ABUNDANCE AND DIVERSITY OF MOSS COMMUNITIES OF CHOPTA-TUNGANATH IN THE GARHWAL HIMALAYA[1]

(*With seven text-figures*)

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Key words: Alpha-diversity, beta-diversity, macrohabitats, microhabitats, moss, taxon rank surrogacy, Tunganath, Garhwal Himalaya

A total of 8,155 colonies of moss from 12 plots of 50 m x 10 m, from four vegetation (macrohabitat) types along gradients of disturbance and elevation (1,400-3,700 m) in the Chopta-Tunganath landscape of the Garhwal Himalaya, yielded 34 families with 87 genera and 177 species. *Thuidium cymbifolium*, *Entodon rubicundus*, and *Racomitrium subsecundum* were wide-niche species, occupying all the three major substrates (microhabitats), namely rock, soil and wood, whereas *Tetraplodon mnioides* and *Timmia megapolitana* were rare, encountered only once during the survey. Macrohabitats and microhabitats were compared with respect to alpha- and beta-diversity of the moss flora. Amongst the macrohabitats, the high altitude (2,900-3,200 m) *Rhododendron* forest had the richest moss communities followed by the middle altitude (2,500-2,800 m) *Quercus* forest, higher altitude grasslands (3,300-3,700 m) and then the lower elevation (1,500 m) *Quercus* forest. Amongst the microhabitats, soil was richer than wood and rock substrates. Species, genus and family level, alpha- as well as beta-diversities were significantly correlated with each other, implying that the higher taxonomic ranks such as genera may be used as surrogates of species for effective periodic monitoring and assessment of moss biodiversity. While unregulated human activities such as excessive fuel wood collection, tourism and fire may adversely affect the diversity of moss, seasonally regulated livestock grazing seems to have no marked impact.

INTRODUCTION

While there has been an appreciable progress in the taxonomic listing and descriptions of species of moss communities during the last three decades (Gangulee 1969-72, Chopra 1975, Kumar and Chopra 1981), the research on their community ecology, quantifying patterns of abundance, diversity and its conservation has only recently begun (Negi and Gadgil 1997, Negi 1999, Negi 2000). Notably enough, much of the past work on biodiversity patterns and processes have been descriptive and concentrated at the regional and global scales (Heywood 1995, Gaston 1996). This paper attempts to present the local scale patterns, particularly abundance, and alpha and beta diversities in moss communities across the gradients of macrohabitats (vegetation types) and disturbance along the altitude, in a landscape of about 500 sq. km, of Chopta-Tunganath in Garhwal Himalaya. Emphasis is given on understanding the local scale patterns, because land-use decisions and management policies are most often implemented only at this level (Ricklefs and Schluter 1993, Negi 1999). The study further examines the efficacy of using higher taxon ranks such as genera as reliable surrogates of species for effective periodic monitoring of the moss diversity. Conservation implications are also discussed.

STUDY AREA

Chopta-Tunganath (30° 20' - 30° 35' N and 79° 10'-79° 20' E; 1,400 m-3,700 m) is a mountainous landscape spreading over 500 sq. km

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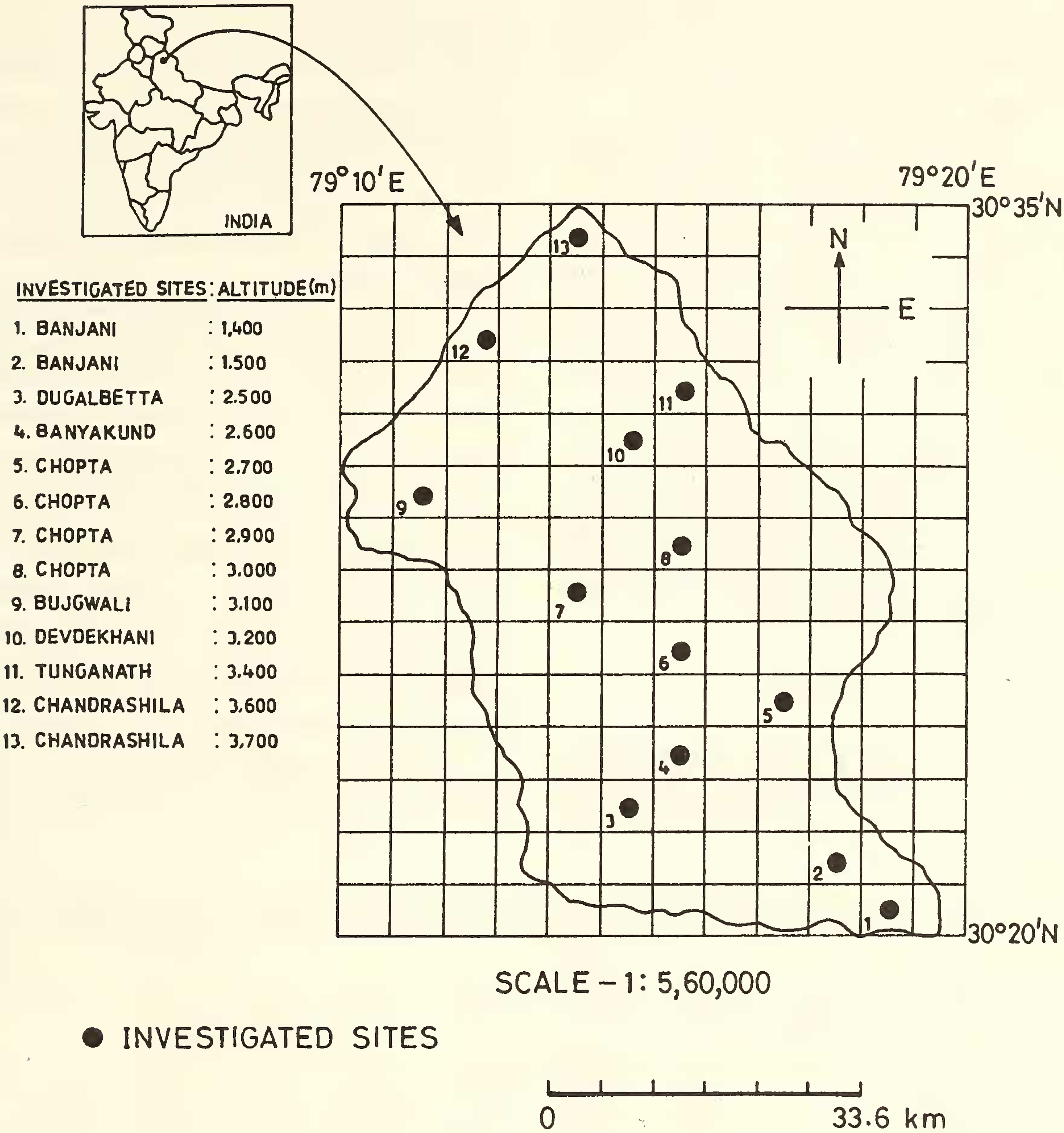

Fig. 1: Location of Chopta-Tunganath landscape

in the Indian Garhwal Himalaya (Fig. 1). The undulating topography of the area provides a variety of edaphic conditions, resulting in a distinctive flora and fauna (Gupta 1964).

The soil is coarse, well drained and acidic, at pH 4 - 5.5 (Sundriyal 1992). There is no detailed analysis of rainfall variation at different sites along the gradient. The average annual precipitation at Okhimath station (30° 30' N; 79° 15' E; 2,500 m), about 10 km west of Chopta, was 1,888.5 ±98.5mm for the last 50 years, with low to heavy snow fall from December to March. The maximum monthly temperature varies between 19-37 °C, from the higher altitude grasslands to the lower elevation *Quercus* forests, respectively, from May to October. The minimum temperature drops to -15 °C in the alpine grasslands in December up to February.

The vegetation of the study area is broadly classified as temperate mixed oak and coniferous forests, sub-alpine forest, alpine scrub and grasslands. The area harbors more than 250 vascular plant species (Semwal and Gaur 1981) and 92 species of lichens (Upreti and Negi 1998) besides a rich diversity of fauna including the highly endangered musk deer (*Moschus chrysogaster*) (Negi 1996). The low elevation woodlands such as *Quercus* forests are open to fodder and fuel wood collection throughout the year. In the sub-alpine forests and alpine meadows, livestock grazing and tourism starts in early June, reaching a peak in July-August and stopping in early October.

