EXTRACTION OF NON-TIMBER FOREST PRODUCTS IN THE FORESTS OF BILIGIRI RANGAN HILLS, INDIA. 4. IMPACT ON FLORISTIC DIVERSITY AND POPULATION STRUCTURE IN A THORN SCRUB FOREST[1]

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Key Words: scrub forest; NTFP extraction; species richness; density; basal area; population structure; regeneration.

The idea that sustainable extraction of non-timber forest products (NTFPs) may provide an alternative to deforestation and ensure conservation of biological diversity in tropical forests is becoming popular (Allegretti 1990; Panayotou and Ashton 1993; Plotkin and Famolare 1992; Salick, Meija and Anderson 1995). The underlying rationale is that NTFPs can be extracted in a sustainable manner, and that the sale of NTFPs can generate, at the same time, enough income for the forest dwellers. Despite the importance of NTFPs in enhancing rural incomes and the conservation of biodiversity, there are few examples of sustainable extraction of NTFPs (Boot and Gullison 1995; Godoy and Bawa 1993).

Extraction of NTFPs, like any other form of exogenous disturbance (clearfelling, slash-and-burn agriculture, mining, and bulldozing), may have both short and long term consequences on the structure and function of forests. Overharvesting or continued extraction may alter population size, growth rates, and reproductive capacity of harvested species, leading to a reduction in the quantities of NTFPs (Hall and Bawa 1993). The impact may vary with the intensity of extraction and the plant part extracted (flower, fruit, seed, leaf, stem, root, tuber or entire plant).

There are few studies that document the impact of NTFP extraction on forest structure and composition (Daniels et al. 1996; Murali et al.

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1996); such studies are required to advance the knowledge of socio-biological mechanisms operating in NTFP extraction systems and to design and develop sustainable extraction systems. A general response of overharvesting or mismanagement of extraction systems is depletion of populations of target NTFP species (Nepstad et al. 1992; Offen 1993; Peters 1992) due to a lack of regeneration as reflected by the absence of recruitment in small size classes (Boot and Gullison 1995).

This paper is concerned with the extraction of non-timber forest products from the Biligiri Rangan Hills in southwest India. Until the close of eighteenth century, the thick hill forests of these hills were hardly accessible even to those people residing in the surrounding plains or foot hills. In those days, the hill forest was inhabited by the aboriginal Soliga tribe. Soligas were primarily hunter-gatherers and lived on a variety on NTFPs such as yams (*Diascorea* spp.), wild edible fruits, honey, and animal flesh (Morab 1976). They also practiced shifting agriculture (locally known as Podu). The Soligas' mode of shifting agriculture differed from that practiced in northeastern India, where the farmers shift from one field to another (Ramakrishnan 1993; Tawnenga, Uma Shankar, and Tripathi 1996). The Soligas shifted whole settlements after cultivating the land for about three consecutive years (Morab 1976). The abandoned land and the settlement were left for natural recovery and not inhabited again for hundreds of years. With only 0.5 ha or less landholding per family, shifting agriculture in the Soliga community was not intensive. A significant factor discouraging large scale investment of energy in cultivation was the heavy damage to crops by elephants and other wild animals. However, cultivation was practiced in spite of the fact that it produced hardly enough grains to meet the food requirement of a family for a quarter of the year.

In an earlier paper in this series, we reported that the harvest of fruits of three species may not only deplete the populations and impair recruitment of the target species, but also may deplete species richness and diversity of a dry deciduous forest community (Murali et al. 1996). Here, we present data on the impact of extraction of NTFPs on a thorn scrub forest. We argue that the thorn scrub community investigated may be a manifestation of long persisting anthropogenic pressure, particularly in form of NTFP extraction, and may represent a downward transition from a deciduous forest to a shrub thicket. Specifically, our objectives are: 1) to determine if the extraction of NTFPs has a negative influence on the recruitment of harvested species and 2) to examine the effect of extraction on ecosystem structure and composition. A following paper further examines the impact of extraction on the structure of the forest in relation to the dispersal mode of species, and another deals with the effects of fuel wood extraction (Uma Shankar, Hegde, and Bawa 1998; Ganeshaiah et al. 1998).

Study Area

A detailed description of the physical environment of the BRT sanctuary is available in Ramesh (1989) and Hegde et al. (1996). BRT sanctuary straddles the Western and Eastern Ghats of peninsular India and receives both southwest monsoon from the west coast and retreating northeast monsoon from the east coast. This peculiar geographical location results in a bimodal distribution of rain at the lower reaches of the hills where scrub is the predominant vegetation. The first monsoon peak is observed in May and the second in September. The period from December to April is extremely dry with a few sporadic events of gentle showers. The average annual rainfall (for 13 years from 1980 to 1992) received in scrub forest is 748 ± 130 mm according to the meteorological records of the Swarnamathi Dam site, which is situated at a radial distance of about 4 km from the study area. This amount of rainfall is low compared to higher elevations in the hills; at 1800 m an average of 1850 mm of rain falls (average from 1926 to 1991). The daily fluctuations in temperature recorded from 1980 to 1992 indicate very little variation in the mean monthly minimum and maximum temperatures. The temperature remains more or less constant all along the year except a gentle dip during winter (December to February). The mean annual temperature is 25.3°C. However, the absolute temperature may sometimes fall as low as 11°C in January and may rise as high as 42°C in April.

As described earlier (see Murali et al. 1996), the natural vegetation of the Biligiri Rangaswamy Temple (BRT) wildlife sanctuary can be classified into five types: wet evergreen, dry deciduous, scrub, grasslands, and high altitude, stunted montane forest. This study pertains to the scrub forests that predominantly occur in the foothills of the sanctuary, particularly from 700 to 1200 m.

