Ecosystem and Species Diversity of Khangchendzonga Biosphere Reserve in Sikkim

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ABSTRACT

The diversity of ecosystems in Khangchendzonga Biosphere Reserve (KBR) was surveyed and ecosystem types were identified based on dominant vegetation. Six major ecosystem types were studied and characterized; these were related to altitudinal gradient. Species diversity in each identified ecosystem type was investigated. Study reveals that the species diversity and richness patterns of the different vegetation component vary with ecosystem types; there is a negative correlation between species diversity and altitude for woody components (trees and shrubs), while the herbaceous components are not significantly correlated. The forest ecosystems hold more plant diversity than other ecosystems, the highest being the riverine forest. Among life forms, herbs are most abundant in all ecosystems; 95% in alpine meadow, 89% in subtropical grassland and 67% in scrub vegetation. However, forest ecosystems have greater equitability in life form distribution than other ecosystems. Species density is correlated with the community structure of the ecosystem. Maximum herbaceous density is seen in the subtropical grassland and the alpine meadow.

Key words: Sikkim Himalayas, KBR, ecosystem diversity, species diversity, community structure.

Introduction

Ecosystem diversity denotes the diversity of habitats, communities and ecological processes within the biosphere. Studies of ecosystem diversity are carried out at different scales, from one ecosystem to an entire region containing several different

ecosystems. Regions containing a great variety of ecosystems are rich in biodiversity. The enormous range of terrestrial and aquatic environments on earth has been classified into a number of ecosystems.

Plants have been used extensively in terrestrial ecological classification systems because they dominate the structure of those communities and are much easier to sample than animals. de Candolle (1874) proposed a classification of plant communities based on life forms because he believed that life forms were determined by climate. More complicated schemes of describing life-forms of plants and characterizing plant communities by the relative dominance of plants with different life-forms and shapes were developed by Raunkaier (1934) and Halle *et al.* (1978). Holdridge's (1967) devised life zone system, using climatic variables, to predict the naturally occurring climax community.

Great variety of environments found in Himalayas has created diverse ecosystem types rich in species and genetic diversity. As a result, the region is one of the richest zones in biological diversity in the world. The Khangchendzonga Biosphere Reserve (KBR), with a total area of 1784 sq. km in the core and 825.92 sq. km in the buffer zone is a representative of Eastern Himalayan region (Singh, 2000). The Biosphere reserve which is located in the Sikkim Himalayas is one of the richest areas of biodiversity in the Himalayan range, being home to about 140 endemic plant species spread over 41 families (Sharma *et al.*, 2001). In addition to the outstanding levels of species diversity and endemism, the eco-region also plays an important role in maintaining altitudinal connectivity between the habitat types that make up the larger Himalayan ecosystem. The topography, the altitudinal variation and the peaks along with the forest wilderness in the biosphere reserve have enriched the KBR with biodiversity. Several workers have studied the pattern of species richness at landscape level (Roy and Behera, 2005). An attempt has been made in the present study to identify and characterize the diversity of ecosystem types in the KBR and to assess the plant species diversity in these ecosystems using geographical and phytosociological data collected through extensive inventory and intensive study.

Study Sites and Methodology

Study sites

The study was conducted in West Sikkim district. The district characteristically represents all the ecosystem types of the KBR owing to its location. The KBR is located at 27°15′ N to 27°57′ N latitude and 88°02′ E to 88°40′ E longitude. The elevation ranges from 1500 m to over 4500 m in the high alpine mountains of Dzongri and Yambung. West Sikkim covers both the buffer and core zones of KBR. The core zone encompasses the higher altitude of temperate and alpine forests. The buffer zone is located in the lower Himalayan belt from subtropical extending to the temperate region. Agricultural activities, human settlements and other land-use, particularly in the buffer zone, increase the landscape heterogeneity into natural and various man-impacted ecosystems. The sampling was done in the north-west and south-west parts of the district, from the subtropical upto the alpine zones of Dzongri and Yambung, respectively. The whole area was inventorized and the ecosystem types were identified based on dominant vegetation.

Methodology

The community characteristics of the identified ecosystems were studied. Thirty 10 m × 10 m quadrats were laid randomly for trees, 5 m × 5 m quadrats for shrubs and 1 m × 1 m quadrats for herbaceous component. The numbers for each vegetation components were determined by species-area curve. Quantitative characters such as frequency, density, abundance and IVI were determined following Misra (1968) and Muller-Dombois and Ellenberg (1974). The vegetation components were further assigned to six life forms viz., trees, scrubs, shrubs, lianas, herbs and epiphytes. For epiphytes, only species composition was studied in all the ecosystems.

Species richness, diversity, equitability and concentration of dominance were also analysed in each ecosystem type, using standard ecological indices such as Shannon-Weiner (1963) diversity index, Beta-diversity index (Whittaker, 1972), evenness index (Pielou, 1969) and dominance index (Simpson, 1949). Major

terrestrial ecosystem types were identified along the altitudinal gradient in the KBR and shown in Table 1.

Results

Ecosystem diversity

The landscape is composed of two major types of ecosystems (i) grasslands, and (ii) forests. The former is represented by the subtropical grassland and alpine meadow, while the latter comprises the forests and alpine scrub ecosystem. In all, six major terrestrial ecosystem types could be identified in the Himalayan terrain of KBR (Table 2). The diverse ecosystem types have originated due to complexity of landscape structure and wide altitudinal variation. The buffer zone comprises the subtropical riverine forest and grassland ecosystems. The subtropical forests of KBR are typically riverine that stretch along the rivers and tributaries in KBR. The temperate forests occupy the mid-altitude in the buffer zone, which gradually merges into the alpine forests in the core zone. The alpine scrubs are located below the tree-line upto an altitude of 4000 m. The alpine meadows are widely distributed between tree line and snow line habitats. Among the grasslands, the alpine meadow represents the natural grassland ecosystem.

Table 1. List of terrestrial ecosystem types identified along the altitudinal gradient

Altitudinal Zone	Altitudinal Range (m)	Ecosystem	Formation Type
Subtropical	1500–2000	Subtropical Riverine Forests	Natural (River-side/ Catchment forest formation)
		Grassland	Man-induced (Jhum land etc.); pasture land
Temperate	2000–3500	Temperate Broad-leaved Forest and	Natural
		Temperate Moist Pasture land	Man-induced
Alpine	3500–4500	Alpine Forest,	Natural
		Meadows and	Natural and induced
		Rhododendron Scrub	Natural and induced

Table 2. Physiographic and soil characteristics of the studied ecosystems

Parameter	Major Terrestrial Ecosystems					
	STRF	STG	TF	AF	AS	AM
Altitude (m)	1520–2000	1700–1780	2000–3300	3300–4000	3700–4000	3500–4500
Latitude (N)	27°19′	27°19′	27°22′	27°22′	27°23′	27°23′
Longitude (E)	88°09′	88°09′	88°10′	88°05′	88°04′	88°05′
Aspect	West facing	West facing	South-west	South facing	South facing	South
Slope angle (°)	20–45	10–30	15–40	10–40	15–35	10–40
Soil Texture	Sandy soil	Loamy sand	Sandy Soil	Sandy loam	Sandy loam	Loamy sand

STRF = Subtropical Riverine Forests, STG = Subtropical Grassland, TF = Temperate Broad-leaved Forest, AF = Alpine Forest, AS = Alpine Scrub, AM = Alpine Meadow.

The distribution of ecosystems in the KBR is strongly correlated with altitude, which follows the general altitudinal pattern of ecosystem formation (Richerson and Lum, 1980). Kaul and Haridasan (1987) have related the distribution of various forest types with altitudinal variation in Arunachal Pradesh. They classified various forest types into six altitudinal zones. Elevation gradients produce diverse climate and soil differentiation, promoting the diversification of plant species (Brown, 2001; Lomolino, 2001).

Species richness and taxonomic diversity

Among the forest ecosystems, the most prevalent typical floral elements of the subtropical forest are low altitude species *Alnus nepalensis, Exbucklandia populnea, Engelhardtia spicata, Ficus nemoralis* and *Rhus javanica*. The important species of the temperate forest are *Betula* sp., *Lithocarpus* sp., *Magnolia campbellii, Rhododendron arboreum, R. falconeri, Litsaea elongata* and others. The alpine forest is characterized by the predominance of *Abies densa*, interspersed by *Tsuga dumosa* and scrub, such as species of *Rhododendron* and *Juniperus*. Man-impacted open forest ecosystem in the subtropical region is chiefly the herbaceous vegetation with widespread Poaceae members. In the alpine region the scrub vegetation is dominated by *Cassiope fastigiata* and various Rhododendrons such as *Rhododendron campanulatum, R. setosum, R. anthopogon, R. lepidotum,* and *R. thomsonii*. Herbs component includes *Primula calderana, Primula primulina, Primula sikkimensis, Juncus* sp., and *Gaultheria trichophylla*. *Rosa sericea* dominates among the shrubs. Alpine meadow is characterized by the prevalence of high altitude herbs such as *Primula* sp., *Agrostis himalayana, Cyananthus lobatus, Corydalis juncea, Polygonum plebeium, Saxifraga parnassifolia, Senecio diversifolius, Anaphalis* sp., and *Gaultheria pyroloides* including various threatened medicinal plants such as *Fritillaria cirrhosa, Megacodon stylophorus, Aconitum* sp., *Rheum* sp., *Gentiana* sp., *Arisaema griffithii* and *Bergenia purpurascens*. Present observation does not agree with the report of Roy and Behera (2005) who reported a decline in the number of medicinal plants with increase in elevation.

The species richness was highest in the subtropical forest with 218 species and lowest in the alpine scrub with 24 species. In

general, species richness decreased with increasing altitude. Taxonomic diversity in terms of genera and family also followed the similar trend (Fig. 1).

Shannon's diversity index for trees and shrubs was highest in the subtropical riverine forest; it decreased steeply in case of higher altitude ecosystems. The diversity value for tree species ranged from 3.54 to 0.63 and for shrubs from 3.25 to 1.08. In case of herbaceous species, the decrease was not so pronounced ($\bar{H}$ = 3.75 to 2.52) (Table 3). On the whole, the forest ecosystems had greater plant diversity; the highest being in the riverine forest. Diversity is often correlated with habitat heterogeneity and complexity at local and regional scales (Wiebe and Martin, 1998; Ricklefs and Lovette, 1999; Boone and Krohn, 2000). Such complexity of habitat is largely a function of microclimatic factors that varies with topography and altitude. The temperature and soil moisture regimes being favoured in the riverine region, they supported high species diversity than alpine scrubs, which had only limited number of species. The major cause for decline in species richness in alpine ecosystem could be due to ecophysiological constrains, such as low temperature and short season (Körner, 1998).

The relative diversity of plants measured as beta-diversity ranges from 0.580 of riverine forest to 0.40 of the alpine scrub.

