Biodiversity and Conservation **12:** 1051–1072, 2003.

Human disturbance and forest diversity in the Tansa Valley, India

RADHA VEACH[1], DAVID LEE[2,3,*] and TOM PHILIPPI[2]
[1]A1/301 Kumar Prerama, Aundh, Pune-7, India; [2]Department of Biological Sciences, Florida International University, FL 33199, USA; [3]Fairchild Tropical Garden, Miami, FL 33199, USA; [*]Author for correspondence (e-mail: leed@fiu.edu; fax: +1-305-348-1986)

Received 31 October 2001; accepted in revised form 30 May 2002

Key words: Biodiversity, Disturbance, Forests, India, Tropical deciduous

Abstract. We assessed the diversity of woody plants at 15 forested sites in the Tansa Valley of Thane District, in Maharashtra, India. The fewest species (11) were seen at a degraded mangrove site near the river mouth, and the greatest number (150) in the rich semi-evergreen forest on Tungar Hill. For all sites there were 141 tree, 25 shrub and 15 liana species, a total of 181 species. Excluding the mangrove site, which had no species in common with the other 14 sites, we analyzed the species distributions in detail. These sites ranged in area from 4 to 30 km^2 each, had woody floras of 89 ± 6 species, and varied in intensity of human impact. Despite a history of exploitation and substantial reduction in biomass from firewood collecting, set fires and illicit tree felling, considerable plant diversity remains in the area. We found a modest increase in species richness in transects away from two villages. We observed the exploitation of the forest by the principal users, primarily of the Warli Tribe. They exploited a wide variety of forest resources (92 species), for medicines, foods, construction materials, household goods, manure and other purposes. They collected 15 items for sale. By far the single most important item collected was firewood, which dramatically reduced forest biomass within 2 km of villages. The species distributions in these forest remnants are strongly nested, mostly due to varying degrees of disturbance at individual sites. The high species diversity on Tungar Hill is most likely a relict of the earlier character of forests throughout much of the valley. It merits the highest priorities for preservation, as a refuge for Western Ghat species at the northern limits of their distributions.

Introduction

Few forested areas on our planet have not been influenced by human activity. Yet, the effects of long-term human influences on forest biodiversity are not very well understood. India's forests have been exploited for millennia, and particularly intensely during the past two centuries. Here we describe and analyse the patterns of woody plant diversity in 15 isolated forest tracts in the Tansa Valley, a rural area northeast of Mumbai in the Thane District, Maharashtra, India (Figure 1a). We speculate about the influences on this diversity, particularly human activity, in the forest remnants.

Floristic diversity and forest types in the Tansa Valley

The Tansa Valley has been studied floristically in the past. Collections in the region

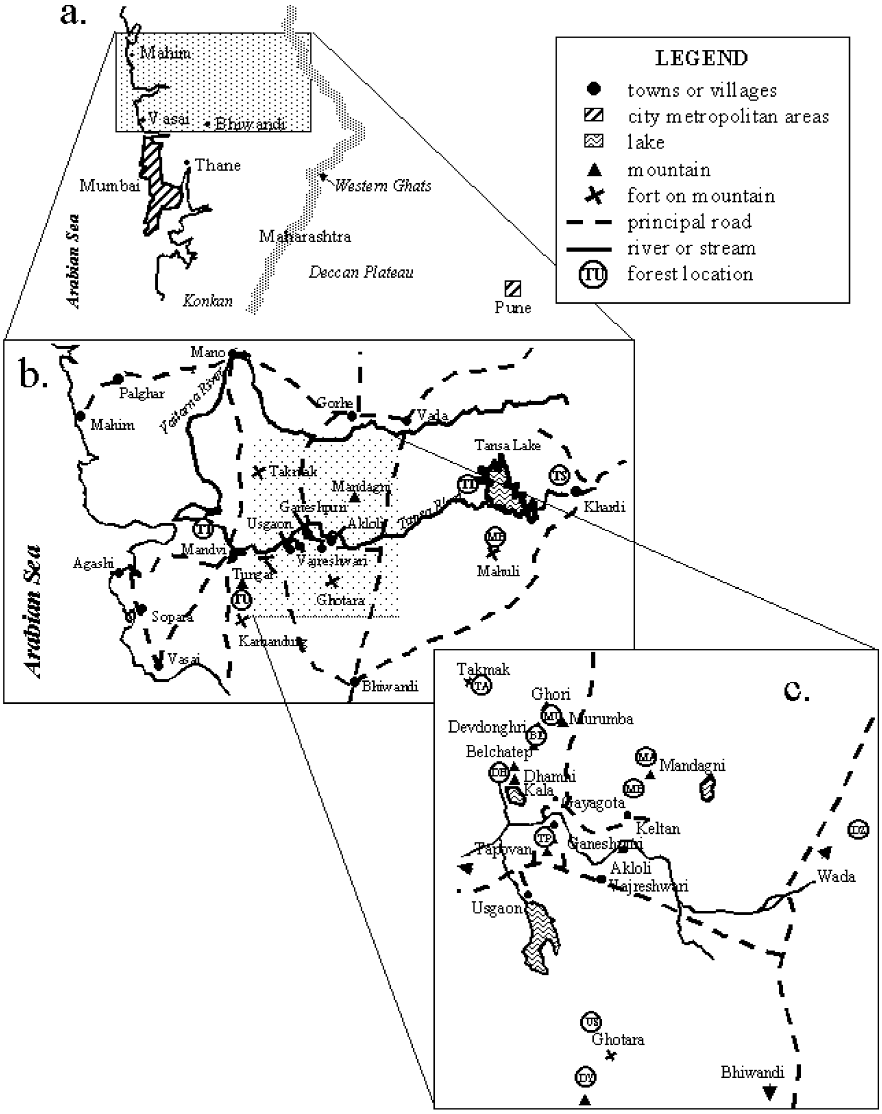

Figure 1. Map of the Tansa Valley, Thane District, in the State of Maharashtra north of Mumbai (Bombay), India. (a) General location of study area, (b) entire valley, (c) central part of the valley with most of the forest remnant locations indicated; symbols are provided in Table 1. The distance from east to west on this map is approximately 18 km.

helped in the completion of the floras of the Bombay Presidency by Cooke (1904) as well as the forest flora by Talbot (1894). Two dissertations (Billore 1972; Koshy and Shah 1987) have added to this information.

Champion and Seth (1968) described the forests of the Thane District as Moist Deciduous Forest Bearing Teak (Type 3B/C1b). Gaussen et al. (1966) described these forests as 'slightly humid' of the series *Tectona-Terminalia-Adina-Anogeissus*. At higher elevations (slightly lower temperatures and more precipitation) a different forest type occurs, described by Champion and Seth (1968) as part of the southern subtropical broadleaved hill forest (8A/C2), specifically the western subtropical hill forest. Gaussen et al. (1966) described these forests as dense and semi-deciduous. The forest types delineated by Champion and Seth and the French Institute were not viewed as pristine, but were partly the result of a history of human intervention. This use has opened up the forest, reduced its ability to store moisture, and has probably shifted the species composition to a more drought- and fire-tolerant mix. Widespread deforestation in the entire region may also have altered local climates (Meher-Homji 1979) by reducing precipitation, and altering the species composition of the remaining forests.

