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Plant Community Structure in Tropical Rain Forest Fragments of the Western Ghats, India[1]

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ABSTRACT

Changes in tree, liana, and understory plant diversity and community composition in five tropical rain forest fragments varying in area (18–2600 ha) and disturbance levels were studied on the Valparai plateau, Western Ghats. Systematic sampling using small quadrats (totaling 4 ha for trees and lianas, 0.16 ha for understory plants) enumerated 312 species in 103 families: 1968 trees (144 species), 2250 lianas (60 species), and 6123 understory plants (108 species). Tree species density, stem density, and basal area were higher in the three larger (> 100 ha) rain forest fragments but were negatively correlated with disturbance scores rather than area *per se*. Liana species density, stem density, and basal area were higher in moderately disturbed and lower in heavily disturbed fragments than in the three larger fragments. Understory species density was highest in the highly disturbed 18-ha fragment, due to weedy invasive species occurring with rain forest plants. Nonmetric multidimensional scaling and Mantel tests revealed significant and similar patterns of floristic variation suggesting similar effects of disturbance on community compositional change for the three life-forms. The five fragments encompassed substantial plant diversity in the regional landscape, harbored at least 70 endemic species (3.21% of the endemic flora of the Western Ghats–Sri Lanka biodiversity hotspot), and supported many endemic and threatened animals. The study indicates the significant conservation value of rain forest fragments in the Western Ghats, signals the need to protect them from further disturbances, and provides useful benchmarks for restoration and monitoring efforts.

Key words: Anamalai hills; biodiversity hotspot; disturbance; endemics; fragmentation; lianas; plant conservation; tree diversity; tropical rain forest; understory plants.

Alarming rates of loss and fragmentation of highly diverse tropical rain forests pose a great threat to global biological diversity (Whitmore & Sayer 1992, Pimm & Raven 2000). With increasing transformation and anthropogenic pressures on tropical forest tracts creating fragmented landscapes, it becomes important to understand their effects on patterns of biological diversity and to assess conservation values and needs of such sub-optimal areas. Studies have shown tropical forest fragmentation to cause ecological changes to the plant community and composition by increasing large tree mortality, damage, and loss of live biomass (Lovejoy *et al.* 1986; Ferreira & Laurance 1997; Laurance *et al.* 1998a,b; Laurance *et al.* 2000), reduction in understory plant diversity and recruitment (Benítez-Malvido & Martínez-Ramos 2003), increase in pioneer species and weeds near edges (Laurance 1998, Laurance *et al.* 1998a), and increase in liana abundance (Oliveira-Filho *et al.* 1997, Viana *et al.* 1997, Laurance *et al.* 2001). Although fragments may contain fewer plant species and an altered community, they play an important role in the maintenance of regional diversity by providing habitat for plants and animals and increasing landscape connectivity (Shafer 1995, Turner & Corlett 1996, Laurance & Bierregaard 1997, Pither & Kellman 2002). Clearly, the debate concerning the conservation potential of small forest fragments could benefit from more empirical data, especially from the tropics (Pither & Kellman 2002) and from relatively less-studied groups such as plants and invertebrates (Turner 1996). In areas with high plant diversity, it is also useful to assess if different plant life-forms show concordant patterns of variation across sites as shown in Amazonian rain forests (Tuomisto & Ruokolainen 1994, Ruokolainen *et al.* 1997) in order to choose the appropriate indicator taxa.

The present work was carried out in tropical rain forest fragments of the Anamalai hills that form a part of the Western Ghats–Sri Lanka biodiversity hotspot. This hotspot harbors 4780 plant species, of which 2180 species (45.6%) are endemic, which contribute to 0.7 percent of the earth's endemic plants (Myers *et al.* 2000). Menon and Bawa (1997) estimated that between 1920 and 1990 forest cover in the Western Ghats declined by 40 percent, with a fourfold increase in the number of fragments and an 83 percent decrease in the size of remnants. In the present-day landscape of the Western Ghats, much of the remaining tropical wet evergreen forest, which supports a large proportion of the plant diversity, survives as such fragments in a human-dominated matrix of plantations (such as tea, coffee, rubber, and eucalyptus) and developed areas. For the Western Ghats–Sri Lanka hotspot, Brooks *et al.* (2002) predicted that in addition to the 1067 endemic plant species already

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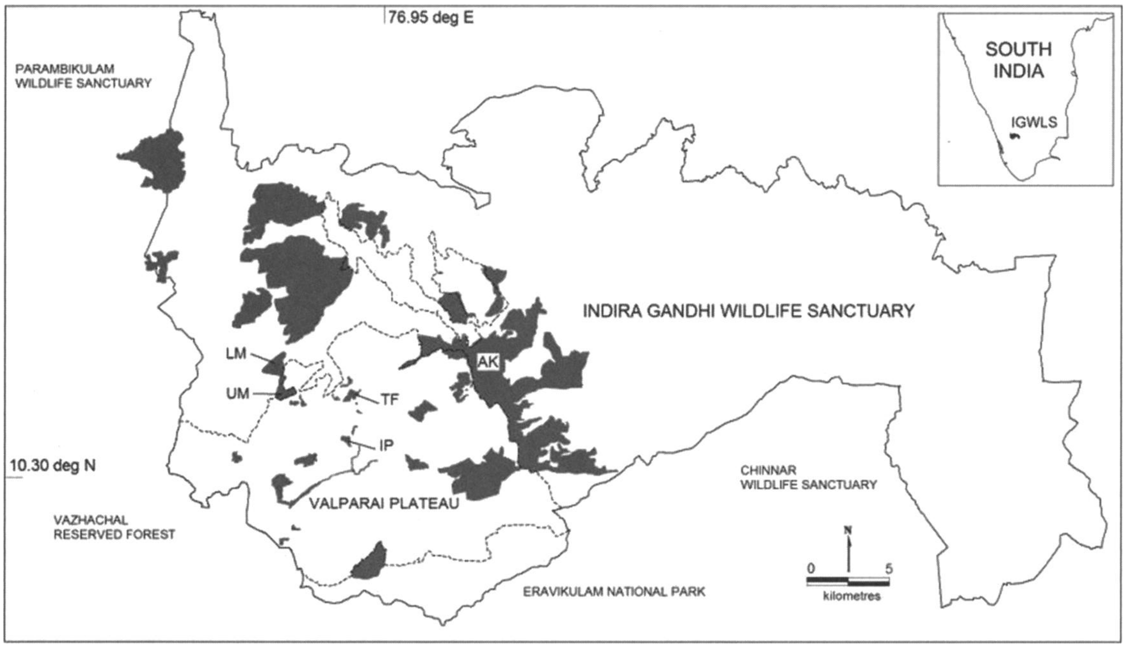

FIGURE 1. Map of the Indira Gandhi Wildlife Sanctuary showing location of Valparai plateau (dashed line) and rain forest fragments (shaded). Study site codes: AK = Akkamalai; UM = upper Manamboli; LM = lower Manamboli; TF = Tata Finlay; IP = Injipara.

threatened or extinct, another 12 species will go extinct within the next 5 yr if the current annual rate of deforestation (0.85%; FAO 1997) continues or, in an alternative scenario, 23 species will go extinct if the hotspot loses an additional area of 1000 km^2 of forest. These threats are significant as this hotspot has one of the highest human population densities (Cincotta *et al.* 2000). Given this background, we were motivated to examine the plant communities and conservation value of forest fragments in the Western Ghats. We examined changes in the community structure of three major plant life-forms (trees, lianas, and understory plants) in relation to disturbance, fragment area, and altitude of forest fragments. We also assessed concordance among the three plant life-forms in community compositional variation across sites in order to evaluate their role in assessing disturbance and conservation value of fragments.

METHODS

STUDY AREA.—The Anamalai hills, located south of the Palghat Gap in the Western Ghats, constitute one of the important centers of plant diversity and endemism in India (Subrahmanyam & Nayar 1974). The Anamalai range includes the Indira Gandhi Wildlife Sanctuary and National Park (987 km^2, 10°12′ N–10°35′N and 76°49′E–77°24′E) in Tamil Nadu state, India. It harbors various forest types ranging from tropical dry thorn, dry deciduous, moist deciduous, semi-evergreen, and evergreen forests to montane grasslands. Surrounded by the sanctuary lies the Valparai plateau (700–1400 m above mean sea level) with extensive areas of private plantations of tea, coffee, cardamom, and *Eucalyptus* spread over an area of 220 km^2 (Fig. 1). The average annual rainfall recorded at Injipara estate on the Valparai plateau over a 10-yr period (1989–1998) was 3497 mm, with over 70 percent of the precipitation occurring during the southwest monsoon (June–September). The natural vegetation of this region is mid-elevation tropical wet evergreen rain forest classified as the *Cullenia exarillata-Mesua ferrea-Palaquium ellipticum* series (Pascal 1988).

The present study was conducted in five tropical wet evergreen forest fragments located on the Valparai plateau (Fig. 1): Akkamalai (AK, 2600 ha), Upper Manamboli (UM, 100 ha), Lower Manamboli (LM, 100 ha), Tata Finlay (TF, 32 ha), and Injipara (IP, 18 ha). Details of site characteristics and disturbance levels in the five sites are provided in Table 1. Of the five sites, AK, LM, and UM represent protected forests within the sanctuary, whereas TF and IP are on private land surrounded by coffee and tea plantations and therefore subjected to greater human interference than the protected sites. TF is a fragment facing moderate levels of human disturbance, whereas IP is a highly disturbed and altered site that was partly a cardamom plantation (with introduced shade trees *Spathodea campanulata,* and *Maesopsis eminii*) and partly a *Eucalyptus grandis* fuel-wood plantation, abandoned about 20 yr ago. Disturbance factors were given a 0–6 score computed as the sum of indices representing area impacted (0–3) and intensity (0–3), with 0 for none, 1 for low, 2 for medium, and 3 for high area/intensity of influence of the factor. Scores for various factors were summed to obtain a total disturbance score for each site (Table 1).

FIELD METHODS.—In each site, vegetation was sampled in 20 randomly placed noncontiguous plots of 20 × 20 m located at least

TABLE 1. *Site and disturbance attributes of the five rain forest study sites in the Anamalai hills, Western Ghats, South India: AK = Akkamalai; UM = upper Manamboli; LM = lower Manamboli; TF = Tata Finlay; IP = Injipara. Scores for various disturbance factors were estimated as described in Methods and summed for each site. Sites UM and LM scored similar disturbance values and are grouped together in Table 1.*

	Sites				
Variable Site attributes	AK	UM	LM	TF	IP
Site attributes					
Area (ha)	2600	*ca* 100	*ca* 100	32	18
Altitude (m)	1260–1360	920–1120	760—800	980–1200	1000–1100
Ownership	Protected (sanctuary)	Protected (sanctuary)	Protected (sanctuary)	Unprotected	Unprotected
Average canopy height (m)	27	32	32	23	20
Canopy closure (%)	93.6	95.7	95.7	95.2	89.4
Nearby plantations	Tea	Tea, coffee	Coffee	Coffee	Tea
Disturbance scores	AK	UM and LM		TF	IP
Surrounding plantations and settlements	4	4		6	6
Plantation within	2	0		0	6
Presence of enclaves	0	4		0	0
Local hunting	4	2		2	2
Illegal timber felling	3	2		6	6
Girdling	0	0		2	2
Removal of dead and fallen wood	2	2		5	4
Past logging	2	2		4	6
Livestock grazing	2	2		6	6
Presence of exotics and invasives	2	2		5	6
NTFP collection	4	5		0	0
Lopping and fuel wood collection	6	5		6	5
Highways and roads	4	4		4	4
Trails	4	2		6	6
Transmission lines (power/telecom)	2	2		0	0
Tourism	2	2		0	0
Fire	2	0		2	2
Total disturbance score	45	40		54	61

50 m apart and at least 20 m into the fragment interior from the edges, major trails, or roads. Within each plot, all trees ≥30cm girth at breast height (gbh, at 1.3 m; corresponding to DBH of 9.55 cm) and lianas ≥1 cm diameter at breast height (DBH) were identified to species, counted, and their girth/diameter measured. For multi-stemmed trees bole girths were measured separately, basal area calculated and summed. For understory plants, 2 × 2 m quadrats were laid at the four corners of the 20 × 20 m plot and all shrubs, undershrubs, herbs, ferns, and small twiners found within the quadrats were enumerated and identified. For vegetatively propagating plants a clump of stems that is basally connected was considered as one individual. Canopy height was measured with a range finder and canopy closure was measured using a spherical densiometer. Vouchers were identified with regional flora (Gamble & Fischer 1915–1935) and confirmed with the Western Ghats collections available in the herbarium of Salim Ali School of Ecology, Pondicherry University, from our previous works in the region (Annaselvam & Parthasarathy 1999; Muthuramkumar & Parthasarathy 2000; Ayyappan & Parthasarathy 2001; Parthasarathy 1999, 2001).