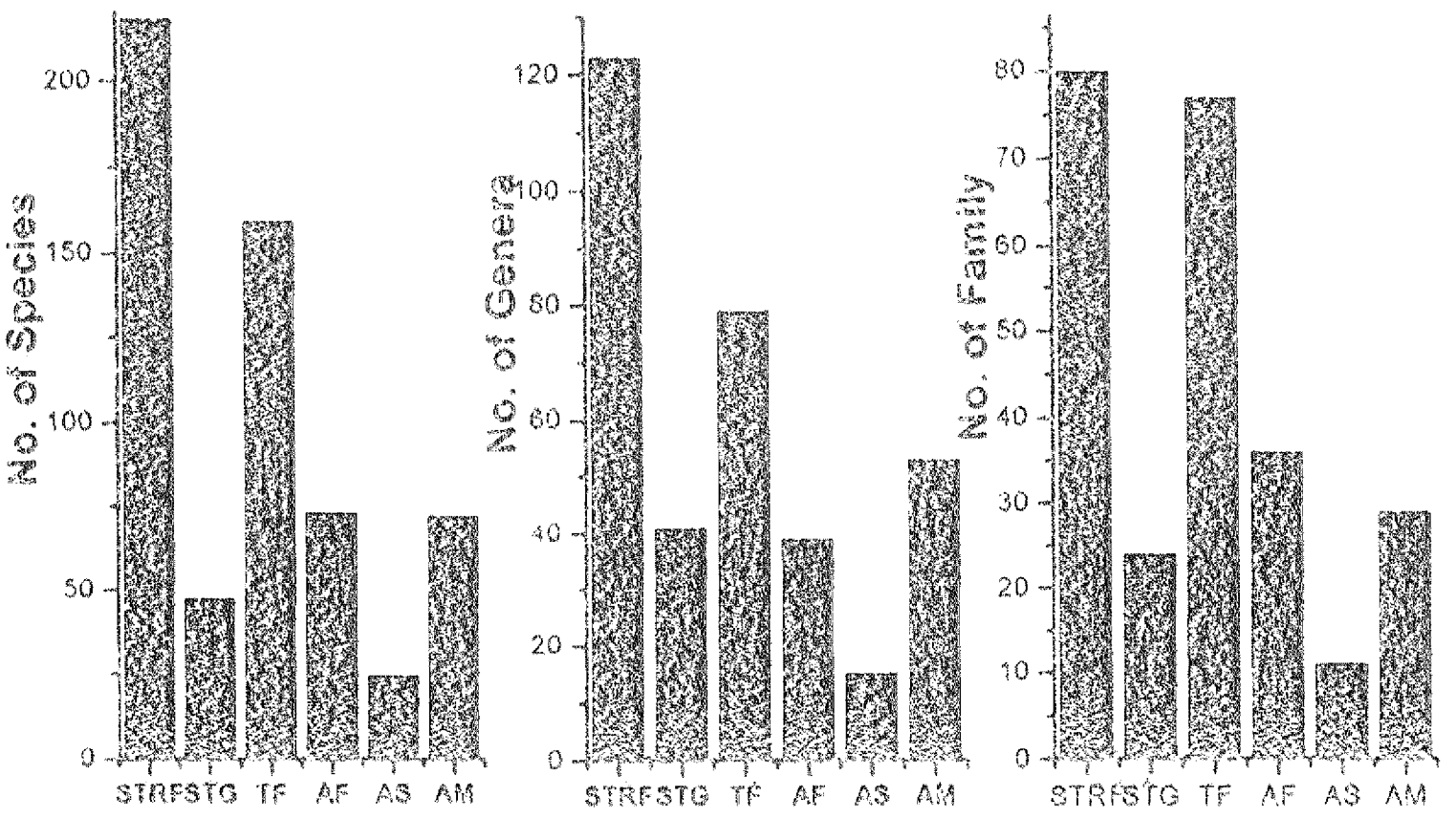

Fig. 1. Taxonomic diversity in different ecosystem types (STRF = Subtropical Riverine Forests (STRF = Subtropical Riverine Forests, STG = Subtropical Grassland, TF = Temperate Broad-leaved Forest, AF = Alpine Forest, AS = Alpine Scrub, AM = Alpine Meadow).

Similarly lower evenness index of riverine forest indicates high heterogeneity of species distribution in the ecosystem (Table 3).

Among life forms herbs were abundant in all ecosystems, comprising 95% in alpine meadow, 89% in subtropical grassland and 67% in scrub vegetation. However, the life-form distribution was more equitable in the forest ecosystems (Fig. 2). Bhattarai *et al.* (2004) have reported significant relationship of woody life-forms (trees, scrubs, shrubs and woody climbers) in the community with climatic variables.

The distribution of plant species in Raunkiaer's frequency classes on one hand shows similarity among subtropical forest, temperate forest and alpine meadows, and on the other hand exhibited dissimilarity among subtropical grassland, alpine forest and alpine scrub. Frequency class-A was dominant in subtropical riverine forest, tropical forest and alpine meadows. The subtropical grassland and the alpine scrub share some similarity with relatively high percentage of class-C and D. However, in all the ecosystems studied the lowest percentage was obtained in frequency class-D, and class-E remained unrepresented in all the ecosystems (Fig. 3).

Table 3. Species richness, diversity index and evenness index of major terrestrial ecosystems

Community characteristics	Vegetation component	STRF	STG	TF	AF	AS	AM
Species richness		218	47	159	73	24	72
Shannon's Diversity Index	Trees/Scrub	3.540	–	3.147	1.542	1.539	0.636
	Shrubs	3.248	1.294	1.539	1.081	–	0
	Herbs	3.756	2.952	3.481	3.353	2.518	3.574
	Lianas						
Beta-diversity		0.580	0.086	0.367	0.141	0.040	0.138
Evenness Index	Trees/scrub	0.887	–	0.916	0.792	0.912	0.918
	Shrubs	0.899	0.804	0.740	0.984	–	–
	Herbs	0.921	0.790	0.868	0.902	0.930	0.844

STRF = Subtropical Riverine Forests, STG = Subtropical Grassland, TF =Temperate Broad-leaved Forest, AF =Alpine Forest, AS = Alpine Scrub, AM = Alpine Meadow.

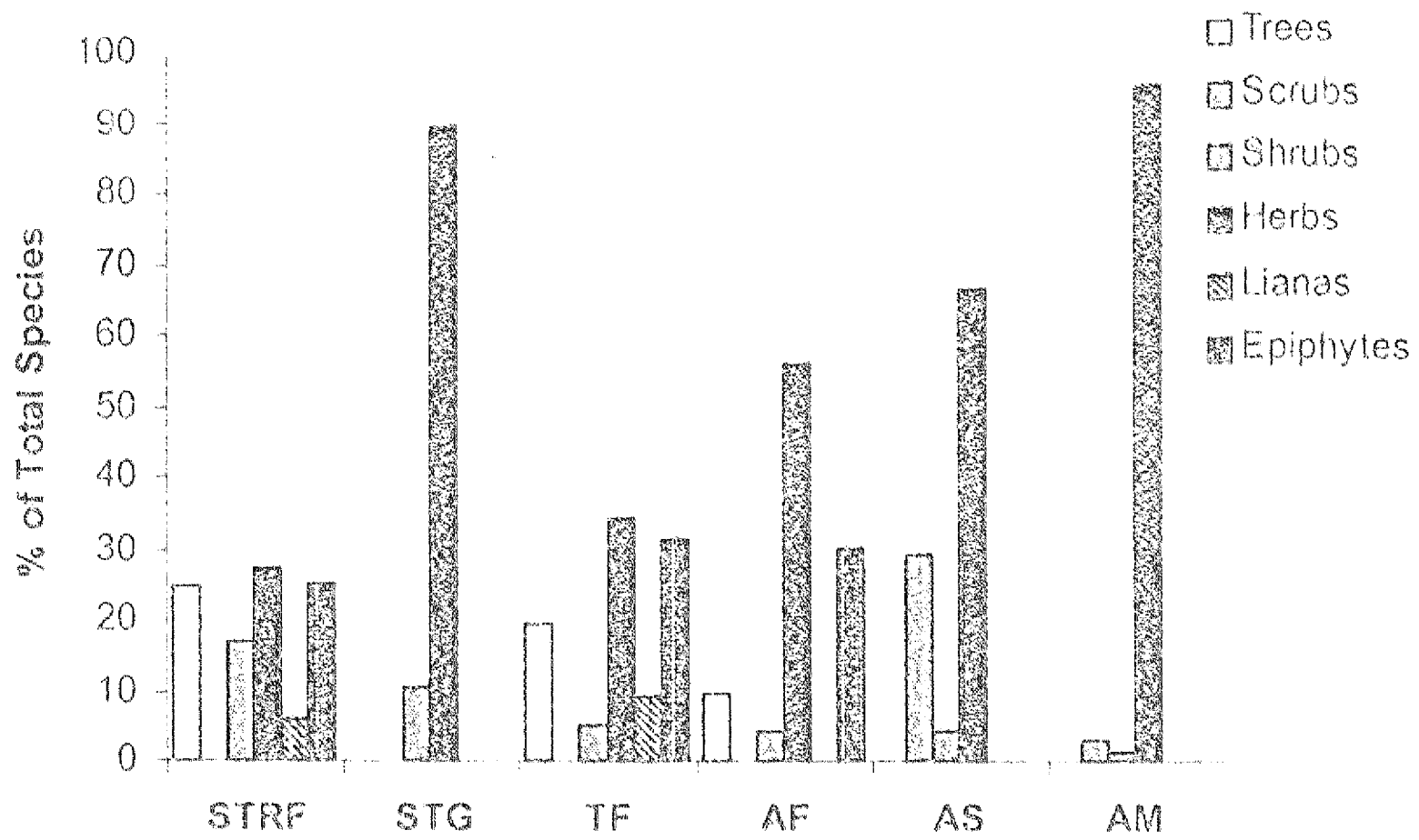

Fig. 2. Life-form composition of different ecosystem types in KBR (STRF = Subtropical Riverine Forests, STG = Subtropical Grassland, TF = Temperate Broad-leaved Forest, AF = Alpine Forest, AS = Alpine Scrub, AM = Alpine Meadow).