Assessing forest diversity

Standard ecological methods for assessing plant diversity involve the random or haphazard establishment of quadrats varying in size and shape, and the enumeration of individuals of species within the quadrats. These data are then subjected to a variety of statistical assessments. Species diversity in Indian tropical forests has been assessed in this way (Chandrashekara and Ramakrishnan 1994; Gaulier et al. 1995; Ganesh et al. 1996; Pascal and Pelissier 1996; Parthasarathy and Sethi 1997; Parthasarathy 1999; Rai 2000). The actual number of species of different classes (i.e. trees, shrubs, lianas) in these surveys was not large compared to the lists of species enumerated for the forests (Pascal 1986; Rai 2000), or compared to diversity documented in other tropical forests.

A problem in this approach, which may be exacerbated in vegetation with a history of disturbance, is that much of the diversity occurs in small refuges, physically isolated from disturbance or supplied with moisture from a small stream or spring. Thus, sampling with quadrats may substantially underestimate the total species diversity. For animal diversity, where mobility discourages the use of such sampling, species lists have long been a source of information for the analysis of isolated communities (Brown and Lomolino 1998). Recently, such methods of analysis have been applied to tree species diversity in forest remnants (Honnay et al. 1999; Ranta et al. 1999). New methods of the analysis of nestedness (Atmar and Patterson 1993; Jonsson 2001) have made such assessments of diversity even more attractive. An additional attractiveness of the use of species lists is that it becomes possible to enlist local knowledge in assessing plant diversity, without the necessity of detailed surveying of quadrats in the field.

The purpose of this research

In this study we address four questions. (1) What are the patterns of woody plant species distribution in the valley? (2) What factors are associated with forest diversity? These may include spatial proximity, elevation range, size of forest remnant, and disturbance intensity. (3) How might present diversity in forest

Table 1. Description of site locations for forest biodiversity surveys.

Abbreviations	Coordinates	Elevation (m)	Name and description; buffer distance (km)/disturbance	Survey area/total forest (km^2)	Species present			Total
					Trees	Shrubs	Lianas	
BE	72°59′ E 19°31′ N	20–300	Belchatep and Devdonghri Two hills north of river and west of Mandagni Peak; 10/5	4/80	63	10	6	79
DH	72°57′ E 19°31′ N	20–400	Dhamni and Kala Forest on two hills south of Takmak Mountain; 10/5	6/80	67	9	7	783
DY	73°02′ E 19°24′ N	50–520	Dyari Hill (US) Slopes and summit ridge adjoining Ghotara Peak; 9/6	8/22	93	12	10	115
DZ	73°07′ E 19°33′ N	50–405	Dauze Hill Isolated pyramid-like hill surrounded by industry; 4/3	6/12	55	6	4	65
MA	73°02′ E 19°32′ N	100–600	Mandagni Peak (MB) Slopes and summit plateau of prominent peak north of Ganeshpuri Village; 12/4	10/14	78	10	5	93
MB	73°01′ E 19°31′ N	20–50	Mandagni Peak Base (MA) Forest to south and southwest of mountain; 3/4	4/14	59	4	5	68
MH	73°14′ E 19°28′ N	100–900	Mahuli Fort Mountain Summit plateau and upper slopes north side; series of forts on all peaks; 10/6	10/65	73	14	5	92
MU	73°00′ E 19°34′ N	50–490	Murumba and Ghori Dongar (MA,TA) Hills northwest of Mandagni, near Nandni and Kalambhai villages; 10/5	6/80	77	10	6	93
TA	72°57′ E 19°34′ N	50–600	Takmak Fort Mountain (MU) To summit forest of main peak and large horn; fort site; 8/5	10/80	76	11	5	92

TL	73°14′ E 19°36′ N	100–150	Tansa Lakeside Forest along reservoir on north and west sides; 4/4	4/80	60	4	5	69
TP	73°00′ E 19°30′ N	20–50	Tapovan Hill Degraded forest on two small hills near Ganeshpuri Village; 1/4	3/3	60	5	4	69
TS	73°22′ E 19°36′ N	100–150	Tansa Source Forest Exploited forest near Khardi Village, along first 2 km of river; 15/3	4/70	50	6	6	62
TT	72°54′ E 19°30′ N	<5	Tansa Mouth Degraded mainly mangrove vegetation from Kanivde Village to confluence with Vaitarna River, tidal; 1/1	4/4	6	4	1	11
TU	72°55′ E 19°26′ N	40–700	Tungar Hill Slopes and summit plateau of most prominent peak in the area; 15/8	30/120	115	21	14	150
US	73°02′ E 19°26′ N	50–600	Usgaon Hills & Ghotara Peak (DY) Slopes, leading towards ridge and main peak south of Usgaon Reservoir, fort site; 8/4	14/22	86	13	8	107
				Totals	141	25	15	181

Each site is given an abbreviation (corresponding to locations on the maps in Figures 1 and 2), coordinates for longitude and latitude, elevations, and a brief description. Buffer distance is the furthest distance from the edge of the forest to the interior of the site, and disturbance (1–10) is described in the Methods section. Locations in parentheses; (BE) denotes another forest remnant connected by degraded forest.

remnants help us to reconstruct the composition of these forests earlier in history? (4) How do the tribal communities exploit these forest areas today, and what effect does this have on forest diversity and health? We obtained data to answer these questions through intensive sampling and the listing of woody species diversity at 15 forest remnants in the valley, three transects near villages adjacent to forest, and observations on minor forest product use by tribal groups. This research has allowed us to determine the places of highest diversity in the valley and the nature of current exploitation. These results will also help devise strategies for forest conservation in this region.

Sites and methods

Sites

The study sites are in the drainage of the Tansa River, 50 km north of Mumbai (Figure 1a). The valley is well known for its hot springs and pilgrimage sites. The Tansa Valley is characteristic of the Konkan, a narrow belt of land along the west coast from Goa in the south to Gujarat in the north. The region is underlain by basalt (Deccan trap) produced at the end of the Jurassic. Erosion has left low (500–900 m) isolated peaks in the valley. Alkaline dark heavy clay soils ('regur' or black cotton) cover most of the valley, with more weathered oxisols on the peaks. The tropical deciduous forests in the area have developed in seasonally dry tropical conditions (average temperature in January of 24 °C compared to 31° in April, and the southwest Monsoon, with rains (ca. 2500 mm) primarily in June–September (Santapau and Randeria 1970; Meher-Homji 1979).

Fifteen forested areas in the valley were selected and examined (Table 1, Figure 1a, b and c), representing the remaining forest cover in the valley. Woody plant diversity was sampled in forest patches of approximately 4–30 km^2. We estimated the size of the area surveyed and the maximum distance within the site to forest edge from our field work. Since all of the sites were heavily disturbed on their fringes, we term this value the 'buffer distance'. We also estimated the area of the total forest in which the fragment was surveyed from satellite imagery (PO94/RO59 L3 QU:2, 21 NOV96/11:21:34 F:N19:28:30/E73:01:20 and 23 JAN99/11:32:36 F:N19:23:09/E073:17:04, National Remote Sensing Agency, Hyderabad, India). We sampled areas that could be adequately sampled in five or more field days (3–14 km^2). The area on Tungar Hill was much larger because of its potentially higher diversity, and was visited over 20 times

Methods

The forest sites were visited by different routes and in different seasons, from 1995 to 2001. The elevations of individual plant observations were determined with an altimeter, and some locations were confirmed by GPS towards the end of the study.

