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Cross-taxon surrogacy of biodiversity in the Indian Garhwal Himalaya

Hans Raj Negi[a,*], Madhav Gadgil[b]

[a]*Biodiversity Division, Institute of Himalayan Bioresource Technology (Council of Scientific & Industrial Research),*
Post Box No. 6, Palampur (H.P.) 176 061, India
[b]*Centre For Ecological Sciences, Indian Institute of Science,*
Bangalore 560 012, India

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Abstract

Biodiversity surveys were conducted in 13, 10×50 m^2 plots located between 1400 to 3700 m above mean sea level in a range of habitats in temperate mixed Oak and Coniferous forests through sub-alpine to the alpine grasslands in Chamoli district of Uttaranchal state in the Indian Garhwal Himalaya. Cross-taxon congruence in biodiversity (α-diversity and β-diversity) across macrolichens, mosses, liverworts, woody plants (shrubs and trees) and ants was investigated, so as to examine the extent to which these groups of organisms can function as surrogates for each other. Although woody plants provided a major substrate for macrolichens and mosses, there was no species-specific association between them. Woody plant species richness was highly positively correlated with mosses ($r^2=0.63$, $P<0.001$), but the relationship was not particularly very strong with lichens and liverworts. While there was a significant correlation in the species turnover (β-diversity) of macrolichens with mosses ($r^2=0.21$, $P<0.005$), the relationship was relatively poor with the woody plants. On the other hand, negative correlations emerged in the species richness of ants with those of macrolichens, mosses and woody plants ($r^2=-0.44$, $P<0.05$), but most of the complementarity (turnover) relationships among them were positive. Since diversity between taxonomic hierarchies within the group was consistently significantly positively correlated in all these taxa, the higher taxonomic categories such as genus and family may be employed as surrogates for rapid assessment and monitoring of species diversity. Although no single group other than macrolichens has emerged as a good indicator of changes in species richness in all other groups, some concordant relationships between them conform to the hypothesis that species assemblages of certain taxonomic groups could still be used as surrogates for efficient monitoring of species diversity in other groups whose distribution may further predict the importance of conserving overall biodiversity in landscapes such as the Garhwal Himalaya. © 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Ants; α-Diversity; β-Diversity; Cross-taxon surrogacy; Garhwal Himalaya; Liverwort; Macrolichen; Moss

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1. Introduction

Exploring distribution of biological diversity and the extent of surrogacy among different sets of organisms are importantly challenging scientific problems in conservation biology (UNEP, 1992; Heywood, 1995; Faith and Walker, 1996; Gaston, 1996, 2000; Negi, 1999). The problem has been particularly investigated in the context of designing efficient programs of monitoring biodiversity and setting out conservation priorities (Oliver and Beattie, 1993; Pollard and Yates, 1993; Balmford and Long, 1995; Gadgil, 1996; Howard et al., 1998; Swengel and Swengel, 1999; Myers et al., 2000). In these contexts, there is a need to assess the extent to which high levels of diversity are correlated among different taxonomic groups in different bio-geographical regions. The organismic groups may be distinctive taxa such as ants and flowering plants, or nested taxonomic groups such as liverworts, mosses and bryophytes. By and large, no consistent levels of positive correlations have been found among distinct taxa, at levels of different types of habitats, such as forests with different levels of

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* Corresponding author. Tel.: +91-1894-30424-26; fax: +91-1894-30433.

E-mail address: negiihbt@yahoo.co.in (H.R. Negi).

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human disturbance, or large geographical regions, such as different grids into which the British Isles are divided (Prendergast et al., 1993; Lawton et al., 1998; Kunte et al., 1999; Pharo et al., 1999). As may be expected, higher, though variable, levels of correlations have been recorded among groups within a nested taxonomic hierarchy at different spatial scales (Noss, 1990; Williams and Gaston, 1994; Andersen, 1995). This is because organisms within such a hierarchy have similar responses to a variety of environmental parameters. In fact, one may postulate that the extent of correlation in levels of diversity in different habitats or geographical locales among different taxa would depend upon similarities or differences in their responses to biotic as well as abiotic parameters and mutualistic, competitive, or antagonistic (prey–predator, host–parasite) relationships amongst the different taxa. In the present study, an attempt is made to explore the possible influence of such factors by looking at five distinctive groups of organisms with variable levels of differences in their responses to environmental parameters and types of biotic interactions. The groups under investigation include macrolichens, mosses, liverworts, woody plants and ants. The lichens and bryophytes accounting for the first three groups occur on soil, rock and wood substrates. Shrubs and trees primarily growing on soil serve as wood substrate for macrolichens and mosses. The ants prefer drier soils underneath rocks, logs and thick moss beds for nesting whereas terricolous liverworts exclusively prefer wet soil. Owing to these habitat preferences, patterns of diversity of macrolichens, mosses and woody plants may be expected to be positively correlated, but be uncorrelated, or perhaps even be negatively correlated with those of liverworts and ants. Another hypothesis of interest may be postulated as while macrolichens and mosses extensively use live woody substrates, they may not be species specific. So while the species richness (α-diversity) of macrolichens and mosses may be positively correlated with that of woody plants, their levels of species turnover (β-diversity) may show little correlation. This investigation further addresses the environmental variables including the local land use factors that may explain significant variation in species richness and turnover in one group of organisms also explaining the variations in other surrogate groups. For example, livestock grazing, excessive lopping and fuel wood collection, especially for sustaining growing tourism in the area urgently needs to be regulated with high priority. If we do not control and monitor such land use patterns and their biodiversity implications, future generation will have to face with local extinction of many species, including wood loving macrolichens and mosses, some of which are medicinal and critical for the survival of the highly endangered Musk deer in the higher Himalaya (Negi, 1996, 1999, 2000a; Negi and Gadgil, 1996).

2. Methods

2.1. Study area

The study area (30°20′ N–30°35′N latitude; 79°10′ E–79°20′E longitude) is located in Chamoli district of Uttaranchal state in the Indian Garhwal Himalaya (Fig. 1). The mountainous landscape with steep to moderate slopes spreads over 500 sq km with elevation ranging between 1400 and 3700 m above mean sea level. The weathering bedrock that provides the bulk of the loose material in these mountains is crystalline and metamorphic with sedimentary deposits formed during the Paleaozoic (Ganser, 1964; Gupta, 1964). Soils in the area are of coarse texture, well drained and acidic with pH levels varying between 4 to 5.5 in the alpine grasslands (Sundriyal, 1992). Although, there is no detailed analysis of variation of rainfall at different sites along the elevation gradient, average annual precipitation at Okhimath (30°30′ N; 79°15′ E, 2500 m) station, about 10 km west from Chopta, records 1888.5 ±98.5 mm for 50 years of observations along with light to heavy snow fall during December to March. The maximum monthly temperature in the area varies from around 19 to 37 °C from the higher altitude grasslands to the lower elevation *Quercus* forest, respectively, during the snow-free months of May to October. Minimum temperature drops as low as −15 °C in the alpine grasslands during the months of December to February.