METHODS

Field Sampling Design: The landscape was stratified into five macrohabitat types, based on the predominant vegetation cover along the gradient 1) Paddy fields; (<1,400 m). 2) Lower altitude (1,500 m) broad-leafed forest; dominated by *Quercus leucotrichophora*. This forest has been protected, from felling by locals, for more than 25 years. 3) Middle altitude (2,500-2,800 m) broad-leafed forest; dominated by *Quercus semecarpifolia*. 4) High altitude (2,900-3,200 m) mixed forests with dominant broad-leafed species e.g. *Rhododendron arboreum* and *Rhododendron campanulatum*, dotted with a few coniferous trees of *Abies pindrow* and *Taxus buccata*. 5) Higher altitude (3,400-3,700 m) grasslands dominated by herbaceous species, e.g. *Anemone*, *Potentilla*, *Aster*, *Geranium*, *Meconopsis*, *Primula* and *Polemonium*, and pockets of shrubs of *Rhododendron anthopogon* and *Juniperus* sp. All the macrohabitat types were exposed to varied degrees of human interference such as rice cultivation in the low land terraces, fuel wood collection from woodland, and seasonal livestock grazing and tourism in the alpine meadows.

Data Recording: 12 plots of 50 m x 10 m, were laid between 1,500 m to 3,700 m above msl,

Table 1: Attributes of 12 plots (50 x 10 sq. m) sampled for mosses and woody plants in Chopta-Tunganath

				Mosses				Woody plants	
Plot No.	Site name	Altitude (x 100 m)	MAC type	Colonies	Species	Genera	Families	Individuals	Species
1	Banjani	15	LQ	508	29	21	14	58	3
2	Dugalbetta	25	MQ	540	31	27	18	7	3
3	Banyakund	26	MQ	1126	47	37	21	9	6
4	Chopta	27	MQ	368	43	33	18	10	3
5	Chopta	28	MQ	330	29	24	16	17	2
6	Chopta	29	HR	732	52	36	20	10	3
7	Chopta	30	HR	681	56	38	19	53	9
8	Bujgwali	31	HR	604	63	41	24	24	9
9	Devdekhani	32	HR	835	29	25	13	16	3
10	Tunganath	34	HG	890	29	24	19	0	0
11	Chandrashila	36	HG	990	26	24	16	19	4
12	Chandrashila	37	HG	551	36	32	18	12	2

MAC = Macrohabitat, LQ = Lower altitude *Quercus* forest, MQ = Middle altitude *Quercus* forest,
HR = High altitude mixed forest of *Rhododendron*, HG = Higher altitude grassland

covering four types of macrohabitat (Table 1). Paddy fields at 1,400 m were excluded from the sampling, as they supported few moss colonies. Three major substrates, namely rock, soil and wood, were selected as microhabitats. The woody substrates included tree trunks, branches, twigs, logs and stumps. Search and collection of all the moss colonies was carried out in each plot from June-October in 1994-95. Representative samples from each colony were preserved in bamboo paper pouches (30 cm x 30 cm). Species level identifications were made with the help of a moss taxonomist at the Botanical Survey of India (BSI). The taxonomy was based mainly on the keys by Chopra (1975) and Gangulee (1969-72). The specimens which could not be identified to the species level were either considered as distinct yet anonymous species (sp.), or assigned to a species which the majority of its structural and ecological characteristics resembled (cf.). Voucher samples of all the recorded species from the study area were preserved in the Herbarium of BSI. The numbers of trees above 10 cm girth at 130 cm height above ground and patches of shrubs (>10 cm height) in all plots were also noted. Although the mosses could not be sampled on trees above a height of 2.5 m, many canopy species were collected from fallen branches and twigs.

Data analysis

Alpha-Beta Diversity: Alpha-diversity was measured as number of species, genera or families of mosses per plot (Whitaker 1972).

Compositional change of species, genera or families from one plot to another (beta-diversity or turnover) was calculated as a Chord-distance or dissimilarity index, preferred over Jaccards similarity index (Ludwig and Reynold 1988). The former index is more robust, as it uses abundance information also, whereas the latter requires only the presence - absence data.

Chord distance between jth and kth plots is given as:

$$D_{jk} = \sqrt{2\left[1 - \frac{\sum_{i=1}^{S_j} N_{ij} \sum_{i=1}^{S_k} N_{ik}}{\sum_{i=1}^{S_j} N_{ij}^2 \sum_{i=1}^{S_k} N_{ik}^2}\right]}$$

Where, N_{ij} and N_{ik} are the numbers of colonies of ith taxon in jth and kth plots, S_j and S_k are the numbers of species, genera or families in jth and kth plots respectively.

The dissimilarity (distance) values vary from 0 to 1.42, for pairs of plots corresponding with having none to completely dissimilar taxonomic composition. The matrix of the dissimilarity values for all pairs of plots was subjected to simple linkage cluster analysis and depicted as a dendrogram after re-scaling the values between 0 to 1 (Mark and Roger 1984).

Rarefaction: Sampling effort in terms of number of moss colonies across macro as well as microhabitats were highly unequal. I have, therefore, employed rarefaction process to compare these habitats for richness of moss diversity. How many species, genera or families do we get for an equal number of colonies sampled from each habitat type? Rarefaction addresses this question, and involves linearly increasing the number of colonies drawn from the pooled data (i.e. all the colonies in a particular habitat type) and the numbers of species, genera and families encountered were recorded. The above process was repeated 100 times, using computer simulations and the mean numbers of species, genera and families were calculated for a number of colonies sampled from each habitat type.

Regression model and simulations: A simple linear regression model was used to interpret the data on the relationships among species, genus and family level alpha and beta diversities. Since the beta-diversity values are not independent of each other, there is every possibility that the observed relationships may have occurred by chance. Moreover, this causes uncertain degrees of freedom while establishing the magnitude of the relationship. To overcome this problem, computer simulations based on randomization process were employed. The beta-diversity values in one of the pairs of taxonomic hierarchy (species, genus or family level) were scrambled with respect to the other, thus randomizing the process and **r** was calculated. This procedure was repeated 1,000 times for each pair yielding 1,000 values of **r**. Level of significance value (p) was calculated as a proportion of the simulated values of **r** that were greater than the observed **r**. Thus, the relationship with **r** value at $p < 0.005$ arrived after simulations was considered significant.

Results

A total of 34 families with 87 genera and 177 species from 8,155 colonies sampled over 6,000 sq. m, constituted the moss community of Chopta-Tunganath. The moss taxa, their occurrence on the major substrates namely rock, soil and wood, elevation range and average abundance per sampled plot are given in Table 2. The distribution of numbers of species, genera and families on these three substrates are depicted in the form of Venn diagrams (Fig. 2). 31.67% of the species, 19.54% of the genera and 17.64% of the families were terricolous (on soil). 17.51%