Problematical species were checked against herbarium specimens from the

Blatter Herbarium (BLAT) at St Xavier's College, The Botanical Survey of India (BSI) in Pune, and the Royal Botanical Gardens, Kew (UK). Herbarium specimens were collected from rare or unidentified taxa and deposited in BLAT. We determined correct scientific names and authorities from Pascal (1986), Ambasta (1986), Almeida (1996–1998), Mabberley (1998), as well as the Index Kewensis. Some family names were changed according to contemporary research (The Angiosperm Phylogeny Group (APG) 1998).

We ranked the degree of forest disturbance at each site on a scale of increasing disturbance from 1 to 10, where 1 would be a forest of closed canopy, no evidence of timber cutting or extraction of minor forest products, with a canopy 20–25 m high, 5 would be occasional stumps of cut trees, evidence of frequent exploitation of minor forest products and a partly open canopy, and 10 would be no standing trees and numerous shrubs.

Two species, not strictly woody, were included because of their size, ecological importance and persistence (see Appendix): *Ensete superbum* and *Strobilanthes callosus*. We also have added some herbaceous species collected by tribal people to the Appendix, although these were not used for the diversity analyses.

We established two transects from the village of Usgaon and one from Keltan (Figure 1c), assessing the forest diversity at 500 m intervals (in 100 m wide strips) away from the villages. We determined the extent of tribal exploitation of forest resources primarily by observing and interviewing collectors during the ca. 150 trips in the forest. We also interviewed two knowledgeable informants from Usgaon Village and one from Gayagota Village, and visited village markets in Vajreshwari and Mandvi, interviewing vendors to determine the items sold and bartered by the tribal people.

The species richness of each forest fragment was indicated by the total number of observed woody species. We tested for the influence of the following factors potentially affecting species richness: (1) total sampled area (in km^2), (2) buffer distance (in km), (3) total forest area (in km^2), and (4) disturbance intensity (minimum of 1 to maximum of 10). The strength of these associations was tested with Spearman rank correlations. The independent contribution of two factors significantly associated with species richness was then assessed with Spearman partial correlations, removing the effect of the other factor. We completed these analyses in SAS v. 8.1 (SAS Institute, Cary, North Carolina).

To visualize the patterns in compositional similarity, non-metric multidimensional scaling was used to produce a graph in which the pairwise Euclidean distances between fragments in the graph were maximally (rank) correlated with the corresponding pairwise Jaccard compositional dissimilarities. Since the presence and absence of species was recorded, and not abundance, we chose the Jaccard metric to estimate compositional similarity between all pairs of fragments. It has the advantage that shared absences (species not present in either of the pair of fragments) are discounted and not considered indicative of any similarity (Legendre and Legendre 1998). Stress (lack of fit) was compared for solutions in 1–4 dimensions; two dimensions were adequate to reflect the variation. In order to test for broad spatial gradients we compared distance between all pairs of sites to their compositional similarity using a Mantel test. Similarly, we performed a Mantel test between pairwise compositional dissimilarity and corresponding differences in disturbance intensity.

Given the disagreement about methodology for estimating nestedness among the forest sites (e.g. Atmar and Patterson 1995; Cook and Quinn 1998), we used more than one method. We applied the 'temperature calculator' of Atmar and Patterson (1995) to provide an overall estimate comparable to existing literature. We also calculated row (the order of species richness in the 14 fragments) and column (the order of occurrences at the 14 sites for all species) marginals for the null model, compared with the observed distributions among the fragments. Finally we used the probabilistic null model RANNEST of Jonsson (2001) to test for nestedness in the strictest sense.

Results

The 15 sites varied in totals of woody species. The smallest value was 11 at a highly degraded mangrove tidal area (TT, Table 1). This area shared no species with the other areas and was excluded from the statistical analyses. The second least diverse site was degraded forest near the source of the Tansa River (TS), with 62 species. The most species-rich site was Tungar Hill, a large forest tract and the closest to the coast (Figures 1c and 2; Table 1), with 150 species. This site contained all but 20 of the total of 170 species observed at all sites other than the mangrove (see Appendix). The total for the 14 sites included 135 trees, 21 shrubs and 14 lianas (Table 1), with a mean total of 89 ± 6 (SE) species. The 14 sites varied in total woody species diversity, area surveyed, total forest area, maximum buffer distance, and degree of disturbance (Table 1, Figure 2).

The species richness varied in the three transects adjacent to two villages in the following ways. For the transect southwest of Usgaon (disturbance indices of 7, 7, 6, and 5 for 0.5 km increments away from the village), species totals were 60, 71, 52 and 61. For the transect northeast of Usgaon (indices of 7, 7, and 8), species totals were 35, 15 and 25. For the transect northwest of Kelthan (indices of 7, 7, 6, and 5), the species totals were 32, 42, 55 and 66. Twenty-four species were observed in 8/11 of the quadrats (see Appendix).

The species richness at the 14 sites was significantly correlated with the areas surveyed and disturbance intensity, but not correlated with maximum forest area or maximum buffer distance (Table 2, Figure 2). Survey area and disturbance intensity were moderately but not significantly correlated with each other (Spearman ρ = 0.488 and P = 0.075), and their separate effects were still significant on diversity after partialling out their effects on each other (Table 2, right column). These effects persisted even when the most diverse site (TU) was removed from the analysis.

Non-metric multidimensional scaling captured the patterns of species composition in two dimensions (Figure 3). The largest gradient in composition was species richness, from TU (150 species) to TS (62 species). A secondary gradient separated

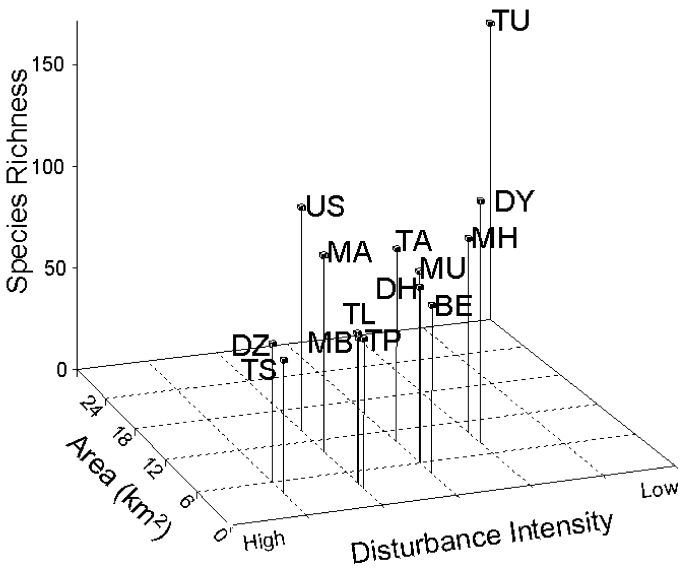

Figure 2. Relationship of species richness (total number of woody species in forest remnant to relative disturbance intensity) and the area of the forest observed (in km^2). Symbols for forest remnants are given in Table 1.

Table 2. Spearman Rank Correlations with species richness from the 14 forest remnants, with significances. Those with significance <0.05 are in bold.

	Direct	Partial
Survey area	**0.83**	**0.81**
	0.0002	0.0007
Disturbance	**0.75**	**0.71**
	0.002	0.006
Maximum area	0.28	
	0.326	
Maximum buffer	0.21	
	0.461	

the composition of TP (69 species) from DZ (65 species), which shared only 50 species, and in general separated the five sites with the lowest species richness.

