting. of the Loranthaceae family are commonly found growing on *Phyllanthus* trees.

Currently, there are about 4000 Soligas living in the forest. The Soliga people traditionally were hunter-gatherers who practiced shifting agriculture until 1972 when the area of BR Hills was declared protected, and timber logging and shifting agriculture were banned. The Soligas were given usufruct rights to harvest NTFPs and ca. 1–2 ha of land per family within the wildlife sanctuary to practice settled agriculture. As the income derived from settled agriculture is low, the Soligas rely extensively on NTFPs for their income; a Soliga household may derive up to 50% of its cash income from extraction of NTFPs (Lele et al., unpublished data). The most heavily harvested NTFPs are fruits from *P. emblica* and *P. indofischeri* which have a high potential for generating revenue and contributing significantly to the Soliga economy and subsistence. Harvesting of fruits from the two *Phyllanthus* spp. contributes approximately 6–11% of the total cash income in a typical Soliga household (Lele, pers. commun.). The Soligas harvest fruits from December to mid-February and sell them to traders through a tribal co-operative society. Harvesting of fruits is an organized effort. Soliga harvesting groups are typically comprised of men, women and children. During the harvest season, all harvesting groups from a village set out early in the morning to predetermined areas. Harvested fruits are carried to a central collection point in the forest where the traders pick up the fruits. The Soligas do not distinguish between the fruits of the two species while trading them. The fruits are used for preparing pickles, jams, herbal medicines, and cosmetics, as well as in tanning and dyeing.

3. Methods

3.1. Patterns of fruit production and harvesting

Data were collected each year from 1995 to 1997 between December and April, using the same methodology for both species. Prior to the fruit harvesting season of December 1995, we visited two populations in the deciduous and three in the scrub forest that were likely to be harvested. All reproductive adults in the populations were tagged and their diameter at breast height (dbh) measured. Data on fruit crop size (FCS; fruit production per tree) and hemiparasite load were also collected for each individual. FCS was measured by estimating the number of fruits on three sample branches and multiplying the average number of fruits per branch by the number of branches. Fruit production of individual trees was used to calculate fruit production at the population level based on the number of individuals fruiting in the population. Hemiparasite load was visually estimated as a percent of the canopy of the tree. In addition, we also collected information on the history of lopping, i.e., if the tree had been lopped in the past during harvesting. We used estimates of the hemiparasite loads and history of lopping to examine whether trees that had been previously lopped (hereafter referred to as harvested trees) carried heavier hemiparasite loads than those that had not been lopped (unharvested). Observations on sites of infestation (for example, on previously cut branches) were also recorded. Fruit production was recorded again during the following fruiting season, 1996–1997.

We accompanied the Soligas on their harvesting trips during the harvesting season of December 1995–February 1996. The quantity of fruits harvested was directly measured by weighing the bags of fruit after the fruits had been collected from each tree. We recorded the harvesting techniques used, i.e., number and size (small or major) of branches lopped, completely cut canopies and stumps. Once fruits from a particular area had been harvested and the harvesters were not likely to return, post-harvest data were collected. The number of fruits unharvested, i.e., fruits remaining on the tree was recorded. The quantity of unharvested fruits was estimated using the same methodology used to estimate FCS. The Soligas tend to leave the lopped branches by the base of the tree. It was thus easy to assess the damage done by the current harvesting techniques. We collected data on the number of small and major branches lopped, and tree stumps if this information had not already been collected during harvesting.

3.2. Effects of hemiparasites on growth rates and fruit production

To examine the effects of hemiparasites on growth rates of trees (measured by the dbh) of the two *Phyllanthus* spp., we selected 30 similar-sized trees, 10 of which were free of hemiparasites (no infestations) and 20 with a hemiparasite load. The hemiparasite

was physically removed by cutting it from 10 of the 20 trees. These treatments (no infestations, hemiparasite infestations and hemiparasite removal) were replicated at three locations in the scrub forest and two in the deciduous forest. In the following fruiting season, prior to any fruit harvesting, all individuals were measured for growth.

We selected a subset of trees that had been tagged in permanent plots in the deciduous and scrub forests; these plots were a part of a demographic study (Sinha, 2000). The trees were approximately of the same diameter and were infested with hemiparasites. Data on fruit production and hemiparasite loads were collected for a total of 60 trees at two locations in the deciduous forest and 73 trees at three locations in the scrub forest using the methodology described above.