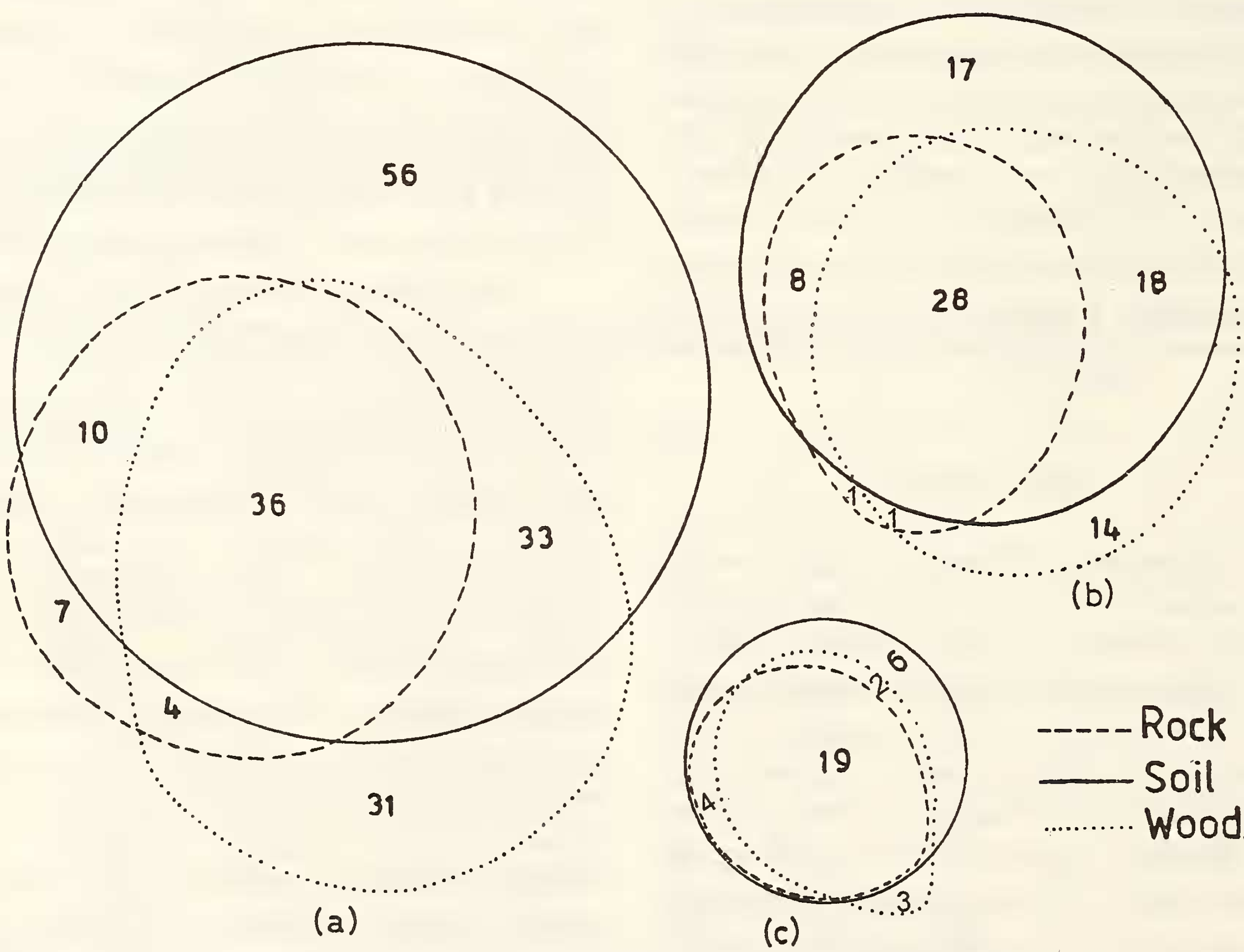

Fig. 2: Venn diagrams depicting distribution of (a) 177 species, (b) 87 genera and (c) 34 families of moss communities on rock, soil and wood

Table 2: Average abundance of mosses [in descending order] per plot and altitude range from Chopta-Tunganath

Family	Taxa Species	Alt. Range Max x100	Min	Fq.	No. of colonies Rock	Soil	Wood	Abun/plot Avg.	Stdev.
Thuidiaceae	*Thuidium cymbifolium* (Doz. et Molk.) Doz. et Molk.	37	25	11	51	595	139	65.42	32.92
Entodontaceae	*Entodon rubicundus* (Mitt.) Jaeg.	37	15	12	26	332	178	44.67	30.32
Grimmiaceae	*Racomitrium subsecundum* (Hook. & Grev.) Mitt.	37	26	10	97	305	11	34.42	40.12
Dicranaceae	*Dicranodontium caespitosum* (Mitt.) Par.	37	25	9	14	353	26	32.75	36.55
Polytrichaceae	*Pogonatum aloides* (Hedw.) P. Beauv.	37	25	11	20	336	8	30.33	22.75
Bryaceae	*Bryum pseudotriquetrum* (Hedw.) Schwaegr.	37	25	8	26	323	5	29.50	47.56
Hypnaceae	*Hypnum cupressiforme* L. ex Hedw.	37	26	10	33	144	84	21.75	17.95
Dicranaceae	*Dicranum spurium* Hedw.	37	34	3	0	220	16	19.67	58.43
Entodontaceae	*Rozea pterogonioides* (Harv.) Jaeg.	36	34	2	26	177	4	17.25	41.96
Hypnaceae	*Ectropothecium cyperoides* (Hook.) Jaeg.	32	25	3	9	138	48	16.25	30.35
Brachytheciaceae	*Rhynchostegium calderii* Vohra	32	25	3	9	138	48	16.25	30.35
Hylocomiaceae	*Hylocomium himalayanum* (Mitt.) Jaeg.	37	26	5	0	153	30	15.25	30.63
Hookeriaceae	*Orontobryum hookeri* (Mitt.) Fleisch	37	25	8	0	129	20	12.42	16.34
Pottiaceae	*Bryoerythrophyllum wallichii* (Mitt.) Chen.	36	26	7	2	120	25	12.25	16.33
Amblystegiaceae	*Amblystegium juratzkanum* Schimp.	32	26	4	3	119	20	11.83	31.25
Pottiaceae	*Oxystegus tenuirostris* (Hook. & Tayl.) A.J.E.Smith	37	15	10	7	115	16	11.50	15.35
Leskeaceae	*Pseudoleskea laevifolia* (Mitt.) Jaeg.	37	26	8	20	87	27	11.17	13.01
Brachytheciaceae	*Rhynchostegiella humillima* (Mitt.) Broth.	37	25	10	6	78	46	10.83	15.20
Leucodontaceae	*Leucodon sciuroides* (Hedw.) Schwaegr.	32	26	6	2	10	116	10.67	19.87
Trachypodaceae	*Trachypodopsis serrulata* (P. Beauv.) Fleisch.	31	15	7	3	40	64	9.08	17.43
Entodontaceae	*Entodon myurus* (Hook.) Hamp.	15	15	1	0	91	16	8.92	30.89
Amblystegiaceae	*Amblystegium serpens* (Hedw.) B.S.G.	37	26	8	1	90	3	7.83	13.90
Polytrichaceae	*Atrichum undulatum* (Hedw.) P.Beauv.	32	25	6	0	85	8	7.75	15.02
Meteoriaceae	*Meteorium buchananii* (Brid.) Broth.	26	25	2	0	0	91	7.58	22.75
Mniaceae	*Mnium rostratum* Schrad.	37	25	7	3	81	2	7.17	18.34
Polytrichaceae	*Pogonatum microstomum* (Schwaegr.) Brid.	37	26	7	0	82	0	7.00	10.01
Brachytheciaceae	*Brachythecium rivulare* B.S.G.	26	25	2	39	35	6	6.67	19.11
Encalyptaceae	*Encalypta streptocarpa* Hedw.	37	34	2	10	68	0	6.50	21.89
Brachytheciaceae	*Brachythecium salebrosum* (WEb. et Mohr) B.S.G.	34	25	8	2	68	5	6.25	10.76
Dicranaceae	*Symblepharis vaginata* (Hook.) Wijk. & Marg.	32	25	6	1	2	72	6.25	13.93
Brachytheciaceae	*Brachythecium kamounense* (Harv.) Jaeg.	32	26	5	0	41	31	6.00	14.60
Dicranaceae	*Atractylocarpus sinensis* (Broth.) Herz.	37	25	4	0	62	2	5.33	8.25
Dicranaceae	*Dicranodontium didictyon* (Mitt.) Jaeg.	34	29	4	5	52	3	5.00	11.14
Orthotrichaceae	*Macromitrium nepalense* (Hook. & Grev.) Schwaegr.	15	15	1	36	5	19	5.00	17.32
Brachytheciaceae	*Brachythecium procumbens* (Mitt.) Jaeg.	34	29	4	7	44	7	4.83	9.32
Neckeraceae	*Homaliodendron sphaerocarpum* Nog.	34	30	3	9	49	0	4.83	15.50
Sematophyllaceae	*Struckia argentata* (Mitt.) C.Muell.	32	26	4	1	5	50	4.67	14.00
Bryaceae	*Bryum badhwari* Ochi	30	25	4	0	48	3	4.25	10.78
Dicranaceae	*Aongstroemia orientalis* Mitt.	37	27	4	2	43	1	3.83	10.03
Bryaceae	*Rhodobryum roseum* (Hedw.) Limpr.	26	15	2	0	46	0	3.83	12.07
Brachytheciaceae	*Eurhynchium striatum* (Hedw.) Schimp.	32	25	3	0	42	2	3.67	6.98
Grimmiaceae	*Racomitrium himalayanum* (Mitt.) Jaeg.	31	29	3	1	34	4	3.25	7.93
Rhytidiaceae	*Rhytidiadelphus triquetrus* (Hedw.) Warnst.	36	34	2	0	37	0	3.08	8.71
Thuidiaceae	*Herpetineuron toccoae* (Sul. et Lesq.) Card.	15	15	1	1	35	0	3.00	10.39
Thuidiaceae	*Thuidium sparsifolium* (Mitt.) Jaeg.	15	15	1	20	0	16	3.00	10.39

Table 2 *(contd.)*: Average abundance of mosses [in descending order] per plot and altitude range from Chopta-Tunganath