The pairwise dissimilarities of species assemblages (Figure 3) were not significantly correlated with their distances from each other ($\rho = 0.268$, $P_{\mathrm{Mantel}} = 0.085$). Compositional dissimilarities from multidimensional scaling were also strongly correlated with differences in survey areas ($\rho = 0.411$, $P_{\mathrm{Mantel}} = 0.009$) and degree of disturbance ($\rho = 0.481$, $P_{\mathrm{Mantel}} = 0.002$).

Woody species compositions of these 14 fragments were highly nested. Patterson and Atmar's temperature of nestedness was 22.56°, with 39.7% of the matrix filled. The temperatures of the 999 randomizations averaged 66.16° with $\sigma = 2.68$, and none had temperatures <57°. Their accelerated significance test gave a probability

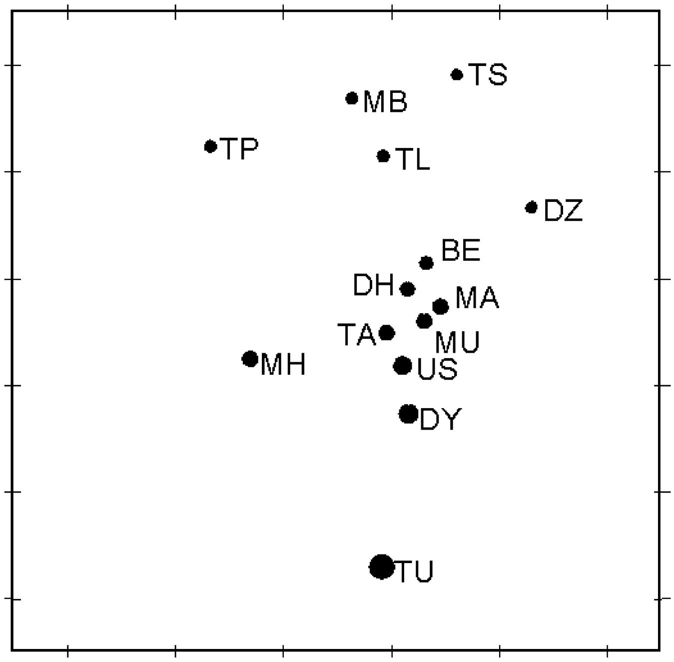

Figure 3. Multidimensional scaling, revealing patterns of compositional similarity among the 14 forest remnants. Symbols for forest remnants are given in Table 1. Sizes of circles reflect species richness in each of the remnants. The axes in this analysis have no dimensions.

$<1.2 \times 10^{-48}$, 12.26 standard deviations between the mean of the randomizations and the observed value. These sites also had more widespread species (on nearly all fragments) and more restricted species (on one or a few fragments) compared to the expected number of distribution in the Atmar and Patterson (1993) null hypothesis (Figure 4, which predicted a range of 71–95 species). Jonsson's (2001) null model for nestedness, conditional on the differences between species frequencies, was also rejected.

Rural dwellers, primarily tribal, collected products from 92 plant species, including eight herbs not censused in the site inventories. Since some species yielded more than one product, 127 items were collected. Some species yielded several items, like *Madhuca indica*. The four most important uses were medicines (45 species), fruit (27), timber (15) and vegetables (13). Fifteen commodities were sold in markets or to middlemen for cash, not including the value of some illicitly cut timber (Ballal 2000).

Discussion

Variation in forest diversity at sites within the Tansa Valley is correlated with other

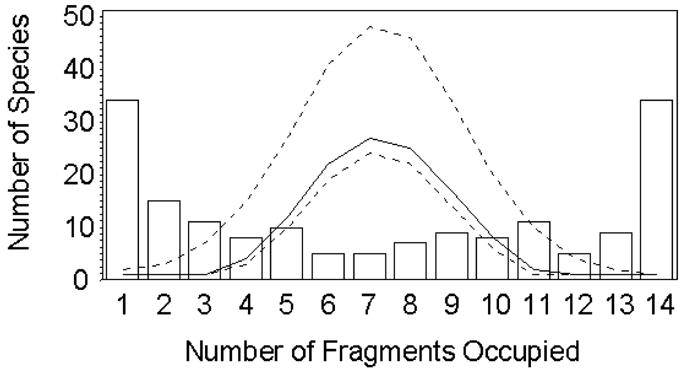

Figure 4. Number of species in relation to the number of fragments occupied. The solid curved line indicates the expected distribution of species if the hypothesis of nestedness is rejected; the dashed lines indicate 95% confidence intervals (Atmar and Patterson 1993, 1995).

site variables. Their analysis has helped us to understand the factors influencing species diversity in the valley, and changes in diversity over time.

Patterns of forest diversity

The diversity of the 14 forest remnants is comparable to that of similar sites in India and other seasonally dry regions in the tropics. The site with the most species was Tungar Hill (TU) with 150 species; the least diverse site (besides the mangrove site with 11 species, excluded from additional analysis) was a site near the river source (TS) with 62 species. These species totals approach or even surpass those published for wet evergreen forests (Chandrashekara and Ramakrishnan 1994; Ganesh et al. 1996; Pascal and Pelissier 1996; Rai 2000), but these estimates are from quadrats. The woody species diversity is less than that of similar sites in Indo-China (Rundel and Boonpragob 1995) or in Latin America (Gentry 1995). Dry forests in Mexico are more species-rich, with less annual rainfall (Lott et al. 1987).

The correspondences with the forest types of Champion and Seth (1968) and Gaussen et al. (1966) are not perfect; some differences would be expected between regions. These forests are floristically more diverse than those described at Sanjay Gandhi National Park in Mumbai (Santapau and Randeria 1970), the uplands on Elephanta Island (Satyanarayan 1959), and consistent with those at moister sites on Deccan trap soils (Legris and Meher-Homji 1979). The 24 predominant species (seen in 13/15 of the sites and 8/11 of the 100 $\times$ 500 m quadrats in the disturbance transects; see Appendix) are all persistent, resistant of fire and cutting, and are indicators of a history of disturbance. The higher frequency of teak is suggestive of this history of disturbance (as well as past silvicultural treatment).

Many species vary in presence from site to site, many are associated with more moist forest associations, and reveal much about the distribution of diversity in the forests, as well as effects of disturbance.

Truly remarkable in its high diversity is the semi-evergreen forest of Tungar Hill, with 150 woody species. Twenty-four of the species at all sites (out of 181 species) are unique to this one location. Other mesic species characteristic of hill forest were also found in neighboring peaks, like Mahuli, Takmak and Ghotara. *Macaranga peltata* and *Pavetta indica* occurred in areas below Ghotara and above Usgaon reservoir, as well as on Takmak, Dyari and Mahuli. *Diospyros Montana* also occurred on Mahuli, Ghotara and Usgaon, Takmak and Mandagni. *Glochidion hohenackeri* occurred on Tungar, Dyari, Takmak and Mahuli.

Legris and Meher-Homji (1977) described the predominant species of the hills of the Peninsula, including those of the northern portion of the Western Ghats, in moister and evergreen forests. Their moist forest species at these 14 sites include (with the number of sites in parentheses): *Dillenia pentagyna* (10), *Diospyros montana* (5), *Firmiana colorata* (9), *Lagerstroemia lanceolata* (13), *Macaranga peltata* (5), *Oroxylum indicum* (7), *Sterculia villosa* (9), *Toona ciliata* (1), and *Ensete superbum* (11). However, in our experience *D. montana*, *S. villosa* and *E. superbum* are actually very drought-tolerant. We would add *Mimusops elengi*, *Carallia brachiata*, *Mammea suriga*, *Ixora brachiata*, *Albizzia procera* and *Bauhinia malabarica* as indicators of moist forest. Four species described as diagnostic of wet evergreen forests were also found on these sites: *Garcinia indica* (2), *Spondias pinnata* (11), *Aporosa lindleyana* and *Sageraea laurifolia* (both TU only).