Higher plant vegetation of the study area is broadly classified as temperate mixed oak and coniferous forests through sub-alpine forest to the alpine grassland along the altitude gradient (Gadgil and Meher-Homji, 1990). The area harbors 92 species of lichens (Upreti and Negi, 1998), 177 species of mosses (Negi and Gadgil, 1997), 85 species of macrolichens (Negi, 2000a) and 250 vascular plant species including herbs (Semwal and Gaur, 1981) besides supporting a number of endangered fauna, such as the Musk Deer (*Moschus chrysogaster*; Negi, 1996).

Historically, the area has been very famous for traditional communities of Indian mountains for many centuries as Tunganath Temple (one of the five "Kedars" i.e. sacred place of Garhwal Himalaya) is situated in the region. Recent developments, such as the construction of guesthouses and motorable roads connecting the area to the nearby National Highway and other Kedars such as Kedarnath, in the region began to attract thousands of tourists from all over the world. Local human population settled in the lowland fringe areas are basically semi-pastoralists with livestock grazing and agriculture as their dominant land use activities. While low-elevation woodlands such as *Quercus* forests are open for fodder and fuel wood collection throughout the year, grazing in the higher elevation forests and grasslands starts in early June, reaching maximum in July–August and stops in early October.

2.2. *Sampling and data recording*

A stratified random sampling method was employed (Greig-Smith, 1983; Krebs, 1989). The study landscape was stratified into five macrohabitat types mainly based on the predominant vegetation cover along the elevation gradient. These types are: (1) agricultural land (< 1400 m); (2) lower altitude (1500 m) broad-leaved forest, dominated by *Quercus leucotrichophora*. This forest has been protected from felling by local people for more than 25 years; (3) middle altitude (2500–2800 m) broad leaved forest, dominated by the trees of *Quercus semecarpifolia*; (4) High altitude (2900–3200 m) mixed forests with dominant broad leaf species as *Rhododendron arboreum*, *R. campanulatum* dotted with a few coniferous trees of *Abies pindrow* and *Taxus baccata*; and (5) higher altitude (3400–3700 m) grasslands dominated by herb species of *Anemone, Potentilla, Aster, Geranium, Meconopsis, Primula* and *Polemonium*, and scattered pockets of shrubs of *Rhododendron anthopogon* and *Juniperus* species.

Data recording involved locating a plot of dimension 10×50 m, in each of the 13 sites distributed between 1400 and 3700 m covering all the five macrohabitat types. Twenty randomly located 100 cm^2 quadrats on each of the five substrates viz. soil, rocks, tree trunks, logs and fallen branches were sampled for macrolichen, moss and liverwort species. For the present paper, data from the 20–100 quadrats (20 quadrats where only soil substrate was available and 100 where all the substrates were present in the plot) were pooled to give species

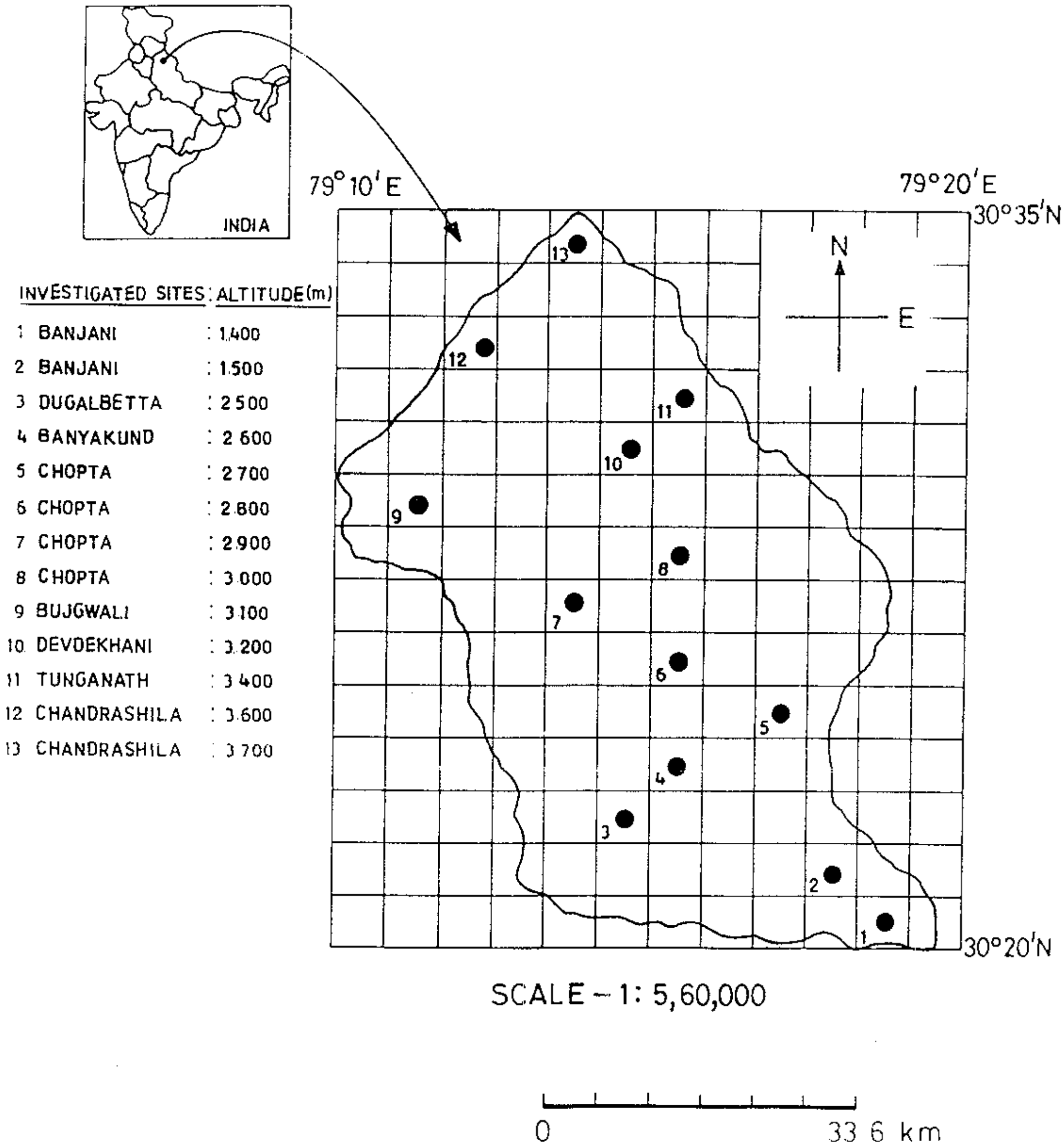

Fig. 1. Location map of the study area.