Family	Taxa Species	Alt. Range Max x100	Alt. Range Min	Fq.	No. of colonies Rock	No. of colonies Soil	No. of colonies Wood	Abun/plot Avg.	Abun/plot Stdev.
Pottiaceae	*Pseudosymblepharis angustata* (Mitt.) Hilp.	37	26	5	0	3	31	2.92	4.34
Mniaceae	*Mnium pseudopunctatum* Bruch & Schimp.	36	34	2	0	34	0	2.83	8.91
Thuidiaceae	*Anomodon rugelli* (C. Muell.) Keissl.	32	27	5	0	13	20	2.75	4.52
Entodontaceae	*Entodon laetus* (Griff.) Jaeg.	15	15	1	0	33	0	2.75	9.53
Entodontaceae	*Entodon plicatus* C.Muell.	15	15	1	0	33	0	2.75	9.53
Funariaceae	*Entosthodon wallichii* Mitt.	37	25	4	5	27	0	2.67	5.37
Bryaceae	*Pohlia minor* Schleich. ex Schwaegr.	37	26	3	0	29	1	2.50	5.32
Pottiaceae	*Anoectangium thomsonii* Mitt.	31	27	4	4	22	3	2.42	5.23
Amblystegiaceae	*Campylium sommerfeltii* (Myr.) Bryhn	36	34	2	0	29	0	2.42	5.65
Bryaceae	*Pohlia flexuosa* Hook.	29	15	2	0	29	0	2.42	7.76
Hypnaceae	*Vesicularia kurzii* (Lac.) Broth.	37	34	3	0	29	0	2.42	6.60
Pottiaceae	*Hyophila involuta* (Hook.) Jaeg.	15	15	1	25	0	3	2.33	8.08
Brachytheciaceae	*Brachythecium longicuspidatum* (Mitt.) Jaeg.	31	28	3	1	8	18	2.25	6.08
Bryaceae	*Pohlia elongata* Hedw.	32	25	5	0	22	5	2.25	4.69
Brachytheciaceae	*Brachythecium populeum* (Hedw.) B.S.G.	32	32	1	0	24	2	2.17	7.51
Sematophyllaceae	*Brotherella pallida* (Ren. & Card.) Fleisch.	32	32	1	0	24	2	2.17	7.51
Bryaceae	*Anomobryum filiforme* (Dicks) Solms in Rabenh.	37	28	2	0	25	0	2.08	6.91
Hypnaceae	*Vesicularia montagnei* (Bel.) Broth.	34	26	3	7	18	0	2.08	4.52
Brachytheciaceae	*Rhynchostegiella sachensis* Dix.	32	27	2	0	17	7	2.00	6.32
Bryaceae	*Brachymenium ochianum* Gangulee	31	15	8	0	6	17	1.92	2.23
Trachypodaceae	*Duthiella declinata* (Mitt.) Zant.	31	26	4	0	2	21	1.92	5.71
Entodontaceae	*Entodon luteonitens* Ren. & Car.	15	15	1	0	23	0	1.92	6.64
Mniaceae	*Mnium cuspidatum* Hedw.	29	28	2	2	20	1	1.92	5.05
Dicranaceae	*Dicranodontium capillifolium* (Dix.) Tak.	36	29	3	0	20	2	1.83	5.44
Amblystegiaceae	*Drepanocladus uncinatus* (Hedw.) Warnst.	36	36	1	0	21	0	1.75	6.06
Entodontaceae	*Entodon luridus* (Griff.) Jaeg.	30	26	2	5	14	2	1.75	4.94
Hypnaceae	*Vesicularia levieri* Card.	32	26	2	0	15	6	1.75	4.35
Ptychomitriaceae	*Ptychomitrium tortula* (Harv.) Jaeg.	31	29	3	0	20	0	1.67	3.63
Sematophyllaceae	*Brotherella amblystegia* (Mitt.) Broth.	36	36	1	0	19	0	1.58	5.48
Encalyptaceae	*Encalypta ciliata* Hedw.	34	31	2	15	4	0	1.58	4.38
Dicranaceae	*Campylopus involutus* (C.Muell) Jaeg.	37	31	3	0	17	1	1.50	4.58
Bartramiaceae	*Fleischerobryum longicolle* (Hamp.) Loesk.	26	26	1	0	18	0	1.50	5.20
Mniaceae	*Mnium japonicum* Lindb.	37	30	2	0	18	0	1.50	4.60
Thuidiaceae	*Thuidium squarrosulum* Ren. et Card.	15	15	1	17	0	0	1.42	4.91
Dicranaceae	*Campylopus alpigena* Broth.	36	36	1	0	16	0	1.33	4.62
Bryaceae	*Bryum capillare* L. ex Hedw.	31	15	2	8	4	3	1.25	4.03
Dicranaceae	*Dicranum* sp.1	37	31	3	0	11	4	1.25	2.73
Hylocomiaceae	*Leptohymenium tenue* (Hook.) Jaeg.	26	25	2	0	0	15	1.25	3.28
Bryaceae	*Pohlia rigescens* (Mitt.) Broth.	37	36	2	0	15	0	1.25	3.11
Pottiaceae	*Barbula asperifolia* (Mitt.) Crum et al.	31	28	4	0	12	2	1.17	2.62
Fabroniaceae	*Fabronia minuta* Mitt.	15	15	1	14	0	0	1.17	4.04
Hypnaceae	*Isopterygium albescens* (Hook.) Jaeg.	31	30	2	0	5	9	1.17	2.72
Bryaceae	*Pohlia longicolla*	26	26	1	0	12	0	1.00	3.46
Grimmiaceae	*Racomitrium fuscescens* Wils.	29	29	1	0	12	0	1.00	3.46
Entodontaceae	*Entodon curvatus* (Griff.) Jaeg.	29	27	3	1	4	6	0.92	1.78
Bryaceae	*Mielichhoferia mielichhoferi* (Hook.) Wijk & Marg.	31	29	3	0	11	0	0.92	1.98
Rhizogoniaceae	*Rhizogonium spiniforme* (Hedw.) Bruch in Krauss	26	25	2	0	11	0	0.92	2.23
Orthotrichaceae	*Zygodon* sp.1	29	25	4	0	0	11	0.92	1.38

Table 2 *(contd.)*: Average abundance of mosses [in descending order] per plot and altitude range from Chopta-Tunganath