Despite Tungar's moderate elevation (Table 1), species that normally grow at much higher elevations have established there. Koshy and Shah (1987) had documented some of this diversity and shown its relationship to the flora at Khandala (Santapau 1954), having in common such taxa as *Diospyros montana, Garcinia indica* and *Mimusops elengi*. They noted 38 woody taxa from Tungar, also seen in our collections. We have found additional rare and unusual taxa from this location, 22 of these species not listed by Koshy and Shah: *Aglaia talbotii*, *Antidesma ghaesembilla*, *Caryota urens*, *Cleidion spiciflorum*, *Chukrasia tabularis* var. *velutina*, *Flacourtia montana*, *Gymnosporia konkanensis*, *Litsea glutinosa*, *Margaritaria indica*, *Persea macrantha*, *Spermadictyon suaveolens*, and others (see Appendix). Some of these species are very rare from this region, collected from the Konkan for the first time (V. Almeida, personal communication); *G. konkanensis* is endemic to this site. A similar list of species was also observed in the summit area of Kamandurg Fort, some 3 km to the south (unpublished observations). This entire region may well represent the largest remaining expanse of western subtropical hill forest (Champion and Seth 1968) in the Konkan, similar in diversity to Khandala to the south (Santapau 1954), but larger in area and perhaps less disturbed.

Factors influencing species diversity

Two factors were strongly correlated with diversity: the disturbance index and the size of the area surveyed (Figure 2, Table 2). Survey of a larger area should increase the probability of detecting rare species, although surveys within quadrats in the disturbance gradients yielded up to 71 species within only 5 ha. Initial recognition of diversity on Tungar led to a more careful surveillance of a larger area. However, the entire forest areas, represented by the sample areas, were not correlated with species richness. Although degree of disturbance was correlated with species diversity, the maximum buffer distance was not. All of the forest remnants were subject to intense pressures of exploitation on their edges. However, neither total size nor buffer distance explained the degree of disturbance within these sites. Some were more protected by steepness of slope and total elevation, distance from graded roads, and smaller human populations in nearby villages.

We expected that rarer species might be confined to the moistest and most remote sites at the highest elevations. The proximity of the isolated mountains to the coast increases their humidity and rainfall, which may lower the distribution limits of many of the trees of this forest (Whitmore 1984; Leuschner 1996), on Tungar Hill and, to a lesser extent, on other mountains in the valley. Actually, the highest elevations were dry and exposed, and most rare species occurred in small and protected valleys beneath the summits. Most of the rare species, including those growing exclusively on TU, actually grow over most of the elevation range, many near the base of the hill (see Appendix). Thus, elevation may not be a very important factor.

Analysis of nestedness (Brown and Lomolino 1998) has developed as a powerful tool in explaining geographical patterns of diversity. Where species assemblages are subsets within larger assemblages, explanations of such patterns invoke filters, such as barriers to dispersal or distance, that remove species from islands or isolated locations. The 14 sites in the Tansa Valley were strongly nested, both in total diversity and in similarity. Only 20 species out of the 170 in the Tansa Valley (removing the mangrove site) were not observed in the most species-rich site, TU. Thus the other locations principally had subsets of species present in this one site. The maximum and minimum number of species were thus significantly greater and smaller than predicted from the null model (Figure 4). However, contrary to a cluster of islands adjacent to a mainland, nestedness in the Tansa Valley was not associated with distance. Species dissimilarity was not associated with distance, despite the similarity and proximity of three of the more species-rich sites (DY, US and TA) to nearby TU (Figure 3).

Human disturbance

Presently the principal pressure on these sites is by tribal residents of villages near the forest margins. Four groups live in the valley: Koli, Warli, Thakur and Katkari (Anonymous 1982). The Warli traditionally used forest products and had an excellent knowledge of forest biodiversity (Save 1945). Such groups have lived in the area before and throughout this history. At low population densities their original impact on these forests was probably minor.

All of the sites were subject to this pressure on their margins, but some contained areas that were more protected because of isolation. Our qualitative assessments of the degrees of disturbance in the most isolated areas of the forest remnants, along with observations of forest products collected in these remnants, document these pressures. Certain observations (like tree stumps) document disturbance at least two decades ago.

The collection of firewood and illicit tree felling are particularly important near forest margins. Most visitors in the forests were collecting firewood. Only certain species important for other uses are exempt from such collecting. These include Mowha (*Madhuca indica*), used in the production of liquor, and fruit trees, particularly jamun (*Syzygium cumini*) and mango (*Mangifera indica*; see Appendix).

These collecting activities drop rapidly beyond 2 km, but other products are gathered throughout the forests. Our survey provides a low-end estimate of plant uses in these forests, particularly for medicinal plants. For instance, 19 additional species in our survey had medicinal uses by Adivasi in Karjat, just south of Thane District (Anonymous 1998). Fire is an additional human impact in these forests, mostly near villages, but burning up-slope for considerable distances. Collection of most minor forest products has little effect on forest structure and biomass, but may sometimes contribute to tree mortality (like gum collecting in *Sterculia urens*).

We assessed the human impacts on forest diversity near two villages, Usgaon and Keltan (Figure 1c). Forests adjacent to these villages were dramatically different compared to more isolated ones nearby, like the hills above Usgaon and those at the base of Mandagni Peak. Intense exploitation for firewood and timber dramatically reduced the biomass in these areas, and also reduced diversity. The only large trees close to the villages are those with a particular value for the villagers, e.g. fruit. Yet, considerable diversity of hacked and stunted plants persisted, even within 500 m of these villages; 35 species to the N–NE and 60 species to the SW of Usgaon Village, and 32 species NW of Keltan. Species diversity only increased with distance along the transect NW of Keltan. In the SW direction from Usgaon the further distances were close to a paved highway. The 1000–1500 m section of the transect NE of Usgaon was on a rocky ridge with fewer plants. The total forest diversity in each of these transects was less than that of the more intact forests studied at further distances, 106 species in Usgaon and Ghotara Peak, and 90 species on the summit and slopes of Mandagni Peak. Presumably the species surviving in the areas near villages are particularly resistant to repeated lopping for firewood, fires and browsing by animals. Still, woody plant diversity is surprisingly high near the villages. These species, typically those with the widest distributions in the valley (see Appendix), are extremely resilient.

All of these sites are within lands managed as Reserve Forest by the Maharashtra Forest Department. Selective cutting continued in these forests, but probably less extensively than by the British (the extraction roads were abandoned), and cutting had been banned by central government decree since 1988. Unfortunately detailed records were not available, but extensive logging had not been observed in these areas for 20 years.

Disturbance history in the Tansa Valley

Over 2500 years of disturbance have affected the forests of the valley, particularly near the river, but it is unclear if demand for timber was great enough to extend well into the isolated hills and these 14 sites until the last two centuries.

The Tansa Valley was a major transportation corridor between the Deccan and the coast, particularly for the important Buddhist center of Sopara (fifth century BCE; Campbell 1882). Timber exploitation for domestic and ship construction, as well as export, probably continued through the succession of local kingdoms, and then increased with the rise of Portuguese Bassein, in the 16th century (Figure 1a), when timber was used for the construction of Portuguese ships (Pereira 1935). A British official, Dr Hove, travelled through the district about 1786 and observed forests thick with teak (evidence of earlier disturbance) northeast of Bassein (Campbell 1882).