DATA ANALYSIS.—We computed species diversity using the Fisher's ∝ index (Krebs 1989). Species density, stem density, and basal areas determined per plot did not deviate significantly from the normal distribution (Kolmogorov-Smirnov one-sample tests, $P > 0.08$). We therefore used one-way analysis of variance (ANOVA) to analyze significant differences across the five sites in these variables and carried out multiple comparisons with *post hoc* Duncan's multiple range tests setting statistical significance at $P < 0.05$ (Zar 1999). We also analyzed the influence of area, altitude, and disturbance score on average tree, liana, and understory species density, stem density, and basal area, using Pearson's product–moment correlation coefficients. For partial correlations, a backward stepwise selection procedure was used for selecting significant variables in the computer program STATISTICA (StatSoft 1999, Zar 1999).

Change in floristic composition between sites was measured by the Bray-Curtis dissimilarity index (Krebs 1989, Clarke & Warwick 1994) scaled from 0 (identical composition) to 100 (maximum dissimilarity): $100 \cdot \sum_{i=1}^{S} |y_{ij} - y_{ik}| / \sum_{i=1}^{S} (y_{ik} + y_{ik})$; where y_{ij} and y_{ik} represent the abundances of species i in samples j and k, and S is the total number of species. We examined congruence between life-forms in plant community change across sites through Pearson's correlations between the corresponding Bray-Curtis dissimilarity matrices using Mantel tests with 10,000 simulations to assess statistical significance (Manly 1994, Hood 2004). The analytical approach of Clarke and Warwick (1994) implemented in the computer program PRIMER (Clarke & Gorley 2001) was used to assess and interpret change in community composition. We used the SIMPER (similarity percentage) procedure in PRIMER to identify how much each plant species contributes to the average dissimilarity between two groups of sites (three protected and two unprotected sites). This is done by first computing the average Bray-Curtis dissimilarity ($\bar{\delta}_{jk}$) between all pairs of inter-group samples (j and k, with j in the first group and k in the second group). The percentage contribution of each species (i) to the Bray-Curtis dissimilarity between two samples, computed as: $\delta_{jk}(i) = 100 \cdot |y_{ij} - y_{ik}| / \sum_{i=1}^{S}(y_{ik} + y_{ik})$, is then averaged across all pairs of inter-group samples j and k to obtain the average contribution $\bar{\delta}_i$ of the ith species to the overall dissimilarity between groups (Clarke & Warwick 1994). Floristic relationships among the fragments were illustrated with nonmetric multidimensional scaling (NMDS) also using the Bray-Curtis dissimilarity index (Clarke & Warwick 1994).

RESULTS

FLORISTIC DIVERSITY AND ABUNDANCE.—In total, 312 species representing 103 families were recorded from the five sites. This included 1968 individuals in 144 tree species and 2250 individuals in 60 liana species in a total area of 4 ha. In addition, 6123 individuals of understory plants which belonged to 108 species were recorded in a total of 0.16 ha sampled (Appendix 1). Species rarity (those represented by <8 individuals or <2 stems/ha) was higher for trees (60% of species) than lianas (38%) in the five study sites. Thirteen understory plant species were represented by single individuals in the 0.16 ha sample area. Among understory plants, 15 species were represented by 100 or more individuals in the 0.16 ha sample. Only 3.5 percent and 1.5 percent of species had ≥64 individuals (≥16 stems/ha) for trees and lianas, respectively.

The most abundant tree species include *Oreocnide integrifolia* (7.5%), *P. ellipticum* (14%), and *Vateria indica* (8.1%) in the larger (>100 ha) rain forest fragments AK, UM, and LM, respectively, whereas *O. integrifolia* (25%) and *S. campanulata* (33.5%) were dominant in the smaller and more disturbed sites TF and IP, respectively (Appendix 1). The most abundant lianas were *Connarus sclerocarpus* in AK (25%) and UM (32%), *Calamus gamblei* (21.8) in LM, *Strychnos vanprukii* (30.5%) in TF and *Polygonum chinense* (23.5%) in IP. Among understory plants, *Elatostemma lineolatum* in AK (23.2%) and TF (17.8%), the introduced robusta coffee *Coffea canephora* in UM (26%) and LM (23%), and the grass *Cyrtococcum trigonum* (13.7%) in IP were the most abundant species (Appendix 1).

Species density of trees and lianas was highest in LM (73 and 38 species, respectively), whereas understory species density was highest in the more disturbed and smaller TF site (50 species, Table 2). All the larger and protected fragments AK, UM, and LM contained greater tree density and stand basal area than the smaller unprotected fragments on private lands, TF and IP. The liana data revealed, in comparison to protected forests, more than four times greater stem density in the unprotected moderately disturbed TF site and a lower stem density in the highly disturbed IP that was partly abandoned plantation area (1029 and 234 individuals/ha, respectively). Liana basal area was over twice as high in TF and less than a fifth in IP of what it was in the protected forests (Table 2). Site IP ranked highest in terms of the stem density of understory plants (1611 individuals) and UM had the least stem density (844 individuals). The Fisher's ∝ diversity index showed similar trends as species density for all the life-forms (Table 2).

One-way ANOVA for the three life-forms showed significant differences across the five sites ($F_{4,95} > 4.0$, $P < 0.05$) for species density and stem density (Fig. 2). *Post hoc* multiple comparisons showed significantly lower tree species density and stem density in the smaller (≤32 ha) unprotected forest fragments, whereas for

TABLE 2. *Consolidated details of plant diversity in the five study sites of Anamalai hills. Site codes as in Table 1.*

Variable	Protected sites			Unprotected sites	
	AK	UM	LM	TF	IP
Trees (≥30 cm gbh)					
Species richness (species/0.8 ha)	69	54	73	55	38
Western Ghats endemics (%)	33	34	32	33	16
Density (stems/0.8 ha)	452	412	453	344	307
Stand basal area (m^2/0.8 ha)	52.18	71.14	79.74	50.64	37.04
Fisher's α (/0.8 ha)	22.69	16.61	24.62	18.48	11.42
Lianas (≥1 cm dbh)					
Species richness (species/0.8 ha)	30	30	38	35	23
Western Ghats endemics (%)	17	17	21	14	17
Density (stems/0.8 ha)	481	462	297	823	187
Basal area (m^2/0.8 ha)	0.30	0.34	0.28	0.76	0.05
Fisher's α (/0.8 ha)	7.09	7.18	11.57	7.42	6.89
Understory plants					
Species richness (species/320 m^2)	48	39	40	50	47
Western Ghats endemics (%)	21	15	20	16	4
Density (stems/320 m^2)	1381	844	1178	1109	1611
Fisher's α (/320 m^2)	9.66	8.45	8.00	10.77	9.06

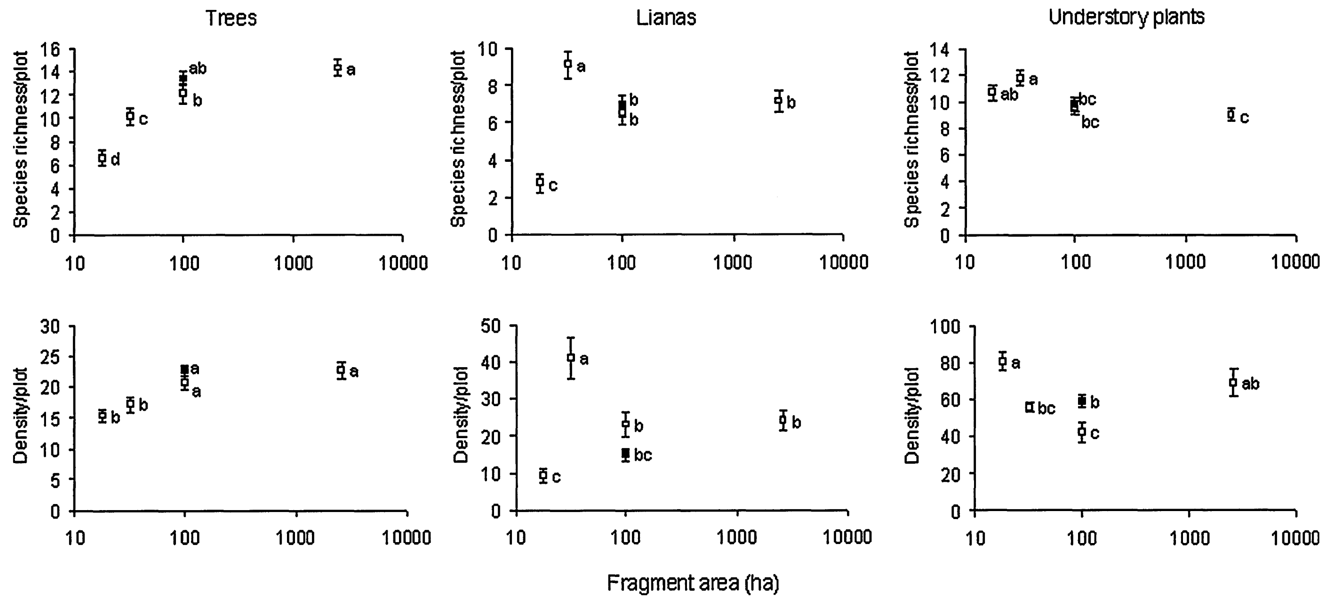

FIGURE 2. Mean species richness and density of plants per quadrat for the three life-forms in relation to fragment area in the Anamalai hills (vertical bars = 1 SE). Different letters indicate significant differences ($P < 0.05$) among sites arranged in increasing area from left to right: IP, TF, LM, UM, and AK (site codes as in Fig. 1). The LM marker is filled to distinguish from UM.

lianas the moderately disturbed TF site had higher and the highly disturbed IP site lower values for liana variables than the protected forests (Duncan's multiple range tests, $P < 0.05$, Fig. 2). Tree species density, stem density, and basal area were significantly negatively correlated to site disturbance score ($r = -0.889$, -0.914, and -0.913, respectively, df $= 3$, $P < 0.05$) and were not significantly correlated with area *per se* (Table 3). In addition, tree basal area was correlated negatively with altitude (partial $r = -0.971$, $P = 0.008$). Liana and understory plant variables also varied significantly across sites, but the variation was not significantly correlated with site characteristics (Table 3). Fragment area alone did not have a strong or direct influence on species density and stem density of the different plant life-forms (Table 3, Fig. 2).

TABLE 3. *Correlations between plant community characteristics (mean values per plot as in Fig. 2) and site characteristics in tropical wet evergreen forest fragments within the Anamalai, India. Pearson's product–moment correlation coefficients (df = 3) are presented with significance levels (*P*) in parentheses.*

Variable	Area	Altitude	Disturbance score
Tree species richness	0.574 (0.31)	0.045 (0.94)	−0.889 (0.04)
Tree density	0.522 (0.37)	−0.084 (0.89)	−0.914 (0.03)
Tree basal area	−0.163 (0.79)	−0.643 (0.24)	−0.913 (0.03)
Liana species richness	0.161 (0.80)	0.07 (0.91)	−0.443 (0.46)
Liana density	0.068 (0.91)	0.333 (0.59)	−0.016 (0.98)
Liana basal area	−0.111 (0.86)	0.092 (0.88)	−0.069 (0.91)
Understory plant species richness	−0.626 (0.26)	−0.141 (0.82)	0.686 (0.20)
Understory plant density	0.280 (0.65)	0.314 (0.61)	0.681 (0.21)

FLORISTIC COMPOSITION: VARIATION ACROSS SITES AND LIFE-FORMS.—Nonmetric multidimensional scaling ordination of the five study sites showed a similar pattern of change in floristic composition for the three life-forms (Fig. 3). Compared to lianas, trees and understory species showed a similar pattern of segregation in

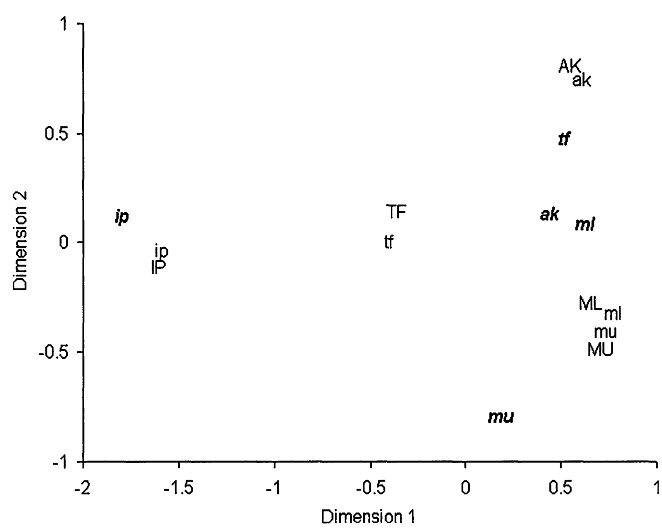

FIGURE 3. Nonmetric multidimensional scaling ordination of floristic composition of trees (uppercase), lianas (bold italics), and understory plants (lowercase) in the five study sites of the Anamalai hills. Site codes as in Figure 1. Stress values of 0.01 for trees and understory plants and <0.01 for lianas were obtained. The sites were arranged along the x-axis in relation to disturbance levels from IP at the left to TF at the center and the larger, protected sites on the right.

floristic composition (Fig. 3). Mantel tests showed that the patterns of change in floristic composition for the three life-forms across the five sites were significantly positively correlated. The tree and understory plants dissimilarity matrices were significantly correlated (Mantel test, $r = 0.980$, $P < 0.001$), as were trees and lianas ($r = 0.779$, $P = 0.015$), and understory plants and lianas ($r = 0.810$, $P = 0.018$).