3.3. Data analysis

All data were transformed appropriately or non-parametric statistical tests were used Sokal and Rohlf, 1994. Growth increments were calculated as a proportion of the original diameter and were thus arc sine transformed. By using proportional growth increments, we accounted for any effects differences in diameters might have had on growth rates even though the trees selected were approximately of the same diameter. A paired-sample *t*-test was used to analyze differences in fruit production between years. To examine whether Soligas' decisions regarding harvesting of fruit was influenced by the FCS of trees, contingency table analyses were used. We ran a regression analysis with categorical data to assess the effects of harvesting techniques, mainly lopping, on fruit production in the following year; there were three categories of harvesting techniques based on the number of branches lopped. A similar analysis could not be done for *P. indofischeri* since there was not enough data on fruit production. Two of the three scrub forest locations were burned in the dry season and many trees did not flower during the second season of data collection. The effects of harvesting practices, specifically lopping, on the susceptibility to infestations by hemiparasites were examined using a contingency table analyses. To assess the effects of hemiparasites on growth rates and fruit production of *Phyllanthus* trees, analysis of variance and correlations were used, respectively.

4. Results

4.1. Patterns of variation in fruit production

There was considerable variation in fruit production in the two species of *Phyllanthus* from one fruiting season to the next. In *P. emblica*, the species found in the deciduous forest, the average productivity during 1995–1996 ($2873.40 \pm$ S.E. 436.17 fruits per tree) was almost four times that of the following year ($723.12 \pm$ S.E. 17.84 fruits per tree). The differences were significant ($t = 4.82, N = 161, p < 0.001$). Fruit production in *P. indofischeri* in the scrub forest showed a 450-fold decline between the two time periods. The average productivity recorded during 1995–1996 was higher ($396.69 \pm$ S.E. 64.19 fruits per tree) than in 1996–1997 (0.88 fruits $\pm$ S.E. 0.26 fruits per tree), and these inter-annual differences were significant ($t = 6.17, N = 245, p < 0.001$).