After the defeat of the Portuguese by the Marathas, the British eventually established control by 1818. Nearby Bombay became a major center of ship construction for the British navy, and depletion of these forests was a matter of strategic concern. Hove noted that these same trees were supplying the Bombay dockyards by 1820. Colonel Jervis, the Chief Engineer at Bombay, reported to the Military Board on his forest survey of the North Konkan in 1843: ‘‘The hills stretching westward from Doogaur and Vijuirabhoy (e.g. Dugad and Vajreshwari) to the sea were formerly covered with wood, but in 1843 on their sea face, there was hardly a bush to be seen; all had been cut away for the Bombay market’’ (Stebbing 1922). Such concerns led to the establishment of a state forest department, and recovery of these forests. The new limits on forest use in the Thane District led to an uprising (Tucker 1979). The descriptions of forests in the Gazetteer of 1882 paint a somewhat refurbished picture (Campbell 1882). Their exploitation continued in the 20th century, first by the British before the independence, then by the Maharashtra State Forest Department. More remote locations may have been exempt from felling, however.

Three of the forest remnants are sites of old hill forts, Mahuli (MH), Ghotara (US) and Takmak (TA), and Kamandurg to the south of the Tungar site. These forts were constructed in the 14–15th centuries and were active until the 18th century (Campbell 1882). At times these sites were densely populated, leading to extensive deforestation as well as introduction of exotic species, some native to other parts of the subcontinent. Some of these forts, like Mahuli, were put under siege, which would have further damaged the vegetation. Scriptures prescribed the planting of auspicious plants in forts (Banerjee 1980), which may explain the presence of naturalized exotics not observed elsewhere in valley forests. *Artocarpus heterophyllus* (MH) is a fruit tree probably native only to the extreme south of India. *Plumeria acuminata* is native to Central America, but was probably brought to India by the Portuguese and planted at MH. *Tamarindus indica* is native to tropical Africa and was seen at US and three other sites. *Vitex negundo*, doubtfully native to this area, has medicinal and religious significance; it was planted on MH, TA and US. Exclusion of these exotics from the statistical analyses did not affect any of our conclusions.

Conclusions

Our results suggest that a history of disturbance, accelerated during the last century, has reduced biomass, canopy height and tree density in forests throughout the valley. The forests and soils have thus retained less of the precipitation of the monsoon and increased the effect of the post-monsoon dry season on the vegetation. More mesic species have disappeared as the effects of disturbance have accumulated over time. Descriptions of forests in the Thane District in the 19th century included a number of common species which are no longer present or extremely rare (Campbell 1882). These include *Michelia champaca* L., *Artocarpus heterophyllus* and *Garcinia indica* (DY and TU). Although all of the forest remnants preserve some diversity in the face of periodic (and presently increasing) disturbance pressures, most of the species in these remnants are tolerant of drought stress, and coppice well in response to cutting and lopping branches.

We have arrived at these conclusions by a direct approach: assessing total woody species diversity by direct observation. This is an approach normally used in studies of vertebrate diversity (Brown and Lomolino 1998). The statistical techniques applicable to such data provide considerable analytical power in comparing such areas (Honnay et al. 1999; Ranta et al. 1999). This is a straightforward approach to analyzing biodiversity in India, but the floristic knowledge to conduct such research has declined in the last two decades. The difficulties in comparing and assessing biodiversity in vegetation remnants lie in the different techniques employed. Use of quadrats probably underestimates diversity, frequently found in small and protected sites, and different sizes and techniques of analysis make their comparisons problematic. The results reported here suggest that the valley forest was richer and more mesic in character, and has declined in biodiversity and water retention capacity during the past century.

Tungar Hill (TU) is remarkable among all of the sites for its semi-evergreen character, high species richness, and presence of numerous rare and mesic species (but partially shared with pockets of forest remnants on nearby hills: DY, TA and US). They represent a forest flora that once was more widely distributed in the Tansa Valley.

Given its proximity to Mumbai and the densely populated suburban corridor on the Western Railway north to Virar, the continuing existence of such a rich and extensive forest is truly remarkable, and it deserves preservation.

Acknowledgements

Many people helped in the completion of this research. Drs S.M. and M.R. Almeida provided much encouragement and helped with plant identifications. The following persons provided additional technical and field assistance (villages in parentheses indicate informants): Brahmananda, Chandu (from Usgaon), Devram (Bhiwali), Claire Elouard, Ganpat Gorule, Rawji Harpade (Usgaon), Janardan Keni, Ratan Kode (Usgaon), Lydia Kos, Ram Chandra Patil, Subhas Patil, B.R. Ramesh, Shantaram (Gayagota), and Stacy West. Travel to India for D.W.L. was supported by the National Science Foundation (#INT-9712753).

Appendix

Distributions and uses of woody plant species observed in the Tansa Valley. S = shrub, L = liana and T = tree; (0–300) indicates the range of elevations in meters where the taxon was found. 1 and 0 indicate presence or absence of taxa at each of the locations, in alphabetical order of abbreviations (see Table 1: BE, DH, DY, DZ, MA, MB, MH, MU, TA, TL, TP, TS, TT, TU, and US). Letters also indicate economic uses observed for the species: A = alcoholic beverage; B = bidi or pan consumption; C = construction (wattle, cord, thatch); D = dyeing or preserving; E = fodder, green manure; F = edible fruit; G = gums or resins; H = household goods (containers, baskets, implements); M = medicines; O = oils; R = religious, esthetic or magical uses; V = non-fruit food items; W = timber for house construction, carts or boats or tools. $ denotes if the product is regularly sold to middlemen or in local markets. * denotes if the plant is exotic to the area but naturalized. # denotes if the plant was observed in 13/15 forest remnants, and Δ if observed in 5/8 disturbance quadrats.