The similarity percentage (SIMPER) analysis of tree species composition in protected and unprotected sites revealed a 78.97% average dissimilarity between the two categories (Appendix 2). The top twenty species contributed to 59.1% of dissimilarity between sites, in which the three introduced species *S. campanulata*, *E. grandis*, *M. eminii*, and the edge species *Meliosma pinnata* subsp. *arnottiana* were recorded only in the unprotected sites, whereas *V. indica*, *Reinwardtiodendron anamallayanum*, *Mesua ferrea*, *Drypetes wightii*, and *Fahrenheitia zeylanica* were found exclusively in the larger protected sites. Average dissimilarity of lianas between protected and unprotected sites was 74.6% (Appendix 2). The top twenty liana species contributed to 85.4% of the difference between the two categories. Lianas such as *Kunstleria keralense*, *Calamus gamblei*, and *Hiptage benghalensis* occurred only in the larger protected sites, whereas *Aristolochia* sp. and *Rubus ellipticus* occurred only in the smaller, more disturbed unprotected sites. Understory plants showed 74.9 percent average dissimilarity between protected and unprotected sites (Appendix 2). The first 20 species accounted for 78.7 percent of the difference between protected and unprotected sites in species composition. Species exclusive to unprotected sites included *Lantana camara* and *Crotalaria laevigata* (invasives), whereas *Nilgirianthus barbatus* (an endemic) occurred only in protected sites.

SIZE-CLASS FREQUENCY DISTRIBUTION OF TREES AND LIANAS.—Tree size-class distribution of the five forest sites showed reverse J- and J-shaped curves for stem density and basal area, respectively (Fig. 4). A comparison of size-class distribution of tree density across the sites revealed significant variation except for sites AK and TF (Kolmogorov-Smirnov two sample tests, $P < 0.05$). The frequency class basal area distribution of the sites was more or less similar except for sites UM, LM, and TF with IP (Kolmogorov-Smirnov tests, $P < 0.05$). Girth-class distribution of trees across the five sites varied significantly for the size classes 30–60, 60–90, 90–120, and >330 cm ($\chi^2 > 17$, df = 4, $P < 0.05$) while it did not vary for the remaining classes ($\chi^2 < 8$, df = 4, $P > 0.05$). The basal area distribution of trees across the sites also did not vary substantially except for the >330 cm class. Compared to the larger protected forests, the smaller unprotected sites had lower stem density and basal area of trees in intermediate size classes (60–120 cm), with the highly disturbed IP site also having comparatively fewer large trees (>240 cm GBH). The diameter class distribution of lianas varied significantly in stem density and basal area (Fig. 5). In terms of liana stem density the protected sites did not vary significantly among themselves but did differ from unprotected sites (Kolmogorov-Smirnov tests, $P < 0.05$). The liana basal area distribution varied significantly among the five sites, with a notably higher abundance and basal area of

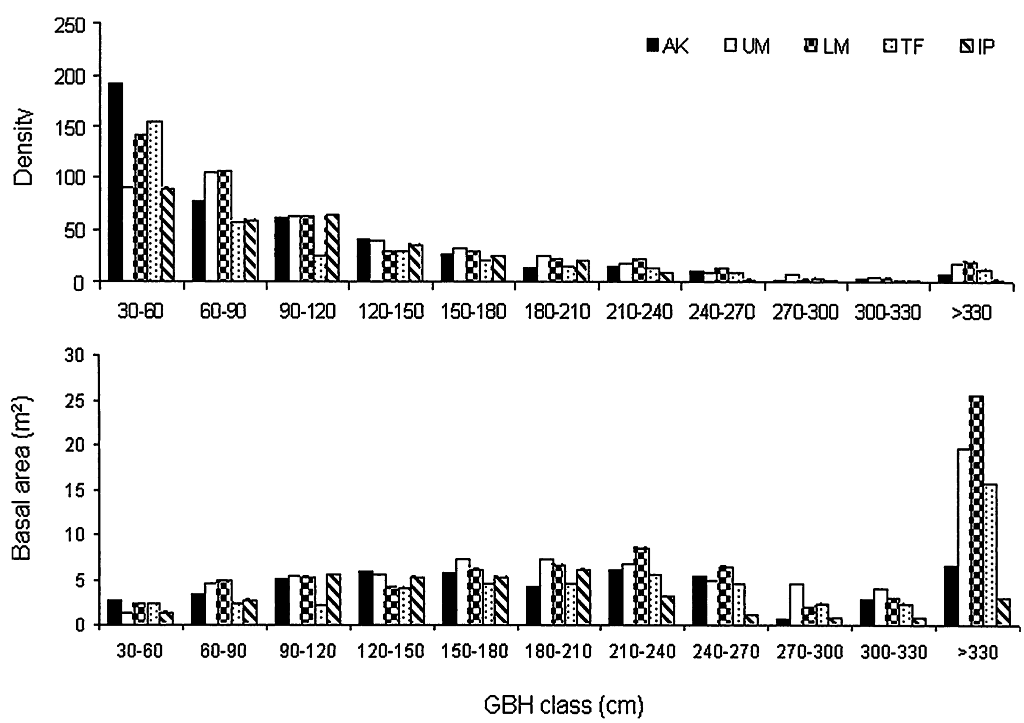

FIGURE 4. Size-class distribution of tree density and basal area in the five study sites. Site codes as in Figure 1.

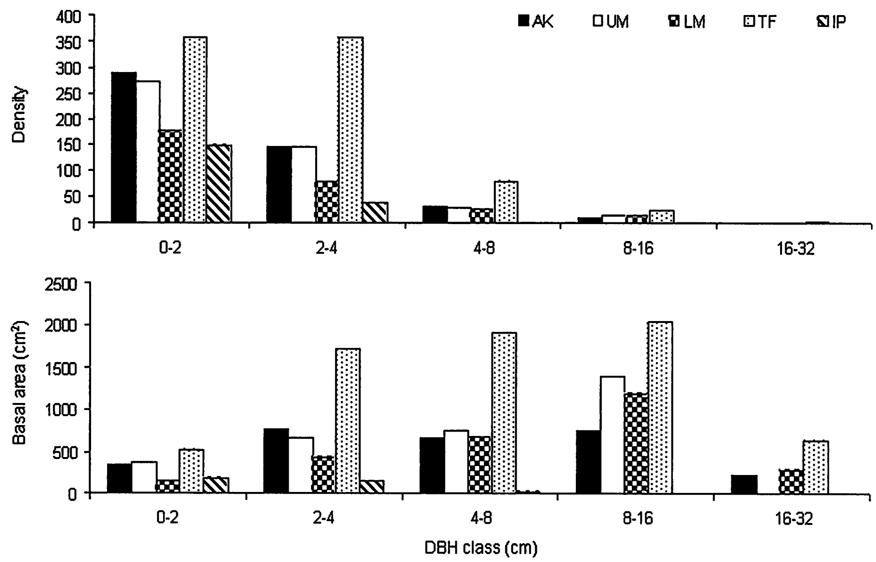

FIGURE 5. Size-class distribution of liana density and basal area in the five study sites. Site codes as in Figure 1.

lianas in the moderately disturbed site TF and an absence of larger lianas from the highly disturbed site IP (Kolmogorov-Smirnov tests, $P < 0.05$).

DISCUSSION

SPECIES DENSITY, STEM DENSITY, AND DISTRIBUTION OF PLANT LIFE-FORMS.—When results from this study for the three life-forms (trees, lianas, and understory plants) are compared with other sites in the Western Ghats (Table 4), tree species density and stem density in the present study sites fell well within the reported range. The higher tree basal area (46.3–99.67 m^2/ha) of the present study sites, particularly those of the larger (>100 ha) fragments (65.2–99.67 m^2 /ha) can be attributed to the relatively less disturbed nature of the sites and also their location in the transition zone of tropical low- and medium-elevation wet evergreen forest types containing voluminous overstory trees, particularly those of the Dipterocarpaceae (*Hopea parviflora* and *V. indica* in our sites). The liana species density in the present study sites remained well within the range (26–48 species) of the Varagalaiar site in the Western Ghats (Table 4), while the stem density was notably high in the moderately disturbed site TF (Table 2). The understory species density also remained within the range reported (Table 4), whereas the stem density of understory plants was two to six times lower in the present study than in the adjacent Varagalaiar forest of the Anamalai hills (Annaselvam & Parthasarathy 1999).

There is little information on the patterns of distribution and abundance of wet forest plant species across replicate sites in the Western Ghats. The lower stem density of understory plants as compared to the relatively undisturbed Varagalaiar site (Table 4) is probably due to altitudinal effects as well as lowered stem density and diversity of recruiting native rain forest plant species here (Balasubramaniam 2003). Lower recruitment in forest fragments than continuous forest of rain forest tree, liana, and understory plant seedlings has been previously reported in Amazonia (Benítez-Malvido & Martínez-Ramos 2003). Although fragments do contain a diverse set of tree and liana species, the rarity of a significant proportion of species indicates that relatively large areas are required if even a few dozen individuals of each species are to be represented within conserved forest sites.

Variation in plant species density appeared to be primarily related to two factors: disturbance and altitude. Disturbance appeared to have a strong negative influence on tree community parameters. The lower tree species density, stem density, and basal area recorded in the unprotected sites (Table 2) of the present study is in conformity with the low tree diversity reported in selectively-felled and frequently disturbed sites of tropical wet evergreen forest in Kalakad-Mundanthurai Tiger Reserve of the southern Western Ghats (Parthasarathy 1999). Although area did not appear to directly influence plant community variables, it may exert a positive influence on plant communities in the larger fragments through lower edge- and exposure-related disturbance (Laurance & Bierregaard 1997). Tree species density and stem density were higher in the larger fragments (Fig. 2) in this study and the lack of a significant effect of area *per se* may be due to the limited number of sites sampled. Coverage of additional sites spanning a wide range of area and disturbance levels is required to elucidate the interactive effects of disturbance and area. The influence of altitude on species density was apparent in the single site that was at a lower elevation, LM. LM was more diverse in trees, lianas, and also in overall species density at the scale of 1 ha (Table 2) although not at the scale of individual quadrats (Fig. 2), probably because this site was at an altitude (~700 m) representing the transition zone of lowland and lower montane forests. As in this study, Lieberman *et al.* (1996) in Costa Rica and Srinivas and Parthasarathy (2000) in Agumbe wet evergreen forest of central Western Ghats found higher tree species

TABLE 4. *A comparison of richness, density, and basal area estimates for trees, lianas, and understory plants across tropical wet evergreen forest localities within the Western Ghats, India.*

Life-form and locality (area sampled)	Species richness (species/ha)	Density (stems/ha)	Basal area (m^2/ha)	Source
Trees				
Nelliampathy	30	496	61.9	Chandrashekara and Ramakrishnan (1994)
Courtallum	57	482	42.6	Parthasarathy and Karthikeyan (1997)
Agumbe (3 × 1 ha)	47–61	304–605	33.2–37.6	Srinivas (1997)
Sengaltheri-Kuliratti (3 × 1 ha)	72–79	557–841	61.4–94.4	Parthasarathy (1999)
Sengaltheri-Kakachi (3 × 1 ha)	64–82	852–965	55–78	Parthasarathy (2001)
Kakachi (3 × 1 ha)	38–50	578–783	49.7–64	Ganesan (2001)
Varagalaiar (30 × 1 ha)	52–79	273–674	25–47	Ayyappan and Parthasarathy (2001)
Valparai	41–78[a]	384–566	46.3–99.7	Present study
Lianas				
Varagalaiar (30 × 1 ha)	26–48	185–500	0.11–0.84	Muthuramkumar (2002)
Valparai	25–41[a]	234–1029	0.06–0.95	Present study
Understory plants				
Varagalaiar	17–83	2939–12,403	–	Annaselvam and Parthasarathy (1999)
Valparai	41–54[a]	1055–2014	–	Present study

[a]For Valparai data, the species richness of 0.8 ha was extrapolated to 1 ha using the formula of Evans *et al.* (1955) to facilitate a valid comparison with other sites.

diversity at lower altitudes. Similarly, for lianas, a decrease in liana diversity with altitude as in this study has been recorded in southern Africa (Balfour & Bond 1993).