abundance per 10×50 m plot. In the case of ants, the number of trails and nests were recorded in each of the plots only during sunny days of the summer season. The number of trees above 10 cm girth at 130 cm height and patches of shrubs (>10 cm in height) was also noted. Although macrolichens and mosses could not be sampled on trees above a height of 2.5 m, many canopy species were encountered through collection of fallen branches and twigs on the ground. Taxonomic nomenclature followed Holldobler and Wilson (1990) for ants, Awasthi (1988) for macrolichens, Chopra (1975) for mosses, Udar (1976) for liverworts and Naithani (1984–1985) for woody plants.

2.3. Ecological variables

Six ecological factors were recorded in each of the plots. The first two, as disturbance variables, are grazing and collection of fuel wood and fodder. Both the activities were known to occur in the study area since time immemorial, but their intensity varied across the plot sites. The intensity of the grazing was measured as the number of months per year the sites were open for the livestock, whereas the extent of fuel wood collection was assessed as low (<25% removal of secondary branches up to 2.5 m), moderate (25–50%) high (50–75%) and severe (>75% removal of the secondary branches). The remaining four variables were elevation, aspect, slope and canopy openings in the forest plots. Elevation ranged between 1400 and 3700 m from mean sea level. Aspect was coded as 1, north; 2, northwest or northeast; 3, east or west; 4, southeast or southwest; and 5, south, assuming the largest difference between south and north. Canopy openings were assessed in the forest plots as <10, 11–30, 31–50, 51–70 and >70%, whereas the value was 100% for the open grasslands and the agricultural field where there were no trees. Slope was measured in degrees from the horizontal.

2.4. Data analyses

2.4.1. α-Diversity and β-diversity

Diversity may be measured at a variety of levels from genes to landscapes. Here the focus is at intermediate level on taxonomic categories of species, genus and family, and on two components, namely packing or α-diversity and turnover or β-diversity. The former refers to diversity at a given plot, the latter refers to turnover across plots but not necessarily along a particular environmental gradient (Whittaker, 1972; Magurran, 1988). While the number of taxa per plot implied as an index of α-diversity, Chord distance was measured as an index of β-diversity as it reflects the relative difference between two plots as projected on to a circle of unit radius (Ludwig and Reynolds, 1988).

Thus, Chord distance between jth and kth plots is given as:

$$D_{jk} = \sqrt{2\left[1 - \frac{\sum\limits_{i=1}^{S_{jk}}(N_{ij}N_{ik})}{\sum\limits_{i=1}^{S_j} N_{ij}^2 \sum\limits_{i=1}^{S_k} N_{ik}^2}\right]}$$

where, S_{jk} is the total number of species in jth and kth plots, N_{ij} and N_{ik} are the numbers of colonies/individuals of ith taxon in jth and kth plots, S_j and S_k are the numbers of species in jth and kth plots, respectively. Chord distance values range between 0 and 1.42 for all the pairs of plots corresponding to identical to completely dissimilar taxonomic composition.

2.4.2. Regression model and simulations

Simple linear regression was used to explain biodiversity relationships across the taxa and at species, genus and family levels. Each turnover value cannot be considered as an independent variable as slight change of species composition in one of the plots influences the value in another plot causing uncertain degrees of freedom. This uncertainty increases the possibility of an observed relationship occurring by chance alone. To overcome this problem, computer simulations based on randomization process were employed. Here β-diversity values in one of the pairs of taxonomic hierarchy (species, genus or family level) was scrambled with respect to the other, thus randomizing the process and regression was performed between the pairs. This procedure was repeated 1000 times for each pair yielding 1000 values of r^2. Level of significance value (P) was calculated as a proportion of the simulated values of r^2 that were greater than the observed r^2. Relationships with $P<0.05$ were considered significant.

2.4.3. Preference index

An index of preference was measured as the proportions of a particular species of macrolichen or moss found across the woody plants, particularly the live tree species. For this assessment, species abundance data was analyzed after randomly drawing five quadrats from randomly selected 10–15 individuals of the live tree species from the plots in which they occurred. Thus the data from a total of 50–75 quadrats per live tree species yielded the distribution of proportion of 17 species of macrolichens and 16 species of mosses across 8–10 tree species. The index values are expressed as percentages and arranged on the basis of reciprocal averaging to assess the extent to which particular macrolichen and moss species was associated with particular tree species.

3. Results

3.1. α-diversity

This investigation involving sampling of a total area of 6500 sq m yielded 13 families with 15 genera and 85 species of macrolichens, 34 families with 87 genera and 177 species of mosses, 13 families with 15 genera and 19 species of liverworts, 15 families with 19 genera and 24 species of wood plants and four sub-families with 18 genera and 26 species of ants. Average species richness of macrolichens at a plot was 18.15±1.60 (S.E.) with an average of 36.15±2.22 for moss species and 3.38±1.67 for liverworts. The average wood plants and ant species richness was 3.62±2.84 and 5.08±3.43, respectively.

Correlations among the groups of organisms showed that lichen species richness was a very good indicator group for predicting moss, liverworts and ant species richness (Table 1). Lichen species richness was also correlated with wood plant species richness but the relationship was not as strong as it was between the moss and the wood plants. Significantly negative correlations emerged between species richness of ants with that of lichen, moss and woody plants. Negative correlation was also seen as species richness of liverworts significantly decreased in the plots rich with the lichens.