Acanthaceae. *Acanthus ilicifolius* L. S(0–5) 000000000000100; *Adhatoda vasica* Nees M; *Strobilanthes callosus* Nees S(70–900) C$ 111110111100011. **Anacardiaceae**. #Δ*Lannea coromandelica* (Houtt.) Merr. T(0–700) 111111111111011; *Mangifera indica* L. T(40–800) F$ 101010101111010; *Semecarpus anacardium* L. f. T(10–300) M 000010100010010; *Spondias pinnata* (L. f.) Kurz T(200–620) F 111111011100011. **Annonaceae**. #Δ*Miliusa tomentosa* (Roxb.) J. Sincl. T(0–700) FW 111111111111011; *Sageraea laurifolia* (Grah.) Blatter T(120–700) 000000000000010. **Apocynaceae**. *Anodendron paniculatum* A. DC. L(200–600) 001000000000010; #Δ*Carissa congesta* Wight. S(0–850) CFM 111111111111011; *Cryptolepis buchanani* Roem. & Schut. M; #Δ*Holarrhena antidysenterica* (L.) Wall. T(0–450) MV 111111111111011; **Plumeria acuminata* Ait. T(90–110) R 000000100000000; *Wrightia arborea* (Dennst.) Mabb. T(20–400) 111000000110011; #Δ*Wrightia tinctoria* R. Br. T(0–850) 111111111111011. **Araceae**. *Amorphophallus campanulatus* Bl. ex Decne V$; *Amorphophallus commutatus* Engl. V$. **Arecaceae**. *Caryota urens* L. T(340–500) A 000000000000010; *Phoenix sylvestris* Roxb. T(50–100) A 000001000000000. **Bignoniaceae**. *Dolichandrone falcata* Seem. var. *lawii* (Seem.) Haines T(20–400) 101110010101000; #*Heterophragma quadriloculare* (Roxb.) K. Schum. T(0–850) MW 111111111111011; *Oroxylum indicum* Vent. T(20–200) M 000001011101011; Δ*Stereospermum personatum* (Hassk.) D. Chatterjee T(10–600) 111111111001011; *Stereospermum xylocarpum* Benth. & Hook. f. T(20–600) V 111110011110011. **Boraginaceae**. #*Cordia dichotoma* Forst. f. T(0–850) F 111111111110011; *Cordia wallichii* G. Don T(20–400) 110010100100000; *Ehretia laevis* Roxb. T(10–300) 000000100010000. **Burseraceae**. #Δ*Garuga pinnata* Roxb. T(0–500) F 111111111111011. **Capparidaceae**. *Capparis zeylanica* L. FM; *Crateva adansonii DC*. var. *odora* (Buch-Ham.) Jacobs T(20–300) 000001000010010. **Celastraceae**. #*Cassine glauca* Kuntze. T(20–500) M 111111111111011; #*Celastrus paniculata* Willd. L(0–600) M 111111111111011; *Gymnosporia konkanensis* Talbot S(40–650) 000000000000010; *Reissantia grahami* (Wight) Ding Hou L(400–700)

000000000000010; *Salacia chinensis* L. S(300–600) 001000000000010. **Clusiaceae**. *Garcinia indica* Choisy T(40–600) F$ 001000000000010; *Mammea suriga* Kosterm. T(60–700) MW 001000001000010. **Combretaceae**. #Δ*Anogeissus latifolia* Wall. ex Bedd. T(20–600) MGW 111111111111011; #Δ*Calycopteris floribunda* Lam. L(0–900) 111111111111011; #*Combretum ovalifolium* Roxb. L(0–800) 111111111111011; #Δ*Terminalia alata* D. Dietr. T(0–850) CDGMW 111111111111011; #Δ*Terminalia bellerica* Roxb. T(0–850) M 111111111111011; *Terminalia chebula* Retz. T(650–900) M 000000100000010. **Cornaceae**. *Alangium salviifolium* (L. f.) Wang. T(20–80) F 000000000000010. **Cucurbitaceae**. *Momordica dioica* Roxb. ex Willd. V$. **Dilleniaceae**. *Dillenia pentagyna* Roxb. T(20–600) 111000011111011. **Dioscoreaceae**. *Dioscorea bulbifera* L. V$; *Dioscorea hispida* L. R. **Ebenaceae**. #Δ*Diospyros melanoxylon* Roxb. T(0–800) BW 111111111111011; *Diospyros montana* Roxb. T(200–700) 001010001000011. **Euphorbiaceae**. *Antidesma ghaesembilla* Gaertn. T(20–500) 000000000010011; *Aporosa lindleyana* Baill. T(40–500) 000000000000010; *Bridelia hamiltoniana* Wall. S(0–600) 110010010000010; #Δ*Bridelia retusa* Spreng. T(0–800) FM 111111111111011; *Cleidion spiciflorum* Merr. T(350–450) 000000000000010; *Drypetes roxburghii* (Wall.) Hurusawa T(30–600) 001010000000011; #*Emblica officinalis* Gaertn. T(20–800) FM 111111111111011; *Euphorbia neriifolia* L. S(20–900) CM 111110111000011; *Excoecaria agallocha* L. T(0–5) 000000000000100; *Glochidion hohenhackeri* Bedd. T(140–850) 001000101000010; *Homonia riparia* Lour. S(0–300) 000000000000010; *Macaranga peltata* (Roxb.) Muell. T(40–800) 001000101000011; *Mallotus aureo-punctatus* M. Arg. S(350–450) 000000000000010; *Mallotus philippensis* Muell. Arg. T(20–850) DM 111010111010011; *Margaritaria indica* Airy Shaw T(40–400) 000000000000010; *Sapium insigne* Trimen T(120–600) 001000010000010; #Δ*Trewia polycarpa* Benth. ex Hook. f. T(0–600) 111111111111011. **Fabaceae**. *Abrus precatorius* L. M; #Δ*Acacia chundra* Willd. T(0–600) BGW 111111111111011; *Acacia nilotica* (L.) Delile T(0–100) C 000000001000000; #*Acacia pennata* (L.) Willd. L(5–600) 111111111111011; *Acacia suma* Buch.-Ham. T(10–100) 000001000010001; *Albizia lebbeck* Benth. T(20–450) 001000010000001; *Albizia procera* Benth. T(20–850) 001011111011011; *Bauhinia foveolata* Dalz. T(60–650) 111111111100011; *Bauhinia malabarica* Roxb. T(30–500) B 011001011100011; #*Bauhinia racemosa* Lam. T(0–850) B 111111111111011; #Δ*Butea monosperma* (Lam.) Kuntze T(0–850) GMH 111111111111011; *Butea parviflora* Roxb. ex DC L(30–800) 111000110001011; #*Cassia fistula* L. T(0–850) M 111111111101011; #Δ*Dalbergia lanceolaria* L. f. T(0–400) 111111110111011; #Δ*Dalbergia latifolia* Roxb. T(0–850) W 111111111111011; *Derris scandens* Benth. L(20–400) M 011001000001011; *Derris trifoliata* Lour. L(0–5) 000000000000100; *Entada pursaetha* DC L(200–500) CM 000000000000010; *Erythrina stricta* Roxb. T(10–500) MW 011001111110011; *Erythrina suberosa* Roxb. T(100–400) 000000000000010; *Mucuna pruriens* (L.) DC M$; *Ougeinia oojeinensis* (Roxb.) Hochr. T(50–600) M 010110111100011; *Pongamia pinnata* Pierre T(0–800) O 001011110001011; *Pterocarpus marsupium* Roxb. T(20–800) M