The mean species density of lianas and understory plants was higher for the disturbed site TF (Fig. 2). This is in conformity with the intermediate disturbance hypothesis (Connell 1978, Grime 1979) that predicts a diversity peak at intermediate intensity of disturbance. Several liana studies have suggested that lianas could be classified as early successional or gap-dependent pioneer species (Hegarty 1991, Dewalt *et al.* 2000). Liana stem density varied considerably among the sites studied with highest abundance in the moderately disturbed TF site. Higher light levels due to disturbance and greater stem density of trees in the 30–60 cm gbh class in TF (Fig. 4) could have facilitated liana colonization. On the other hand, liana abundance was least in the most disturbed site IP (an abandoned cardamom plantation area). This is attributable to liana cutting during plantation establishment, invasion by the thorny straggler *Lantana camara*, and low stem density of trees, thus depriving lianas of suitable stems that can act as trellises. At present, IP is in a process of liana recovery.

Part of the reason for higher understory species density in the disturbed sites is disturbance-related invasion by weedy species, which is an important consequence of fragmentation. For instance, the disturbed sites are invaded in the understory by weeds such as *Ageratum conyzoides*, *Mimosa pudica*, *Sida cordata*, *Tithonia diversifolia*, *Urena lobata*, and *Solanum torvum* (in IP) and *Eupatorium glandulosum*, *Lantana camara*, *Mikania* sp., and *Sida rhombifolia* (IP and TF). Only two species, *E. glandulosum* and *Mikania* sp., occurred in very low stem density in the less disturbed sites AK and UM, respectively, and none of the weedy species colonized LM. The introduced species *Coffea canephora* was more abundant in the protected sites UM and LM, because the site is surrounded by coffee plantation and its fruits are dispersed into the area by mammals such as the Asian elephants *Elephas maximus*, primates, and civets.

CHANGES IN FLORISTIC COMPOSITION.—Ordination analysis of plant life-forms (trees, lianas, understory plants) produced similar patterns of floristic composition, which separated the abandoned cardamom plantation site IP away from the other sites (Fig. 3). Therefore, understory plants may be used for predicting the general floristic pattern at a local scale for rapid biodiversity assessments because of the ease of sampling as established in earlier studies in Amazonian rain forests (Tuomisto & Ruokolainen 1994, Ruokolainen *et al.* 1997). Trees and lianas may be more important for rain forest fauna (especially arboreal mammals and birds) and dependent plant life-forms such as epiphytes, and may therefore be important for biodiversity surveys pertinent to such species.

A limitation of this study is that only few sites could be covered during the study. Sampling of more rain forest fragments and preparation of complete inventories of species are required for a more thorough examination of patterns of floristic variation and its relation to fragment and environmental variables. For restoration and conservation programs, sound data are required about the distribution of different life-forms and their persistence in disturbed forests. The present status of the unprotected site IP with low species density and stem density of trees reflects the lingering effect of past land-use pattern on the present floristic composition of forests, with a high stem density of trees such as *S. campanulata*, *E. grandis*, and *M. eminii* planted in cardamom estate as shade trees, and followed by the light demanding pioneer species *Macaranga peltata* and *Meliosma pinnata*.

SIZE DISTRIBUTIONS OF TREES AND LIANAS.—The study fragments faced chronic low-intensity disturbance in the form of illegal wood removal (primarily fuel-wood and poles for domestic use, though occasionally trees were girdled and later felled for the purpose). The moderately disturbed TF site had fewer trees in intermediate size class (60–210 cm gbh; Fig. 4) probably due to selective felling of medium-sized trees for household purposes. The highly disturbed IP site had lower stem density of trees in all size classes (except 90–210 cm gbh) and representation of very few trees in higher girth-classes reflecting the disturbance history. This accounts for the lower tree species density, stem density, and basal areas in the disturbed sites, particularly in intermediate and large size classes. Similar effects of disturbance on tree species density, stem density, and forest stand structure have been noted in other tropical wet evergreen forests of the Western Ghats (Parthasarathy 1999), northeast India (Bhuyan *et al.* 2003), and in other regions of the world (Turner 1996, Laurance 1998, Laurance *et al.* 1998a,b).

CONSERVATION VALUE OF RAIN FOREST FRAGMENTS.—Forest fragments such as those of our present study sites contribute substantially to the conservation of biodiversity by providing habitat for plants and food for animals, seed sources for the expansion of forests in the future (Schelhas & Greenberg 1996), and by maintaining regional biodiversity of the natural ecosystem. Among the five forest fragments studied, with the exception of the most disturbed site IP, tree species density, stem density, and basal area were higher, particularly in the three larger less disturbed fragments, and further, about one-third of the total number of tree species are endemics. The understory species density was comparatively higher in the disturbed sites TF and IP, because the number of invasive species is greater in these sites (10% and 11% as against 0–2.5% in the less disturbed sites). In these two disturbed sites, however, the percentage of endemics was low, particularly in IP (6.4% of species are endemics as against 17–21% in the other sites). Thus, higher degree of disturbance led to colonization by invasive species (see Appendix 1) and this affected the local flora in a long run. This study area, although fragmented due to plantations and related activities, harbors rich flora including endemics, and constitutes one of the important forests in the Western Ghats–Sri Lanka biodiversity hot spot. The importance of small fragments should not be ignored in biodiversity conservation. For instance, in Malaysia, Thomas (2004) reported that a large proportion of the regional tree diversity was represented in a dozen small fragments of tropical forest. Overall, in the present study, of the total of 312 species enumerated in the five forest fragments, 70 species are endemics, which constitute 3.21 percent of the endemic flora of the Western Ghats–Sri Lankan biodiversity hotspot. Besides, the presently studied five forest fragments harbor economically important tree species such as *V. indica* (for white dammar & timber) and *H. parviflora* of Dipterocarpaceae, *P. ellipticum* of Sapotaceae (timber), forest nutmeg species *Myristica dactyloides* of Myristicaceae, mature trees of black dammar *Canarium strictum* (Burseraceae), and *Mastixia arborea* (Cornaceae); and an important fruit tree *C. exarillata* for the endemic primate lion-tailed macaque *M. silenus* and other keystone species (*Ficus* spp.). Thus, the need for protecting forest fragments in the current context of increasing tropical deforestation and forest fragmentation in order to conserve regional biodiversity is evident, particularly because the Indian Western Ghats has such high levels of endemism.

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LITERATURE CITED

ANNASELVAM, J., AND N. PARTHASARATHY. 1999. Inventories of understory plants in a tropical evergreen forest in the Anamalais, Western Ghats, India. Ecotropica 5: 197–211.

AYYAPPAN, N., AND N. PARTHASARATHY. 2001. Patterns of tree diversity within a large-scale permanent plot of tropical evergreen forest, Western Ghats, India. Ecotropica 7: 61–76.

BALASUBRAMANIAM, P. 2003. Floristic composition and patterns of regeneration of rainforest trees in the fragmented forests of the Anamalai hills, southern Western Ghats. M.Sc. Dissertation, Wildlife Institute of India, Saurashtra University, Rajkot.

BALFOUR, D. A., AND W. J. BOND. 1993. Factors limiting climber distribution and abundance in a southern African forest. J. Ecol. 81: 93–99.

BENÍTEZ-MALVIDO, J., AND M. MARTÍNEZ-RAMOS. 2003. Impact of forest fragmentation on understory plant species richness in Amazonia. Conserv. Biol. 17: 389–400.

BHUYAN, P., M. L. KHAN, AND R. S. TRIPATHI. 2003. Tree diversity and population structure in undisturbed and human-impacted stands of tropical wet evergreen forest in Arunachal Pradesh, Eastern Himalayas, India. Biodivers. Conserv. 12: 1753–1773.

BROOKS, T. M., R. A. MITTERMEIER, C. G. MITTERMEIER, G. A. B. DA FONSECA, A. B. RYLANDS, W. R. KONSTANT, P. FLICK, J. PILGRIM, S. OLDFIELD, G. MAGIN, AND C. HILTON-TAYLORS, C. 2002. Habitat loss and extinction in the hotspots of biodiversity. Conserv. Biol. 16: 909–923.

CHANDRASHEKARA, U. M., AND P. S. RAMAKRISHNAN. 1994. Vegetation and gap dynamics of a wet evergreen forest in the Western Ghats of Kerala, India. J. Trop. Ecol. 10: 337–354.

CINCOTTA, R. P., J. WISNEWSKI, AND R. ENGELMAN. 2000. Human population in the biodiversity hotspots. Nature 404: 990–992.

CLARKE, K. R., AND R. N. GORLEY. 2001. Primer v5: User manual/tutorial. PRIMER-E, Plymouth.

———, AND R. M. WARWICK. 1994. Change in marine communities: An approach to statistical analysis and interpretation. Plymouth Marine Laboratory, Plymouth.

CONNELL, J. H. 1978. Diversity in tropical rain forests and coral reefs. Science 199: 1302–1310.

DEWALT, S. J., S. A. SCHNITZER, AND J. S. DENSLOW. 2000. Density and diversity of lianas along a chronosequence in a central Panamanian lowland forest. J. Trop. Ecol. 16: 1–19.

EVANS, F. C., P. J. CLARK, AND R. H. BRAND. 1955. Estimation of the number of species present in a given area. Ecology 36: 342–343.

FERREIRA, L. V., AND W. F. LAURANCE. 1997. Effects of forest fragmentation on mortality and damage of selected trees in central Amazonia. Conserv. Biol. 11: 797–801.

FOOD AND AGRICULTURE ORGANIZATION (FAO). 1997. State of the world's forest 1997. FAO, Rome, Italy.

GAMBLE, J. S., AND C. E. C. FISCHER. 1915–1935. Flora of the presidency of Madras, Parts I to XI. Secretary of State for India, London.

GANESAN, R. 2001. Tree diversity and regeneration in logged wet evergreen forests of the Agasthyamalai range in south Western Ghats, India. Ph.D. thesis, University of Madras, Chennai.

GRIME, J. P. 1979. Plant strategies and vegetation processes. Wiley, New York.

HEGARTY, E. E. 1991. Vine-host interactions. *In* F. E. Putz and H. A. Mooney (Eds.). The biology of vines, pp. 357–375. Cambridge University Press, Cambridge.

HOOD, G. M. 2004. PopTools version 2.6.2. Internet URL: http://www.cse.csiro.au/poptools.

KREBS, C. J. 1989. Ecological methodology. Harper and Row, New York.

LAURANCE, W. F. 1998. Effects of forest fragmentation on recruitment patterns in Amazonian tree communities. Conserv. Biol. 12: 460–464.

———, AND R. O. BIERREGAARD (Eds.). 1997. Tropical forest remnants: Ecology, management and conservation of fragmented communities. University of Chicago Press, Chicago.

———, P. DELAMÔNICA, S. G. LAURANCE, H. L. VASCONCELOS, AND T. E. LOVEJOY. 2000. Rainforest fragmentation kills big trees. Nature 404: 386.

———, L. V. FERREIRA, C. GASCON, AND T. E. LOVEJOY. 1998a. Biomass decline in Amazonian forest fragments. Science 282: 1611a.

———, ———, J. M. RANKIN-DE MERONA, AND S. G. LAURANCE. 1998b. Rain forest fragmentation and the dynamics of Amazonian tree communities. Ecology 79: 2032–2040.

———, D. PÉREZ-SALICRUP, P. DELAMÔNICA, P. M. FEARNSIDE, S. D'ANGELO, A. JEROZOLINSKI, L. POHL, AND T. E. LOVEJOY. 2001. Rainforest fragmentation and the structure of Amazonian liana communities. Ecology 82: 105–116.

LIEBERMAN, D., M. LIEBERMAN, R. PERALTA, AND G. S. HARTSHORN. 1996. Tropical forest structure and composition on a large-scale altitudinal gradient in Costa Rica. J. Ecol. 84: 137–152.

LOVEJOY, T. E., R. O. BIERREGAARD, A. B. RYLANDS, J. R. MALCOLM, C. E. QUINTELA, L. H. HARPER, K. S. BROWN, A. H. POWELL, G. V. N. POWELL, H. O. R. SCHUBART, AND M. B. HAYS. 1986. Edge and other effects of isolation on Amazon forest fragments. *In* M. E. Soulé (Ed.). Conservation biology: The science of scarcity and diversity, pp. 257–285. Sinauer, Sunderland, Massachusetts.