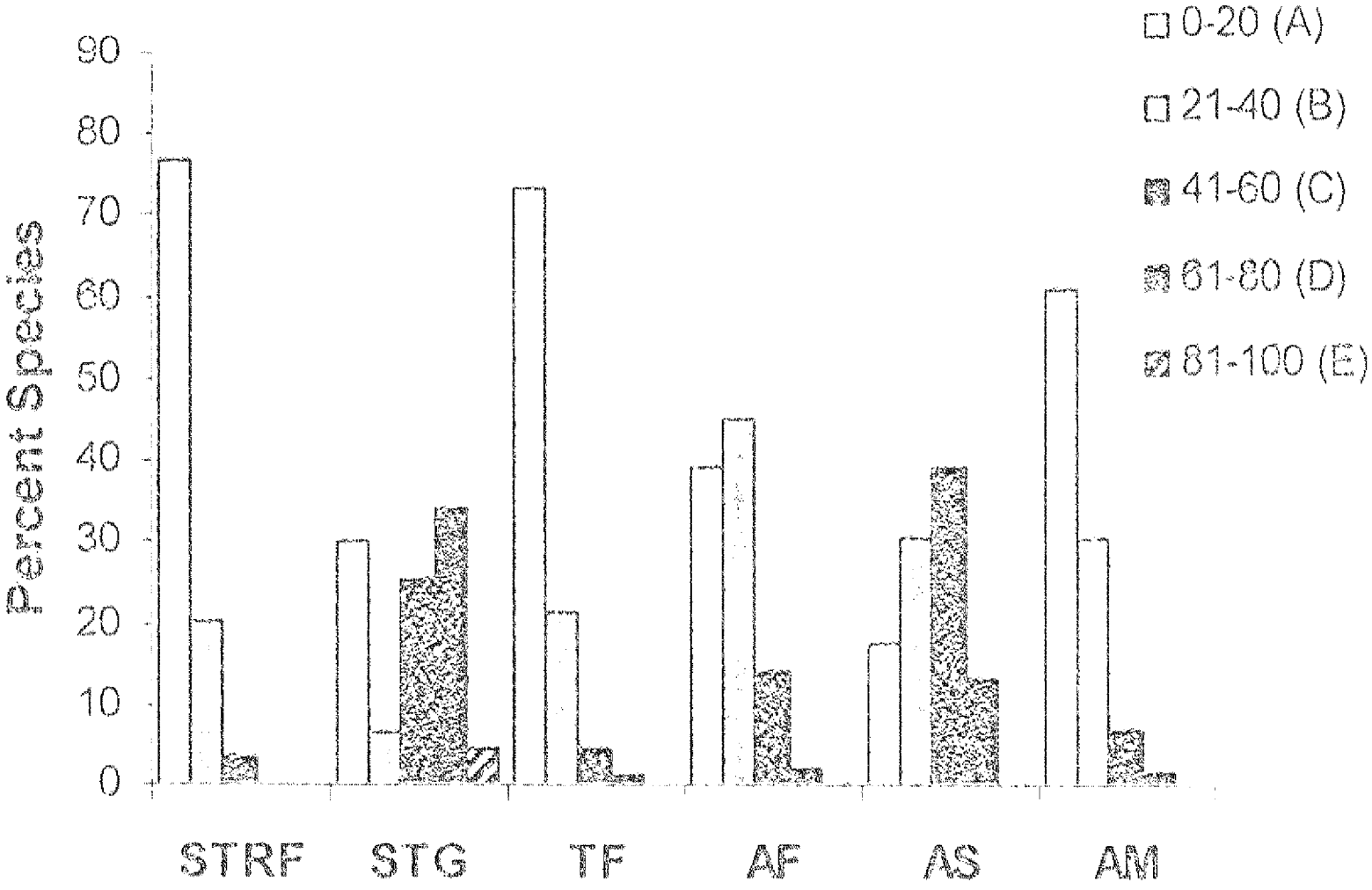

Fig. 3. Distribution of plant species in Raunkiaer's frequency classes in the different ecosystem types in KBR (STRF = Subtropical Riverine Forests, STG = Subtropical Grassland, TF = Temperate Broad-leaved Forest, AF = Alpine Forest, AS = Alpine Scrub, AM = Alpine Meadow).

Density and dominance

Tree density was highest in the subtropical forest with 900 trees per ha followed by temperate forest with 536 trees per ha and lowest in alpine forest with 324 trees per ha. Herbaceous density was highest in the alpine meadow with 8,98,332 plants per ha followed by grassland and temperate forest with 8,34,400 plants per ha and 500666 plants per ha, respectively. Shrub density was also highest (5627 plants per ha) in subtropical forest followed by the grassland (4112 plants per ha), temperate forest (2720 plants per ha), alpine forest (707 plants per ha), alpine scrub (300 plants per ha) and least by alpine meadow (253 plants ha) (Fig. 4). Density of primitive taxa was high in all the ecosystems (Appendix 1). It is obvious from these findings that with increase in altitude the density of plants decreased except for the herbs, which often increased.

The dominance index for herbs was low ranging from 0.03 to 0.10; the highest being in the alpine meadow. The dominance index for the shrubs was higher than the herbs; the highest value was obtained in the alpine ecosystems (scrub and meadow), which was dominated by *Rosa sericea*. Dominance index for trees was highest in the alpine forest (0.23).

The dominance distribution among the species of the given growth form varied widely in different ecosystems. While it was most equitable among the herbaceous species in all ecosystems, it was most inequitable among trees/shrubs in subtropical grassland, alpine scrub, alpine forest, alpine meadows and temperate forest. The most equitable distribution of dominance among the tree species was noticed in subtropical riverine forest and temperate forest (Fig. 5).

Discussion

Several terrestrial ecosystems were identified both in the core and buffer zones of the KBR, but detailed study could be made only in the selected ones. The major ecosystem types described above were identified chiefly on the basis of vegetation characteristics and elevation. The species richness and diversity of different vegetation component varied in different ecosystem types, showing strong influence of altitude and other related environmental

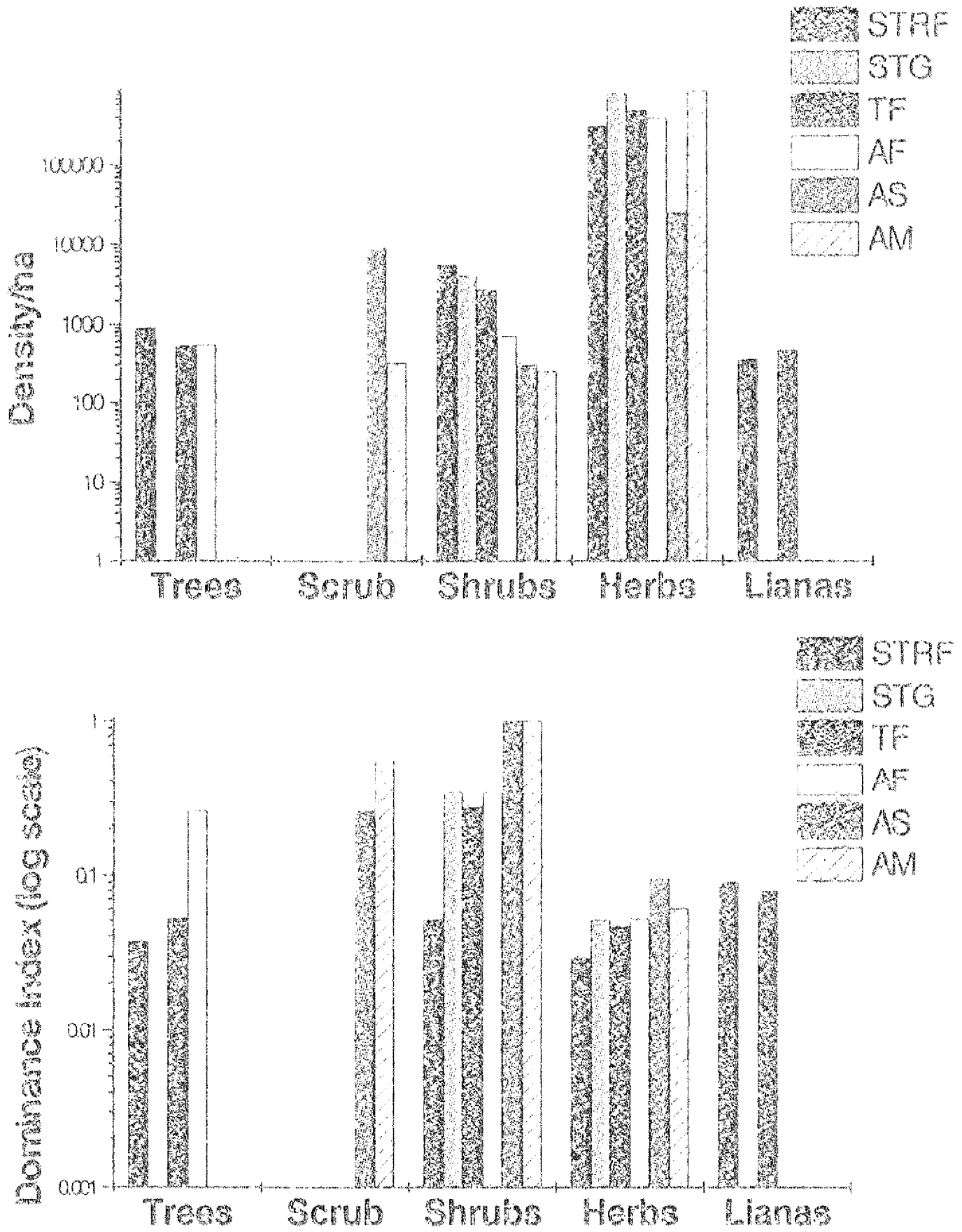

Fig. 4. Density and dominance distribution pattern of different growth forms in different ecosystem types in KBR. (STRF = Subtropical Riverine Forests, STG = Subtropical Grassland, TF = Temperate Broad-leaved Forest, AF = Alpine Forest, AS = Alpine Scrub, AM = Alpine Meadow).

variables. A decreasing trend in species richness with altitude has been reported by several workers such as Yoda (1967) and Odland and Birks (1999). Grytnes and Vetaas (2002) reported a gradual decline of species diversity with altitude, this is also seen in the present study for trees and shrubs, but herbs exhibited a different pattern of diversity, which more or less supports Rahbek's (1995) finding of mid-altitude peak in species diversity. While species richness was affected by altitude, species density especially of herbs was affected more by the community structure i.e. close or open