4.2. Harvesting patterns, decisions and techniques

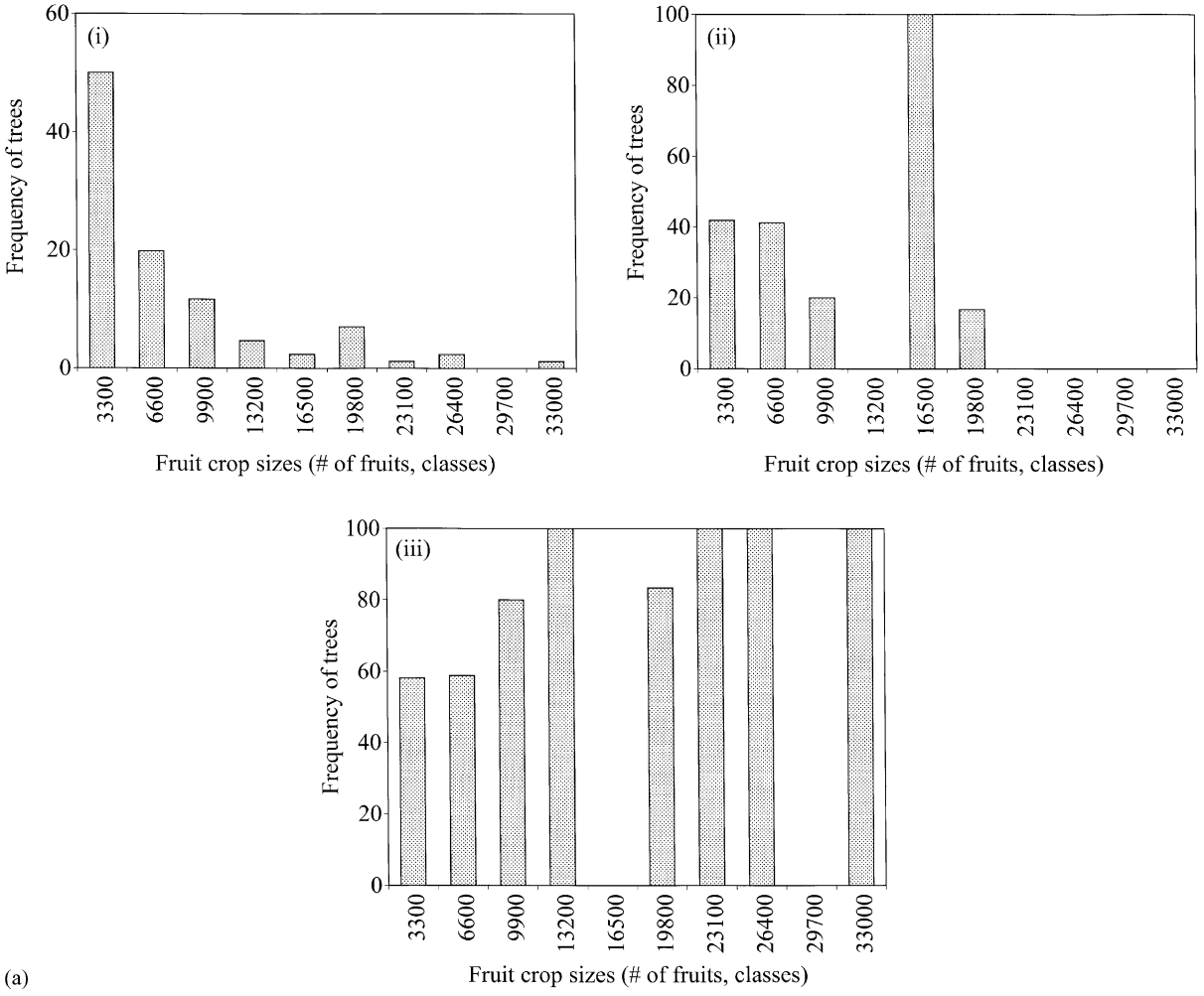
Quantity of fruit yields harvested by the Soligas differed in the two species of *Phyllanthus*. In the deciduous forest, the Soligas harvested an average of $86 \pm 17.72\%$ of the total yield per tree in *P. emblica*, though the actual range is very variable (43–99.5%). At the population level, 64.75% of the total yield was harvested in the study locations. In *P. indofischeri* found in the scrub forest, higher quantities of yields were harvested; about $94.17 \pm 6.9\%$ (mean $\pm$ S.D., range 62.55–100%) was harvested at the individual tree level and 86.6% at the population level. Harvesting techniques used were more harmful in the case of *P. indofischeri* than in *P. emblica*. Almost 15% of the trees of *P. indofischeri* from which fruits had been collected were cut at the base during harvesting. Trees of *P. emblica* had not been cut at the base; instead 5% of the trees had completely lopped canopies.

Levels of productivity of a tree were found to influence the decision-making process of the Soligas whether to harvest fruits from a given tree. The Soligas tend to harvest fruits from trees that have larger FCS more frequently than from those bearing smaller FCS (Fig. 1a and b). A contingency table analysis of the data showed this patterns in *P. emblica* ($G_{\text{adj}} = 4.17$, d.f. $= 1, p < 0.05$, Table 1, Fig. 1a) as well as in

P. indofischeri ($G_{adj} = 147.07$, d.f. $= 1$, $p < 0.05$, Table 1, Fig. 1b). The impacts of harvesting techniques, such as lopping, on fruit production in the subsequent year in *P. emblica* are negative. Lopping of major branches of the tree reduces fruit production in the following year (fruit production (log) $= 3.20 - 0.86$ (harvesting techniques), $R^2 = 0.27$, $p = 0.03$, $N = 18$). The frequency of infestation by the hemiparasitic plants on *P. emblica* was found to be independent of whether the tree had been previously lopped during harvesting ($G_{adj} = 2.40$, d.f. $= 1$, ns, Table 2).

4.3. Effects of hemiparasites on growth rates and fruit production

The presence of hemiparasites significantly affected the growth rates of trees. In *P. emblica*, the variation observed in growth rates of trees in the three treatments (no hemiparasite infestations, hemiparasite infestations, and hemiparasite removal) was significantly different (two-way ANOVA, $F = 3.37$, $p < 0.05$). When growth rates of trees free of infestations were compared with those of infested trees, we found



(a)

Fig. 1. (a) Relationship between fruit production and Soligas' harvesting preferences in *P. emblica*: (i) distribution of fruit crop size, (ii) distribution of unharvested fruit crop sizes, (iii) distribution of harvested fruit crop sizes. (b) Relationship between fruit production and Soligas' harvesting preferences in *P. indofischeri*: (i) distribution of fruit crop size, (ii) distribution of unharvested fruit crop sizes, (iii) distribution of harvested fruit crop sizes.