Aspect showed significant influence on the species richness of lichens, mosses and liverworts (Table 2). The effect was limited for ants and wood plants. In contrast, elevation explained significant variation in ant species richness ($r^2=-0.45$, $P<0.005$). Canopy opening does not seem to strongly influence the species richness in all the groups as none of the correlations were particularly significant. While the lopping and fuel wood collection may affect the species diversity, particularly in wood borne lichen and moss communities, its intensity was yet not severe in all the woodland plots, thereby showing very poor correlations.

Table 1
Cross-taxon regression (r^2) in change in species richness across plots

	Mosses	Liverworts	Woody plants	Ants
Macrolichens	0.57	−0.45	0.26	−0.40
	$P<0.005$	$P<0.01$	$P<0.05$	$P<0.05$
Mosses		−0.05	0.63	−0.35
		NS[a]	$P<0.001$	$P<0.05$
Liverworts			−0.08	0.04
			NS[a]	NS[a]
Woody plants				−0.26
				$P<0.05$

[a] NS, not significant.

Table 2
Regression (r^2) of specie richness of the five groups of organisms with six ecological variables[a]

Ecological variable	Macrolichens	Mosses	Liverworts	Wood plants	Ants
Elevation	0.04	0.17	0.04	0.04	*−0.45*
					$P<0.05$
Grazing pressure	0.01	0.02	−0.00	0.02	0.01
Fuelwood collection	0.07	0.04	−0.04	0.06	0.00
Aspect	*−0.85*	*−0.25*	*0.55*	−0.05	0.21
	$P<0.001$	$P<0.05$	$P<0.005$		
Slope	−0.01	0.03	0.08	0.00	−0.04
Canopy opening	−0.22	−0.11	0.07	−0.07	0.07

[a] Signifcant values are in italic.

3.2. β-diversity

Average rate of species turnover was highest in woody plants (1.34±0.17) followed with liverworts (1.31±0.10), lichens (1.23±0.24), mosses (1.16±0.21) and then in ants (1.13±0.32). By cross-taxon regression and simulations, we found that lichen species turnover was significantly correlated with the species turnover in the moss community (Table 3). Moss and ant species turnover were also highly significantly correlated ($r^2=0.44$; $P<0.001$). Although species turnover in lichen and moss communities was positively correlated with woody plants, none of the relationships were particularly strong. This indicates poor species-specific associations among them conforming to our hypothesis that neither macrolichens nor moss species on live wood substrates display any marked preferences towards particular wood species. Tables 4 and 5 assess this assumption for 17 species of macrolichens and 16 species of mosses occurring in more than 75% of the quadrates in the sampled plots for the 8–10 species of live trees which harbor them. While three species of macrolichens are restricted to one wood species, the vast majority of macrolichen and moss species exhibit little specificity for the wood species.

Table 3
Cross-taxon regression (r^2) in change in species composition (turnover) across plots[a]

	Mosses	Liverworts	Woody plants	Ants
Macrolichens	0.21	0.03	0.16	0.16
	$P<0.005$	NS	$P<0.05$	$P<0.05$
Mosses		0.06	0.06	0.44
		NS	NS	$P<0.001$
Liverworts			−0.01	0.02
			NS	NS
Woody plants				0.15
				$P<0.05$

[a] NS, not significant. + and − signs indicate the direction of the effect.

Elevation was the strongest environmental predictor of species turnover in all the groups of organisms, other than liverworts, showing negative relationships (Table 6). Habitat slope significantly governs species turnover in ant communities ($r^2 = -0.45$, $P < 0.005$), whereas aspect explained moss and macrolichen species turnover ($P < 0.05$).

3.3. Nested taxon rank diversity relationship

Fig 2 shows regression of species, genus and family richness in all five taxonomic groups. As expected, significantly positive ($P < 0.005$) relationships emerged between the higher taxonomic categories such as genus