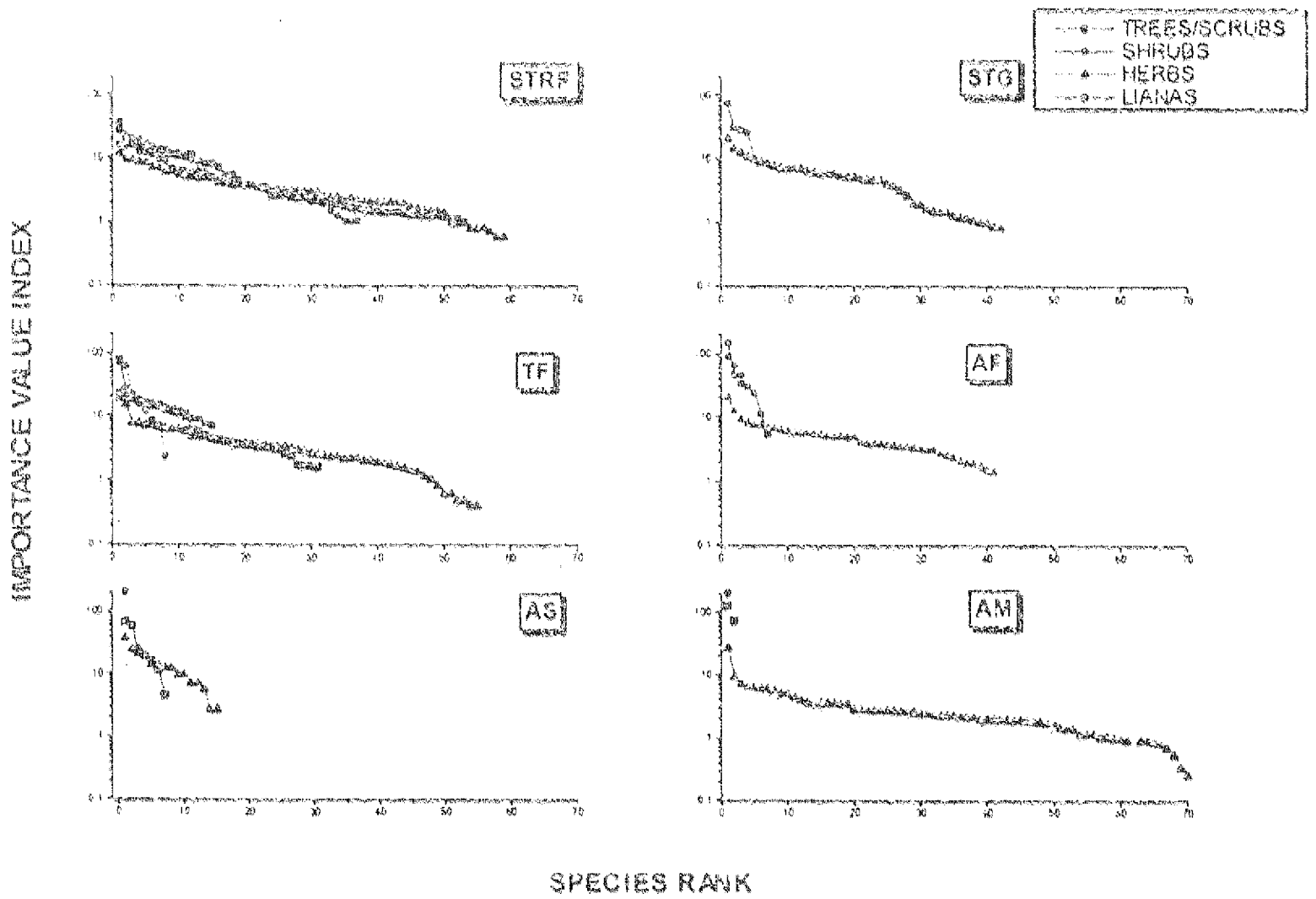

Fig. 5. Dominance distribution pattern of plant species in different ecosystem types in KBR (STRF = Subtropical Riverine Forests, STG = Subtropical Grassland, TF = Temperate Broad-leaved Forest, AF = Alpine Forest, AS = Alpine Scrub, AM = Alpine Meadow).

nature of the community. Maximum herbaceous density was in the subtropical grassland and the alpine meadow. To sum it all, the KBR being a region of diverse topography and elevation, has a variety of ecosystems each having a distinct vegetation type, supporting rich plant diversity but diverse phytosociological characteristics.

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APPENDIX–I

Frequency, density (ha^{-1}), abundance, tree basal cover (m^2ha^{-2}) and importance value index (IVI) of plants in all the studied ecosystems of KBR.

SUB-TROPICAL RIVERINE FOREST

Trees	Family	Frequency	Density	Abundance	Basal Cover	IVI
Acer campbellii Hk. f. and Thoms.	Aceraceae	3.33	3.33	1.00	0.28	1.45
Acer oblongum Wall.	Aceraceae	6.67	10.00	1.50	0.71	3.55
Albizia chinensis (Osbeck) Merr.	Leguminosae	6.67	6.67	1.00	0.30	2.39
Alnus nepalensis D. Don	Betulaceae	56.67	73.33	1.29	9.58	35.86
Beilschmiedia sikkimensis King	Lauraceae	3.33	6.67	2.00	0.21	1.68
Castanopsis hystrix A. DC.	Fagaceae	30.00	53.33	1.78	2.55	15.69
Castanopsis indica (Roxb ex Lindl.) A.DC.	Fagaceae	16.67	30.00	1.80	1.40	8.71
Castanopsis tribuloides (Sm.) A. DC.	Fagaceae	26.67	36.66	1.38	3.46	15.07
Cedrela toona Roxb.	Meliaceae	3.33	3.33	1.00	0.28	1.46
Cinnamomum impressinervium Meisn.	Lauraceae	3.33	6.67	2.00	0.32	1.89
Cinnamomum bejolghota (Buch.-Ham.) Sweet	Lauraceae	3.33	3.33	1.00	0.15	1.19
Daphne papyracea Wall. ex Steud	Thymelaceae	3.33	6.67	2.00	0.37	1.99
Dendrocalamus hamiltonii Nees et Arn. ex Munro	Poaceae	3.33	6.67	2.00	0.13	1.53
Elaeocarpus lanceaefolius *Roxb.*	Elaeocarpaceae	20.00	26.66	1.33	1.66	9.39
Engelhardtia colebrokiana Lindl.	Juglandaceae	20.00	43.33	2.17	1.32	10.57
Engelhardtia spicata Lesch ex Bl.	Juglandaceae	36.67	53.33	1.45	4.60	20.73
Eugenia formosa Wall.	Myrtaceae	3.33	3.33	1.00	0.20	1.29
Eurya acuminata DC.	Theaceae	16.67	23.33	1.40	0.15	5.55

Eurya cerasifolia (D. Don) Kobuski	Theaceae	3.33	3.33	1.00	0.12	1.13
Eurya japonica Thunb.	Theaceae	23.33	26.66	1.14	0.71	8.06
Exbucklandia populnea (R. Br ex Griff.) R. Br.	Hamamelidaceae	33.33	46.66	1.40	3.02	16.38
Ficus neriifolia Sm.	Moraceae	30.00	36.66	1.22	2.08	12.92
Ficus auriculata Lour.	Moracaeae	3.33	13.33	4.00	0.32	2.64
Ficus semicordata Buch.-Ham ex Sm.	Moracaeae	3.33	3.33	1.00	0.18	1.25
Glochidion acuminatum Mull.	Euphorbiaceae	3.33	3.33	1.00	1.35	3.53
Indigofera dosua Buch.-Ham. ex D. Don	Leguminosae	3.33	3.33	1.00	0.12	1.14
Juglans regia L.	Juglandaceae	3.33	6.67	2.00	0.45	2.15
Laurocerasus acuminata Roem.	Rosaceae	6.67	6.67	1.00	0.32	2.43
Leucosceptrum canum Sm.	Lamiaceae	30.00	40.00	1.33	0.41	10.04
Litsaea cubeba Bl.	Laurceae	3.33	10.00	3.00	0.50	2.61
Lithocarpus elegans (Bl.) Hatus ex Soepadmo	Fagaceae	33.33	36.66	1.10	0.87	11.09
Lyonia ovalifolia (Wall.) Drude	Ericaceae	3.33	10.00	3.00	0.37	2.36
Macaranga denticulata (Bl.) Muell.-Arg.	Moraceae	23.33	23.33	1.00	0.38	7.05
Macaranga indica Wight	Moraceae	3.33	6.67	2.00	0.19	1.64
Macaranga pustulata King ex Hk. f.	Moracaeae	3.33	3.33	1.00	0.17	1.24
Myrsine semiserrata Wall.	Myrsinaceae	3.33	6.67	2.00	1.70	4.58
Pentapanax leschenaultii (DC.) Seem.	Araliaceae	3.33	6.67	2.00	0.14	1.55
Prunus cerasoides D. Don	Rosaceae	26.67	30.00	1.13	1.81	11.12
Quercus lineata Bl.	Fagaceae	3.33	3.33	1.00	0.27	1.43
Rhus hookeri Sahni and Bahadur	Anacardiaceae	3.33	6.67	2.00	0.47	2.18
Rhus javanica Hk. f.	Anacardiaceae	33.33	36.66	1.10	2.29	13.86
Ricinus communis L.	Euphorbiaceae	3.33	10.00	3.00	0.50	2.61
Saurauia napaulensis DC	Saurauiaceae	3.33	3.33	1.00	0.20	1.29
Schefflera impressa (C.B. Clarke) Harms	Araliaceae	3.33	3.33	1.00	0.26	1.42
Symplocos glomerata King ex Gamble	Symplocaceae	3.33	30.00	9.00	2.15	8.05
Talauma hodgsonii Hk. f. and Thoms.	Magnoliaceae	3.33	3.33	1.00	0.24	1.36

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Appendix-I ... *contd.*

Trees	Family	Frequency	Density	Abundance	Basal Cover	IVI
Toricellia tillifolia DC.	Toricelliaceae	3.33	6.67	2.00	0.35	1.95
Trevesia palmata (Roxb.) Vis.	Araliaceae	3.33	3.33	1.00	0.17	1.24
Viburnum cylindricum Buch.-Ham. ex D. Don	Caprifoliaceae	6.67	13.33	2.00	0.66	3.84
Viburnum mullaha Buch.-Ham. ex D. Don	Caprifoliaceae	3.33	6.67	2.00	0.26	1.77
Viburnum nervosum D. Don	Caprifoliaceae	23.33	33.33	1.43	0.09	3.91
Wendlandia paniculata DC.	Rubiaceae	3.33	3.33	1.00	0.01	0.91
		16.67	16.67	1.00	0.53	5.54
			900.00		51.32	300.00
Shrubs						
Aconogonum molle (D. Don) Hara	Polygonaceae	16.67	80.00	1.20	3.87	
Artemisia nilagirica (C.B. Clarke) Pamp.	Asteraceae	30.00	599.99	5.00	15.08	
Bambusa nutans Wall. ex Munro	Poaceae	10.00	66.67	1.67	2.66	
Boehmeria macrophylla D. Don	Urticaceae	10.00	66.67	1.67	2.66	
Boehmeria platyphylla D. Don	Urticaceae	3.33	40.00	3.00	1.20	
Clerodendron colebrookianum Walp.	Verbenaceae	16.67	93.33	1.40	4.11	
Daphne bholua Buch.-Ham. ex D. Don	Thymelaceae	13.33	53.33	1.00	2.91	
Debregeasia longifolia (Burm. f.) Wedd.	Urticaceae	13.33	53.33	1.00	2.91	
Desmodium confertum DC.	Leguminosae	10.00	93.33	2.33	3.13	
Dichroa febrifuga Lour.	Hydrangeaceae	10.00	66.67	1.67	2.66	
Dicranopteris linearis (Burm. f.) Underw	Dicranopteridaceae	6.67	53.33	2.00	1.93	
Dobinea vulgaris Buch.-Ham. ex D. Don	Anacardiaceae	3.33	13.33	1.00	0.73	
Edgeworthia gardneri (Wall.) Meisn.	Thymelaceae	46.67	466.66	2.50	15.16	
Elsholtzia flava (Benth.) Benth.	Lamiaceae	10.00	93.33	2.33	3.13	