Currently, at least six species found in the scrub forest are extracted by the Soligas for subsistence and income generation. *Phyllanthus emblica* L., a species valued for its fruits, is regularly extracted for large scale commercial sale (Uma Shankar et al. 1996). *Strychnos potatorum* L., another fruit crop species, is intermittently extracted for commercial sale on a relatively smaller scale. Two additional species, viz., *Anogeissus latifolia* Wall. and *Grewia oppositifolia* Roxb. are preferred by the Soligas for fuelwood and for poles for constructing houses and traditional agricultural implements (Uma Shankar, Hegde and Bawa 1998). The remaining two species, *Acacia sundra* DC. and *Chloroxylon swietenia* DC. are also extracted for fuelwood, but to a lesser extent than the previously mentioned species. The six species together constitute about 70% of the total individuals in the forest, indicating that most trees in the forest are in some way economically important to the Soliga community and that the majority of the impact of NTFP extraction may be on these species. However, some other species may be extracted for subsistence use on a smaller scale.

METHODOLOGY

The scrub forest covers about 28.2% of the 540 km^2 area of the sanctuary. An inventory of vegetation was undertaken in 1992–1993 in the southern range of the scrub forest adjoining a human settlement (Budhipadaga). Two stands were demarcated, one (proximal) in the proximity of the settlement and the other (distant) 4–6 km from the settlement. To take into account microsite differences, four transects were sampled in each stand. The two stands were considered different from each other with respect to a particular parameter if the variation between the transects within one stand was statistically greater or lesser than that in the other.

Vegetation in each stand was sampled from a 2 ha area in the form of four 500 m long and 10 m wide linear transects (one transect equalling 0.5 ha) laid to obtain desired replication in environmental and harvest intensity variation (Hall and Bawa 1993). Each transect was a continuum of five plots, each of which was 100 m long and 10 m wide, with a total area of 1000 m^2 or 0.1 ha. Hence, there were 20 such plots in each stand. All individuals with a diameter of $\geq$1 cm at breast height (1.3 m) were enumerated.

Ecological analysis of data was done separately for the two sample stands, distant and proximal. In each stand, vegetation was distinguished into two strata, viz., tree layer and understory. All the species recorded in tree layer and understory were classified into two classes, "large woody species" and "small woody species," on the basis of growth form. Large woody species include medium to large sized tree species, and small woody species include small trees and shrubs, particularly those bearing thorns. The tree layer includes all the individuals with dbh $\geq$10 cm, and the understory includes all the individuals with dbh $\geq$1 cm but $<$10 cm. The calculations for various phytosociological parameters were performed as follows. Density was the total number of individuals in unit sample area. Frequency was the number of sample plots in which a species occurred. Basal area was the area occupied by a cross section of the stem at breast height. In case of multiple stems at breast height, basal areas of individual stems were summed. Relative values of frequency, density, and basal area of a species were obtained by dividing its frequency, density, and basal area by the sum of frequencies, densities, and basal areas of all the species, respectively. Relative values were multiplied by 100 in order to be expressed as a percentage. Importance value index (IVI) for each species was calculated as the sum of the relative values of frequency, density, and basal area. Shannon's diversity index (H′) was calculated following Margalef (1968). Floristic composition between two stands was compared by calculating Sørenson's dissimilarity index (100-similarity index) both qualitatively (based on species commonness) and quantitatively (based on minimum common density) as described in Mueller-Dombois and Ellenberg (1974). We should caution, however, that the conclusions drawn from the comparison of the distant and proximal site are valid only as a comparison of the two stands. In order to draw robust conclusions regarding the effect of proximity to settlement on forest structure, further study of multiple stands would be necessary, due to problems associated with pseudo-replication.

The population structure of the two stands was studied separately. All individuals were cat-

TABLE 1. COMPARISON OF DENSITY, BASAL AREA, AND SPECIES RICHNESS OF LARGE WOODY SPECIES AND SMALL WOODY SPECIES BETWEEN DISTANT AND PROXIMAL STANDS IN TWO VEGETATION STRATA OF BRT SCRUB.

Vegetation stratum	Large woody species		Small woody species	
	Distant stand	Proximal stand	Distant stand	Proximal stand
Tree layer				
Density (ha^{-1})	39.5 ± 30.6	20.0 ± 8.2	64.5 ± 19.4	64.0 ± 8.2
Basal area (m^2 ha^{-1})	1.04 ± 0.66	0.68 ± 0.35	1.15 ± 0.39	1.37 ± 0.2
Species richness	16	11	13	13
Species (ha^{-1})	17.0 ± 6.2	10.0 ± 5.9	14.0 ± 1.6	16.5 ± 1.9
Understory				
Density (ha^{-1})	1848.5 ± 227.1	1119.5 ± 215.6	827.5 ± 426.7	1283.0 ± 107.8
Basal area (m^2 ha^{-1})	4.16 ± 0.65	1.88 ± 0.51	2.32 ± 0.96	3.16 ± 0.20
Species richness	23	21	28	37
Species (ha^{-1})	19.0 ± 1.8	14.3 ± 1.7	10.8 ± 3.3	26.8 ± 1.5

egorized into 1–10, >10–20, >20–30, >30–40 and >40 cm dbh classes. The 1–10 cm size class exhibited more than 96% of the total individuals. Therefore, this class was further divided into nine 1 cm wide subclasses. The number of individuals in each subclass was calculated, converted into percentage, and plotted on a bar diagram to represent the population structure of the understory stratum. The statistical treatments to the data were given following Sokal and Rohlf (1969).

RESULTS

The scrub forest in the BRT sanctuary is characterized by many species that bear thorny structures (spine, bristle or prickle), especially those belonging to Mimosoideae, Rubiaceae, Rhamnaceae, and Euphorbiaceae. Hence, the forest can be labelled as a thorn scrub. The details of floristic composition of the tree layer is given in Appendix I and that of the understory in Appendix II. Mosses and orchids occur rarely in this forest. Vines and lianas are also scarce. A few loranthaceous hemiparasites such as *Taxillus tomentosus* (Roth.) Var. Tiegh, *Dendrophthoe falcata* (L.f.) Etting, and *Viscum angulatum* Heyne ex DC, occur frequently on individuals of many species, but especially on *Phyllanthus emblica* trees.