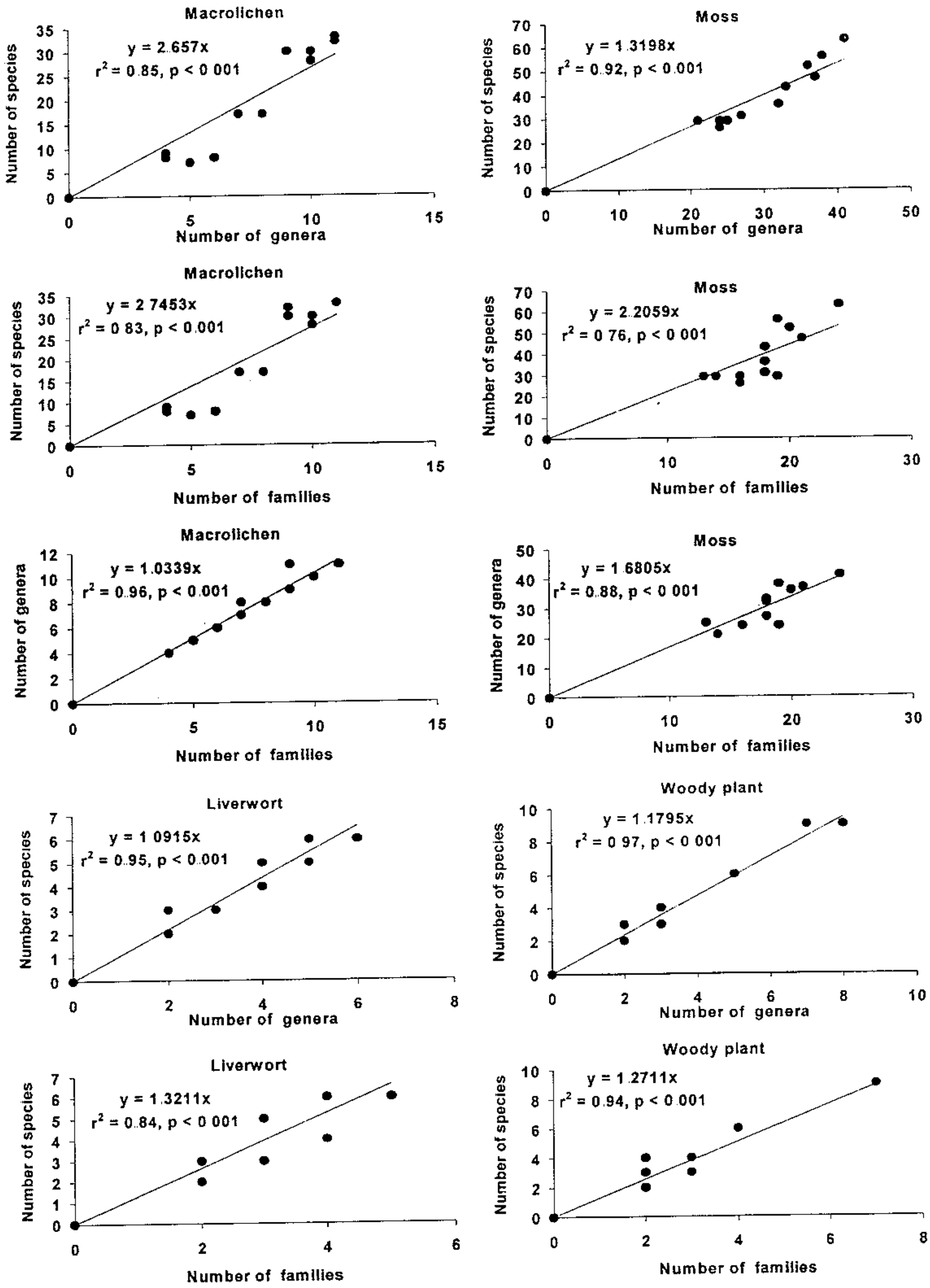

Fig 2. Regression among species, genus and family/sub-family richness across the five taxonomic groups.

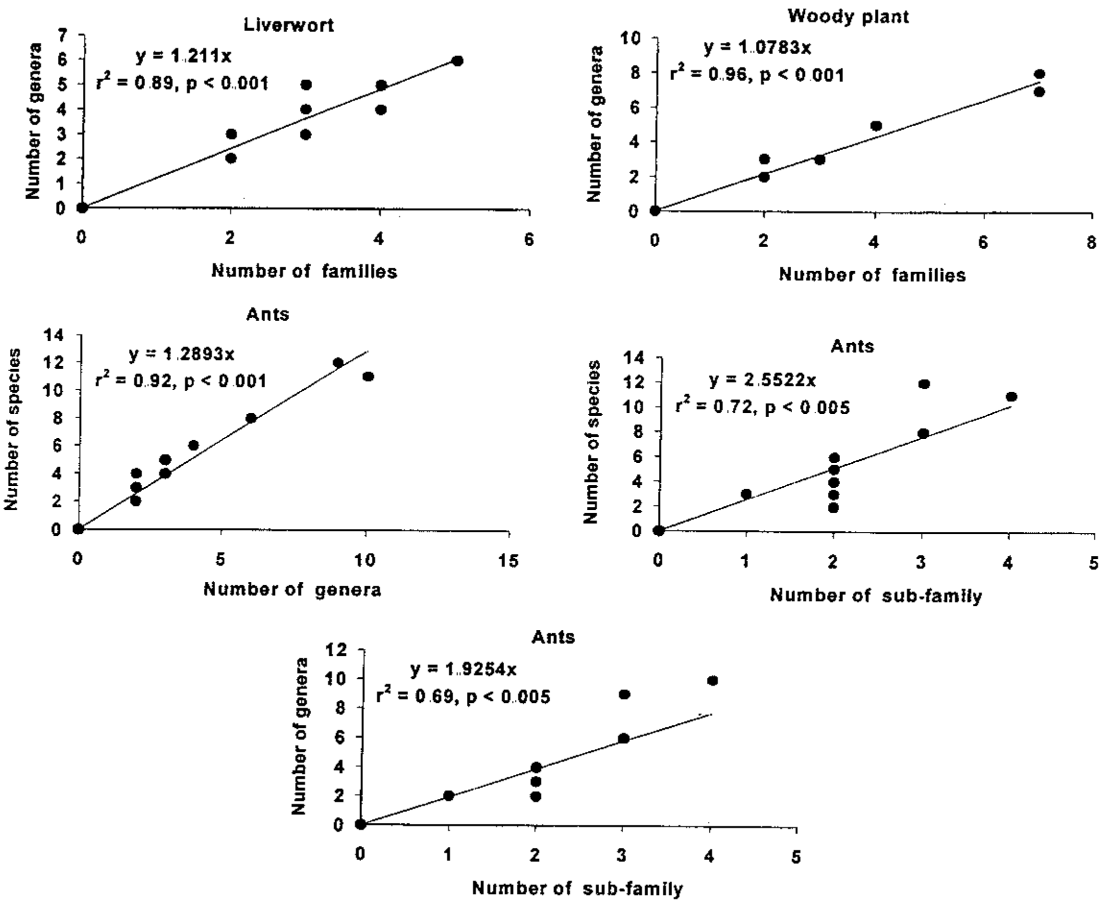

Fig 2 Continued.

Table 4

Index of preference values expresed as percentages for the 17 species of macrolichens across eight species of of woody plants aranged after reciprocal averaging Woody plants ($n = 10–15$)[a]

Macrolichens ($n = 50–75$)	*Ql*	*Ai*	*Ra*	*Ap*	*Qs*	*Rc*	*Pc*	*Qd*
Parmelia cirrhata Fr	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heterodermia diademata (Tayler) Awasthi	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Parmelia nilgherensis Nyl.	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Usnea perplexans Stirton	83.12	0.00	11.59	5.29	0.00	0.00	0.00	0.00
Leptogium delavayi Hue	68.11	16.55	3.60	5.04	6.71	0.00	0.00	0.00
Usnea orientalis Mot.	0.00	0.00	61.80	35.62	2.58	0.00	0.00	0.00
Parmelia nepalensis Taylor	0.00	0.00	0.00	95.09	4.91	0.00	0.00	0.00
Cladonia fimbriata (Florke) Sprengel	0.00	7.30	39.19	3.05	12.01	38.45	0.00	0.00
Leptogium pedicellatum P. Jorge.	0.00	35.26	6.84	10.49	29.03	18.39	0.00	0.00
Lobaria retigera (Bory) Trevisan	0.00	31.86	5.12	11.91	25.62	14.13	11.36	0.00
Heterodermia leucomela (L.) Poelt	0.00	21.14	7.57	6.11	6.34	11.98	16.56	30.30
Heterodermia pseudospeciosa (Kurok)Culb	0.00	0.00	26.61	18.95	0.00	17.54	36.90	0.00
Parmelia paresorediosa Nyl	0.00	0.00	14.97	11.44	30.08	0.00	43.50	0.00
Ramalina roesleri	0.00	0.00	0.00	7.77	39.17	53.06	0.00	0.00
Cladonia coniocraea (Florke) Sprengel	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Usnea longissima Ach	0.00	5.96	8.02	11.08	3.11	0.00	29.13	42.69
Leptogium trichophorum Mull. Arg	0.00	0.00	0.00	13.75	6.43	11.56	0.00	68.26