MANLY, B. F. J. 1994. Multivariate statistical methods: A primer, 2nd edition. Chapman and Hall, London.

MENON, S., AND K. S. BAWA. 1997. Applications of geographical information systems, remote sensing and a landscape ecology approach to biodiversity conservation in the Western Ghats. Curr. Sci. 73: 134–145.

MUTHURAMKUMAR, S. 2002. Diversity and ecology of lianas in a tropical evergreen forest in the Anamalais, Western Ghats, India. Ph.D. thesis,, Pondicherry University, Pondicherry.

———, AND N. PARTHASARATHY. 2000. Alpha diversity of lianas in a tropical evergreen forest in the Anamalais, Western Ghats, India. Divers. Distrib. 6: 1–14.

MYERS, N., R. A. MITTERMEIER, C. G. MITTERMEIER, G. A. B. DA FONSECA, AND J. KENT. 2000. Biodiversity hotspots for conservation priorities. Nature 403: 853–858.

OLIVEIRA-FILHO, A. T., J. M. DE MELLO, AND J. R. S. SCOLFORO. 1997. Effects of past disturbance and edges on tree community structure and dynamics within a fragment of tropical semideciduous forest in southeastern Brazil over a five-year period (1987–1992). Plant Ecol. 131: 45–66.

PARTHASARATHY, N. 1999. Tree diversity and distribution in undisturbed and human-impacted sites of tropical wet evergreen forest in southern Western Ghats, India. Biodivers. Conserv. 8: 1365–1381.

———. 2001. Changes in forest composition and structure in three sites of tropical evergreen forest around Sengaltheri, Western Ghats. Curr. Sci. 80: 389–393.

———, AND R. KARTHIKEYAN. 1997. Biodiversity and population density of woody species in a tropical evergreen forest in Courtallum reserve forest, Western Ghats, India. Trop. Ecol. 38: 297–306.

PASCAL, J. P. 1988. Wet evergreen forests of the Western Ghats of India: Ecology, structure, floristic composition and succession. Institut Français de Pondichéry, Pondicherry, India.

PIMM, S. L., AND P. RAVEN. 2000. Extinction by numbers. Nature 403: 843–845.

PITHER, R., AND M. KELLMAN. 2002. Tree species diversity in small, tropical riparian forest fragments in Belize, Central America. Biodivers. Conserv. 11: 1623–1636.

RUOKOLAINEN, K., A. LINNA, AND H. TUOMISTO. 1997. Use of Melastomataceae and pteridophytes for revealing phytogeographical patterns in Amazonian rain forests. J. Trop. Ecol. 13: 243–256.

SCHELHAS, J., AND R. GREENBERG. 1996. Introduction: The value of forest patches. *In* J. Schelhas and R. Greenberg (Eds.). Forest patches in tropical landscapes, pp. xv–xxxvi. Island Press, Washington, DC.

SHAFER, C. L. 1995. Values and shortcomings of small reserves. Bioscience 45: 80–88.

SRINIVAS, V. 1997. Tree community structure, floristics, and changes with altitude in the tropical lowland evergreen forests of Agumbe, central Western Ghats, India. M.S. thesis, Pondicherry University, Pondicherry.

———, AND N. PARTHASARATHY. 2000. Comparative analysis of tree diversity and dispersion in the tropical lowland evergreen forest of Agumbe, Central Western Ghats, India. Trop. Biodivers. 7: 45–60.

StatSoft, Inc. 1999. Electronic statistics textbook. StatSoft, Tulsa, Oklahoma. Internet URL: http://www.statsoft.com/textbook/stathome.html.

SUBRAHMANYAM, K., AND M. P. NAYAR. 1974. Vegetation and phytogeography of the Western Ghats. *In* M. S. Mani (Ed.). Ecology and biogeography of India, pp. 178–196. Dr. W. Junk Publishers, The Hague, The Netherlands.

THOMAS, S. C. 2004. Ecological correlates of tree species persistence in tropical forest fragments. *In* E. C. Losos and E. G. Leigh. (Eds.). Forest diversity and dynamism: Findings from a large-scale plot network, pp. 279–313. University of Chicago Press, Chicago, Illinois.

TUOMISTO, H., AND K. RUOKOLAINEN. 1994. Distribution of Pteridophyta and Melastomataceae along an edaphic gradient in an Amazonian rain forest. J. Veg. Sci. 5: 25–34.

TURNER, I. M. 1996. Species loss in fragments of tropical rain forest: A review of the evidence. J. Appl. Ecol. 33: 200–209.

———, AND R. T. CORLETT. 1996. The conservation value of small isolated fragments of lowland tropical rain forest. Trends Ecol. Evol. 11: 330–333.

VIANA, V. M., A. A. TABANEZ, AND J. BATISTA. 1997. Dynamics and restoration of forest fragments in the Brazilian Atlantic moist forest. *In* W. F. Laurance and R. O. Bierregaard (Eds.). Tropical forest remnants: Ecology, management and conservation of fragmented communities, pp. 351–365. University of Chicago Press, Chicago.

WHITMORE, T. C., AND J. A. SAYER. 1992. Deforestation and species extinction in tropical moist forests. *In* T. C. Whitmore and J. A. Sayer (Eds.). Tropical deforestation and species extinction, pp. 1–14. Chapman and Hall, London.

ZAR, J. H. 1999. Biostatistical analysis, 4th edition. Prentice-Hall, New Jersey.

APPENDIX 1. List of plant species and the number of individuals recorded in the five sites in the Anamalai hills, Western Ghats, India, arranged in decreasing order of their total abundance. Species endemic to Western Ghats are indicated by an asterisk (*), and invasive species by double asterisk (**).

				Sites							
				Less disturbed				More disturbed			
Sl. No.	Species	Voucher No.	Family	AK	UM	LM	Subtotal	TF	IP	Subtotal	Total
	Trees										
1	*Oreocnide integrifolia* (Gaudich.) Miq.	T 2421	Urticaceae	34	37	0	71	85	3	88	159
2	*Palaquium ellipticum* (Dalz.) Baillon*	T 2490	Sapotaceae	16	58	32	106	15	0	15	121
3	*Spathodea campanulata* Beauv.	T 2573	Bignoniaceae	0	0	0	0	0	103	103	103
4	*Vateria indica* L.*	T 2407	Dipterocarpaceae	0	43	56	99	0	0	0	99
5	*Cullenia exarillata* A. Robyns	T 2542	Bombacaceae	16	26	22	64	14	0	14	78
6	*Reinwardtiodendron anamallayanum* (Bedd.) Saldanha*	T 2402	Meliaceae	0	3	51	54	0	0	0	54
7	*Drypetes malabarica* (Bedd.) Airy Shaw*	T 2597	Euphorbiaceae	0	45	4	49	4	0	4	53
8	*Macaranga peltata* (Roxb.) Muell.-Arg.	T 2422	Euphorbiaceae	2	9	8	19	23	11	34	53
9	*Antidesma menasu* (Tul.) Miq.ex Muell.-Arg.	T 2403	Stilaginaceae	23	7	6	36	10	1	11	47
10	*Dendrocnide sinuata* (Blume) Chew	T 2494	Urticaceae	0	16	0	16	28	1	29	45
11	*Myristica dactyloides* Gaertn.	T 2424	Myristicaceae	16	9	13	38	4	0	4	42
12	*Mesua ferrea* L.	T 2445	Clusiaceae	20	16	5	41	0	0	0	41
13	*Syzygium densiflorum* Wall. ex Wight & Arn.*	T 2550	Myrtaceae	24	3	12	39	2	0	2	41
14	*Drypetes wightii* (Hook.f.) Pax & Hoffm.*	T 2437	Euphorbiaceae	8	13	19	40	0	0	0	40
15	*Fahrenheitia zeylanica* (Thw.) Airy Shaw	T 2410	Euphorbiaceae	0	12	23	35	0	0	0	35
16	*Gomphondra coriacea* Wt.	T 2540	Icacinaceae	21	5	3	29	4	0	4	33
17	*Eucalyptus grandis* Hill ex Maiden	T 2599	Myrtaceae	0	0	0	0	0	33	33	33
18	*Artocarpus heterophyllus* Lam.	T 2524	Moraceae	7	0	3	10	10	12	22	32
19	*Clerodendrum viscosum* Vent.	T 2479	Verbenaceae	11	0	0	11	18	1	19	30
20	*Holigarna nigra* Bourd.*	T 2545	Anacardiaceae	14	6	0	20	8	0	8	28
21	*Litsea glabrata* (Wall.ex Nees) Hook.*	T 2594	Lauraceae	21	0	0	21	4	3	7	28
22	*Maesopsis eminii* Engl.	T 2543	Rhamnaceae	0	0	0	0	5	20	25	25
23	*Diospyros sylvatica* Roxb.	T 2402	Ebenaceae	1	11	12	24	0	0	0	24
24	*Croton malabaricus* Bedd.	T 2460	Euphorbiaceae	0	9	15	24	0	0	0	24
25	*Persea macrantha* (Nees) Kosterm.	T 2579	Lauraceae	7	1	3	11	4	8	12	23
26	*Meliosma pinnata* (Roxb.) Walp. subsp. *arnottiana* (Walp.) Beus.	T 2405	Sabiaceae	0	0	0	0	7	15	22	22
27	*Diospyros assimilis* Bedd.*	T 2580	Ebenaceae	18	0	0	18	2	0	2	20
28	*Mastixia arborea* (Wight) Bedd.*	T 2504	Cornaceae	10	5	0	15	4	0	4	19
29	*Aglaia simplicifolia* (Bedd.) Harms*	T 2466	Meliaceae	1	8	0	9	9	0	9	18
30	*Dimocarpus longan* Lour.	T 2499	Sapindaceae	3	1	3	7	6	3	9	16
31	*Dimorphocalyx beddomei* (Benth.) Airy Shaw*	T 2452	Euphorbiaceae	0	5	11	16	0	0	0	16
32	*Euodia lunu-ankenda* (Gaertn.) Merr.	T 2491	Rutaceae	0	0	3	3	5	8	13	16
33	*Bhesa indica* (Bedd.) Ding Hou	T 2430	Celastraceae	13	0	0	13	2	0	2	15
34	*Cryptocarya bourdillonii* Gamble*	T 2595	Lauraceae	13	0	0	13	1	0	1	14
35	*Aglaia elaeagnoidea* (A.Juss.) Benth.	T 2581	Meliaceae	0	0	14	14	0	0	0	14
36	*Vernonia arborea* Buch.-Ham.	T 2471	Asteraceae	0	0	1	1	3	10	13	14
37	*Canarium strictum* Roxb.	T 2514	Burseraceae	0	3	2	5	5	3	8	13
38	*Syzygium hemisphericum* (Wight) Alston	T 2618	Myrtaceae	0	3	4	7	6	0	6	13
39	*Erythrina mysorensis* Gamble	T 2517	Papilionaceae	0	0	0	0	0	13	13	13
40	*Pseudoglochidion anamalayanum* Gamble*	T 2650	Euphorbiaceae	13	0	0	13	0	0	0	13
41	*Ficus nervosa* Heyne ex Roth	T 2526	Moraceae	2	2	4	8	2	2	4	12
42	*Acronychia pedunculata* (L.) Miq.	T 2484	Rutaceae	2	0	2	4	4	4	8	12
43	*Cleidion spiciflorum* (Burm.f.) Merr.	T 2558	Euphorbiaceae	0	0	12	12	0	0	0	12
44	*Margaritaria indica* (Dalz.) Airy Shaw	T 2639	Euphorbiaceae	0	0	12	12	0	0	0	12
45	*Maesa indica* (Roxb.) DC.	T 2446	Myrsinaceae	5	0	0	5	5	0	5	10