SPECIES RICHNESS AND DIVERSITY

We hypothesized that the floristic composition of the tree layer may differ between the two stands, and the distant site would exhibit greater diversity than the proximal site. According to Shannon's diversity index, which takes into account both qualitative and quantitative features, diversity of the tree layer was greater in the distant than the proximal stand, with a value of 1.20 for the distant stand, and 1.03 in the proximal stand. The number of tree layer species in individual transects ranged between 13 and 19 (mean = 15.5, sd = 2.6) in distant, and between 11 and 16 (mean = 13.3, sd = 2.6) in proximal stand. The distant stand contained a total of 29 species belonging to 24 genera and 18 families, as compared to 24 species in 20 genera and 17 families in proximal stand.

Likewise, we tested the same hypothesis with regard to the understory layer. Shannon's diversity index also did not show much difference between the distant and the proximal stands for the understory layer; with a value of 1.05 for the distant stand and 0.99 in the proximal stand. The number of understory species in individual transects ranged from 34 to 46 (mean = 39.8, sd = 4.9) in the distant stand, and from 40 to 46 (mean = 41.8, sd = 2.9) in the proximal stand. The distant stand contained 51 species belonging to 39 genera and 24 families, as compared to 58 species of 43 genera and 26 families in the proximal stand.

A remarkable change was perceptible in vegetation structure when the species were grouped in large woody and small woody classes. The lower accumulation of species in tree layer was found to be associated with a decrease in large woody species from distant to proximal stand (Table 1). Conversely, the greater accumulation of species in understory was associated with an

TABLE 2. COMPARISON OF STAND DENSITY AND BASAL AREA BETWEEN DISTANT AND PROXIMAL SITES OF BRT SCRUB.

	Distant stand	Proximal stand	t value
Density (ha^{-1})			
Tree layer	104.0 ± 13	84.0 ± 15	8.1[a]
Understory	2676.0 ± 643	2402.5 ± 243	3.2[b]
NTFP species	1928 ± 561	1765 ± 229	3.8[b]
Other species	852 ± 89	722 ± 171	3.5[b]
Basal area (m^2 ha^{-1})			
Tree layer	2.19 ± 0.32	2.06 ± 0.51	1.8[c]
Understory	6.48 ± 1.58	5.04 ± 0.33	7.2[a]
NTFP species	5.41 ± 1.51	4.79 ± 0.70	4.1[b]
Other species	3.26 ± 0.26	2.30 ± 0.16	5.8[b]

[a] Significance level of $P < 0.01$ for 3 degrees of freedom.
[b] Significance level of $P < 0.05$ for 3 degrees of freedom.
[c] Not significant for 3 degrees of freedom.

increase in small woody species from the distant to the proximal stand; although two large woody species decreased from the distant to the proximal stand in the understory (Table 1).

DOMINANCE

The stand density and basal area declined significantly from the distant to the proximal stand, both in the tree layer and the understory for NTFP and other species (Table 2). This was mainly due to a decline in the density and basal area of large woody species (Table 1). The density and basal area of small woody species remained almost unchanged in the tree layer and increased moderately in the understory (Table 1).

Six NTFP species were also the most abundant species in the community and together they constituted a large proportion of the density and basal area. The density of *P. emblica*, an intensely collected fruit crop species, declined from the distant to the proximal stand both in the tree layer and the understory (Table 3), resulting in a decrease in basal area (Table 4). On the other hand, *S. potatorum*, a less intensely collected fruit crop species did not show a sig-

TABLE 3. DENSITY (INDIVIDUALS HA^{-1}) OF SIX NTFP SPECIES (TWO FRUIT CROP, TWO PREFERRED FUELWOOD AND TWO LESS-PREFERRED FUELWOOD) IN TREE LAYER AND UNDERSTORY OF DISTANT AND PROXIMAL STANDS OF BRT SCRUB.

	Tree layer			Understory		
NTFP species	Distant stand	Proximal stand	t value	Distant stand	Proximal stand	t value
Fruit crop						
Phyllanthus emblica	3.0 ± 0.95	1.5 ± 0.35	3.0[a]	134.5 ± 14.0	28.5 ± 4.4	14.5[c]
Strychnos potatorum	16.5 ± 2.35	11.5 ± 0.85	1.6[d]	76.5 ± 10.9	81.0 ± 5.4	0.7[d]
Preferred fuelwood						
Anogeissus latifolia	4.5 ± 1.3	10.5 ± 0.75	8.0[c]	1182.5 ± 77.0	992.5 ± 43.5	4.3[b]
Chloroxylon swietenia	10.5 ± 2.2	23.0 ± 1.45	9.5[c]	135.5 ± 23.1	257.5 ± 4.2	10.4[c]
Less-preferred fuelwood						
Acacia sundra	17.5 ± 1.05	12.5 ± 1.1	6.6[c]	154.5 ± 10.9	162.5 ± 5.1	1.3[d]
Grewia oppositifolia	0.5 ± 0.25	1.0 ± 0.3	2.6[a]	192.0 ± 10.6	182.5 ± 12.2	1.2[d]

[a] Significance level of $P < 0.1$ for 3 degrees of freedom.
[b] Significance level of $P < 0.05$ for 3 degrees of freedom.
[c] Significance level of $P < 0.01$ for 3 degrees of freedom.
[d] Not significant for 3 degrees of freedom.

TABLE 4. BASAL AREA (TREE LAYER + UNDERSTORY) OF SIX NTFP (TWO FRUIT CROP, TWO PREFERRED FUELWOOD AND TWO LESS-PREFERRED FUELWOOD) SPECIES IN DISTANT AND PROXIMAL STAND IN SCRUB FOREST.