[a] Woody plant species: *Ai*, *Asculus indicus* (Bixaceae); *Ra*, *Rhododendron arboreum* (Aricaceae); *Ap*, *Abies pindrow* (Pinaceae) ; *Rc*. *Rhododendron campanulatum* (Aricaceae); *Pc*, *Prunus cornuta* (Rosaceae); *Ql Quercus leucotrichophylla* (Fagaceae); *Qd*. *Quercus dilatata* (Fagaceae) ; *Qs Quarcus semicarpifolia* (Fagaceae)

Table 5
Index of preference values expressed as percentages for the 16 species of mosses across 10 species of woody plants arranged after reciprocal averaging woody plant species ($n = 10$–15)[a]

Mosses ($n = 50$–75)	Pc	Rc	Ap	Qd	Ra	Tb	Qs	Ai	Ql	Ac
Brachythecium kamounense (Harv.) Jaeg.	75.80	10.71	13.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Struckia argentata (Mitt.) C.Muell.	37.68	47.77	13.14	0.00	0.00	0.00	1.41	0.00	0.00	0.00
Symblepharis vaginata (Hook.) Wijk. & Marg.	22.55	34.91	9.27	32.55	0.73	0.00	0.00	0.00	0.00	0.00
Leucodon sciuroides (Hedw.) Schwaegr	21.57	2.29	32.86	0.00	17.29	10.71	11.29	4.00	0.00	0.00
Ectropothecium cyperoides (Hook.) Jaeg.	0.00	19.64	17.72	0.00	28.63	0.00	0.00	34.02	0.00	0.00
Rhynchostegium calderii Vohra	0.00	19.64	17.72	0.00	28.63	0.00	0.00	34.02	0.00	0.00
Pseudosymblepharis angustata (Mitt.) Hilp.	0.00	29.15	37.64	0.00	10.89	0.00	22.32	0.00	0.00	0.00
Hypnum cupressiforme L. ex Hedw.	0.00	21.51	23.34	0.00	10.43	15.25	12.65	16.82	0.00	0.00
Pseudoleskea laevifolia (Mitt.) Jaeg.	0.00	5.27	2.38	0.00	2.28	37.33	25.34	27.40	0.00	0.00
Thuidium cymbifolium (Doz. et Molk.) Doz. et Molk	0.00	8.30	5.50	0.00	10.14	54.73	4.15	17.18	0.00	0.00
Rhynchostegiella humillima (Mitt.) Broth	0.00	0.00	33.47	0.00	27.12	0.00	39.41	0.00	0.00	0.00
Trachypodopsis serrulata (P. Beauv.) Fleisch	0.00	0.00	2.00	18.28	14.95	0.00	15.03	7.70	0.00	42.04
Hylocomium himalayanum (Mitt.) Jaeg.	0.00	16.08	0.00	0.00	83.92	0.00	0.00	0.00	0.00	0.00
Entodon rubicundus (Mitt.) Jaeg.	0.00	1.31	2.14	16.21	7.38	3.72	10.41	2.76	41.10	14.97
Bryoerythrophyllum wallichii (Mitt.) Chen	0.00	0.00	2.53	0.00	0.00	0.00	9.00	48.66	0.00	39.82
Meteorium buchananii (Brid.) Broth	0.00	0.00	8.32	33.45	23.40	0.00	34.84	0.00	0.00	0.00

[a] Woody plant species: Ac. *Acer caesium (Sapindaceae)*; Ql, *Quercus leucotrichophylla (Fagaceae)*; Ai, *Asculus indicus (Bixaceae)*; Qs, *Quarcus semicarpifolia (Fagaceae)*; Ap, *Abies pindrow* (Pinaceae); Ra. *Rhododendron arboreum* (Aricaceae); Pc, *Prunus cornuta* (Rosaceae); Rc. *Rhododendron campanulatum* (Aricaceae); Qd. *Quercus dilatata* (Fagaceae); Tb, *Taxus buccata* (Taxaceae)

Table 6
Regression (r^2) of the specie turnover of the five groups of organisms with six ecological variables[a]

Ecological variable	Macrolichens	Mosses	Liverworts	Wood plants	Ants
Elevation	*−0.63* $P<0.001$	*−0.44* $P<0.005$	−0.10	*−0.48* $P<0.005$	*−0.39* $P<0.05$
Grazing pressure	0.11	0.01	0.00	0.11	0.05
Fuelwood collection	0.13	0.02	0.00	0.09	0.11
Aspect	*0.25* $P<0.05$	*0.30* $P<0.05$	0.06	0.04	0.11
Slope	0.24	0.19	0.01	0.12	*−0.45* $P<0.005$
Canopy opening	0.02	0.01	0.00	0.00	0.07

[a] + and − signs indicate the direction of the effect. Signifcant values are in italic.

and family richness with that of the species richness. Similarly, statistically significant ($P<0.005$) relationships among the taxonomic hierarchies occurred with respect to their turnover rates as well in all the groups (Fig. 3).

4. Discussion

The study attempted to identify surrogates across and within taxonomic groups to simplify the task of landscape level biodiversity assessment and monitoring. In India, biodiversity surveys are rarely comprehensive enough to sample and identify all the species in a given area. This is mainly because numbers of species are generally very high and the identification is time consuming. Moreover the species level taxonomy of Indian taxa, particularly in ants and lower plant groups, is poorly explored. This is because neither the required taxonomic expertise nor enough resources are available. A reduced set of taxa or taxonomic ranks other than species may therefore be useful for rapid and cost-effective assessment of bio-diversity (Prance, 1994; Williams and Gaston, 1994). But prior to this, it is necessary to establish a relationship of species diversity and the surrogate taxa to be used. The present investigation established such a relationship and showed that even genus level inventory of taxa may be helpful in predicting species diversity. Higher taxonomic hierarchy units such as genera are effective indicators of species diversity in the communities such as lichens, mosses and ants. This may appear self-evident, but there is evidence that such a relationship may not always hold, for instance while using the genus diversity as surrogate for the species richness in comparing across habitats for ants in Australia (Anderson, 1995).