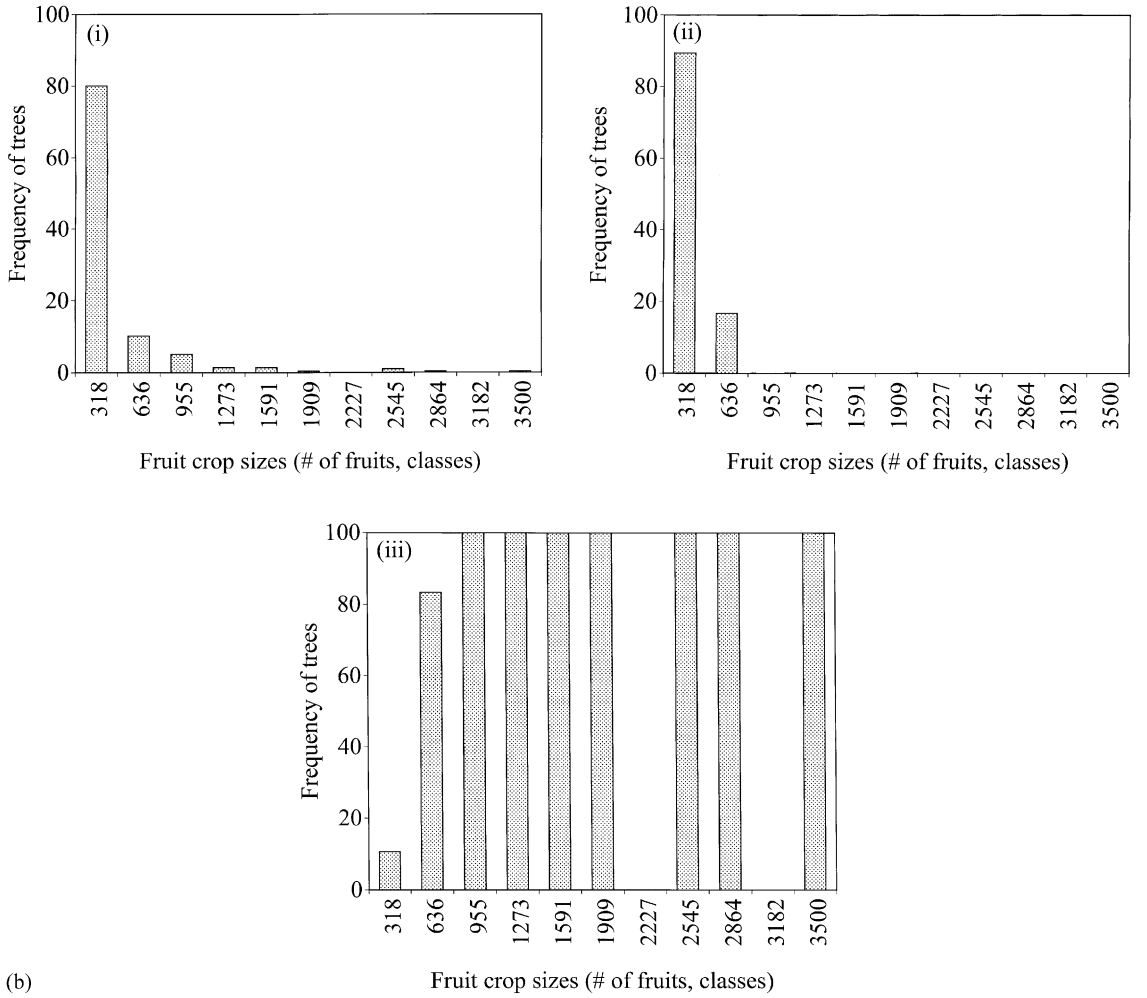


Fig. 1. (*Continued*).