Family	Taxa Species	Alt. Range Max x100	Min	Fq.	No. of colonies Rock	Soil	Wood	Abun/plot Avg.	Stdev.
Hypnaceae	*Isopterygium lignicola* (Mitt.) Jaeg.	32	15	3	1	4	5	0.83	2.29
Sematophyllaceae	*Meiothecium speciosa*	29	27	2	0	3	7	0.83	2.12
Thuidiaceae	*Thuidium* sp.1	26	26	1	0	0	10	0.83	2.89
Plagiotheciaceae	*Stereophyllum wightii* (Mitt.) Jaeg.	15	15	1	0	0	9	0.75	2.60
Brachytheciaceae	*Brachythecium plumosum* (Hedw.) B.S.G.	31	29	2	0	8	0	0.67	1.56
Amblystegiaceae	*Campylium chrysophyllum* (Brid.) J. Lauge	37	26	2	0	6	2	0.67	1.78
Ditrichaceae	*Ditrichum darjeelingense* Ren. & Card.	28	27	2	0	8	0	0.67	1.78
Brachytheciaceae	*Brachythecium pachytheceum* (Dix.) Vohra	31	31	1	0	4	3	0.58	2.02
Bryaceae	*Bryum recurvulum* Mitt.	30	30	1	0	7	0	0.58	2.02
Amblystegiaceae	*Hygrohypnum nairii* Vohra	25	25	1	7	0	0	0.58	2.02
Leskeaceae	*Lindbergia longinervis* Card. et Dix.	25	25	1	0	0	7	0.58	2.02
Splachnaceae	*Splachnobryum indicum* Hamp. et Hamp.	37	34	2	2	5	0	0.58	1.73
Dicranaceae	*Campylopus milleri* Ren. et Card.	28	27	2	0	6	0	0.50	1.17
Hylocomiaceae	*Macrothamnium submacrocarpum* (Ren. & Card.) Fleisch.	31	29	3	2	4	0	0.50	0.90
Plagiotheciaceae	*Plagiothecium denticulatum* (Hedw.) B.S.G.	36	29	2	0	6	0	0.50	1.45
Sematophyllaceae	*Pylaisiopsis speciosa* (Mitt.) Broth.	30	29	2	3	3	0	0.50	1.17
Sematophyllaceae	*Sematophyllum micans* (Mitt.) Braithw.	29	27	2	0	4	2	0.50	1.24
Neckeraceae	*Thamnobryum subseriatum* (Hook.) Nog.	31	30	2	0	3	3	0.50	1.45
Sematophyllaceae	*Trolliella euendostoma* Herz.	37	37	1	0	6	0	0.50	1.73
Polytrichaceae	*Atrichum flavisetum* Mitt.	37	32	2	0	5	0	0.42	1.16
Dicranaceae	*Campylopus ericoides* (Griff.) Jaeg.	31	31	1	0	5	0	0.42	1.44
Hypnaceae	*Ectropothecium buitenzorgii* (Bel.) Mont.	29	25	2	0	0	5	0.42	1.16
Hypnaceae	*Isopterygium longitheca* (Mitt.) Jaeg.	31	31	1	0	0	5	0.42	1.44
Pottiaceae	*Barbula constricta* (Mitt.) Saito	31	31	1	0	4	0	0.33	1.15
Pottiaceae	*Bryoerythrophyllum dentatum* (Mitt.) Chen.	28	27	2	1	0	3	0.33	0.89
Bryaceae	*Bryum atrovirens* Brid.	25	25	1	0	0	4	0.33	1.15
Rhytidiaceae	*Gollania clarescens* (Mitt.) Broth.	25	25	1	0	0	4	0.33	1.15
Hylocomiaceae	*Macrothamnium macrocarpum* (Reinw. & Hornseh.) Fleisch.	26	26	1	0	4	0	0.33	1.15
Brachytheciaceae	*Rhynchostegiella divaricatifolia* (Ren. et Card.) Broth.	30	27	2	0	4	0	0.33	0.89
Splachnaceae	*Splachnobryum* sp.1	31	31	1	4	0	0	0.33	1.15
Meteoriaceae	*Aerobryidium filamentosum* (Hook.) Fleisch.	15	15	1	0	0	3	0.25	0.87
Brachytheciaceae	*Brachythecium buchananii* (Hook.) Jaeg.	31	31	1	0	3	0	0.25	0.87
Brachytheciaceae	*Brachythecium curvatulum* (Broth.) Par.	37	29	2	0	3	0	0.25	0.62
Dicranaceae	*Brothera leana* (Sull.) C. Muell.	28	27	2	1	1	1	0.25	0.62
Pottiaceae	*Bryoerythrophyllum recurvum* (Griff.) Saito	37	27	3	0	2	1	0.25	0.45
Bryaceae	*Bryum plumosum* Doz. et Molk.	15	15	1	3	0	0	0.25	0.87
Neckeraceae	*Calyptothecium pinnatum* Nog.	15	15	1	0	0	3	0.25	0.87
Dicranaceae	*Campylopus laetus* (Mitt.) Jaeg.	31	31	1	0	3	0	0.25	0.87
Sematophyllaceae	*Glossadelphus zollingeri* (C.Muell.) Fleisch.	29	26	2	0	0	3	0.25	0.62
Grimmiaceae	*Grimmia reduncа* Wils. ex Mitt.	31	31	1	0	3	0	0.25	0.87
Grimmiaceae	*Grimmia* sp.1	31	31	1	0	3	0	0.25	0.87
Hypnaceae	*Isopterygium minutirameum* (C.Muell.) Jaeg.	29	27	2	0	1	2	0.25	0.62
Leskeaceae	*Lindbergia koelzii* Williams	15	15	1	0	0	3	0.25	0.87
Orthotrichaceae	*Macromitrium moorcroftii* (Hook. & Grev.) Schwaegr.	25	25	1	0	0	3	0.25	0.87

Table 2 *(contd.)*: Average abundance of mosses [in descending order] per plot and altitude range from Chopta-Tunganath

Family	Taxa Species	Alt. Range Max x100	Min	Fq.	No. of colonies Rock	Soil	Wood	Abun/plot Avg.	Stdev.
Plagiotheciaceae	*Plagiothecium neckeroideum* B.S.G.	15	15	1	3	0	0	0.25	0.87
Pottiaceae	*Weisia rutilans* (Hedw.) Lindb.	31	31	1	0	3	0	0.25	0.87
Brachytheciaceae	*Brachythecium falcatulum* (Broth.) Par.	31	31	1	0	2	0	0.17	0.58
Brachytheciaceae	*Brachythecium obsoletinerve* Dix.	31	29	2	0	1	1	0.17	0.39
Bryaceae	*Bryum paradoxum* Schwaegr.	28	28	1	0	2	0	0.17	0.58
Hylocomiaceae	*Macrothamnium stigmatophyllum* Fleisch.	37	37	1	0	2	0	0.17	0.58
Mniaceae	*Mnium integrum* Bosch & Lac.	30	15	2	1	1	0	0.17	0.39
Plagiotheciaceae	*Plagiothecium cavifolium* (Brid.) Iwats.	29	28	2	1	0	1	0.17	0.39
Leskeaceae	*Pseudoleskea incurvata* (Hedw.) Loesk.	31	31	1	0	2	0	0.17	0.58
Brachytheciaceae	*Rhynchostegium celebicum* (Lac.) Jaeg.	26	26	1	0	2	0	0.17	0.58
Cryphaeaceae	*Schoenobryum concavifolium* (Griff.) Gangulee	15	15	1	0	0	2	0.17	0.58
Sematophyllaceae	*Sematophyllum subhumile* (C.Muell.) Fleisch.	32	32	1	0	0	2	0.17	0.58
Hypnaceae	*Vesicularia succosa* (Mitt.) Broth.	31	30	2	0	1	1	0.17	0.39
Sematophyllaceae	*Wijkia tanytricha* (Mont.) Crum	30	30	1	0	2	0	0.17	0.58
Thuidiaceae	*Anomodon thraustus* C. Muell.	29	29	1	0	0	1	0.08	0.29
Pottiaceae	*Barbula eroso-denticulata* (C.Muell.) Saito	27	27	1	0	0	1	0.08	0.29
Pottiaceae	*Barbula hastata* (Mitt.) Zander	30	30	1	0	0	1	0.08	0.29
Brachytheciaceae	*Brachythecium brachycladum* (Broth.) Par.	28	28	1	0	1	0	0.08	0.29
Brachytheciaceae	*Brachythecium formosanum* Takaki	30	30	1	0	1	0	0.08	0.29
Brachytheciaceae	*Brachythecium wichurae* (Broth.) Par.	30	30	1	0	0	1	0.08	0.29
Pottiaceae	*Bryoerythrophyllum recurvirostrum* (Hedw.) Chen.	31	31	1	0	1	0	0.08	0.29
Bryaceae	*Bryum caespiticium* L. ex Hedw.	31	31	1	0	1	0	0.08	0.29
Brachytheciaceae	*Cirriphyllum cirrhosum* (Schwaegr.) Grout	30	30	1	0	0	1	0.08	0.29
Fabroniaceae	*Fabronia secunda* Mont.	27	27	1	0	1	0	0.08	0.29
Fissidentaceae	*Fissidens* sp.1	26	26	1	0	0	1	0.08	0.29
Pottiaceae	*Hyophila rosea* Williams	15	15	1	1	0	0	0.08	0.29
Hypnaceae	*Isopterygium* sp.1	29	29	1	0	0	1	0.08	0.29
Orthotrichaceae	*Macromitrium hymenostomum* Mont.	15	15	1	0	0	1	0.08	0.29
Pterobryaceae	*Penzigiella cordata* (Hook.) Fleisch.	31	31	1	0	1	0	0.08	0.29
Bartramiaceae	*Philonotis fontana* (Hedw.) Brid.	31	31	1	0	1	0	0.08	0.29
Bartramiaceae	*Philonotis nitida* Mitt.	29	29	1	0	1	0	0.08	0.29
Polytrichaceae	*Pogonatum neesi* (C.Muell.) Mitt.	30	30	1	0	1	0	0.08	0.29
Brachytheciaceae	*Rhynchostegiella menadensis* (Lac.) Bartr.	31	31	1	0	0	1	0.08	0.29
Cryphaeaceae	*Scopelophila* sp.1	15	15	1	0	0	1	0.08	0.29
Sematophyllaceae	*Sematophyllum caespitosum* (Hedw.) Mitt.	30	30	1	0	0	1	0.08	0.29
Sematophyllaceae	*Sematophyllum humile* (Mitt.) Broth.	30	30	1	0	0	1	0.08	0.29
Sematophyllaceae	*Sematophyllum phoeniceum* (C.Muell.) Fleisch.	29	29	1	0	0	1	0.08	0.29
Splachnaceae	*Tetraplodon mnioides* (Hedw.) B.S.G.	37	37	1	0	1	0	0.08	0.29
Timmiaceae	*Timmia megapolitana* Hedw.	31	31	1	0	1	0	0.08	0.29
Pottiaceae	*Trichostomum bombayense* C.Muell.	30	30	1	0	0	1	0.08	0.29