APPENDIX 1. *Continued.*

Sl. No.	Species	Voucher No.	Family	Sites: Less disturbed AK	UM	LM	Subtotal	More disturbed TF	IP	Subtotal	Total
46	*Semecarpus travancorica* Bedd.*	T 2522	Anacardiaceae	0	2	0	2	0	8	8	10
47	*Elaeocarpus tuberculatus* Roxb.	T 2605	Elaeocarpaceae	4	1	0	5	0	5	5	10
48	*Knema attenuata* (Wall. ex Hook.f. & Thoms.) Warb.*	T 2425	Myristicaceae	0	2	8	10	0	0	0	10
49	*Cinnamomum malabatrum* (Burm.f.) Blume*	T 2516	Lauraceae	0	0	2	2	3	4	7	9
50	*Aphanamixis polystachya* (Wall.) Parker	T 2593	Meliaceae	6	1	2	9	0	0	0	9
51	*Trichilia connaroides* (Wight & Arn.) Bentvelzen	T 2535	Meliaceae	0	0	0	0	6	3	9	9
52	*Calophyllum polyanthum* Wall. ex Choisy	T 2671	Clusiaceae	0	0	8	8	0	0	0	8
53	*Hydnocarpus alpina* Wt.	T 2651	Flacourtiaceae	4	4	0	8	0	0	0	8
54	*Nothopegia racemosa* (Dalz.) Ramam.	T 2663	Anacardiaceae	6	0	1	7	0	1	1	8
55	*Aglaia jainii* Viswa. & Ramachan.*	T 2600	Meliaceae	0	4	4	8	0	0	0	8
56	*Calophyllum austroindicum* Kosterm. ex Stevens*	T 2454	Clusiaceae	8	0	0	8	0	0	0	8
57	*Ficus hispida* L.f.	T 2477	Moraceae	0	0	0	0	1	7	8	8
58	*Litsea floribunda* (Blume) Gamble*	T 2495	Lauraceae	0	2	1	3	3	2	5	8
59	*Diospyros nilgirica* Bedd.*	T 2582	Ebenaceae	7	0	0	7	0	0	0	7
60	*Agrostistachys borneensis* Becc.	T 2566	Euphorbiaceae	3	4	0	7	0	0	0	7
61	*Cinnamomum sulphuratum* Nees*	T 2509	Lauraceae	3	2	0	5	2	0	2	7
62	*Actinodaphne angustifolia* Nees*	T 2440	Lauraceae	1	1	0	2	0	5	5	7
63	*Aglaia exstipulata* (Griff.) Theob.*	T 2459	Meliaceae	0	3	1	4	3	0	3	7
64	*Agrostistachys indica* Dalz.	T 2614	Euphorbiaceae	4	3	0	7	0	0	0	7
65	*Casearia rubescens* Dalz.	T 2664	Flacourtiaceae	5	2	0	7	0	0	0	7
66	*Drypetes longifolia* (Blume) Pax & Hoffm.	T 2617	Euphorbiaceae	0	0	7	7	0	0	0	7
67	*Dysoxylum malabaricum* Bedd. ex Hiern*	T 2528	Meliaceae	0	2	5	7	0	0	0	7
68	*Neolitsea scrobiculata* (Meisner) Gamble	T 2408	Lauraceae	6	0	0	6	1	0	1	7
69	*Heritiera papilio* Bedd.*	T 2420	Sterculiaceae	5	0	1	6	0	0	0	6
70	*Litsea bourdillonii* Gamble*	T 2438	Lauraceae	5	0	0	5	1	0	1	6
71	*Canthium dicoccum* (Gaertn.) Teijsm & Binn. var. *umbellata* (Wight) Sant. & Merch.	T 2549	Rubiaceae	6	0	0	6	0	0	0	6
72	*Ficus exasperata* Vahl.	T 2644	Moraceae	0	0	0	0	1	5	6	6
73	*Garcinia talbotii* Raiz. ex Sant.*	T 2675	Clusiaceae	6	0	0	6	0	0	0	6
74	*Glochidion ellipticum* Wt.*	T 2541	Euphorbiaceae	2	3	0	5	1	0	1	6
75	*Mallotus stenanthus* Muell.-Arg.*	T 2570	Euphorbiaceae	0	4	2	6	0	0	0	6
76	*Scolopia crenata* (Wt. & Arn.)	T 2620	Flacourtiaceae	6	0	0	6	0	0	0	6
77	*Ardisia rhomboidea* Wt.*	T 2655	Myrsinaceae	3	0	0	3	2	0	2	5
78	*Ficus beddomei* King	T 2585	Moraceae	3	2	0	5	0	0	0	5
79	*Croton laccifer* L.	T 2609	Euphorbiaceae	5	0	0	5	0	0	0	5
80	*Lepisanthes decipiens* (Wt. &Arn.) Thw.	T 2632	Sapindaceae	5	0	0	5	0	0	0	5
81	*Nothopegia beddomei* Gamble*	T 2624	Anacardiaceae	0	1	4	5	0	0	0	5
82	*Otonephelium stipulaceum* (Bedd.) Radlk.*	T 2659	Sapindaceae	0	0	5	5	0	0	0	5
83	*Toona ciliata* M.Roem.	T 2673	Meliaceae	0	0	1	1	3	1	4	5
84	*Mangifera indica* L.	T 2633	Anacardiaceae	0	3	1	4	0	0	0	4
85	*Baccaurea courtallensis* (Wt.) Muell.-Arg.*	T 2559	Euphorbiaceae	0	0	4	4	0	0	0	4
86	*Elaeocarpus munronii* (Wt.) Mast.*	T 2496	Elaeocarpaceae	1	0	0	1	3	0	3	4
87	*Hydnocarpus pentandra* (Buch.-Ham.) Oken	T 2513	Flacourtiaceae	0	0	3	3	1	0	1	4
88	*Meiogyne pannosa* (Dalz.) Sinclair	T 2556	Annonaceae	2	0	2	4	0	0	0	4
89	*Ormosia travancorica* Bedd.	T 2631	Papilionaceae	4	0	0	4	0	0	0	4
90	*Polyalthia fragrans* (Dalz.) Bedd.*	T 2666	Annonaceae	0	0	4	4	0	0	0	4
91	*Sterculia guttata* Roxb.ex DC.	T 2515	Sterculiaceae	0	0	0	0	0	4	4	4

APPENDIX 1. *Continued.*

Sl. No.	Species	Voucher No.	Family	Sites: Less disturbed AK	UM	LM	Subtotal	More disturbed TF	IP	Subtotal	Total
92	*Phoebe paniculata* Nees	T 2480	Lauraceae	0	0	1	1	2	0	2	3
93	*Turpinia malabarica* Gamble	T 2451	Staphylaceae	2	1	0	3	0	0	0	3
94	*Diospyros bourdillonii* Brandis*	T 2472	Ebenaceae	0	1	2	3	0	0	0	3
95	*Harpullia arborea* (Blanco) Radlk.	T 2508	Sapindaceae	0	1	2	3	0	0	0	3
96	*Neolitsea zeylanica* (Nees) Merr.	T 2487	Lauraceae	1	0	0	1	2	0	2	3
97	*Garcinia morella* (Gaertn.) Desr.	T 2461	Clusiaceae	1	0	1	2	0	0	0	2
98	*Elaeocarpus serratus* L.	T 2434	Elaeocarpaceae	0	0	0	0	1	1	2	2
99	*Litsea* sp.	T 2465	Lauraceae	1	0	0	1	1	0	1	2
100	*Actinodaphne bourdillonii* Gamble*	T 2523	Lauraceae	1	0	0	1	1	0	1	2
101	*Actinodaphne tadulingamii* Gamble	T 2574	Lauraceae	1	0	1	2	0	0	0	2
102	*Antiaris toxicaria* (Pers.) Lesch.	T 2628	Moraceae	0	1	1	2	0	0	0	2
103	*Bombax ceiba* L.	T 2658	Bombacaceae	0	0	0	0	1	1	2	2
104	*Chrysophyllum roxburghii* G.Don	T 2635	Sapotaceae	0	0	2	2	0	0	0	2
105	*Diospyros buxifolia* (Blume) Hiern	T 2638	Ebenaceae	0	0	2	2	0	0	0	2
106	*Ficus microcarpa* L.f.	T 2601	Moraceae	0	0	1	1	1	0	1	2
107	*Ficus talbotii* King	T 2551	Moraceae	2	0	0	2	0	0	0	2
108	*Ficus virens* Ait.	T 2507	Moraceae	1	0	0	1	1	0	1	2
109	*Garcinia gummi-gutta* (L.) Robs.*	T 2481	Clusiaceae	0	1	0	1	0	1	1	2
110	*Hopea parviflora* Bedd.*	T 2458	Dipterocarpaceae	0	0	2	2	0	0	0	2
111	*Isonandra lanceolata* Wt.	T 2435	Sapotaceae	0	0	0	0	2	0	2	2
112	*Mallotus philippensis* (Lam.) Muell.-Arg.	T 2407	Euphorbiaceae	0	0	1	1	0	1	1	2
113	*Orophea erythrocarpa* Bedd.	T 2417	Annonaceae	0	0	2	2	0	0	0	2
114	*Palaquium bourdillonii* Brandis*	T 2453	Sapotaceae	0	2	0	2	0	0	0	2
115	*Phoebe lanceolata* Nees	T 2497	Lauraceae	0	1	1	2	0	0	0	2
116	*Syzygium gardneri* Thw.	T 2572	Myrtaceae	0	1	0	1	1	0	1	2
117	*Syzygium laetum* (Buch.-Ham.) Gandhi*	T 2672	Myrtaceae	2	0	0	2	0	0	0	2
118	*Terminalia bellirica* (Gaertn.) Roxb.	T 2645	Combretaceae	0	0	2	2	0	0	0	2
119	*Beilschmiedia wightii* (Nees) Benth. ex Hook.f.	T 2636	Lauraceae	1	0	0	1	0	0	0	1
120	*Tricalysia apiocarpa* (Dalz.) Gamble	T 2604	Rubiaceae	1	0	0	1	0	0	0	1
121	*Aglaia elaeagnoidea* (Juss.) Benth. var. *beddomei* (Gamble) K.K.N. Nair	T 2568	Meliaceae	0	0	1	1	0	0	0	1
122	*Alstonia scholaris* (L.) R. Br.	T 2537	Apocynaceae	0	0	0	0	0	1	1	1
123	*Apollonias arnottii* Nees*	T 2527	Lauraceae	0	0	0	0	1	0	1	1
124	*Aporusa lindleyana* (Wt.) Baill.	T 2625	Euphorbiaceae	0	0	0	0	0	1	1	1
125	*Bischofia javanica* Blume	T 2646	Bischofiaceae	0	1	0	1	0	0	0	1
126	*Casearia esculenta* Roxb.	T 2660	Flacourtiaceae	0	0	1	1	0	0	0	1
127	*Cassine glauca* (Rottb.) Kuntze	T 2674	*Celastraceae*	1	0	0	1	0	0	0	1
128	*Coffea canephora* Pierre ex Frochner**	T 2637	Rubiaceae	0	0	1	1	0	0	0	1
129	*Drypetes subsessilis* (Kurz) Pax & Hoffm.	T 2602	Euphorbiaceae	0	0	1	1	0	0	0	1
130	*Filicium decipiens* (Wt. & Arn.) Thw.	T 2626	Sapindaceae	0	0	1	1	0	0	0	1
131	*Flacourtia montana* Graham*	T 2411	Flacourtiaceae	0	0	1	1	0	0	0	1
132	*Litsea mysorensis* Gamble*	T 2450	Lauraceae	1	0	0	1	0	0	0	1
133	*Mallotus tetracoccus* (Roxb.) Kurz	T 2483	Euphorbiaceae	1	0	0	1	0	0	0	1
134	*Memecylon sisparense* Gamble*	T 2518	Melastomataceae	0	0	1	1	0	0	0	1
135	*Michaelia champaca* L.	T 2575	Magnoliaceae	0	0	0	0	0	1	1	1
136	*Nageia wallichiana* (Presl.) Kuntze	T 2565	Podocarpaceae	1	0	0	1	0	0	0	1
137	*Prunus ceylanica* (Wight) Miq.	T 2667	Rosaceae	1	0	0	1	0	0	0	1