Species	Basal area (m^2 ha^{-1})		t value
	Distant stand	Proximal stand	
Fruit crop			
Phyllanthus emblica	0.62 ± 0.08	0.11 ± 0.02	12.37[a]
Strychnos potatorum	0.56 ± 0.05	0.41 ± 0.04	4.68[a]
Preferred fuelwood			
Anogeissus latifolia	2.38 ± 0.19	0.96 ± 0.13	12.34[a]
Chloroxylon swietenia	0.59 ± 0.09	1.42 ± 0.07	14.56[a]
Less-preferred fuelwood			
Acacia sundra	0.79 ± 0.04	0.59 ± 0.02	8.94[a]
Grewia oppositifolia	0.48 ± 0.02	0.35 ± 0.02	9.19[a]

[a] Significance level $P < 0.01$ for 3 degrees of freedom.

nificant change in density from the distant to the proximal stand (Table 3). Nonetheless, the basal area of this species decreased marginally from the distant to the proximal stand (Table 4).

In contrast with the fruit crop species, the density of preferred fuelwood species (*A. latifolia* and *C. swietenia*) increased from distant to proximal site in both the vegetation strata; however, understory density of *A. latifolia* decreased from the distant to the proximal site (Table 3). The increase in density caused a significant rise in basal area, particularly in case of *C. swietenia* (Table 4). The basal area of *A. latifolia* declined, presumably due to a decrease in its density in understory (Table 4). The less preferred fuelwood species (*G. oppositifolia* and *A. sundra*) did not show a conspicuous difference in density between the two stands, except a decline in tree density of *A. sundra* from distant to proximal stand (Table 3). Although the densities of less preferred fuelwood species remained almost unchanged, their basal area declined significantly from distant to proximal stand (Table 4).

POPULATION STRUCTURE

The overall population structure does not differ between proximal and distant sites, with >96% of the individuals in the 1–10 cm size class, both for all species combined and for the six combined NTFP species. More detailed examination of the size class distribution within the smaller individuals (<10 cm) reveals that the frequency distribution of all species in 1–10 cm dbh classes is asymmetrical normal both in distant and proximal stands (Fig. 1a). Lesser number of individuals in 1–2 cm dbh class in the proximal stand, and 1–2 cm and 2–3 cm dbh classes in the distant stand, indicates a decline in the recruitment of individuals. If this decline in recruitment is due to poor regeneration of the six NTFP species, a plot of frequency distributions separately for NTFP species and all other species should demonstrate the differences better. As shown in Fig. 1b there is a conspicuous lack of recruitment in 1–2 cm and 2–3 cm dbh classes, both in the distant and the proximal stands, in case of NTFP species. Other species, however, lack regeneration only in 1–2 cm dbh class, but to not the extent of NTFP species (Fig. 1c). The impact of NTFP extraction on population structure is more pronounced in "all species," "NTFP species" and "other species" categories in the proximal stand than those in the distant stand (Fig. 1a,b,c). In other words, the rate of mortality of individuals is higher in proximal than distant stand irrespective of whether the species belong to the NTFP category. The frequency distribution of the individuals belonging to 1–10 cm dbh class into 1 cm wide subclasses characterizes the population structure more explicitly (Fig. 2). All the six NTFP species exhibit asymmetrical normal distribution with reduced recruitment in smaller size-classes and increased mortality in bigger size classes. The mode varies in shape and position for different species due to varied skew. The skew increases from the distant to the proximal site for all species, except *P. emblica* and *G. oppositi-*

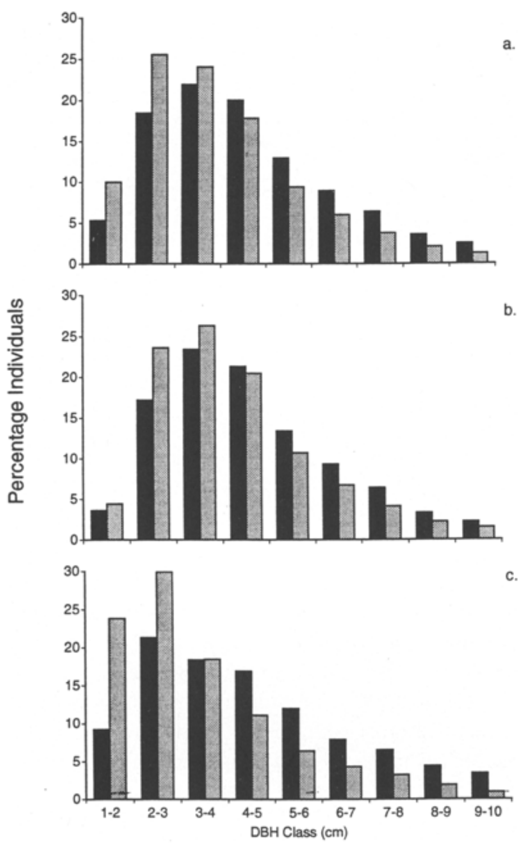

Fig. 1. A comparison of composite diameter frequency distribution between the distant stand (black) and the proximal stand (grey) of all individuals ≥1 cm but <10 cm dbh, separately for all species (a), six NTFP species (b) and those other than NTFP species (c).

folia. The species extracted for fruits severely lack recruitment in 1–2 and 2–3 cm dbh classes (Fig. 2a,b). A lack of recruitment in 1–2 cm dbh class, and a severe mortality in 7–8 cm dbh class and beyond is noted for fuelwood species (Fig. 2c–f).

Discussion

Although the scrub forest in the BRT Wildlife Sanctuary is currently protected from indiscriminate disturbance such as clearfelling, the floristic composition and population structure of the forest continue to be impacted by NTFP extraction. This study demonstrates that extraction of NTFP's is correlated with a) a decline in stand density and basal area, b) an increase in the dominance of small woody species over large woody species, and c) a decrease in the recruitment of NTFP species.

A decline in stand density and basal area from distant to proximal site was a general community level response to NTFP extraction. Higher levels of NTFP extraction, particularly of poles and fuelwood from trees and larger (>7 cm dbh) individuals in the understory were presumably the major factors responsible for this trend. A greater positive skew in the composite population structure of all species (Fig. 1a) and NTFP species (Fig. 1b) at the proximal than at the distant site explains the increased woodcutting/mortality of individuals. A decline in density and basal area has been reported as a consequence of NTFP extraction in a dry deciduous community (Murali et al. 1996), and as a consequence of other forms of anthropogenic pressure such as selective logging and fuelwood cutting.