111110111110011; **Tamarindus indica* L. T(10–600) F 011010100000001. **Flacourtiaceae**. *Casearia elliptica* Willd. T(40–500) 001010111000011; #Δ*Casearia graveolens* Dalz. T(0–500) 111111111111011; #Δ*Flacourtia indica* Merrill T(0–850) F 111111111110011; *Flacourtia montana* Grah. T(250–700) 000000000000010. **Gnetaceae**. *Gnetum ula* Brongn. L(50–550) V$ 001000000000010. **Lauraceae**. *Alseodaphne semicarpifolia* Nees. var. *angustifolia* Meissn. T(80–700) 000000000000010; *Beilschmiedia dalzelli* (Meissn.) Kosterm. T(400–700) 001000000000010; *Litsea glutinosa* (Lour.) C.B. Robins T(40–500) 000000000000010; *Persea macrantha* Kosterm. T(150–650) 000000000000010. **Lecythidaceae**. *Barringtonia acutangula* Gaertn. T(0–2) 000000000000100; #*Careya arborea* Roxb. T(10–800) M 111011111111011. **Liliaceae**. *Gloriosa superba* L. MR. **Lythraceae**. #Δ*Lagerstroemia lanceolata* Wall. T(20–800) VW 111011111111011; *Lagerstroemia parviflora* Roxb. T(40–400) 000100100101000; *Woodfordia fruticosa* Kurz S(0–800) 111110111001011. **Malpighiaceae**. *Hiptage benghalensis* Kurz S(100–850) 001000100000010. **Malvaceae**. #Δ*Bombax ceiba* L. T(0–800) HM 111111111111011; *Bombax insigne* Wall. T(100–600) 011010010000011; *Erinocarpus nimmonii* J. Grah. T(60–200) 001001000001001; *Eriolaena candollei* Wall. T(60–600) 111110011000001; *Firmiana colorata* R. Br. T(20–700) 011100101011011; *Grewia disperma* Rottler ex Spreng S(50–550) 001000000000011; #*Grewia tiliaefolia* Vahl T(20–850) F 111111111111011; #*Helicteres isora* L. S(10–500) M 111111111111011; *Hibiscus hirtus* L. M; *Kydia calycina* Roxb. T(60–650) 011000010000011; *Microcos paniculata L.* T(40–850) 000000100000010; *Sterculia guttata* Roxb. T(60–650) V 111110011000011; #*Sterculia urens* Roxb. T(10–800) GM$ 111111111111011; *Sterculia villosa* Roxb. T(150–600) 011110110100011. **Melastomataceae**. *Memecylon umbellatum* Burm. f. T(250–700) 001000000000010. **Meliaceae**. *Aglaia talbotii* S. Raghavan T(150–700) 000000000000010; *Chukrasia tabularis* A. Juss. var. *velutina* King T(250–400) 000000000000010; *Toona ciliata* Roemer T(150–700) 000000000000010. **Menispermaceae**. *Tinospora cordifolia* (Willd.) Miers ex Hook f. & Thoms. M. **Moraceae**. **Artocarpus heterophyllus* Lam. T(20–850) F$ 000000100000000; *Ficus amplissima* Sm. T(10–700) 001010111010010; *Ficus arnottiana* Miq. T(20–900) 111110111010011; *Ficus benghalensis* L. T(5–100) EFM 000000000110000; *Ficus drupacea* Thunb. var. *pubescens* (Roth) Corner T(40–400) 000000000000010; *Ficus exasperata* Vahl. T(20–500) 001010001010001; *Ficus gibbosa* Blume T(20–500) 001000000010010; *Ficus heterophylla* L. f. T(5–300) 001000001000011; *Ficus hispida* L. f. T(10–500) 111010011000011; *Ficus infectoria* Roxb. var. *lambertiana* King T(10–850) 001010110000011; *Ficus nervosa* Heyne ex Roth. T(60–700) 000000000000010; #*Ficus racemosa* Roxb. T(0–850) EFHM 111111111111011; **Ficus religiosa* L. T(10–100) 000000100000000; *Ficus talboti* King T(400–550) 001000000000001; *Streblus asper* Lour. T(20–250) C 000000000000010. **Moringaceae**. *Moringa concanensis* Nimmo T(100–400) MV 000010010000000. **Musaceae**. *Ensete superbum* Cheeseman S(100–800) HV$ 111110111010011. **Myrsinaceae**. *Aegiceras corniculatus* Blanco S(0–5) 000000000000100; *Embelia tsjeriam-cottam* A. DC S(0–800) 101011110001011. **Myrtaceae**. *Syzygium cumini* (L.) Skeels T(0–850)

AFM$ 111000111110011; *Syzygium heyneanum* Wall. ex Gamble T(0–850) MF 111011101101011; *Syzygium* sp. T(350–600) 000000000000010. **Olacaceae**. *Olax imbricata* Roxb. L(200–600) 001000001000010. **Oleaceae**. *Jasminum malabaricum* Wight S(20–850) 001000101000011; *Olea dioica* Roxb. T(40–700) 000000000000010; *Schrebera swietenioides* Roxb. T(10–200) 000111000110001. **Pandanaceae**. *Pandanus furcatus* Roxb. S(500–850) 000000100000010. Poaceae: *Bambusa arundinacea* Willd. T(20–850) CHV 111010111001011; *Dendrocalamus strictus* Nees T(5–600) CH 101011011100011. **Rhamnaceae**. *Ventilago bombaiensis* Dalz. L(100–700) 000000000000010; *Ventilago calyculata* Tul. L(50–450) 000000000000010; *Zizyphus mauritiana* Lam. T(0–600) FM 001111001111011; *Zizyphus oenoplia* Mill. S(10–400) M 000001000010011; *Zizyphus rugosa* Lam. S(20–900) F 111010111101011; *Zizyphus xylopyra* Hoechst. ex A. Rich. T(20–500) FM 111111011001011. **Rhizophoraceae**. *Carallia brachiata* (Lour.) Merr. T(140–800) 011010111001011. **Rubiaceae**. #*Adina cordifolia* Benth. & Hook. f. T(0–600) W 111111111111011; *Canthium diccocum* (Gaertn.) Merr. var. *umbellatum* Santapau and Merch. T(400–700) 000000000000010; *Gardenia resinifera* Korth. T(40–250) M 000000000000010; #*Hymenodictyon excelsum* Wall. T(20–600) 111111011111011; *Hymenodictyon obovatum* Wall. T(50–700) 101110110000011; *Ixora brachiata* Roxb. T(20–800) 111010111101011; #Δ*Meyna laxiflora* Robyns T(10–850) F 111111111111011; #*Mitragyna parvifolia* (Roxb.) Korth. T(0–850) 111111111111011; *Morinda tinctora* Roxb. T(0–400) W 111111011110011; *Pavetta indica* L. var. *tomentosa* Hook. f. S(100–800) 001000101000011; *Spermadictyon suaveolens* Roxb. S(300–900) 110110111000011; #Δ*Xeromphis spinosa* (Thunb.) Keay S(0–850) 111011111111011; *Xeromphis uliginosa* (Retz.) Mahesh. T(20–300) V 001011000000011. **Rutaceae**. *Aegle marmelos* Correa ex. Roxb. T(20–300) MR 100111101000000. **Salvadoraceae**. *Salvadora persica* L. T(0–5) 000000000000100. **Sapindaceae**. *Sapindus trifoliatus* L. T(20–500) H$ 111010011000011; #*Schleichera oleosa* Merr. T(10–800) FW 111111111101011. **Sapotaceae**. #Δ*Madhuca indica* J. F. Gmelin. T(0–400) AEFOV$ 111111111111011; *Manilkara hexandra* (Roxb.) Dugard T(10–60) F$ 000000100000010; *Mimusops elengi* L. T(40–700) FR 001000000000010. **Sonneratiaceae**. *Sonneratia apetala* Buch.-Ham. T(0–5) 000000000000100. **Ulmaceae**. *Holoptelea integrifolia* Planch. T(0–600) 111111111010011; *Trema orientalis* Bl. T(0–850) 000000100010010. **Verbenaceae**. *Avicennia acutissima* Stapf ex Mold. S(0–5) 000000000000100; *Avicennia marina* (Forssk.) Vierh. T(0–5) 000000000000100; *Avicennia officinalis* L. T(0–5) 000000000000100; *Callicarpa tomentosa* (L.) Murr. S(200–700) 000000000000010; *Clerodendron inerme* (L.) Gaertn. S(0–5) 000000000000100; *Gmelina arborea* Roxb. T(10–600) MW 111011011110011; #Δ*Tectona grandis* L. f. T(0–550) CGW 111111111111011; **Vitex negundo* L. S(0–850) M 000000101000011. **Zingiberaceae**. *Costus speciosus* L. M.

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