APPENDIX 1. *Continued.*

				Sites							
				Less disturbed				More disturbed			
Sl. No.	Species	Voucher No.	Family	AK	UM	LM	Subtotal	TF	IP	Subtotal	Total
138	*Rapanea wightiana* (Wall. ex DC.) Mez.	T 2498	Myrsinaceae	1	0	0	1	0	0	0	1
139	*Spondias pinnata* (L.f.) Kurz.	T 2511	Anacardiaceae	0	0	1	1	0	0	0	1
140	*Strombosia ceylanica* Gardn.	T 2561	Olacaceae	0	0	1	1	0	0	0	1
141	*Symplocos cochinchinensis* (Lour.) Moore subsp. *laurina* (Retz.) Nooteb.	T 2587	Symplocaceae	0	0	1	1	0	0	0	1
142	*Syzygium caryophyllatum* (L.) Alston	T 2467	Myrtaceae	1	0	0	1	0	0	0	1
143	*Tetrameles nudiflora* R. Br.	T 2412	Datiscaceae	0	0	0	0	0	1	1	1
144	*Zanthoxylum rhetsa* (Roxb.) DC.	T 2441	Rutaceae	0	0	1	1	0	0	0	1
	Total			452	412	453	1317	344	307	651	1968
	Lianas										
1	*Connarus sclerocarpus* (Wight & Arn.) Schellenb.	L 2878	Connaraceae	121	149	13	283	69	2	71	354
2	*Strychnos vanprukii* Craib*	L 2864	Loganiaceae	8	56	14	78	251	7	258	336
3	*Opilia amentacea* Roxb.	L 2898	Opiliaceae	26	17	9	52	175	7	182	234
4	*Piper nigrum* L.	L 2890	Piperaceae	40	29	34	103	30	10	40	143
5	*Zanthoxylum ovalifolium* Wight	L 2803	Rutaceae	28	6	18	52	57	14	71	123
6	*Aganosma cymosa* (Roxb.) G. Don	L 2880	Apocynaceae	89	1	2	92	1	0	1	93
7	*Kunstleria keralense* Mohanan & Nair*	L 2816	Papilionaceae	0	77	15	92	0	0	0	92
8	*Grewia rhamnifolia* Heyne ex Roth	L 2853	Tiliaceae	1	2	0	3	54	28	82	85
9	*Calamus gamblei* Becc.ex Becc. & Hook.f.*	L 2843	Arecaceae	0	0	65	65	0	0	0	65
10	*Elaeagnus conferta* Roxb.	L 2817	Elaeagnaceae	20	3	2	25	33	3	36	61
11	*Erythropalum populifolium* (Arn.) Mast.*	L 2804	Erythropalaceae	16	14	2	32	27	1	28	60
12	*Ancistrocladus heyneanus* Wall. ex Graham	L 2833	Ancistrocladaceae	0	43	7	50	3	0	3	53
13	*Polygonum chinense* L.	L 2908	Polygonaceae	1	0	0	1	0	44	44	45
14	*Calamus pseudo-tenuis* Beccari ex Beccari & Hook.f.	L 2887	Arecaceae	23	0	0	23	15	0	15	38
15	*Salacia chinensis* L.	L 2806	Hippocrateaceae	18	7	4	29	2	3	5	34
16	*Tetrastigma sulcatum* (Lawson) Gamble	L 2881	Vitaceae	9	9	3	21	8	4	12	33
17	*Aristolochia* sp.	L 2871	Aristolochiaceae	0	0	0	0	0	32	32	32
18	*Derris brevipes* (Benth.) Baker*	L 2822	Papilionaceae	9	10	2	21	1	1	2	23
19	*Gnetum ula* Brongn.	L 2836	Gnetaceae	0	1	6	7	13	1	14	21
20	*Pseudaidia speciosa* (Bedd.) Tirveng.	L 2854	Rubiaceae	6	5	9	20	1	0	1	21
21	*Hiptage benghalensis* (L.) Kurz	L 2802	Malpighiaceae	0	3	17	20	0	0	0	20
22	*Cayratia pedata* (Lam.) Juss. ex Gagnep.	L 2873	Vitaceae	5	2	1	8	7	3	10	18
23	*Caesalpinia cucullata* Roxb.	L 2811	Caesalpiniaceae	11	1	0	12	4	2	6	18
24	*Allophylus concanicus* Radlk.*	L 2919	Sapindaceae	16	0	0	16	1	0	1	17
25	*Canthium angustifolium* Roxb.	L 2900	Rubiaceae	0	2	7	9	6	0	6	15
26	*Derris benthamii* (Thw.) Thw.var. *benthamii*	L 2830	Papilionaceae	2	0	13	15	0	0	0	15
27	*Luvunga sarmentosa* (Blume) Kurz	L 2813	Rutaceae	4	1	4	9	6	0	6	15
28	*Rubus micropetalus* Gard.	L 2851	Rosaceae	3	0	0	3	10	2	12	15
29	*Ventilago madraspatana* Gaertn.	L 2882	Rhamnaceae	0	5	6	11	4	0	4	15
30	*Allophylus serratus* (Roxb.) Kurz	L 2897	Sapindaceae	0	1	0	1	4	8	12	13
31	*Jasminum rottlerianum* Wall. ex A.DC.*	L 2826	Oleaceae	0	0	1	1	10	1	11	12
32	*Canthium rheedii* DC.	L 2848	Rubiaceae	0	0	0	0	11	0	11	11
33	*Rourea minor* (Gaertn.) Alston	L 2906	Connaraceae	0	7	0	7	4	0	4	11
34	*Rubus ellipticus* Smith	L 2805	Rosaceae	0	0	0	0	1	10	11	11
35	*Hippocratea bourdillonii* Gamble*	L 2904	Hippocrateaceae	7	1	1	9	0	0	0	9
36	*Artabotrys zeylanicus* Hook.f. & Thoms.	L 2927	Annonaceae	0	1	5	6	2	0	2	8
37	*Carissa inermis* Vahl	L 2815	Apocynaceae	1	0	2	3	5	0	5	8

APPENDIX 1. *Continued.*

				Sites							
				Less disturbed				More disturbed			
Sl. No.	Species	Voucher No.	Family	AK	UM	LM	Subtotal	TF	IP	Subtotal	Total
38	*Combretum latifolium* Bl.	L 2807	Combretaceae	1	3	3	7	0	0	0	7
39	*Erycibe paniculata* Roxb.	L 2903	Convolvulaceae	0	2	2	4	3	0	3	7
40	*Parsonsia alboflavescens* (Dennst.) Mabberley	L 2859	Apocynaceae	0	0	7	7	0	0	0	7
41	*Croton caudatus* Geiseler	L 2874	Euphorbiaceae	0	0	6	6	0	0	0	6
42	*Piper mullesua* Buch.-Ham.ex D. Don	L 2863	Piperaceae	6	0	0	6	0	0	0	6
43	*Chilocarpus atrovirens* (G.Don) Bl.	L 2812	Apocynaceae	0	0	5	5	0	0	0	5
44	*Derris trifoliata* Lour.	L 2915	Papilionaceae	0	3	2	5	0	0	0	5
45	*Cosmostigma racemosum* (Roxb.) Wight	L 2829	Asclepiadaceae	1	0	0	1	1	2	3	4
46	*Embelia basaal* A.DC.	L 2825	Myrsinaceae	4	0	0	4	0	0	0	4
47	*Ehretia canarensis* (Clarke) Gamble	L 2905	Boraginaceae	3	0	0	3	0	0	0	3
48	*Ampelocissus erioc1adus* (Wight & Arn.) Planch.	L 2844	Vitaceae	0	0	2	2	0	0	0	2
49	*Capparis moonii* Wight	L 2930	Capparaceae	0	0	0	0	2	0	2	2
50	*Jasminum scandens* Vahl	L 2824	Oleaceae	1	0	0	1	0	1	1	2
51	*Myxopyrum serratulum* A.W. Hill	L 2921	Oleaceae	0	0	2	2	0	0	0	2
52	*Salacia malabarica* Gamble*	L 2862	Hippocrateaceae	0	0	2	2	0	0	0	2
53	*Salacia* sp.	L 2852	Hippocrateaceae	0	0	2	2	0	0	0	2
54	*Celastrus paniculatus* Willd.	L 2883	Celastraceae	0	0	0	0	1	0	1	1
55	*Jasminum azoricum* L.	L 2904	Oleaceae	0	1	0	1	0	0	0	1
56	*Mussaenda belilla* Buch.-Ham.	L 2926	Rubiaceae	0	0	0	0	0	1	1	1
57	*Olax scandens* Roxb.	L 2846	Olacaceae	0	0	1	1	0	0	0	1
58	*Rhaphidophora laciniata* (Burm.f.) Men.	L 2837	Araceae	0	0	0	0	1	0	1	1
59	*Sarcostigma kleinii* Wight & Arn.	L 2916	Icacinaceae	0	0	1	1	0	0	0	1
60	*Smilax perfoliata* Lour.	L 2823	Smilacaceae	1	0	0	1	0	0	0	1
	Total			481	462	297	1240	823	187	1010	2250
	Understory plants										
1	*Elatostemma lineolatum* Wight	U 3020	Urticaceae	321	111	166	598	198	12	210	808
2	*Cyrtococcum trigonum* (Retz.) A. Camus	U 3663	Poaceae	8	8	43	59	135	374	509	568
3	*Coffea canephora* Pierre ex Frochner	U 3094	Rubiaceae	0	220	272	492	2	0	2	494
4	*Oplismenus compositus* (L.) P. Beauv.	U 3087	Poaceae	83	1	2	86	60	286	346	432
5	*Pellionia heyneana* Wedd.	U 3051	Urticaceae	0	33	228	261	46	0	46	307
6	*Asplenium inequilaterale* Willd.	U 3113	Aspleniaceae	187	58	22	267	18	13	31	298
7	*Pteris multiaurita* Ag.	U 3032	Pteridaceae	68	50	14	132	80	50	130	262
8	*Bolbitis semicordata* (Moore) Ching	U 3149	Bolbitidaceae	200	2	25	227	3	2	5	232
9	*Psychotria nigra* (Gaertn.) Alston	U 3025	Rubiaceae	22	3	11	36	136	0	136	172
10	*Mackenziea caudata* (T. And.) Ramam.*	U 3055	Acanthaceae	40	0	129	169	2	0	2	171
11	*Curcuma amada* Roxb.	U 3191	Zingiberaceae	2	59	28	89	79	2	81	170
12	*Mikania* sp.**	U 3052	Asteraceae	0	1	0	1	29	135	164	165
13	*Lantana camara* L.**	U 3111	Verbenaceae	0	0	0	0	3	154	157	157
14	*Zingiber zerumbet* (L.) J.E. Smith	U 3093	Zingiberaceae	6	45	17	68	74	5	79	147
15	*Hydrocotyle javanica* Thunb.	U 3114	Apiaceae	32	1	1	34	28	38	66	100
16	*Crotalaria laevigata* Lam.	U 3095	Papilionaceae	0	0	0	0	5	87	92	92
17	*Nilgirianthus barbatus* (Nees) Bremek.*	U 3176	Acanthaceae	79	0	8	87	0	0	0	87
18	*Croton zeylanicus* Muell.-Arg.	U 3171	Euphorbiaceae	3	53	1	57	27	0	27	84
19	*Arisaema leschenaultii* Bl.*	U 3200	Araceae	21	36	4	61	21	1	22	83
20	*Clematis* sp.	U 3039	Ranunculaceae	1	0	0	1	17	64	81	82
21	*Commelina paludosa* Bl.	U 3117	Commelinaceae	8	0	0	8	0	73	73	81
22	*Mackenziea gracilis* (Bedd.) Bremek.*	U 3101	Acanthaceae	0	27	41	68	6	0	6	74