An increasing dominance of small woody species over large woody species was evident in several ways. Species richness in tree layer declined from 29 at distant site to 24 at proximal site. All of the five species absent at the latter site belonged to large woody species category. Field observations suggest that the Soligas prefer large woody species over small woody species as a fuel source because the large woody species have a) favorable architecture in form of a prominent trunk and branches, accumulating greater biomass per unit volume, and b) collection facilitated by the lack of spiny structures. On the other hand, species richness in understory increased from 51 at the distant site to 58 at the proximal site. Here again, 9 small woody species were added, while large woody species were lost from the proximal site. In addition to an increase in richness, small woody species had greater density and basal area in the community. Increasing dominance of small woody species suggests that a dry deciduous forest may degrade to a thorn scrub forest in the face of anthropogenic pressures. Pascal (1988) has suggested that as deciduous forest becomes open, low, and stunted following anthropogenic pressures, the extremely dry conditions favor small woody species that are more resistant to dry conditions.

The impact of extraction on individual NTFP species varied depending on the plant part extracted and the intensity of extraction. The species extracted for fruits, *P. emblica* and *S. potatorum*, exhibited a decline in density and basal area. Furthermore, this decline was more severe for the for-

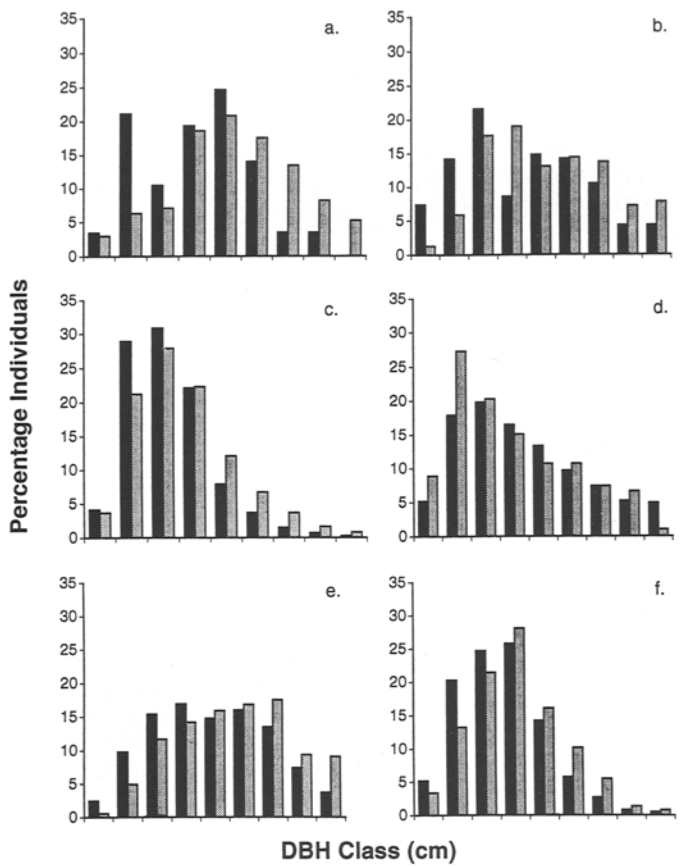

Fig. 2. A comparison of diameter frequency distribution between the distant stand (black) and the proximal stand (grey) of all individuals ≥1 cm but <10 cm dbh, individually for six NTFP species. a: *Phyllanthus emblica* (ds: n = 269, skew = 0.372; ps: n = 57, skew = 0.284); b: *Strychnos potatorum* (ds: n = 153, skew = −0.286; ps: n = 162, skew = 0.511); c: *Anogeisus latifolia* (ds: n = 2365, skew = 0.649; ps: n = 1985, skew = 0.859); d: *Chloroxylon swietenia* (ds: n = 271, skew = 0.223; ps: n = 515, skew = 0.335); e: *Acacia sundra* (ds: n = 309, skew = −0.706; ps: n = 162, skew = −0.638); f: *Grewia oppositifolia* (ds: n = 384, skew = 0.650; ps: n = 365, skew = 0.477).

mer (experiencing more intense harvest) than the latter (experiencing less intensive harvest). Among the fuelwood species, *A. latifolia* registered a decrease and *A. sundra* and *G. oppositifolia* registered no change in density, but basal area of all these species declined with increase in extraction levels. On the other hand, *C. swietenia* showed a remarkable increase in its dominance (density and basal area) in the community. Increasing dominance of *C. swietenia* as a function of increasing levels of NTFP extraction is probably favored by its wind dispersal mode. Ganeshaiah et al. (1998) found in the dry deciduous forests of the BRT sanctuary that wind dispersed species are favored over animal dispersed or passively dispersed species as a consequence of increasing anthropogenic pressure in form of NTFP extraction. Of the six major NTFP species in BRT scrub, *P. emblica, S. potatorum* and *G. oppositifolia* are animal dispersed, *A. latifolia* is passively dispersed, *A. sundra* exhibits passive to wind dispersal mode, and *C. swietenia* is wind dispersed. The dispersal in *C. swietenia* occurs through light-weight, winged seeds.

The anthropogenic pressures on the BRT sanctuary not only have altered the stand structure, but also may be responsible for changes in large scale vegetation units. The scrub forests themselves may represent degradation of dry deciduous forests from persistent human pressures going back many, many decades, if not not a few centuries. The first source of evidence for this arguement is a great deal of similarity in floristic composition between the scrub (this study) and dry deciduous (Murali et al. 1996) forests in BRT sanctuary. In fact, more than 80% of large woody species found in BRT scrub are in common with the dry deciduous forest. Moreover, the dominant family in both these forests is Combretaceae by virtue of the dominance of *A. latifolia.*

The second piece of evidence of downward transition of BRT scrub comes from an occasional occurrence of large sized (>30 cm dbh) individuals typically found in dry deciduous forests as reflected in composite population structure of all species both in distant and proximal stands. The large sized individuals were well spread over all sample transects, indicating a more or less random distribution pattern. This leads to the conclusion that the formerly existing dry deciduous community was well spread over study area.