Elsholtzia fruticosa (D. Don) Rehder	Lamiaceae	30.00	399.99	3.33	11.52
Girardina diversifolia (Link) Friis	Urticaceae	43.33	519.99	3.00	15.61
Gleichenia longissima Bl.	Gleicheniaceae	6.67	80.00	3.00	2.40
Hedychium spicatum Sm.	Zingiberaceae	3.33	13.33	1.00	0.73
Luculia gratissima (Wall.) Meisn.	Rubiaceae	33.33	173.33	1.30	7.98
Maesa chisia Buch.-Ham ex D.Don	Myrsinaceae	16.67	93.33	1.40	4.11
Maesa ramentacea Wall. ex Roxb.	Myrsinaceae	33.33	253.33	1.90	9.40
Melastoma malabathricum L.	Melastomataceae	16.67	173.33	2.60	5.53
Melastoma normale D. Don	Melastomataceae	36.67	293.33	2.00	10.61
Mussaenda treutleri Stapf	Rubiaceae	20.00	160.00	2.00	5.78
Neillia rubiflora D. Don	Rosaceae	6.67	26.67	1.00	1.45
Osbeckia sikkimensis Craib.	Melastomataceae	23.33	186.66	2.00	6.75
Oxyspora paniculata (D. Don) DC	Melastomataceae	16.67	106.66	1.60	4.35
Pavetta indica L.	Rubiaceae	13.33	80.00	1.50	3.38
Photinia integrifolia Lindl.	Rosaceae	20.00	80.00	1.00	4.36
Rubia manjith Roxb ex Fleming	Rubiaceae	26.67	120.00	1.13	6.05
Rubus ellipticus Sm.	Rosaceae	20.00	120.00	1.50	5.07
Rubus mollucanus L.	Rosaceae	20.00	200.00	2.50	6.50
Sambucus adnata Wall. ex DC.	Sambucaceae	13.33	106.66	2.00	3.86
Thysanolaena maxima (Roxb.) Kuntz	Poaceae	26.67	133.33	1.25	6.29
Viburnum nervosum D. Don	Caprifoliaceae	36.67	373.32	2.55	12.03
Xeromphis spinosa (Thunb.) Keay	Rubiaceae	3.33	26.67	2.00	0.96
Zanthoxylum oxyphyllum Edgew.	Rutaceae	13.33	66.67	1.25	3.15
			5627		200.00
Herbs					
Achyranthes aspera L.	Amaranthaceae	20.00	5600.00	2.50	3.75
Agrimonia pilosa Ledeb.	Rosaceae	13.33	2666.66	2.00	2.29

contd....

Appendix-I ... *contd.*

Trees	Family	Frequency	Density	Abundance	Basal Cover	IVI
Anaphalis triplinervis (Sims) C.B. Clarke	Asteraceae	16.67	2333.33	1.40		2.54
Anaphalis margaritacea (L.) Benth.	Asteraceae	6.67	666.67	1.00		0.93
Anisomeles indica (L.) O. Kuntz.	Lamiaceae	10.00	3000.00	3.00		2.03
Anthogonium gracile Lindl.	Orchidaceae	10.00	3333.33	3.33		2.14
Artemisia nilagirica (Clarke) Pamp.	Asteraceae	30.00	14999.99	5.00		8.00
Artemisia vulgaris L.	Asteraceae	16.67	2000.00	1.20		2.43
Arundinella bengalensis (Spreng.) Druce	Poaceae	16.67	9333.32	5.60		4.76
Astilbe rivularis Buch.-Ham. ex D. Don	Saxifragaceae	6.67	666.67	1.00		0.93
Athyrium rubricaule (Edgew. ex C.B. Clarke) Bir	Athyriaceae	36.67	6333.33	1.73		5.97
Begonia rubella Buch.-Ham. ex D. Don	Begoniaceae	6.67	4333.33	6.50		2.10
Bidens pilosa L.	Asteraceae	3.33	1333.33	4.00		0.78
Bidens biternata (Lour.) Merr. and Sherff.	Asteraceae	23.33	6999.99	3.00		4.74
Campanula pallida Wall.	Campanulaceae	10.00	3000.00	3.00		2.03
Carex filicina Nees	*Cyperaceae*	10.00	2666.66	2.67		1.93
Cautleya gracilis (Sm.) Dandy	Zingiberaceae	3.33	1000.00	3.00		0.68
Chlorophytum nepalense (Lindl.) Baker	Liliaceae	13.33	5000.00	3.75		3.03
Coniogramme cautata (Wall. ex Ettingshausen) Ching	Hemionitidaceae	3.33	666.67	2.00		0.57
Cuphea balsamona Cham. et Schlechtend	Lythraceae	10.00	6333.33	6.33		3.09
Cyanotis vaga (Lour.) Schult. and Schult. *f.*	Commelinaceae	23.33	3666.66	1.57		3.68
Cynodon dactylon (L.) Pers.	Poaceae	20.00	13666.65	6.83		6.50
Desmodium multiflorum DC.	Leguminosae	10.00	3000.00	3.00		2.03
Dicrocephala integrifolia (Lf) Kuntz.	Asteraceae	6.67	2333.33	3.50		1.46
Dryopteris chrysocoma (Christ.) C. Chr.	Dryopteridaceae	33.33	5666.66	1.70		5.40
Dryopteris sparsa (D. Don) O. Kuntz.	Dryopteridaceae	20.00	5666.66	2.83		3.96

Elsholtzia blanda (Benth.) Benth.	Lamiaceae	6.67	666.67	1.00	0.93
Equisetum diffusum D. Don	Equisetaceae	6.67	7666.66	11.50	3.15
Erigeron bellidioides (Buch.-Ham. ex D. Don) Benth. ex C.B. Clarke	Asteraceae	10.00	7333.33	7.33	3.41
Erigeron karvinskianus DC.	Asteraceae	13.33	5666.66	4.25	3.24
Eupatorium adenophorum Spreng.	Asteraceae	3.33	666.67	2.00	0.57
Fragaria nubicola Lindl. ex Lacaita	*Rosaceae*	33.33	10333.32	3.10	6.88
Galium mullago Hk. f.	Rubiaceae	20.00	5000.00	2.50	3.75
Geranium nepalense Sweet.	Geraniaceae	13.33	2000.00	1.50	2.07
Gnaphalium luteo-album L.	Asteraceae	10.00	1000.00	1.00	1.40
Gonostegia hirta (Bl. ex Hassk) Miq.	Urticaceae	20.00	19666.65	9.83	8.40
Hedyotis scandans D. Don	Rubiaceae	6.67	2333.33	3.50	1.46
Herminium lanceum (Thunb. ex Sw.) Vuijk	Orchidaceae	3.33	1333.33	4.00	0.78
Hydrocotyle nepalensis Hk.	*Apiaceae*	20.00	9333.32	4.67	5.12
Hypoestes triflora Roem. and Sch.	Acanthaceae	10.00	4333.33	4.33	2.45
Hypoxis aurea Lour.	Amaryllidaceae	46.67	11999.99	2.57	8.85
Impatiens drepanophora Hk.	Balsaminaceae	13.33	3000.00	2.25	2.39
Knoxia sumatrensis (Roxb.) Korth	Rubiaceae	13.33	5000.00	3.75	3.03
Lecanthus peduncularis (Royle) Wedd.	Urticaceae	23.33	10666.66	4.57	5.90
Leucostegia immersa (Wall.) Presl.	Davalliaceae	16.67	4333.33	2.60	3.17
Oplismenus compositus (L.) P. Beauv.	Poaceae	10.00	1333.33	1.33	1.50
Osbeckia stellata Ker.-Gawl.	Melastomataceae	26.67	5666.66	2.13	4.68
Paradavallodes multidentatum (Wall.) Ching	Davalliaceae	13.33	3000.00	2.25	2.39
Paspalum destichum L.	Poaceae	20.00	8666.66	4.33	4.91
Persicaria runcinata (Buch.-Ham. ex D. Don) H. Gross	Polygonaceae	10.00	2000.00	2.00	1.71
Pilea scripta (Buch.-Ham. ex D. Don) Wedd.	Urticaceae	33.33	23999.98	7.20	11.22
Pogonatherum paniceum (Lam.) Hack.	Poaceae	13.33	4666.66	3.50	2.92
Polygonum capitatum Buch.-Ham. ex D. Don	Polygonaceae	20.00	3666.66	1.83	3.32

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Appendix-I ... *contd.*

Trees	Family	Frequency	Density	Abundance	Basal Cover	IVI
Rubus mollucanus L.	Rosaceae	20.00	5000.00	2.50		3.75
Scoparia dulcis DC.	Scrophulariaceae	3.33	1333.33	4.00		0.78
Spilanthes paniculatus Wall. ex DC.	Asteraceae	16.67	5000.00	3.00		3.39
Swertia chirayita (Roxb. ex Flem.) Karst.	Gentianaceae	10.00	1666.67	1.67		1.61
Valeriana hardwickii Wall.	Valerianaceae	16.67	6999.99	4.20		4.02
Viola pilosa Bl.	Violaceae	43.33	13999.99	3.23		9.12
			315000.00			200.00
Lianas						
Dicentra macrocapnos (D. Don) G. Don	Papaveraceae	23.33	20.00	0.86		13.16
Parthenocissus himalayana (Royle) Planch.	Vitaceae	20.00	16.67	0.83		11.15
Smilax ferox Wall. ex Kunth	Smilacaceae	36.67	30.00	0.82		20.29
Smilax orthoptera A. DC.	Smilacaceae	33.33	30.00	0.90		19.20
Ampelocissus rugosa (Wall.) Planch.	Smilacaceae	16.67	23.33	1.40		11.92
Tetrastigma rumicispermum (M.A. Lawson) Planch.	Vitaceae	13.33	26.66	2.00		11.76
Lonicera glabrata Wall.	Caprifoliaceae	43.33	33.33	0.77		23.39
Entada Phaseoloides (L.) Merr.	Fabaceae	10.00	10.00	1.00		6.04
Embelia floribunda Wall.	Myrsinaceae	20.00	30.00	1.50		14.86
Codonopsis viridis Wall.	Campanulaceae	20.00	16.67	0.83		11.15
Periploca sp.	Asclepiadaceae	16.67	30.00	1.80		13.77
Clematis acuminata DC.	Ranunculaceae	30.00	59.99	2.00		26.45
Parthenocissus semicordata (Wall.) Planch.	Vitaceae	23.33	33.33	1.43		16.87
			360.00			200.00

Trees	Family	Frequency	Density	Abundance	Basal Cover	IVI
Edgeworthia gardneri (Wall.) Meisn.	Thymelacea	44.00	368.00	2.09	27.59	
Elsholtzia fruticosa (D. Don) Rehder	Lamiaceae	48.00	2176.00	11.33	73.26	
Luculia gratissima (Wall.) Sweet	Rubiaceae	48.00	416.00	2.17	30.46	
Rubus ellipticus Sm.	Rosaceae	16.00	112.00	1.75	9.50	
Rubus paniculatus Sm.	Rosaceae	44.00	272.00	1.55	25.26	
			3344.00		200.00	
Herbs						
Ageratum conyzoides L.	Asteraceae	72.00	26800.00	3.72	6.83	
Anaphalis triplinervis (Sims) C.B. Clarke	Asteracese	32.00	12400.00	3.88	3.09	
Anaphalis margaritacea (L.) Benth.	Asteracese	16.00	5200.00	3.25	1.43	
Artemisia vulgaris L.	Asteracese	80.00	65600.00	8.20	11.88	
Artemisia niligarica (C.B. Clarke) Pamp.	Asteracese	48.00	23600.00	4.92	5.24	
Artemisia dubia Wall. ex Besser	Asteracese	12.00	2800.00	2.33	0.94	
Arundinella bengalensis (Spreng.) Druce	Poaceae	8.00	3600.00	4.50	0.83	
Bidens pilosa L.	Asteraceae	28.00	10400.00	3.71	2.65	
Campanula pallida Wall.	Campanulaceae	24.00	6000.00	2.50	1.92	
Crassocephalum crepidioides (Benth.) S. Moore	Asteraceae	64.00	16000.00	2.50	5.13	
Cyperus rotundus L.	Cyperaceae	12.00	3600.00	3.00	1.03	
Desmodium elegans DC.	Fabaceae	60.00	22800.00	3.80	5.74	
Dobinea vulgaris Buch.-Ham. ex D. Don	Anacardiaceae	12.00	4800.00	4.00	1.18	
Dryopteris barbigera (Hk.) O. Kuntz.	Dryopteridaceae	64.00	44800.00	7.00	8.58	
Elatostemma obtusum Wedd.	Urticaceae	16.00	5600.00	3.50	1.47	
Elatostemma sessile J.R. and G. Forst	Urticaceae	72.00	25600.00	3.56	6.68	

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Appendix-I ... *contd*.