Alt. = altitude; Max = maximum; Min = minimum; Fq = frequency of occurrence in plots; Abun = abundance
Avg. = average; Stdev. = standard deviation

of the species, 16.09% of the genera and 8.82% of the families were lignicolous (on wood). 3.95% of the species and 1.15% of the genera and none of the families, were saxicolous (on rock). Whereas 55.88% of the families with 20.3% of the species and 32.18% of the genera were

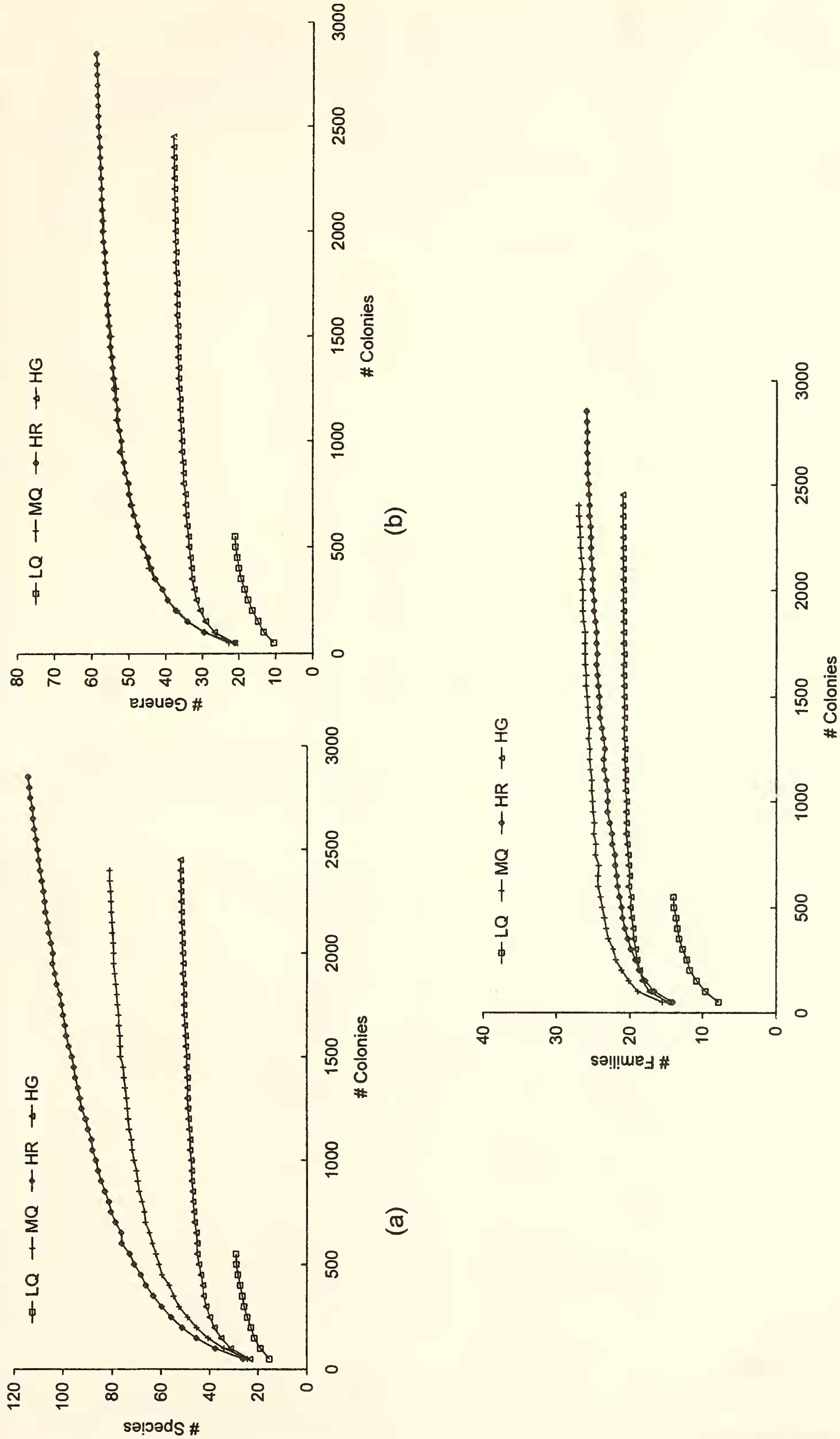

Fig. 3a-c: Accumulation of species (a), genera (b) and families (c) of moss with increasing number of colonies in different macrohabitat types. The macrohabitat types are: LQ; lower altitude *Quercus* forest (1,500 m), MQ; Middle altitude *Quercus* forest (2,500-2,800 m), HR; high altitude *Rhododendron* forest (2,900-3,200 m), HG; higher altitude grassland (3,400-3,700 m). The number of species, genera and families at each interval is an average of 100 simulations

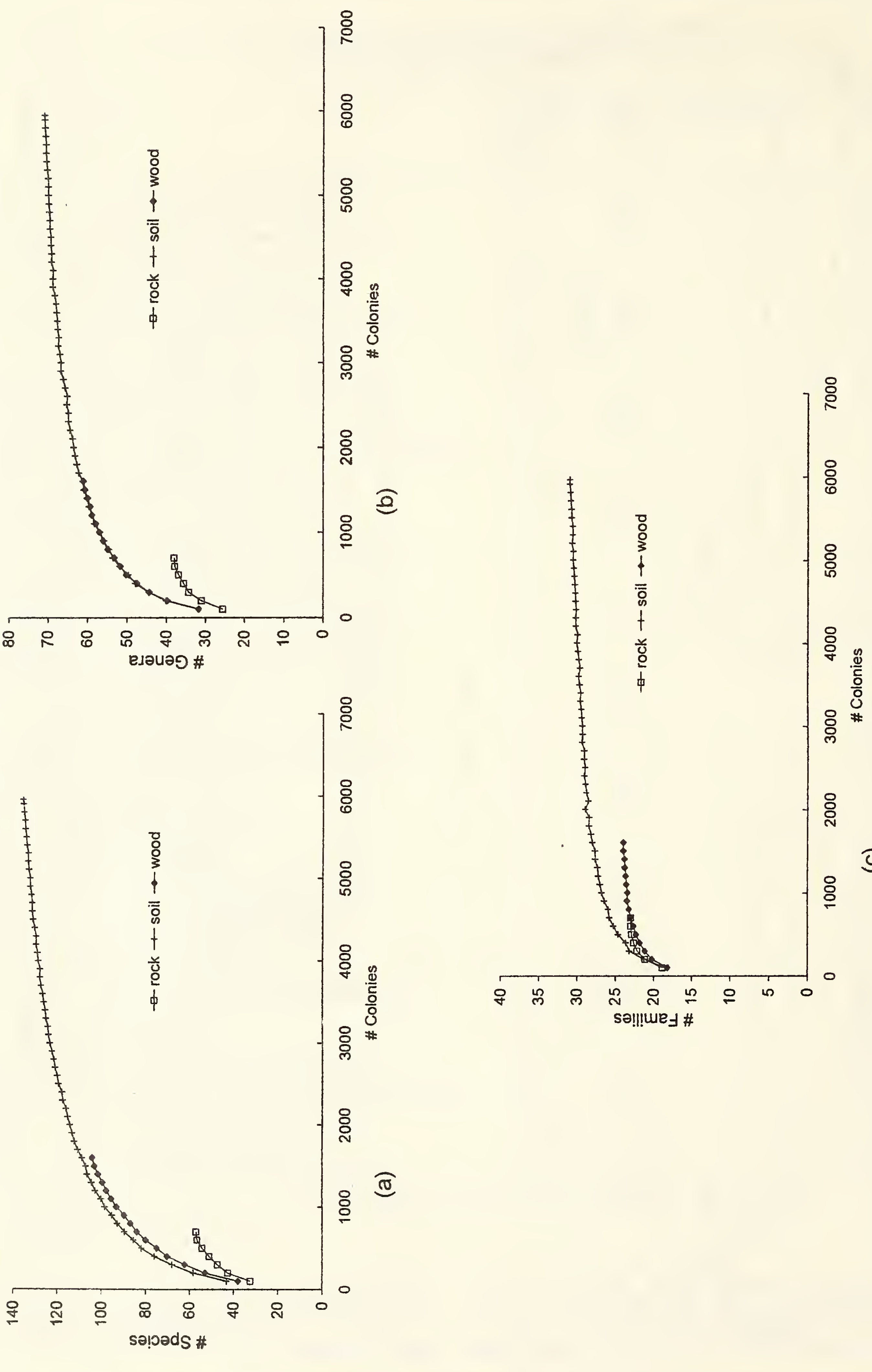

Fig. 4a-c: Accumulation of species (a), genera (b) and families (c) of moss with increasing number of pooled colonies in three microhabitat types namely rock, soil and wood. The number of species, genera and families at each interval is an average of 100 simulations