The third form of evidence is the preponderance of small sized individuals, which is an expression of a successional community indicating a past disturbance in the form of large scale extraction of various forest products including timber. The composite population structure of all species in BRT scrub exhibited a L-shape curve both at proximal and distant sites, indicating a very high concentration (*ca.* 96%) of small sized (≥1 to <10 cm dbh) individuals. A strong bias for small size of individuals as a consequence of past clearing has been observed at Chamela in Mexico (Lott, Bullock, and Solis-Magallanes 1987) and Guanica in Puerto Rico (Murphy and Lugo 1986). While studying the *terra firme* Amazonian rainforests, Boom (1986) also reported the abundance of small diameter individuals as an evidence of an early successional community. The old forest records confirmed that the extraction of wood for fuel and agricultural implements has been reckless prior to the introduction of planned management (Anonymous 1911).

Finally, the last source of evidence is the location of settlements and the demographic patterns within and around BRT sanctuary that suggests the long persisting nature of anthropogenic pressure for a variety of forest products. While Soliga aborigines have inhabited the core forest, a large population of other ethnic groups has been residing on the fringe of BRT sanctuary for many decades. The current population at higher elevations (core forest) is only about 7000 in comparison to 66000 people at foot hills (fringe), resulting into a substantially more pressure for woodcutting at the foot hills (85%) than at higher hills (15%) (Uma Shankar, Hegde and Bawa 1997).

Conclusions

With increasing depletion in biological diversity, more forested areas in India and other countries are being incorporated into the existing protected area network as reserve forests, wildlife sanctuaries, or national parks. The protected conservation areas curb logging for timber, thus depriving the forest dwellers of a principal source of income through logging labor. Efforts have been made to mitigate the financial hardship of the forest dwellers by allowing them to collect NTFPs in some protected areas, such as the BRT Sanctuary. However, there is a lack of consensus about the quantities of NTFPs that may be extracted without deleterious impact on populations of NTFP species. This study shows that continued NTFP harvest, without management interventions, may lead to substantial changes in various phytosociological attributes of a forest community. The density and basal area, and consequently biomass may decline. Small woody species may increase at the expense of large woody species. The population structure of target NTFP species may become more skewed due to increasing mortality and lack of regeneration. The forest community may thus degrade. Management interventions, as in the case of timber extraction, may be required to spread NTFP extraction over a large area; for example, dividing the forest area into 'compartments', extracting a few compartments at a given time, and allowing the forest to recover following extractions. The level of harvests can also be reduced and the reduction can be accompanied by value additions of NTFPs (Uma Shankar et al. 1996) so that the total income of the local community is increased rather that reduced.

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APPENDIX I. FLORISTIC COMPOSITION OF TREE LAYER (INDIVIDUALS ≥10 CM DBH) IN DISTANT AND PROXIMAL STANDS OF SCRUB FOREST IN BRT SANCTUARY WITH FREQUENCY, DENSITY, BASAL AREA AND IMPORTANCE VALUE (IVI) OF EACH SPECIES. EACH SPECIES HAS BEEN CLASSIFIED INTO LARGE WOODY SPECIES (LWS) OR SMALL WOODY SPECIES (SWS) CATEGORY. THE SPECIES ARE ARRANGED IN DESCENDING ORDER ACCORDING TO THE IMPORTANCE VALUE CALCULATED AFTER POOLING OF DATA FOR THE TWO STANDS. SPELLINGS AND AUTHORITIES OF THE SPECIES HAVE BEEN ADOPTED FROM BRANDIS (1906). THE MEASUREMENT UNIT OF DENSITY IS PER 2 HA AREA, AND THAT OF BASAL AREA IS CM^2 PER 2 HA.

			Distant sites				Proximal sites				
Botanical name	Soliga name	Family	Fre-quency	Density	Basal area	IVI	Fre-quency	Density	Basal area	IVI	Nature of species
Chloroxylon swietenia DC.	Urgilu	Meliaceae	11	21	4444	30.0	19	46	11 956	75.4	SWS
Acacia sundra DC.	Kaggali	Mimosoideae	15	35	4734	40.9	13	25	2867	34.8	SWS
Strychnos potatorum L.	Chilla	Loganiaceae	8	33	5922	36.4	11	23	3681	33.6	SWS
Anogeissus latifolia Wall.	Bejja	Combretaceae	6	9	1187	12.3	12	21	6841	41.1	LWS
Morinda tinctoria Roxb.	Maddi	Rubiaceae	10	18	3330	25.1	4	4	1885	11.0	SWS
Vateria indica L.	Dhupa	Dipterocarpaceae	3	5	8621	24.7					LWS
Dalbergia lanceolaria L.	Buduga	Papilionatae	7	12	2340	17.3	3	3	1173	7.6	LWS
Erythroxylon monogynum Roxb.	Jeevdale	Erythroxylaceae	1	1	165	1.7	8	12	2834	22.0	SWS
Zizyphus sp.	Totti	Rhamnaceae	2	2	2022	7.3	5	7	2127	14.3	SWS
	Kanneru		10	12	1611	18.3					SWS
Diospyros melanoxylon Roxb.	Tubare	Ebenaceae	3	3	1319	7.1	2	4	1097	7.0	LWS
Phyllanthus emblica L.	Nelli	Euphorbiaceae	3	6	603	6.9	3	3	764	6.6	LWS
Boswellia serrata Roxb.	Chalugedhupa	Burseraceae	4	7	1557	10.5	1	1	82	1.8	LWS
Terminalia crenulata Roth.	Matti	Combretaceae	5	10	1212	12.0					LWS
Bridelia retusa Spreng.	Sironne	Euphorbiaceae	3	7	1361	9.1					LWS
Terminalia paniculata Roth.	Uluge	Combretaceae	3	5	769	6.8	1	1	430	2.6	LWS
Shorea talura Roxb.	Jala	Dipterocarpaceae	4	6	824	8.3					LWS
Maytenus emarginata (Willd.) Ding Hou	Tandarchi	Celastraceae	1	1	111	1.6	3	3	711	6.5	SWS
Zizyphus xylopyrus Willd.	Gotti	Rhamnaceae	3	3	474	5.2	1	1	111	1.9	LWS
Pterocarpus marsupium Roxb.	Honne	Papilionatae					2	2	1747	7.4	LWS
Buchanania lanzan Spreng.	Murki	Anacardiaceae	1	1	82	1.6	2	2	238	3.8	LWS
Grewia oppositifolia Roxb.	Dadasu	Tiliaceae	1	1	104	1.6	2	2	234	3.8	SWS
Naringi crenulata (Roxb.) Nicols.	Naibela	Rutaceae					2	2	658	4.8	SWS

APPENDIX I. CONTINUED.