Trees	Family	Frequency	Density	Abundance	Basal Cover	IVI
Elsholtzia blanda (Benth.) Benth.	Lamiaceae	12.00	4400.00	3.67	1.13	
Eupatorium adenophorum Spreng.	Asteraceae	88.00	47600.00	5.41	10.12	
Fragaria nubicola Lindl. ex Lacaita	Rosaceae	64.00	19200.00	3.00	5.51	
Galium asperifolium Wall.	Rubiaceae	52.00	17600.00	3.38	4.72	
Girardinia diversifolia (Link) Friis	Urticacea	64.00	15600.00	2.44	5.08	
Gnaphalium luteo-album L.	Asteraceae	52.00	10800.00	2.08	3.90	
Gonostegia hirta (Bl. ex Hassk) Miq.	Urticaceae	80.00	82800.00	10.35	13.94	
Hydrocotyle nepalensis Hk.	Apiaceae	12.00	8400.00	7.00	1.61	
Hypoxis aurea Lour.	Amaryllidaceae	56.00	14800.00	2.64	4.58	
Impatiens aff. radiata Hk. f.	Balsaminaceae	56.00	14800.00	2.64	4.58	
Kyllingia brevifolia Rottb.	Cyperaceae	16.00	8800.00	5.50	1.86	
Leucus lanata Benth.	Lamiaceae	20.00	3600.00	1.80	1.44	
Lindenbergia grandiflora (Buch.-Ham. ex D. Don) Benth.	Scrophulariaceae	16.00	3600.00	2.25	1.23	
Nepeta lamiopsis Benth. ex Hk. f.	Lamiaceae	68.00	22000.00	3.24	6.05	
Osbeckia stellata Ker.-Gawl.	Melastomataceae	72.00	28000.00	3.89	6.97	
Paspalum destichum L.	Poaceae	84.00	41200.00	4.90	9.15	
Persicaria runcinata (Buch.-Ham. ex D. Don) H. Gross	Polygonaceae	72.00	31200.00	4.33	7.35	
Phleum alpinum L.	Poaceae	80.00	136000.00	17.00	20.32	
Pilea scripta (Buch.-Ham. ex D. Don.) Wedd.	Urticacea	68.00	38000.00	5.59	7.97	
Plantago erosa Wall.	Plantaginaceae	12.00	3200.00	2.67	0.99	
Polygonum chinense L.	Polygonaceae	60.00	11600.00	1.93	4.40	
Pteris vittata L.	Pteridaceae	72.00	17200.00	2.39	5.68	
Rubus mollucanus L.	Rosaceae	52.00	8400.00	1.62	3.62	

Selaginella sp.	Selaginellaceae	12.00	2000.00	1.67	0.84	
Setaria palmifolia (Koenig) Stapf.	Poaceae	64.00	22800.00	3.56	5.95	
Viola pilosa Bl.	Violaceae	68.00	29200.00	4.29	6.91	
			834400.00		200.00	

TEMPERATE FOREST

Trees	Family	Frequency	Density	Abundance	Basal Cover	IVI
Acer campbellii Hk. f. and Thoms ex Hiern.	Aceraceae	23.33	33.33	1.43	5.28	17.61
Acer papilio King	Aceraceae	3.33	10.00	3.00	0.82	3.55
Acer thomsonii Miq.	Aceraceae	26.67	23.33	0.88	1.65	13.39
Alangium alpinum (C.B. Clarke) Sm. and Cave	Alangiaceae	3.33	3.33	1.00	0.23	1.77
Alangium begoniaefolium Baill.	Alangiaceae	3.33	3.33	1.00	0.17	1.72
Alnus nepalensis D. Don	Betulaceae	3.33	3.33	1.00	0.04	1.60
Aucuba himalaica Hk. f. and Thoms.	Cornaceae	3.33	3.33	1.00	0.14	1.69
Betula alnoides Buch.-Ham. ex D. Don	Betulaceae	10.00	10.00	1.00	1.51	6.07
Cinnamomun impressinervium Meisn.	Lauraceae	6.67	6.67	1.00	0.08	3.20
Daphne bholua Buch.-Ham. ex D. Don	Thymelaceae	3.33	20.00	6.00	0.26	4.91
Elaeocarpus lanceaefolius Roxb.	Elaeocarpaceae	23.33	23.33	1.00	1.65	12.45
Eurya japonica Thunb.	Theaceae	6.67	6.67	1.00	0.19	3.30
Euodia fraxinifolia Hk. f.	Rutaceae	6.67	10.00	1.50	0.62	4.31
Hydrangea aspera Buch.-Ham. ex D. Don	Hydrangeaceae	6.67	6.67	1.00	0.27	3.37
Ilex fragilis Hk. f.	Aquifoliaceae	6.67	6.67	1.00	0.57	3.64
Leucosceptrum canum Sm.	Lamiaceae	3.33	6.67	2.00	0.21	2.38
Lithocarpus pachyphylla (Kurz) Rehder	Fagaceae	30.00	46.66	1.56	65.82	76.89
Litsaea elongata (Wall. ex Nees.) Benth. et Hk. f.	Lauraceae	16.67	26.66	1.60	5.35	14.54
Lyonia ovalifolia (Wall.) Drude	Ericaceae	13.33	40.00	3.00	0.33	11.53

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Appendix-I ... *contd.*

Trees	Family	Frequency	Density	Abundance	Basal Cover	IVI
Magnolia campbellii Hk. f. and Thoms.	Magnoliaceae	20.00	26.66	1.33	6.62	16.64
Neolitsea pallens (D. Don) Momiyama and Hara	Lauraceae	6.67	10.00	1.50	0.30	4.02
Persea gammieana (King ex Hk. f.) Kosterm ex Kosterm. and Charter	Lauraceae	36.67	50.00	1.36	6.28	25.39
Prunus cornuta (Royle) Steud.	Rosaceae	3.33	6.67	2.00	0.47	2.61
Quercus lamellosa Sm.	Fagaceae	10.00	30.00	3.00	2.54	10.72
Quercus lineata Bl.	Fagaceae	6.67	10.00	1.50	0.67	4.36
Rhododendron arboreum Sm.	Ericaceae	3.33	10.00	3.00	0.32	3,09
Rhododendron falconeri Hk. f.	Ericaceae	20.00	36.66	1.83	3.22	15.41
Skimmia laureola (DC.) Sieb. and Zucc ex Walp.	Rutaceae	10.00	13.33	1.33	0.43	5.70
Symplocos ramosissima Wall. ex D. Don	Symplocaceae	26.67	33.33	1.25	3.03	16.50
Symplocos theifolia D. Don	Theaceae	6.67	6.67	1.00	0.63	3.70
Viburnum nervosum D. Don	Caprifolilaceae	3.33	13.33	4.00	0.45	3.84
			537.00		**110.16**	**300.00**
Shrubs						
Arundinaria maling Gamble	Poaceae	3.33	173.33	13		8.26
Berberis sikkimensis Ahrendt	Berberidaceae	20	266.66	3.33		21.12
Deutzia compacta Craib	Hydrangeaceae	50	906.64	4.53		61.64
Edgeworthia gardneri (Wall.) Meisn.	Thymelaceae	3.33	13.33	1		2.38
Rosa sericea Lindl.	Rosaceae	16.67	159.99	2.4		15.32
Skimmia melanocarpa Rehder and E.H. Wilson	Rutaceae	60	1026.64	4.28		71.71
Vaccinium retusum (Griff.) Hk ex C.B. Clarke	Ericaceae	13.33	133.33	2.5		12.45
Zanthoxylum oxyphyllum Edgew.	Rutaceae	10	39.99	1		7.13
			2720.00			**200.00**

Herbs					
Ainsliaea aptera DC.	Asteraceae	6.67	2333.33	3.50	1.15
Anaphalis triplinervis (sims) C.B. Clarke	Asteraceae	10.00	3666.66	3.67	1.76
Anisadenia saxatilis Wall. ex Meisn.	Linaceae	23.33	5666.66	2.43	3.52
Arisaema griffithii Schott.	Araceae	23.33	3000.00	1.29	2.99
Arundinella bengalensis (Spreng.) Druce	Poaceae	26.67	9999.99	3.75	4.73
Athyrium rubricaule (Edgew. ex C.B. Clarke) Bir	Athyriaceae	13.33	3333.33	2.50	2.03
Campylandra aurantiaca Baker	Liliaceae	13.33	12666.65	9.50	3.90
Chrysosplenium carnosum Hk. f. and Thoms.	Saxifragaceae	3.33	12333.32	37.00	2.80
Craniotome furcata (Link) Kuntz.	lamiaceae	30.00	16333.32	5.44	6.33
Cyanotis vaga (Lour.) Schult. and Schult. f.	Commelinaceae	16.67	8999.99	5.40	3.50
Cyathula capitata Miq.	Lamiaceae	10.00	2333.33	2.33	1.49
Cyperus niveus Retz.	Cyperaceae	26.67	8666.66	3.25	4.46
Cyperus rotundus L.	Poaceae	13.33	2666.66	2.00	1.90
Cyperus rotundus L.	Cyperaceae	23.33	24666.64	10.57	7.32
Dryopteris barbigera (Hk.) O. Kuntz.	Dryopteridaceae	20.00	10666.66	5.33	4.18
Elatostema obtusum Wedd.	Urticaceae	10.00	3000.00	3.00	1.62
Elatostemma platyphylla Wedd.	Urticaceae	23.33	6333.33	2.71	3.65
Elatostemma sessile J.R. and G. Forst.	Urticaceae	33.33	11333.32	3.40	5.68
Elsholtzia fruticosa (D. Don) Rehder	Lamiaceae	16.67	6999.99	4.20	3.10
Erigeron karvinskianus DC.	Asteraceae	10.00	2000.00	2.00	1.42
Euphorbia sikkimensis Boiss.	Euphorbiaceae	13.33	4000.00	3.00	2.16
Fragaria nubicola Lindl. ex Lacaita	Rosaceae	46.67	66999.93	14.36	18.16
Galium elegans Wall. ex Roxb.	Rubiaceae	63.33	41333.29	6.53	14.74
Galium asperifolium Wall.	Rubiaceae	16.67	29666.64	17.80	7.63
Gonatanthus pumilus (D. Don) Engler and Krause	Araceae	16.67	4666.66	2.80	2.64
Gynura cusimbua (D. Don.) S. Moore	Asteraceae	16.67	1666.67	1.00	2.04
Hemiphragma heterophyllum Wall.	Scrophulariaceae	3.33	1333.33	4.00	0.61

contd....