Table 1
Relationship between fruit production (fruit crop size, FCS) and Soligas' harvesting preferences

Fruit production (FCS)	Frequency of trees		*G*-statistic	*P*
	Harvested	Unharvested		
P. emblica (deciduous forest)				
Small FCS (<6600 fruits)	35	25	4.17	0.05
Large FCS (>6600 fruits)	21	5		
P. indofischeri (scrub forest)				
Small FCS (<318 fruits)	25	211	147.07	0.05
Large FCS (>318 fruits)	54	5		

Table 2
Relationship between past harvesting techniques and susceptibility to infestations by hemiparasites in *P. emblica*

Category	Frequency of hemiparasite infestations		*G*-statistic	*P*
	Presence	Absence		
Harvested	55	18	2.40	ns
Unharvested	57	32		

that growth rates were significantly different (two-way ANOVA, $F = 5.41, p < 0.05$). However, the differences in growth rates between the two treatments, hemiparasite infestation and hemiparasite removal, were not significant. In all cases, the location effects were insignificant. In *P. indofischeri* trees, growth rates were significantly different across locations between the three treatments, i.e., no hemiparasite infestations, hemiparasite infestations, and hemiparasite removal (two-way ANOVA, $F = 7.87, p < 0.001$), hemiparasite infestations and no infestation (two-way ANOVA, $F = 6.52, p < 0.003$), and hemiparasite infestations and hemiparasite removal (two-way ANOVA, $F = 5.88, p < 0.004$). However, the treatments effects, i.e., no hemiparasite infestations, hemiparasite infestations, and hemiparasite removal, were not significant.

There was a negative correlation between hemiparasite load and fruit production in *P. emblica* trees

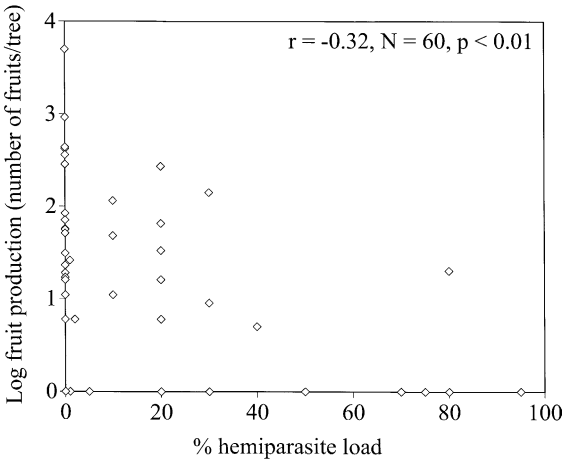


Fig. 2. Relationship between hemiparasite load (%) and fruit production (number of fruits per tree) in *P. emblica* in the deciduous forest.

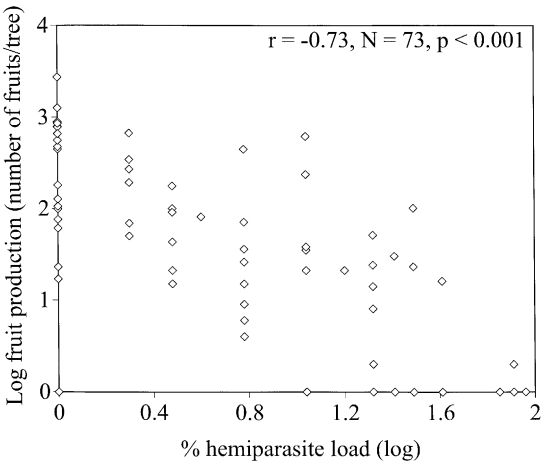


Fig. 3. Relationship between hemiparasite load (%) and fruit production (number of fruits per tree) in *P. indofischeri* in the scrub forest.

($r = -0.32, N = 60, p < 0.013$, Fig. 2). Similarly, a decline in the fruit production with an increase in the hemiparasite load was observed in *P. indofischeri* ($r = -0.73, N = 73, p < 0.001$, Fig. 3).