Botanical name	Soliga name	Family	Distant sites: Fre-quency	Density	Basal area	IVI	Proximal sites: Fre-quency	Density	Basal area	IVI	Nature of species
Mitragyna parvifolia (Roxb.) Korth.	Kadaba	Rubiaceae					1	1	1029	4.1	LSW
Cassia fistula L.	Kakke	Caesalpinoideae	1	1	113	1.6	1	1	177	2.0	LSW
Santalum album L.	Gandha	Santalaceae	1	1	189	1.8	1	1	87	1.8	SWS
Acacia sinuata (Lour.) Merr.	Sige	Mimosoideae	1	1	79	1.5	1	1	79	1.8	SWS
Terminalia chebula Retz.	Arale	Combretaceae	2	2	209	2.9					LWS
Ixora brachiata Roxb.	Garuva	Rubiaceae	1	2	173	2.2					SWS
Acacia latronum Willd.	Sarai	Mimosoideae					1	1	177	2.0	SWS
Gardenia gummifera L.	Doddakambi	Rubiaceae	1	1	126	1.7					SWS
Limonia acidissima L.	Bela	Rutaceae					1	1	155	2.0	SWS
	Kappali		1	1	97	1.6					LWS
Stereospermum personatum Chatterjee	Padure	Bignoniaceae	1	1	80	1.5					LWS
Total	34 species		113	208	43 858	300	100	168	41 140	300	

APPENDIX II. FLORISTIC COMPOSITION OF UNDERSTORY (INDIVIDUALS $\geq$1 CM AND $<$10 CM DBH) IN DISTURBED AND PROXIMAL STANDS OF SCRUB FOREST IN BRT SANCTUARY WITH FREQUENCY, DENSITY, BASAL AREA AND IMPORTANCE VALUE (IVI) OF EACH SPECIES. EACH SPECIES HAS BEEN CLASSIFIED INTO LARGE WOODY SPECIES (LWS) AND SMALL WOODY SPECIES (SWS) CATEGORY. THE SPECIES ARE ARRANGED IN DESCENDING ORDER ACCORDING TO THE IMPORTANCE VALUE CALCULATED AFTER POOLING OF DATA FOR THE TWO STANDS. SPELLINGS AND AUTHORITIES OF THE SPECIES HAVE BEEN ADOPTED FROM BRANDIS (1906). THE MEASUREMENT UNIT OF DENSITY IS PER 2 HA AREA, AND THAT OF BASAL AREA IS CM^2 PER 2 HA.

Botanical name	Soliga name	Family	Distant sites: Fre-quency	Density	Basal area	IVI	Proximal sites: Fre-quency	Density	Basal area	IVI	Nature of species
Anogeissus latifolia Wall.	Bejja	Combretaceae	20	2365	46 420	84.3	20	1985	31 399	77.1	LWS
Chloroxylon swietenia DC.	Urgilu	Meliaceae	16	271	7311	14.1	20	515	16 362	31.6	SWS
Acacia sundra DC.	Kaggali	Mimosoideae	20	309	10 979	18.5	20	325	8868	20.2	SWS
Grewia oppositifolia Roxb.	Dadasu	Tiliaceae	20	384	9404	18.7	20	365	6782	18.9	SWS
Phyllanthus emblica L.	Nelli	Euphorbiaceae	20	269	11 777	18.4	17	57	1510	6.6	LWS
Strychnos potatorum L.	Chilla	Loganiaceae	15	153	5271	10.1	17	162	4554	11.8	SWS

APPENDIX II. CONTINUED.