The study also identifies surrogates across different taxonomic groups. Macrolichen and moss taxa emerged as excellent surrogates for each other, and woody plants for mosses and ants. These results are contrary to the studies from boreal forests in Sweden where no relationship was found between bryophyte and vascular plant species richness (Soderstrom, 1981). Similar to the Sonderstrom's findings were also reported from the

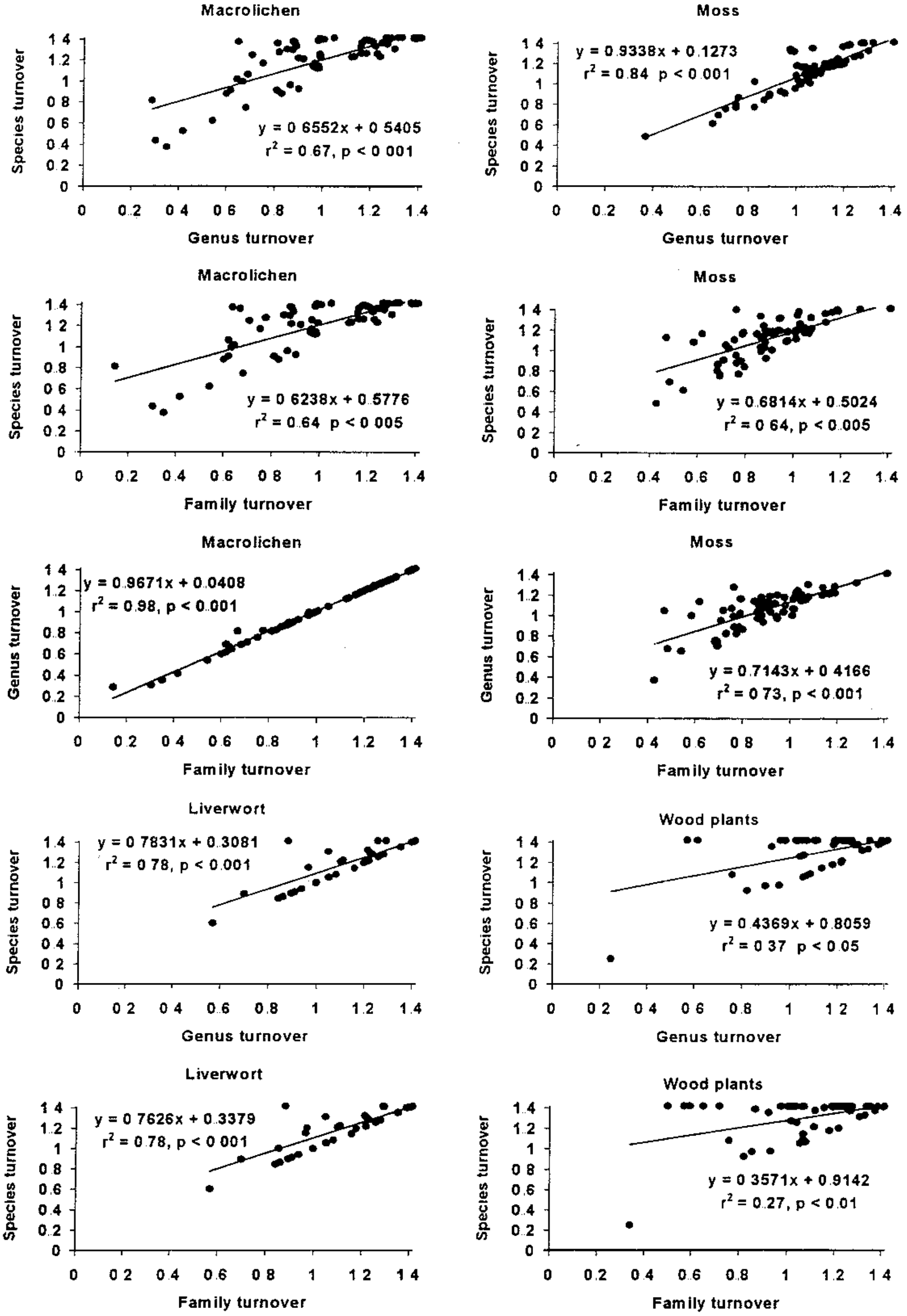

Fig. 3. Regression among species genus and family/sub-family *turnover* across the five taxonomic groups

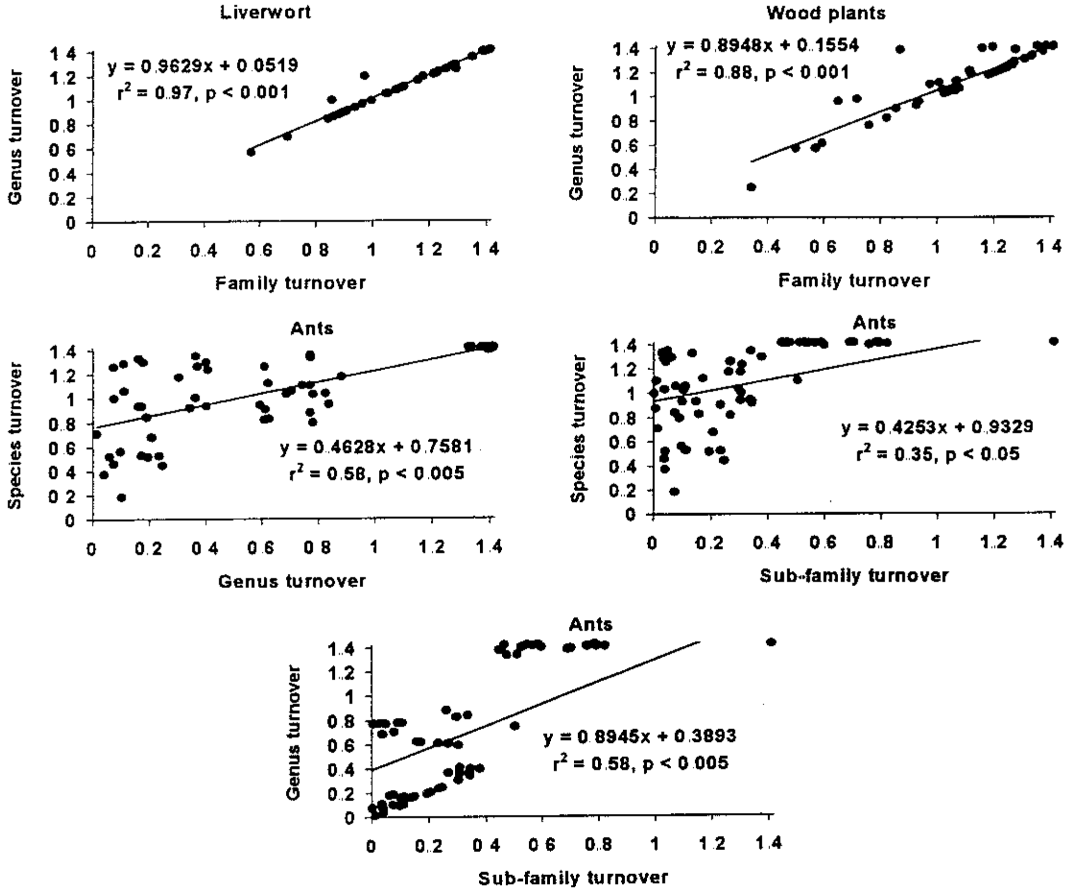

Fig. 3. Continued.