5. Discussion

5.1. Patterns of variation in resource base

Fruit production in the two *Phyllanthus* spp. showed significant variation from 1 year to another during the study period. A long term study in BR Hills that has been monitoring production of NTFP species has also shown high inter-annual variation in fruit production over a period of 5 years (1995–2000) in an area of 7 ha (Setty, pers. commun.). High fruit production every other year may be intrinsic to the biology of both the focal species. Such patterns of fruit production have been found in other forest tree species (Janzen, 1971; Janick and Moore, 1975) as well as in fruit trees such as apple, prunes, pecan and avocado (Kozlowski and Pallardy, 1997 and references therein). However, in BR Hills, Sinha (2000) found that inter-annual differences in fruit production are more pronounced in areas that are burned than at those that are not. The fire season in BR Hills coincides with the flowering season. Intense fires can burn the canopy and destroy buds and flowers, leading to low or no fruit production

in the subsequent fruiting season. This might also explain the 450-fold difference observed in the levels of fruit production in *P. indofischeri* in the scrub forest as two of the study locations had been burned soon after the initial data collection. However, in an area like BR Hills where human influence is pervasive, controls are difficult to establish as fires occur randomly.

5.2. Harvesting patterns, decisions and techniques

The Soligas have distinct harvesting preferences; they selectively harvest fruits from trees that produce large quantities of fruits, thereby ensuring relatively high economic returns per unit effort. Such a harvesting strategy may give them more time to search for other fruiting individuals, ultimately increasing the absolute quantities of fruits harvested. Similar preferences were observed among extractors of Brazil nut, *Bertolletia excelsa*, in the forest of Peru (see Salafsky et al., 1993) and Tagua nut (vegetable ivory from *Phytelephas aequatorialis*) in Ecuador (Runk, 1998), where fruits from the most productive trees were collected and the collection strategies ensured higher net gains while decreasing the risks. The effects of such harvesting preferences observed in the Soligas of BR Hills may be neutralized by the inter-annual variation in fruit production; trees that are heavily harvested one year may produce lower fruit yields in the following year and therefore, will be avoided by the Soligas.

Approximately, 86–94% of fruit yield per tree gets harvested in the two *Phyllanthus* spp. Since the Soligas selectively harvest fruits from the most productive trees, not all fruiting trees in a population are harvested. A detailed study of the population dynamics and demography of the two *Phyllanthus* spp. in the forest of BR Hills suggests that the number of seeds available for germination had a much smaller effect on the population growth rate than other population parameters, i.e., survival and growth (Sinha, 2000). Moreover, current harvesting levels of fruits per se seem to have less effect on population growth rates than some other anthropogenic pressures (Sinha, 2000). Similarly, Peters (1990) found that up to 80% of the fruit production could be harvested without negatively affecting the regeneration of *Grias peruviana* in the Peruvian Amazon.

Soligas resort to lopping the entire or most of the canopy or cutting the tree during harvesting. The frequency of such harvesting techniques is lower in *P. emblica* in the deciduous forest than in *P. indofischeri* in the scrub forest; a greater percent of tree stumps were recorded in the scrub forest. Trees in the scrub forest are smaller in size (reproductive adults can have dbh as small as 5 cm). Harvesters are unable to climb such small, unstable trees. Therefore, lopping of branches and cutting of canopies makes collections of fruits from the ground more efficient. In addition, harvesting techniques that do not involve lopping and cutting may require longer collection times since a single individual must climb the tree to collect the fruits.

Today, in many parts of the world, harmful harvesting methods of NTFPs have become one of the immediate threats to the continued use of NTFPs. In many places, traditional, non-destructive methods of extraction of NTFPs have been replaced by methods that are less time consuming and labor-intensive. In situations where the target species is damaged or killed during the process of extraction, NTFP extractions seem to be generally unsustainable. For instance, Peters et al. (1989a) cite many examples of how harmful harvesting methods and excessive harvesting of various products from oligarchic forests of the Amazonia have resulted in reduced fruit yields and abundance of the target species, as well as damage to forest structure. Destructive harvesting practices are used to harvest palm hearts from *Euterpe oleracea* in the Amazon estuary making the harvest of palm hearts unsustainable (Clay, 1997). In Peru, female *Mauritia flexuosa* palms are cut to facilitate harvesting of fruits; since this palm is dioecious, the population structure becomes biased towards male plants over time (Kahn, 1988; Vasquez and Gentry, 1989). In the case of extractions of gharu, a resin from *Aquilaria* spp., the entire tree is cut (Salafsky et al., 1993). Local communities in central India that collect flowers of *Madhuca latifolia* tend to break the apical twigs of the trees; such a practice affects flower production in the following year (Ramakrishna Mission Lokashiksha Parishad, 1992). Some other studies have reported forest degradation due to uncontrolled exploitation of forest products (Rawat, 1997; Southgate, 1998; Neumann and Hirsch, 2000 and references therein). However, it may be argued that pruning and thinning