Botanical name	Soliga name	Family	Distant sites: Fre-quency	Distant sites: Density	Distant sites: Basal area	Distant sites: IVI	Proximal sites: Fre-quency	Proximal sites: Density	Proximal sites: Basal area	Proximal sites: IVI	Nature of species
Catunaregam rugulosa (Thw.) Tiruv.	Kare	Rubiaceae	13	158	847	6.4	20	395	1670	14.5	SWS
Erythroxylon monogynum Roxb.	Jeevdale	Erythroxylaceae	14	51	2210	5.6	20	167	6418	14.5	SWS
Pterolobium hexapetalum (Roth) Sant. & Wagh.	Inda	Caesalpinoideae	8	41	1923	4.0	19	152	5912	13.4	SWS
Boswellia serrata Roxb.	Chalugedhupa	Burseraceae	20	198	5331	12.1	7	38	850	3.3	LWS
Maytenus emarginata (Willd.) Ding Huo	Tandarchi	Celastraceae	12	44	2161	5.0	19	127	3685	10.7	SWS
Diospyros melanoxylon Roxb.	Tubare	Ebenaceae	19	98	2031	7.4	15	47	1069	5.5	LWS
Gardenia latifolia Aiton	Sannakambi	Rubiaceae	18	187	1900	8.8	3	3	13	0.8	LWS
Terminalia chebula Retz.	Arale	Combretaceae	18	100	2324	7.5	5	8	183	1.5	LWS
Zizyphus oenoplia (L.) Mill.	Sudli	Rhamnaceae	2	6	524	0.9	19	95	2650	9.0	SWS
Dalbergia lanceolaria L.	Buduga	Papilionatae	15	55	1375	5.3	11	22	345	3.3	LWS
Zizyphus xylopyrus Willd.	Gotti	Rhamnaceae	16	33	1081	4.9	12	23	547	3.8	LWS
Terminalia crenulata Roth.	Matti	Combretaceae	12	118	3177	7.2	1	2	35	0.3	LWS
Morinda tinctoria Roxb.	Maddi	Rubiaceae	13	33	1277	4.4	10	18	635	3.3	SWS
Stereospermum personatum Chatterjee	Padure	Bignoniaceae	14	42	1137	4.6	8	15	439	2.6	LWS
Naringi crenulata (Rosb.) Nicols.	Naibela	Rutaceae	6	13	308	1.8	15	58	1117	5.8	SWS
Diospyros sp.	Asare	Ebenaceae	7	24	331	2.2	10	28	567	3.5	SWS
	Kanneru		13	28	1401	4.4	3	3	118	0.9	SWS
Bridelia retusa Spreng.	Sironne	Euphorbiaceae	12	33	1193	4.1	3	4	19	0.8	LWS
Acacia sinuata (Lour.) Merr.	Sige	Mimosoideae	10	31	761	3.3	6	8	77	1.6	SWS
	Tarade						14	41	840	4.9	SWS
Cassia fistula L.	Kakke	Caesalpinoideae	7	18	668	2.3	7	8	391	2.2	LWS
Terminalia paniculata Roth.	Uluge	Combretaceae	9	34	1513	3.7	2	2	51	0.6	LWS
Ficus bengalensis L.	Ale	Moraceae	11	26	486	3.2	1	1	3	0.3	LWS
Pterocarpus marsupium Roxb.	Honne	Papilionatae	7	8	152	1.8	6	13	253	1.9	LWS
Buchanania lanzan Spreng.	Murki	Anacardiaceae	10	21	451	2.9	1	1	26	0.3	LWS
Shorea talura Roxb.	Jala	Dipterocarpaceae	5	51	1162	2.9					LWS
Lantana camara L.	Lantana	Verbenaceae	1	3	29	0.3	9	18	327	2.8	SWS
Zizyphus sp.	Totti	Rhamnaceae	3	5	106	0.8	6	11	586	2.2	SWS
Dodonaea viscosa L.	Angarike	Sapindaceae	7	17	223	2.0	3	4	9	0.8	SWS
Gardenia gummifera L.	Doddakambi	Rubiaceae	8	31	467	2.6					SWS
Lagerstroemia parviflora Roxb.	Chennangi	Lythraceae	7	27	744	2.6					LWS
	Notadake		10	13	147	2.5					SWS
Bauhinia racemosa L.	Kittarasa	Caesalpinoideae	1	1	15	0.2	8	12	347	2.4	SWS

APPENDIX II. CONTINUED.

Botanical name	Soliga name	Family	Distant sites				Proximal sites				Nature of species
			Fre-quency	Density	Basal area	IVI	Fre-quency	Density	Basal area	IVI	
Atlantia monophylla Correa	Kadunimbe	Rutaceae	4	7	72	1.0	5	10	78	1.4	SWS
Schrebera swietenioides Roxb.	Gante	Oleaceae	3	6	145	0.9	4	5	270	1.3	LWS
	Marade		5	9	220	1.4	2	2	11	0.5	SWS
Acacia latronum Willd.	Sarai	Mimosoideae	1	1	94	0.3	5	5	238	1.5	SWS
Ixora brachiata Roxb.	Garuva	Rubiaceae	6	16	238	1.8					SWS
Vitex altissima L.	Naviladi	Verbenaceae					5	6	397	1.7	SWS
Santalum album L.	Gandha	Santalaceae					4	6	189	1.2	SWS
Canthium sp.	Kudgilu	Rubiaceae					3	4	243	1.0	SWS
Capparis zeylanica L.	Kattari	Capparidaceae					4	4	144	1.1	SWS
Premna tomentosa Willd.	Inje	Verbenaceae	1	1	13	0.2	3	3	118	0.9	SWS
Canthium parviflorum Lam.	Doddakare	Rubiaceae					3	4	77	0.9	SWS
Limonia acidissima L.	Bela	Rutaceae					3	4	69	0.8	SWS
Securinega leucopyrus Muell.-Arg.	Huli	Euphorbiaceae	1	1	3	0.2	2	4	31	0.6	SWS
	Nagare		2	4	16	0.5					SWS
Tectona grandis L.	Teak	Verbenaceae	2	3	4	0.5					LWS
Vateria indica L.	Dhupa	Dipterocarpaceae	2	2	69	0.5					LWS
	Matile						1	3	63	0.4	SWS
Diospyros montana Roxb.	Jagalganti	Ebenaceae					2	2	18	0.5	LWS
Givotia rottleriformis Griff.	Bhutale	Euphorbiaceae					2	2	17	0.5	SWS
Mitragyna parvifolia (Roxb.) Korth.	Kadaba	Rubiaceae					1	1	81	0.3	LWS
	Kappali						1	1	26	0.3	LWS
	Nageambu						1	1	3	0.3	SWS
Albizzia odoratissima Benth.	Sele	Mimosoideae	1	1	27	0.3					LWS
Cochlospermum gossypium DC.	Bettatavare	Bixaceae					1	1	3	0.3	SWS
Cordia obliqua Willd. var. *tomentosa*	Selle	Boraginaceae					1	1	16	0.3	LWS
Dendrocalamus sp.	Bamboo	Poaceae					1	1	9	0.3	SWS
Feronia elephantum Correa	Antinbela	Rutaceae	1	1	35	0.3					SWS
Holarrhena antidysenterica Wall.	Beppale	Apocynaceae	1	1	6	0.2					LWS
Jasmium auriculatum Vahl.	Jaji	Oleaceae					1	1	8	0.3	SWS
Toddalia asiatica (L.) Lam.	Kadumenasu	Rutaceae					1	1	2	0.3	SWS
Total	69		469	5352	129 559	300	433	4805	100 758	300	