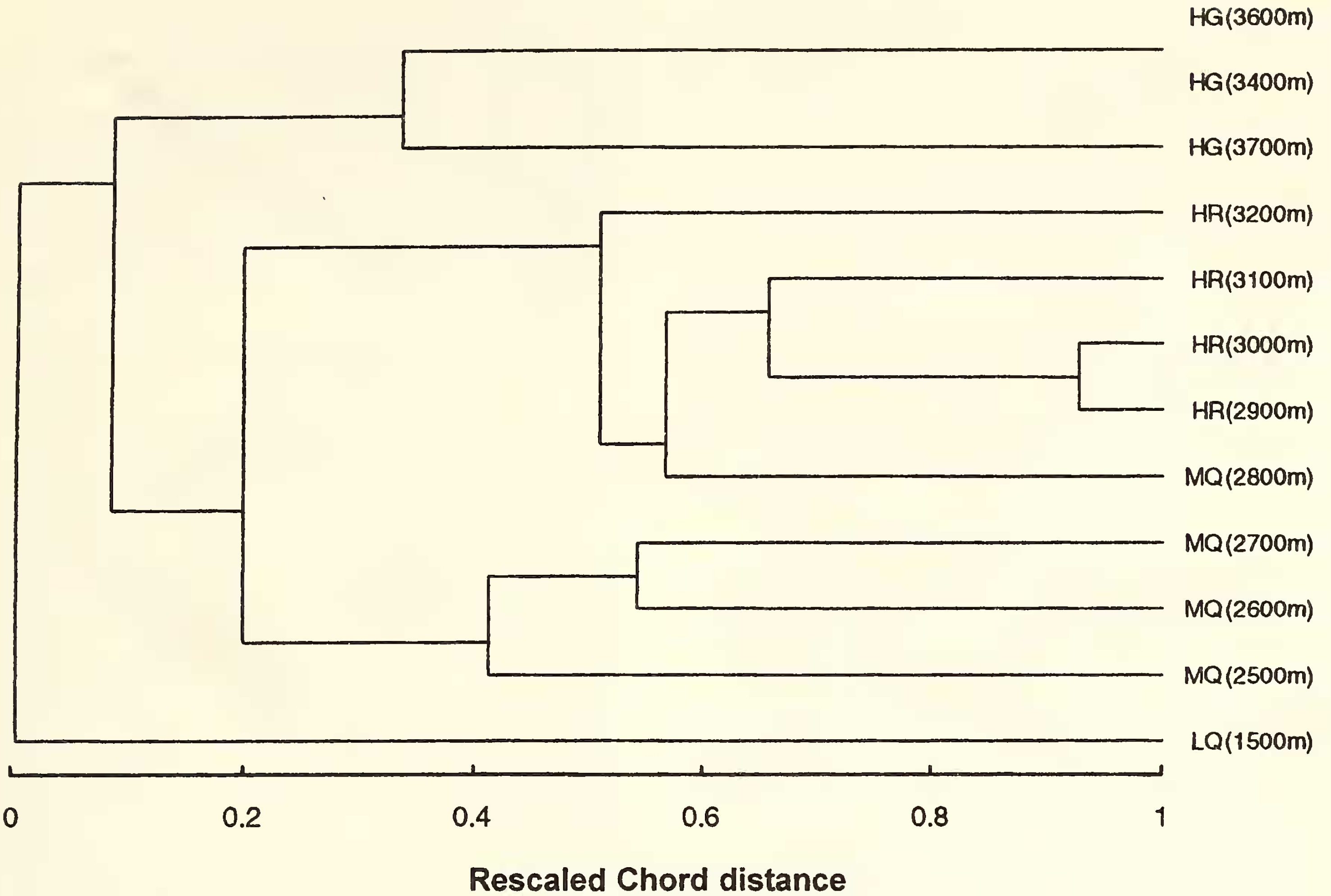

Fig. 5: Complete linkage dendrogram of 12 plots sampled in different macrohabitat types based on Chord distance with respect to species composition. Macrohabitats are LQ: lower altitude *Quercus* forest, MQ: middle altitude *Quercus* forest, HR: high altitude *Rhododendron* forest, HG: higher altitude grassland

generalists, occurring in all three substrates. The rest of the taxa shared two of the three microhabitats in the area.

Entodon rubicundus, *Racomitrium subsecundum* and *Thuidium cymbifolium* were the most abundant, wide-niche generalist species with wide elevation range, frequently occurring in all three substrates. *Philonotis nitida*, *Pogonatum neesi*, *Tetraplodon mnioides* and *Timmia megapolitana*, encountered only once during the study, were rare. Species such as *Pogonatum microstomum*, moderately abundant in more than 58% of the macrohabitat types in the area, may be considered as habitat specialists, confined to soil microhabitats.

High altitude mixed forests of *Rhododendron* have the highest number of moss species, followed by middle altitude *Quercus* forests, higher altitude grasslands and finally lower altitude *Quercus* forest. For family level richness, middle altitude *Quercus* forest is the richest, followed by high altitude mixed *Rhododendron* forest, higher altitude grassland and lower altitude *Quercus* forest. Middle altitude *Quercus* forests and high altitude mixed forest of *Rhododendron* were equally rich in the number of genera in equal numbers of sampled moss colonies (Fig. 3a-c).

Soil microhabitats support the highest number of species, followed by wood and rock substrates (Fig. 4a-c). But at genus level, wood turns up as rich as the soil. The majority of species, genera and families prefer soil and wood microhabitats. However, a few species consistently grow exclusively on rocks. This indicates the importance of rock, soil and wood