APPENDIX 1. *Continued.*

Sl. No.	Species	Voucher No.	Family	Sites							
				Less disturbed				More disturbed			
				AK	UM	LM	Subtotal	TF	IP	Subtotal	Total
23	*Eupatorium glandulosum* HB. & K.	U 3027	Asteraceae	10	0	0	10	6	49	55	65
24	*Stenosiphonium wightii* Bremek.*	U 3151	Acanthaceae	53	0	0	53	0	0	0	53
25	*Dryopteris serrato-dentata* (Bedd.) Hayata	U 3199	Dryopteridaceae	50	0	0	50	0	0	0	50
26	*Cyathula prostrata* (L.) Blume	U 3116	Amaranthaceae	0	0	2	2	6	36	42	44
27	*Arachniodes aristata* (Forsk.f.) Tindale	U 3036	Aspidiaceae	7	11	0	18	22	3	25	43
28	*Saprosma glomeratum* (Gard.) Bedd.*	U 3119	Rubiaceae	0	7	13	20	21	0	21	41
29	*Sida rhombifolia* L.**	U 3161	Malvaceae	0	0	0	0	2	39	41	41
30	*Xenacanthus pulneyensis* (Clarke) Bremek.	U 3046	Acanthaceae	41	0	0	41	0	0	0	41
31	*Aneilema montana* (Wight) Clarke	U 3092	Commelinaceae	0	0	23	23	0	16	16	39
32	*Sarcandra chloranthoides* Gard.	U 3160	Chloranthaceae	0	26	0	26	12	0	12	38
33	*Stephania japonica* (Thunb.) Miers	U 3185	Menispermaceae	0	2	1	3	6	29	35	38
34	*Lepianthes umbellata* (L.) Rafin.	U 3121	Piperaceae	4	10	17	31	3	0	3	34
35	*Ophiopogon intermedius* Don	U 3023	Haemodoraceae	20	0	4	24	4	6	10	34
36	*Tabernaemontana gamblei* Subram. & Henry	U 3112	Apocynaceae	0	25	5	30	1	0	1	31
37	*Amomum cannicarpum* (Wight) Benth.*	U 3192	Zingiberaceae	0	5	21	26	2	0	2	28
38	*Pteris pellucida* Presl.	U 3126	Pteridaceae	20	0	3	23	0	0	0	23
39	*Sida cordata* (Burm.f.) Borssum**	U 3096	Malvaceae	0	0	0	0	3	20	23	23
40	*Solena angulata* (Chakaravarthy) Babu*	U 3145	Cucurbitaceae	0	1	1	2	1	18	19	21
41	*Amomum hypoleucum* Thw.	U 3193	Zingiberaceae	0	2	6	8	9	2	11	19
42	*Dracaena terniflora* Roxb.	U 3097	Agavaceae	0	0	17	17	0	0	0	17
43	*Nilgirianthus ciliatus* (Nees) Bremek.*	U 3009	Acanthaceae	16	0	0	16	0	0	0	16
44	*Dioscorea oppositifolia* L.	U 3083	Dioscoreaceae	0	0	0	0	0	15	15	15
45	*Rauvolfia densiflora* (Wall.) Benth. ex Hook.f.	U 3147	Apocynaceae	0	0	0	0	0	15	15	15
46	*Curculigo trichocarpa* (Wight) Ben. & Raiz.	U 3186	Hypoxidaceae	0	0	12	12	2	0	2	14
47	*Ecbolium viride* (Forssk.) Alston	U 3195	Acanthaceae	2	0	12	14	0	0	0	14
48	*Elettaria cardamomum* (L.) Maton	U 3013	Zingiberaceae	1	1	1	3	0	11	11	14
49	*Psychotria* sp.1	U 3129	Rubiaceae	0	12	1	13	1	0	1	14
50	*Leptochilus* sp.	U 3140	Polypodiaceae	11	1	0	12	0	0	0	12
51	*Colebrookea oppositifolia* J.E. Smith	U 3164	Lamiaceae	0	11	0	11	0	0	0	11
52	*Pandanus* sp.	U 3184	Pandanaceae	7	3	0	10	1	0	1	11
53	*Psychotria* sp.2	U 3137	Rubiaceae	4	0	4	8	3	0	3	11
54	*Ageratum conyzoides* L.	U 3109	Asteraceae	0	0	0	0	0	9	9	9
55	*Asplenium erectum* Bory ex Willd.	U 3069	Aspleniaceae	9	0	0	9	0	0	0	9
56	*Impatiens* sp.	U 3048	Balsaminaceae	9	0	0	9	0	0	0	9
57	*Cayratia tenuifolia* (Wight & Arn.) Gagnep.	U 3152	Vitaceae	0	2	6	8	0	0	0	8
58	*Cyrtococcum oxyphyllum* (Steud.) Stapf	U 3188	Poaceae	0	3	0	3	0	5	5	8
59	*Thottea siliquosa* (Lam.) Ding Hou	U 3122	Aristolochiaceae	4	0	0	4	4	0	4	8
60	*Tropidia angulosa* (Lindl.) Bl.	U 3070	Orchidaceae	1	3	4	8	0	0	0	8
61	*Solanum melongena* L. var. *insanum* (L) Prain	U 3012	Solanaceae	0	0	0	0	5	2	7	7
62	*Amomum muricatum* Bedd.*	U 3133	Zingiberaceae	1	0	0	1	5	0	5	6
63	*Laportea bulbifera* (Sieb. & Zucc.) Wedd.	U 3170	Urticaceae	1	0	0	1	5	0	5	6
64	*Rubus niveus* Thunb.	U 3189	Rosaceae	0	0	0	0	0	6	6	6
65	*Zingiber wightianum* Thw.	U 3029	Zingiberaceae	0	0	0	0	3	3	6	6
66	*Begonia picta* Sm.	U 3010	Begoniaceae	0	0	5	5	0	0	0	5
67	*Phlebophyllum versicolor* (Wight) Bremek.*	U 3071	Acanthaceae	5	0	0	5	0	0	0	5
68	*Tectaria* sp.	U 3110	Dryopteridaceae	5	0	0	5	0	0	0	5
69	*Urena lobata* L.	U 3148	Malvaceae	0	0	0	0	0	5	5	5

APPENDIX 1. *Continued.*

				Sites							
				Less disturbed				More disturbed			
Sl. No.	Species	Voucher No.	Family	AK	UM	LM	Subtotal	TF	IP	Subtotal	Total
70	*Paspalum conjugatum* Berg.	U 3182	Poaceae	0	0	0	0	0	4	4	4
71	*Stachyphrynium spicatum* K. Schum.*	U 3153	Marantaceae	0	0	0	0	4	0	4	4
72	*Staurogyne zeylanica* (Nees) Kuntze	U 3128	Acanthaceae	0	0	0	0	0	4	4	4
73	*Anaphyllum beddomei* Engler*	U 3099	Araceae	0	0	3	3	0	0	0	3
74	*Premna paucinervis* (Clarke) Gamble*	U 3040	Verbenaceae	0	3	0	3	0	0	0	3
75	*Ranunculus* sp.	U 3078	Ranunculaceae	0	3	0	3	0	0	0	3
76	*Scutellaria wightiana* Benth.	U 3106	Lamiaceae	3	0	0	3	0	0	0	3
77	*Tithonia diversifolia* (Hemsl.) A. Gray**	U 3014	Asteraceae	0	0	0	0	0	3	3	3
78	*Trigonospora ciliata* (Benth.) Holtt.	U 3050	Thelypteridaceae	0	0	3	3	0	0	0	3
79	*Adiantum incisum* Forsk.	U 3090	Adiantaceae	2	0	0	2	0	0	0	2
80	*Amorphophallus hohenackeri* Engl.*	U 3107	Araceae	0	2	0	2	0	0	0	2
81	*Begonia malabarica* Lam.	U 3053	Begoniaceae	2	0	0	2	0	0	0	2
82	*Cyclea peltata* (Lam.) Hook.f.& Thoms.	U 3016	Menispermaceae	0	0	0	0	0	2	2	2
83	*Dendrocalamus strictus* (Roxb.) Nees	U 3037	Poaceae	2	0	0	2	0	0	0	2
84	*Globba ophioglossa* Wight	U 3054	Zingiberaceae	0	0	0	0	2	0	2	2
85	*Ixora nigricans* R.Br. ex Wight & Arn.	U 3086	Rubiaceae	2	0	0	2	0	0	0	2
86	*Mimosa pudica* L.**	U 3141	Mimosaceae	0	0	0	0	0	2	2	2
87	*Nicandra physalodes* (L.) Gaertn.	U 3156	Solanaceae	0	0	0	0	2	0	2	2
88	*Ophiorrhiza hirsutula* Wight ex Hook*	U 3173	Rubiaceae	2	0	0	2	0	0	0	2
89	*Sarcococca saligna* (D. Don) Muell.-Arg.	U 3190	Buxaceae	0	0	0	0	0	2	2	2
90	*Schumannianthus virgatus* (Roxb.) Rolfe	U 3104	Marantaceae	0	0	2	2	0	0	0	2
91	*Scleria lithosperma (*L.) Sw.	U 3033	Cyperaceae	2	0	0	2	0	0	0	2
92	*Solanum torvum* Sw.	U 3057	Solanaceae	0	0	0	0	0	2	2	2
93	*Strobilanthes* sp.	U 3021	Acanthaceae	0	0	0	0	2	0	2	2
94	*Tainia bicornis* (Lindl.) Reichb.f.	U 3046	Orchidaceae	2	0	0	2	0	0	0	2
95	*Vigna umbellata* (Thunb.) Ohwi & Ohashi	U 3122	Papilionaceae	0	0	0	0	0	2	2	2
96	*Amomum pterocarpum* Thw.*	U 3178	Zingiberaceae	0	1	0	1	0	0	0	1
97	*Anisocampium cumingianum* Presl.	U 3158	Athyriaceae	1	0	0	1	0	0	0	1
98	*Argyreia hirsuta* Wight & Arn.	U 3130	Convolvulaceae	0	0	0	0	0	1	1	1
99	*Asparagus racemosus* Willd.	U 3191	Liliaceae	0	0	0	0	1	0	1	1
100	*Breynia vitis-idaea* (Burm.f.) Fischer	U 3047	Euphorbiaceae	0	1	0	1	0	0	0	1
101	*Carex* sp.	U 3017	Cyperaceae	0	0	0	0	1	0	1	1
102	*Ipomoea indica* (Burm.f.) Merr.	U 3146	Convolvulaceae	0	0	0	0	0	1	1	1
103	*Kedrostis courtallensis* (Arn.) Jeffrey	U 3102	Cucurbitaceae	0	1	0	1	0	0	0	1
104	*Passiflora subpeltata* Ortega	U 3048	Passifloraceae	0	0	0	0	0	1	1	1
105	*Phaseolus* sp.	U 3030	Papilionaceae	0	0	0	0	0	1	1	1
106	*Pilea melastomoides* (Poir.) Bl.	U 3015	Urticaceae	1	0	0	1	0	0	0	1
107	*Selaginella tenera* (Hk.et Grew) Spring	U 3041	Selaginellaceae	0	0	0	0	0	1	1	1
108	*Solanum giganteum* Jacq.	U 3102	Solanaceae	0	0	0	0	1	0	1	1
	Total			1381	844	1178	3403	1109	1611	2720	6123

APPENDIX 2. Plant species contributing to differences in floristic composition between protected and unprotected sites. SIMPER analysis results are listed for the top 20 species contributing most to the dissimilarity between protected and unprotected sites.

Species	Average abundance		Contribution %
	Protected	Unprotected	(Cumulative %)
Trees			
Spathodea campanulata	0	51.5	8.75
Oreocnide integrifolia	23.67	44	6.89
Vateria indica	33	0	5.50
Palaquium ellipticum	35.33	7.5	4.71
Reinwardtiodendron anamallayanum	18	0	2.94
Eucalyptus grandis	0	16.5	2.80
Drypetes malabarica	16.33	2	2.68
Cullenia exarillata	21.33	7	2.42
Dendrocnide sinuata	5.33	14.5	2.31
Mesua ferrea	13.67	0	2.27 (41.27)
Drypetes wightii	13.33	0	2.21
Maesopsis eminii	0	12.5	2.10
Syzygium densiflorum	13	1	1.96
Fahrenheitia zeylanica	11.67	0	1.93
Meliosma pinnata	0	11	1.84
Myristica dactyloides	12.67	2	1.77
Macaranga peltata	6.33	17	1.74
Clerodendrum viscosum	3.67	9.5	1.50
Antidesma menasu	12	5.5	1.46
Litsea glabrata	7	3.5	1.34 (59.12)
Lianas			
Strychnos vanprukii	26	129	14.33
Connarus sclerocarpus	94.33	35.5	12.96
Opilia amentacea	17.33	91	9.69
Grewia rhamnifolia	1	41	5.98
Polygonum chinense	0.33	22	5.00
Kunstleria keralense	30.67	0	4.98
Aganosma cymosa	30.67	0.5	4.63
Calamus gamblei	21.67	0	4.30

APPENDIX 2. *Continued.*

Species	Average abundance		Contribution %
	Protected	Unprotected	(Cumulative %)
Aristolochia sp.	0	16	3.65
Zanthoxylum ovalifolium	17.33	35.5	3.09 (68.61)
Piper nigrum	34.33	20	3.04
Ancistrocladus heyneanus	16.67	1.5	2.63
Elaeagnus conferta	8.33	18	1.98
Erythropalum populifolium	10.67	14	1.91
Calamus pseudo-tenuis	7.67	7.5	1.47
Hiptage benghalensis	6.67	0	1.28
Rubus ellipticus	0	5.5	1.20
Pseudaidia speciosa	6.67	0.5	1.10
Salacia chinensis	9.67	2.5	1.09
Allophylus serratus	0.33	6	1.08 (85.39)
Understory plants			
Cyrtococcum trigonum	19.67	254.5	12.16
Coffea canephora	164	1	9.29
Oplismenus compositus	28.67	173	7.80
Elatostemma lineolatum	199.33	105	6.82
Pellionia heyneana	87	23	4.45
Mikania sp.	0.33	82	4.16
Psychotria nigra	12	68	4.03
Lantana camara	0	78.5	3.86
Asplenium inequilaterale	89	15.5	3.78
Bolbitis semicordata	75.67	2.5	3.64 (59.99)
Mackenziea caudate	56.33	1	2.92
Crotalaria laevigata	0	46	2.28
Curcuma amada	29.67	40.5	2.14
Clematis sp.	0.33	40.5	2.06
Zingiber zerumbet	22.67	39.5	1.96
Commelina paludosa	2.67	36.5	1.80
Pteris multiaurita	44	65	1.51
Nilgirianthus barbatus	29	0	1.43
Eupatorium glandulosum	3.33	27.5	1.29
Hydrocotyle javanica	11.33	33	1.28 (78.66)