Appendix-I ... *contd.*

Trees	Family	Frequency	Density	Abundance	Basal Cover	IVI
Hypoxis aurea Lour.	Hypoxidaceae	3.33	666.67	2.00		0.47
Impatien urticifolia Wall.	Balsaminaceae	16.67	3000.00	1.80		2.31
Lysimachia laxa Baudo	Primulaceae	6.67	8666.66	13.00		2.41
Natochaete hamosa Benth.	Urticaceae	16.67	14333.32	8.60		4.57
Oxalis acetosella L.	Oxalidaceae	16.67	14999.99	9.00		4.70
Oxalis corniculata L.	Oxalidaceae	23.33	7999.99	3.43		3.99
Panax pseudo ginseng Wall.	Araliaceae	16.67	2333.33	1.40		2.17
Paris polyphylla Sm.	Trilliaceae	16.67	3000.00	1.80		2.31
Persicaria runcinata (Buch.-Ham. ex D. Don.) H. Gross	Polygonaceae	3.33	666.67	2.00		0.47
Phlomis bracteosa Royle ex Benth.	Lamiaceae	13.33	2333.33	1.75		1.83
Pilea scripta (Ham.) Wedd.	Urticaceae	16.67	25999.97	15.60		6.90
Pilea umbrosa Bl.	Urticaceae	10.00	25666.64	25.67		6.15
Plantago erosa Wall.	Plantaginaceae	6.67	1666.67	2.50		1.02
Poa annua L.	Poaceae	6.67	666.67	1.00		0.82
Poa himalayana Nees ex Steud.	Poaceae	16.67	9666.66	5.80		3.64
Polygonum chinense L.	Polygonaceae	23.33	5999.99	2.57		3.59
Polygonum hydropiper L.	Polygonaceae	46.67	10666.66	2.29		6.91
Polystichum prescotianum (Wall.) Moore.	Dryopteridaceae	36.67	12666.65	3.45		6.28
Pteris sp.	Pteridaceae	23.33	5000.00	2.14		3.39
Ranunculus diffusus DC.	Ranunculaceae	26.67	4333.33	1.63		3.60
Rubia manjith Roxb. ex Fleming	Rubiaceae	3.33	333.33	1.00		0.41
Rumex nepalensis Spreng.	Polygonaceae	3.33	1333.33	4.00		0.61
Sanicula elata Buch.-Ham. ex D. Don	Apiaceae	20.00	6333.33	3.17		3.31
Senecio wallichii DC.	Asteraceae	36.67	11999.99	3.27		6.15
Stellaria sikkimensis Hk. f. Edgew. and Hk. f.	Caryopyllaceae	3.33	5000.00	15.00		1.34

Mimulus nepalensis Benth.	Scrophulariaceae	16.67	4333.33	2.60	2.57
Urtica dioica L.	Urticaceae	3.33	333.33	1.00	0.41
Viola biflora L.	Violaceae	13.33	4000.00	3.00	2.16
			500666.00		200.00
Lianas					
Actinidia callosa Lindl.	Actindiaceae	30.00	43.33	1.44	17.94
Actinidia strigosa Hk. F. and Thom. Ex Benth.	Actiniadaceae	16.67	43.33	2.60	14.09
Holboellia latifolia Wall.	Lardizabalaceae	16.67	20.00	1.20	9.09
Hydrangea anomala D. Don	Hydrangeaceae	33.33	63.33	1.90	23.19
Clematis Montana Ham.	Caprifoliaceae	26.67	20.00	0.75	11.98
Lonicera acuminata Wall.	Caprifoliaceae	20.00	16.67	0.83	9.34
Lonicera glabrata Wall.	Cprifoliaceae	43.33	33.33	0.77	19.64
Lonicera lanceolata Wall.	Cprifoliaceae	10.00	20.00	2.00	7.17
Marsdenia tenacissima (Roxb.) Moon	Asclepiadaceae	36.67	50.00	1.36	21.29
Pericampylus glaucus (lamk.) Merr.	Menispermaceae	13.33	23.33	1.75	8.85
Schisandra grandiflora (Wall.) Hk. f. and Thom.	Schisandraceae	20.00	36.66	1.83	13.63
Trachelospermum axillare Hk. f.	Apocynaceae	16.67	13.33	0.80	7.66
Trachelospermum lucidum (D. Don) H. Sch.	Apocynaceae	30.00	26.66	0.89	14.37
Zanthoxylum oxyphyllum Edgew.	Rutaceae	16.67	26.66	1.60	10.52
Clematis buchananiana DC.	Caprifoliaceae	16.67	30.00	1.80	11.24
			467.00		200.00

ALPINE FOREST

Herbs	Family	Frequency	Density	Abundance	Basal Cover	IVI
Abies densa Griffith.	Pinaceae	80	233.31	2.91	53.74	149.16
Prunus rufa var. *rufa* Hk. f.	Rosaceae	10	6.66	0.66	0.35	5.33

contd....

Appendix-I ... *contd.*

Trees	Family	Frequency	Density	Abundance	Basal Cover	IVI
Rhododendron campanulatum D. Don	Ericaceae	50	126.65	2.53	3.98	46.98
Rhododendron thomsonii Hk. f.	Ericaceae	33.33	49.99	1.5	1.90	23.94
R. grande Wight	Ericaceae	43.33	56.66	1.30	3.01	30.37
R. arboreum Sm.	Ericaceae	46.67	59.99	1.28	3.69	33.17
Tsuga dumosa (D. Don) Eichler	Pinaceae	13.33	13.33	1	2.62	11.04
			547.00		**69.29**	**300.00**
Shrubs						
Berberis wallichiana DC.	Berberidaceae	43.33	293.36	1.69		89.66
Rhododendron setosum D. Don	Ericaceae	16.67	186.66	2.8		44.93
Juniperus recurva Buch.-Ham. ex D. Don	Cupressaceae	30	226.66	1.89		65.41
			707.00			**200.00**
Herbs						
Aconitum spicatum (Burhl) Stapf.	Ranunculaceae	20.00	4666.66	2.33		3.26
Aletris pauciflora (Klotzsch) Hand.-Mazz.	Nartheciaceae	10.00	1666.67	1.67		1.46
Anaphalis triplinervis (Sims) C.B. Clarke var. *intermedia*	Asteraceae	10.00	9333.32	9.33		3.37
Anaphilis busua (Buch.-Ham. ex D. Don) DC.	Asteraceae	23.33	10333.32	4.43		5.02
Arisaema concinnum Schott.	Araceae	20.00	6333.33	3.17		3.67
Arisaema griffithii Schott.	Araceae	33.33	5333.33	1.60		4.82
Arisaema jacquemontii Bl.	Araceae	10.00	4000.00	4.00		2.04
Begonia josephii DC.	Begoniaceae	16.67	2333.33	1.40		2.33
Bistorta affinis (D. Don) Greene	Polygonaceae	20.00	7333.33	3.67		3.92

Bupleurum longicaule Wall. ex DC.	Apiaceae	23.33	11666.66	5.00	5.35
Caltha palustris L.	Ranunculaceae	23.33	10666.66	4.57	5.10
Cirsium verutum (D. Don) Spreng.	Asteraceae	16.67	5000.00	3.00	2.99
Clintonia udensis Trautv. and Mey.	Liliaceae	13.33	5000.00	3.75	2.64
Clematis montana Buch.-Ham. ex DC.	Ranunculaceae	13.33	1333.33	1.00	1.73
Dryopteris sp.	Ophioglossaceae	16.67	3000.00	1.80	2.50
Fragaria nubicola Lindl. ex Lacaita	Rosaceae	23.33	12333.32	5.29	5.52
Fritillaria cirrhosa D. Don	Liliaceae	10.00	1333.33	1.33	1.38
Galium elegans Wall. ex Roxb.	Rubiaceae	26.67	14666.65	5.50	6.45
Hackelia uncinata (Royle ex Benth.) C. Fischer	Boraginaceae	6.67	4666.66	7.00	1.86
Hemiphragma heterophyllum Wall.	Scrophulariaceae	26.67	13333.32	5.00	6.12
Hypericum elodeoides Choisy	Clusiaceae	20.00	6666.66	3.33	3.76
Juncus thomsonii Buchenau	Juncaceae	30.00	18999.98	6.33	7.88
Meconopsis villosa (Hk. f.) G. Taylor	Papaveraceae	23.33	2666.66	1.14	3.11
Megacodon stylophorus (C.B. Clarke) Sm.	Gentianaceae	13.33	2000.00	1.50	1.90
Persicaria polystachya (Wall. ex Meisn.) Gross	Polygonaceae	30.00	14333.32	4.78	6.72
Persicaria capitata (Buch.-Ham. ex D. Don) Gross	Polygonaceae	33.33	14666.65	4.40	7.15
Pilea symmeria Wedd.	Urticaceae	26.67	8333.33	3.13	4.87
Poa alpina L.	Poaceae	33.33	67666.60	20.30	20.34
Poa himalayana Nees ex Steud.	Poaceae	6.67	10666.66	16.00	3.35
Polygonum plebeium R. Br.	Polygonaceae	26.67	7999.99	3.00	4.79
Potentilla arbuscula D. Don.	Rosaceae	20.00	4333.33	2.17	3.18
Potentilla eriocarpa Wall. ex Lehm.	Rosaceae	26.67	4000.00	1.50	3.79
Primula calderana Balf. F. and Cooper	Primulaceae	26.67	11666.66	4.38	5.70
Primula capitata Hk. f.	Primulaceae	23.33	9999.99	4.29	4.94
Primula caveana Sm.	Primulaceae	53.33	25999.97	4.88	12.07
Ranunculus pulchellus C. Meyer	Ranunculaceae	23.33	13333.32	5.71	5.77
Rheum australe D. Don	Polygonaceae	23.33	4333.33	1.86	3.53
Selenium tenuifolium Wall. ex C.B. Clarke	Apiaceae	36.67	6666.66	1.82	5.51

contd....