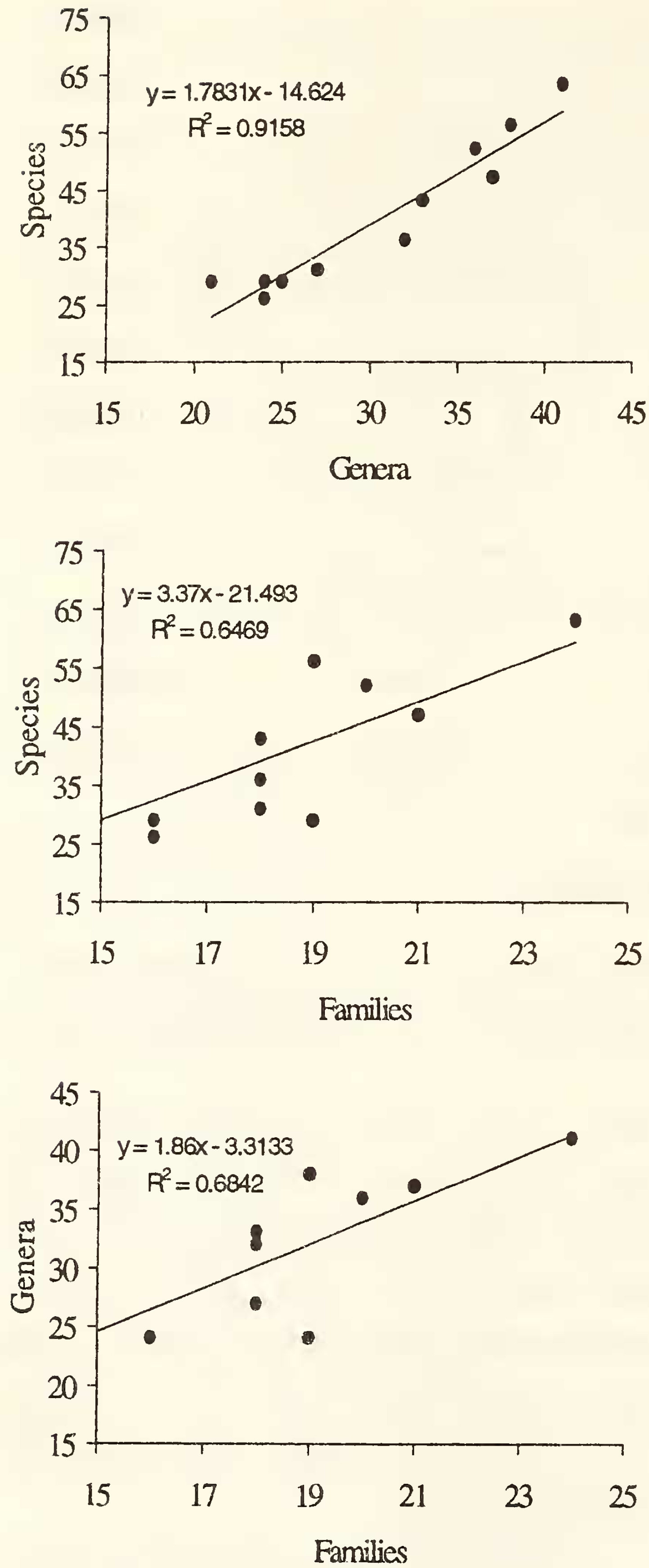

Fig. 6: Relationship between species, genus and family level richness of moss

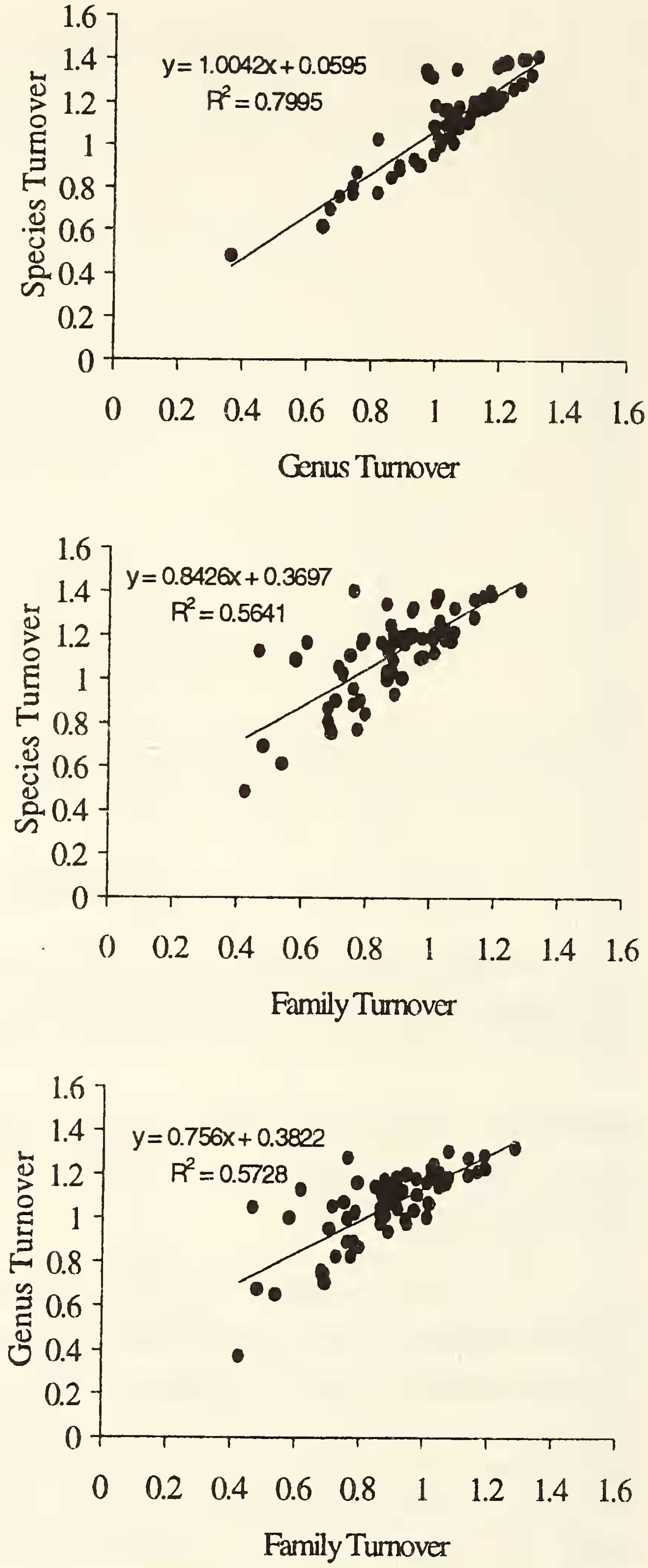

Fig. 7: Relationship between species, genus and family level turnover of moss community

combinations in microhabitats for diversity of moss communities.

The change of composition of moss species across the plots i.e. beta-diversity or turnover along the elevation is depicted in Fig. 5. The plots belonging to the same macrohabitat tend to cluster, depending on the moss species composition. The moss assemblages, therefore, appear to reflect the characteristics of the macrohabitats in which they occur.

The relationships among taxonomic ranks of species, genera and families of mosses with respect to their alpha and beta diversities along with fitted regression equations are given in Figs 6 and 7. There is a significant positive correlation ($p < 0.005$) between species, genus and family level in alpha (Fig. 6) as well as beta-diversity (Fig. 7).

Discussion

Floristic studies in India, particularly on the lower plants, lack objective oriented field methodology. This has hindered the long term monitoring of biological diversity (Negi and Gadgil 1997, Negi 1999, Negi 2000). In this study, replicable methodological approach is adopted that may in turn facilitate comparable studies in future. Numbers of species or any other higher ranks of taxonomic organization at sites (richness or alpha-diversity) and change across the habitats (turnover or beta-diversity) are important parameters of biodiversity in environmental monitoring and conservation evaluation (Magurran 1988, Pressey *et al.* 1994, Negi 1999).

We found that a mosaic of macrohabitats and microhabitats vary in terms of these biodiversity attributes. Higher altitude *Rhododendron* forest is the richest habitat for mosses. Interestingly, the lower altitude *Quercus* forest is consistently poorer than the higher altitude grassland, which hardly has any woody microhabitats for the wood loving taxa. It may be that though the lower altitude *Quercus* forest is managed by the locals for cutting and lopping, there is no control over grazing and collection of fuel wood throughout the year. This probably rendered the forest with only tree trunk bark inhabiting species along with a few saxicolous moss taxa. Higher altitude grasslands are open for grazing, but only during the summer season. Lower diversity of woody plants may also contribute to the paucity of moss in the lower elevation *Quercus* forest. However, there was no significant relationship between numbers of species of woody plants and the moss species diversity in the area. Although the majority of the species were soil specific, the moss richness seemed to be greatly affected by woody microhabitats, as many species occur only on this substrate. This pattern brings out the importance of such microhabitats in the area and cautions us about the potential adverse anthropogenic impacts of deforestation, habitat degradation and fire, the frequency of which is increasing alarmingly in the region (Semwal and Mehta 1996).

The study identifies rare species in the moss community, with quantitative information on the patterns of distribution, populations, taxa in the landscape. Without such information, any program for conservation and sustainable management of bioresources in the fragile ecosystems of the Himalaya will remain on shaky ground.

There is neither time nor funds adequate to sample and identify all the species in a given area for periodically monitoring large diverse lower plant communities such as moss. This is because numbers of species is generally high and the identification is time consuming. Therefore, a reduced set of taxonomic ranks other than the species may be used as surrogates for cost-effective assessment of biodiversity (Williams and Gaston 1994, Prance 1994, Negi 1999). It is therefore necessary to establish a relationship of species diversity with the higher taxonomic ranks. The present investigation attempted to establish such a relationship, and showed that even at the family level, inventory of moss community may be helpful in accurately predicting its species diversity. Similar results have also been shown in the same communities, but from a different landscape in the same region of the Himalaya (Negi 2000).

Conclusions and conservation implications: Moss diversity sharply declines from the seasonally grazed high altitude *Rhododendron* forest and alpine meadows to the highly disturbed *Quercus* forest in the lower elevation. The richness of mosses is related to the moderate levels of disturbance by grazing and other factors, such as frequency of human visits for fuel wood and fodder collection, which goes on throughout the year in the *Quercus* forests. However, low temperature and high humidity in the high elevation habitats of *Rhododendron* and grasslands might have also contributed to the rich diversity of moss. These factors should be taken care of while designing conservation plans. Apart from livestock grazing, tourism has emerged as the major land use pressure in the high altitude zones of the Chopta-Tunganath. Its increasing demands may lead to overgrazing of higher altitude grasslands and excessive wood collection from the woodlands, leading to severe damage to the moss communities, including the loss of rare species. Thus, the dynamics of biodiversity of moss in relation to the livestock grazing and tourism as major land use activities in the Himalaya needs further research.

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