drier forests of Australia (Pharo et al., 1999). However, in both the studies liverworts and mosses were lumped together as bryophytes. Negative relationship of the species richness of ants with that of woody plants in this Himalayan environment contradicts with Gadagkar et al. (1993), where they showed significantly positive correlation between the two taxonomic groups in the dry tropical forests of the Western Ghat region in India.

Differences in rates of species turnover among different taxonomic groups could indicate that different combinations of habitat types may be required for conservation of overall biodiversity. In the present case study, moss, lichen and ant communities exhibited lower species turnover as compared to woody plants and liverworts. This agrees with the results reported from western Canada where terrestrial bryophytes had a lower turnover than shrubs or tree layers (Rey Benayas, 1995). This is contrary to some other reports where the rate of species turnover of bryophytes and the vascular plant categories were either similar or revealed that bryophyte community layer has a higher turnover than the wood plant components (McCune and Antos, 1981; Pharo et al., 1999).

Apart from identifying particular surrogates, the study elucidates local environmental factors governing the patterns of congruence in diversity across the taxa. Elevation appears to differentially influence species diversity in different taxonomic categories. Species richness and turnover of ants significantly declined with the altitude. Consistent variations were also seen in the rates of change of species composition in rest of the taxa. The absence of significant variation in liverwort species composition with altitude may be due to poor number of species encountered in the study sites. While this seems to have followed generally accepted patterns observed in most of the higher taxon groups, the decline in species richness from low to high altitudes and a peak of richness at mid-altitudes have been observed in ant communities of Phillipines (Samson, 1997) and lichens in the Indian Trans Himalaya (Negi and Upreti, 2000).

Ongoing traditional ways of livestock grazing, lopping and fuel wood collection seem to have a very little impact on the diversity of ants and lower plant groups in the area. This seems to coincide with higher levels of richness of ants in optimally disturbed open forests than in the closed undisturbed primary rain forests in the Western Ghats (Basu, 1997). But it is likely that large-scale environmental factors such as fires may cause a devastating effects on the flora and fauna of the region. Reportedly, more than 63% of fires in the Garhwal

Himalayas are caused by humans (Semwal and Mehta, 1996). There are also some firm evidence of reduction in ant species richness after slashing and burning of a tropical forest in Mexico (Mackay et al., 1991). Indiscriminate bonfires by tourists for pleasure in guesthouse premises in the study area may increase the chances of such fires and may therefore lead to the loss of local genetic diversity. Excessive lopping and fuel wood collection, especially for sustaining growing tourism in the area urgently needs to be regulated with high priority. Otherwise we may have to face with local extinction of many wood-loving macrolichens and mosses some of which are critical for the survival of the highly endangered Musk deer in the higher Himalaya (Negi, 1996; Negi and Gadgil, 1996).

The urgent task of conservation of biodiversity calls for information on the whole spectrum of diversity of taxonomic groups at several scales ranging from microhabitats to landscapes through regional to global. Today, such information is available only for a few well known groups, especially on a global scale. This has led to the compilation of very useful products, such as the Status of Earth's Living Resources and the Atlas of Endemic Bird Areas of the World (Groombridge, 1992; Stattersfield et al., 1998). These include a few major Indian regions such as Western Ghats and Eastern Himalayas, which are included in other lists such as Myers' (1988) list of biodiversity hot spots. But such global syntheses based on a few well-known groups have their limitations. For instance, Prendergast et al. (1993) have demonstrated that at the scale of grids of 10×10 km areas of richness of all species or endemic species do not coincide for different taxonomic groups, such as birds, flowering plants and liverworts. At a lower scale, that of a series of quadrats stretching over 100 km along a gradient of annual rainfall of 1000–5000 mm, Daniels et al. (1992) demonstrated that bird and woody plant species diversity is inversely correlated. At an even smaller scale, Lawton et al. (1998) show lack of concordance in levels of diversity among the groups such as birds, butterflies and ants in 1–3 ha plots representing forest vegetation subject to different levels of human disturbance. It is then important to look beyond a few well-known groups of organisms. This is all the more relevant today because modern biotechnological advances have conferred potential economic value on obscure groups of organisms. Taxa such as lichens and liverworts with their interesting chemical make-up therefore become highly relevant in attempts to understand patterns of distribution and cross-taxon congruence in biodiversity.

It is also necessary to look at smaller spatial scales, for while global level analysis may point to significance of large regions such as Western Ghats, actual conservation efforts will have to focus on much smaller protected areas, and equally significantly on proper management of the landscape (Ricklefs and Schuluter, 1993; Tracy and Brussard, 1994; Negi, 1999). Thus, as Pramod et al. (1997) also pointed out that a significant conservation priority for the Western Ghats was safeguarding of the high altitude evergreen shola-grassland complex, within as well as outside protected areas. Also of significance is the management of specific microhabitats, such as dead and rotten wood (Soderstrom, 1993; Negi and Gadgil, 1997; Crites and Dale, 1998; Negi, 2000a). Forest managers tend to remove such wood from all forest reserves, but it is evident that it may be a critical habitat for certain taxonomic groups such as wood-rotting fungi, corticolous lichens, mosses or in case of standing dead trees for the wood hole nesting birds (Negi and Gadgil, 1996; Pramod et al., 1997; Negi 2000b). The present study may also be viewed as a contribution in these contexts. Finally, the study confirms that distribution of diversity and cross-taxon congruence patterns are highly complex and call for extensive locality and taxon specific assessments, including at lower spatial scales such as landscapes to enable us to design effective conservation strategies.

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