of trees can increase fruit yields; Anderson and Jardim (1989) found that pruning of *Euterpe oleraceae* (acai palm) increased fruit production though the increase was not significant. In the forest of BR Hills, the current harvesting techniques used by the Soligas are negatively impacting the very resource that sustains them in two ways. First, in one of the focal species, *P. emblica*, lopping of branches reduces fruit production in the following year. Second, cutting of trees may make the extraction of *Phyllanthus* spp. unsustainable. A high percent of the tree stumps ultimately die and are more prone to death from fire (Sinha, unpublished data). In a demographic study of the two *Phyllanthus* spp., Sinha (2000) reports that survival of reproductive adults is an important parameter that determines the rate at which populations grow. Thus, any factor, such as harmful harvesting techniques, that lowers the survival probability of adults will decrease the rates at which the populations grow thereby, making the extraction of *Phyllanthus* spp. unsustainable.

Fruits of the Loranthaceae hemiparasites are eaten by birds, which regurgitate the seeds (pers. obs). Since the seeds are viscous, they stick to the branches, and subsequently germinate. We found that lopping of branches does not have a direct bearing on the probability of a tree being infested or the hemiparasites establishing more easily.

5.3. Effects of hemiparasites

Infestation by hemiparasitic plants influenced the growth rates of trees as well as levels of fruit production in *Phyllanthus* spp. There was significant variation in growth rates subjected to the three treatments, no hemiparasite infestations, hemiparasite infestations, and hemiparasite removal, across both the study locations in the deciduous forest. Given that there were no unusual location-related disturbances during the study period in the deciduous forest, the trends observed might be safely attributed to the hemiparasitic load each individual tree carried. Patterns in the scrub forest were less distinct, perhaps, due to intense fires. However, the role of fire needs more investigation. Furthermore, trees of both *P. emblica* and *P. indofischeri* that carried a greater load of the hemiparasites produced lower fruit yields. Infestation by hemiparasites must mean a drain of resources for the trees.

5.4. Fostering sustainable use of Phyllanthus fruits in BR Hills

In BR Hills, NTFPs have always played a critical role in the subsistence of the Soligas and, over the last few decades, in their economy. The current patterns of resource use and extractions by the Soligas may be driven by market forces, such that low-impact resource-use is being replaced by harmful harvesting techniques. The prospect of long term solutions to the ecological problems outlined in this paper will most likely be found in the form of improving the institutional and policy framework, and offering incentives to the Soligas for conservation and better management of their resources. One such incentive involves value addition to the NTFPs, which will ensure higher economic returns to the Soligas for their efforts, thereby permitting a change from harmful harvesting techniques to more benign ones. However, the more immediate management intervention is to encourage the Soligas to adopt harvesting techniques that minimize the impacts of harvesting fruits on *Phyllanthus* trees by creating awareness. This is currently being done through meetings between the Soligas and various non-government organizations working in BR Hills, and participatory resource monitoring. Findings from our research, in concert with other ongoing work in BR Hills, are being used to equip the various parties involved (i.e., indigenous and local people, forest managers, non-government organizations, and the scientific community) with information and knowledge for developing approaches and plans for conservation, and sustainable use and management of NTFP species in this region.

6. Conclusion

The forests of BR Hills have had a long history of human influence through various activities, such as harvesting of fruits, fire and the spread of invasive plant species, and their intensity and frequency have changed over the years. We show that the current strategies and harvesting techniques of *P. emblica* and *P. indofischeri* fruits used by the Soligas focus on maximizing the economic returns by adopting methods of extraction such as lopping of major branches and the canopy, as well as cutting of trees.

Such harvesting techniques are compromising the long term sustainable use of these NTFP resources. Furthermore, infestations by hemiparasites have negative impacts on fruit production. Harmful harvesting techniques and presence of hemiparasites may also have interactive effects on growth rates and fruit yields, a very resource that sustains the Soligas. However, in a place like BR Hills, linking conservation and use of forest resources with the economic interests of local people can still be a viable management option that might foster sustainable use of *Phyllanthus* fruits.

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