Appendix-I ... *contd.*

Trees	Family	Frequency	Density	Abundance	Basal Cover	IVI
Senecio chrysanthemoides DC.	Asteraceae	43.33	17666.65	4.08		8.94
Senecio diversifolius Wall. ex DC.	Asteraceae	46.67	9999.99	2.14		7.38
Smilacina oleraceae (Baker) Hk. f.	Convallariaceae	23.33	5333.33	2.29		3.78
			401666.00			**200.00**

ALPINE SHRUBS

Trees	Family	Frequency	Density	Abundance	IVI
Cassiope fastigiata (Wall.) D. Don	Ericaceae	10.00	80.00	2.00	4.57
R. anthopogon D. Don	Ericaceae	50.00	2960.00	14.80	59.56
Rhododendron campanulatum D. Don	Ericaceae	50.00	3400.00	17.00	68.41
R. lepidotum Wall. ex G. Don	Ericaceae	20.00	480.00	6.00	16.32
Rhododendron setosum D. Don	Ericaceae	40.00	920.00	5.75	20.64
R. thomsonii Hk. f.	Ericaceae	40.00	840.00	5.25	18.84
R. triflorum Hk. f.	Ericaceae	40.00	520.00	3.25	11.67
			9200.00		**200.00**
Shrubs					
Rosa sericea Lindl.	Rosaceae		300.00		200.00
Herbs					
Anemone rupicola Cambess	Ranunculaceae	40.00	1000.00	3.00	9.48
Bergenia purpurascens (Hk. f. and Thoms.) Engl.	Saxifragaceae	30.00	5000.00	3.33	24.11
Bistorta affinis (D. Don) Greene	Polygonaceae	70.00	1000.00	2.57	13.59
Gaultheria pyroloides Hk. f. and Thoms ex Miq.	Ericaceae	70.00	7000.00	7.43	37.59

Hemiphragma heterophyllum Wall.	Scrophulariaceae	60.00	4000.00	3.67	24.22
Hypoxis aurea Lour.	Amaryllidaceae	50.00	0.00	3.40	6.85
Juncus thomsonii Buchenau.	Juncaceae	50.00	3000.00	3.80	18.85
Meconopsis villosa (Hk. f.) G. Taylor	Papaveraceae	40.00	2000.00	2.75	13.48
Megacodon stylophorus (C.B. Clarke) Sm.	Gentianaceae	20.00	0.00	3.00	2.74
Potentilla cuneata Wall. ex Lehm.	Rosaceae	60.00	1000.00	3.33	12.22
Potentilla microphylla D. Don	Rosaceae	50.00	0.00	4.20	6.85
Primula sikkimensis Hk. f.	Primulaceae	40.00	0.00	2.00	5.48
Primula calderana Balf. F. and Cooper	Primulaceae	70.00	0.00	2.86	9.59
Primula primulina (Spreng.) Hara	Primulaceae	60.00	1000.00	5.00	12.22
Sibbaldia purpurea Royle	Rosaceae	20.00	0.00	1.00	2.74
			25000.00		**200.00**

ALPINE MEADOW

Scrub

Juniperus recurva Buch.-Ham. ex D. Don	Cupressaceae	23.33	106.66	1.14	74.51
Rhododendron setosum D. Don	Ericaceae	33.33	213.33	1.60	125.49
			320.00		**200.00**

Shrubs

Berberis angulosa Wall. ex Hk. f. and Thoms.	Berberidaceae		254.00		200.00

Herbs

Aconitum bhedingense Lauener	Ranunculaceae	20.00	5000.00	2.50	1.89
Aconitum violaceum Jacquem ex Stapf.	Ranunculaceae	13.33	2000.00	1.50	1.11
Agrostis himalayana Nees ex Steud.	Poaceae	80.00	189999.81	23.75	26.48
Agrostis myriantha Hk. f.	Poaceae	36.67	30999.97	8.45	5.90

contd....

Appendix-I ... *contd.*

Trees	Family	Frequency	Density	Abundance	IVI
Anaphalis busua (Buch. Ham. ex D. Don) DC	Asteraceae	36.67	16333.32	4.45	4.26
Anaphalis triplinervis (Sims) C.B. Clarke	Asteraceae	30.00	44999.96	15.00	7.01
var. *intermediaAndrosace sarmentosa* Wall.	Primulaceae	16.67	10333.32	6.20	2.26
Arisaema griffithii Schott.	Araceae	63.33	13666.65	2.16	5.74
Aster himalaicus C.B. Clarke	Asteraceae	30.00	13333.32	4.44	3.48
Bergenia purpurascens (Hook. f and Thoms.) Engl.	Saxifragaceae	20.00	3666.66	1.83	1.74
Bistorta affinis (D. Don) Greene	Polygonaceae	16.67	14666.65	8.80	2.74
Bistorta vaccinifolia (Wall. ex Meisn.) Greene	Polygonaceae	10.00	16666.65	16.67	2.52
Bupleurum longicaule Wall. ex DC.	Apiaceae	20.00	11999.99	6.00	2.67
Caltha palustris L.	Ranunculaceae	23.33	2666.66	1.14	1.85
Cassiope fastigiata (Wall.) D. Don	Ericaceae	20.00	36999.96	18.50	5.45
Corydalis juncea Wall:	Papaveraceae	23.33	7666.66	3.29	2.41
Corydalis gerdae Fedde	Papaveraceae	13.33	9333.32	7.00	1.93
Cremanthodium reniforme (DC.) Benth.	Compositae	10.00	18666.65	18.67	2.74
Cremanthodium retusum (Wall. ex Hk. f.) R. Good	Compositae	20.00	5000.00	2.50	1.89
Cyananthus incanus Hk. f. and Thoms.	Campanulaceae	20.00	8999.99	4.50	2.34
Cyananthus lobatus Wall. ex Benth.	Campanulaceae	40.00	31999.97	8.00	6.23
Elsholtzia eriostachya (Benth.) Benth.	Lamiaceae	10.00	8666.66	8.67	1.63
Epilobium wallichianum Haussk.	Onagraceae	13.33	8666.66	6.50	1.85
Eriophyton wallichii Benth.	Lamiaceae	20.00	5000.00	2.50	1.89
Fragaris daltoniana Gay	Rosaceae	16.67	7333.33	4.40	1.93
Fragaria nubicola Lindl. ex Lacaita	Rosaceae				
Fritlilaria cirrhosa D. Don	Liliaceae	26.67	8666.66	3.25	2.74
Galium asperifolium Wall.	Rubiaceae	43.33	16999.98	3.92	4.78
Gentiana phyllocalyx C. B. Clarke	Gentianaceae	13.33	11666.66	8.75	2.19
Hemiphragma heterophyllum Wall.	Lobeliaceae	16.67	13999.99	8.40	2.67

Juncus himalensis Klotzsch	Juncaceae	13.33	8666.66	6.50	1.85
Juncus membranaceous Royle ex D. Don	Juncaceae	16.67	13333.32	8.00	2.60
Jurinea dolomiaea Boiss	Asteraceae	16.67	2666.66	1.60	1.41
Maharanga emodi (Wall.) A.DC.	Boraginaceae	3.33	333.33	1.00	0.26
Mandragora caulescens C.B. Clarke	Solanaceae	10.00	2000.00	2.00	0.89
Meconopsis napaulensis DC.	Papaveraveae	10.00	2651.00	2.19	1.51
Meconopsis paniculata Prain	Papaveraceae	30.00	6333.33	2.11	2.71
Megacodon stylophorus (C.B. Clarke) Sm.	Gentianaceae	10.00	3000.00	3.00	1.00
Nardostachys grandiflora DC.	Valerianaceae	20.00	6999.99	3.50	2.11
Nepeta connata Royle ex Benth.	Lamiaceae	10.00	2666.66	2.67	0.96
Oxalis acetosella L.	Oxalidaceae	33.33	11333.32	3.40	3.48
Pedicularis chelianthifolia Schrenk	Scrophulariaceae	23.33	4666.66	2.00	2.08
Pedicularis megalantha D. Don	Scrophulariaceae	6.67	2000.00	3.00	0.67
Persicaria capitata (Buch.-Ham. ex D. Don) Gross	Polygonaceae	10.00	1333.33	1.33	0.82
Poa himalayana Nees ex Steud.	Poaceae	6.67	5333.33	8.00	1.04
Polygonum plebeium R. Brown	Polygonaceae	36.67	21333.31	5.82	4.82
Polygonum nepalense Meisn.	Polygonaceae	26.67	8333.33	3.13	2.71
Potentilla microphylla D. Don	Rosaceae	10.00	5999.99	6.00	1.33
Pratia nummularia (Lam.) A. Br. and Asch.	Scrophulariaceae	30.00	11999.99	4.00	3.34
Primula calderana Balf. F. and Cooper	Primulaceae	60.00	20333.31	3.39	6.26
Primula caveana Sm.	Primulaceae	10.00	2000.00	2.00	0.89
Primula glabra Klatt	Primulaceae	16.67	9333.32	5.60	2.15
Primula irregularis Craib	Primulaceae	3.33	1000.00	3.00	0.33
Ranunculus tricuspis Maxim.	Ranunculaceae	16.67	4666.66	2.80	1.63
Rheum australe D. Don	Polygonaceae	36.67	9999.99	2.73	3.56
Rheum nobile Hk. f. and Thoms.	Polygonaceae	10.00	1000.00	1.00	0.78
Rhodiola cretinii (R. Hamet) H. Ohba	Crassulaceae	20.00	10999.99	5.50	2.56
Rubus foliolosus D. Don	Rosaceae	33.33	10666.66	3.20	3.41
Rumex nepalensis Spreng.	Polygonaceae	23.33	16999.98	7.29	3.45

contd....

Appendix-I ... *contd.*

Trees	Family	Frequency	Density	Abundance	IVI
Saussurea nepalensis Spreng.	Asteraceae	10.00	13999.99	14.00	2.23
Saussurea simpsoniana (Field. and Gardn.) Lipsch.	Asteraceae	16.67	2333.33	1.40	1.37
Saxifraga engleriana Harry Sm.	Saxifragaceae	10.00	9999.99	10.00	1.78
Saxifraga parnassifolia D. Don	Saxifragaceae	23.33	5999.99	2.57	2.22
Selinum tenuifolium Wall. ex C.B. Clarke	Apiaceae	10.00	4000.00	4.00	1.11
Senecio chrysanthemoides DC.	Asteraceae	66.67	41666.63	6.25	9.08
Senecio diversifolius Wall. DC.	Asteraceae	33.33	14333.32	4.30	3.82
Senecio graciliflorus DC.	Asteraceae	10.00	4000.00	4.00	1.11
Sibbaldia purpurea Royle	Rosaceae	26.67	15666.65	5.88	3.52
Swertia cuneata D. Don	Gentianaceaea	10.00	2000.00	2.00	0.89
Swertia hookeri C.B. Clarke	Gentianaceae	6.67	666.67	1.00	0.52
Tanacetum atkinsonii (C.B. Clarke) Kitam	Asteraceae	10.00	2333.33	2.33	0.93
			898333.00		200.00