Patterns of distribution of macrolichens in western parts of Nanda Devi Biosphere Reserve

Hans Raj Negi[1] and Madhav Gadgil[1,2]

[1]Centre for Ecological Sciences, Indian Institute of Science, Bangalore 560 012, India
[2]Biodiversity Unit, Jawaharlal Nehru Centre for Advanced Scientific Research, Jakkur P.O., Bangalore 560 064, India

A total of 76 species of macrolichens were recorded from 16 transects of 50 m × 10 m between altitudes of 2100 m and 4500 m in western parts of Nanda Devi Biosphere Reserve of Garhwal Himalayas. Forty-one of these are lignicolous species occurring on woody, 14 are terricolous growing on soil and 10 are saxicolous inhabiting rocks only. The other 11 species occur on more than one major types of substrate. Lichen species diversity is at its highest in middle altitudes between 2700 m and 3700 m where all three major substrates are simultaneously available. Lichen species diversity of Nanda Devi Biosphere Reserve appears to be under threat from deforestation and fires, as well as from loss of soil microhabitats due to overgrowth of weeds seemingly caused by cessation of summer grazing in alpine pastures.

LICHENS, the most successful of symbiotic organisms on earth, constitute the dominant life form over as much as 8% of earth's surface[1]. They are amongst the most significant bioindicators[2–6] besides having many economic applications[7,8]. While there have been some systematic studies of the 697 species rich macrolichen flora of India[9], there have been no investigations of their community ecology. We report here the first such community level study from the western parts of Nanda Devi Biosphere Reserve (NDBR) (30°30′ to 30°38′ N latitudes and 79°44′ to 79°86′ E longitudes). The entire biosphere reserve extends over an area of 2236.74 sq km in the upper reaches of Garhwal and Kumaon Himalayas spanning an altitudinal range of 1000 m to 7817 m. Our study area falls within the range of 2100 m to 4500 m above mean sea level in the landscapes of the Garhwal Himalayas with an estimated area of 500 sq km (ref. 10) (Figure 1). This rugged mountainous landscape includes crystalline rocks belonging to Vaikrita Group and lower parts of the Tethys sediments along the river Rishi Ganga[11]. Although there are no records, precipitation is estimated to range over 1000 mm–1500 mm per year including heavy snow fall during December to March. Except alpine meadows, all other study sites are exposed to various levels of human interferences including grazing and fuel wood collection.

Methodology

Lichen communities were investigated in the western parts of NDBR over an altitudinal range of 2100 m to 4500 m during September–October 1993. Since a large part of study area falls within core zone of the reserve, administrative and logistic constraints did not allow us to sample areas above 4500 m. The sampling method involved laying down 16 transects of 50 m × 10 m in different localities covering temperate pine forest, subalpine birch-rhododendron forest and alpine meadows along with road-side grass and scrub at the lower altitude. A thorough search of 500 sq m transect consumed between 1 and 4 hours. Records were maintained of macrohabitat types, mesohabitat conditions with respect to exposure to sun, exposure to wind, habitat slope and humidity as well as of microhabitats of all the lichen colonies encountered (Table 1). These include three major substrates, viz. rocks, soil and wood; with further discrimination of 9 soil microhabitat types and 31 types of microhabitats in relation to species-specific wood, position on a tree and whether the wood is live or dead (Table 2). Mesohabitat levels were assigned on the basis of ordinal scaling whereas the macrohabitat types were nominally categorized[12] based on the ground vegetation. While lichens 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.

Results and discussion

Lichen flora

A total of 76 species belonging to 24 genera and 18 families constituted the macrolichen community of the western part of NDBR occurring in 204 colonies over the 8000 sq m sampled[13] (Table 3). Figure 2 shows levels of species richness in our study area along with 8 other investigations in different parts of the country[14–17]. Evidently our sampling has yielded a higher level of species diversity in relation to the area sampled compared

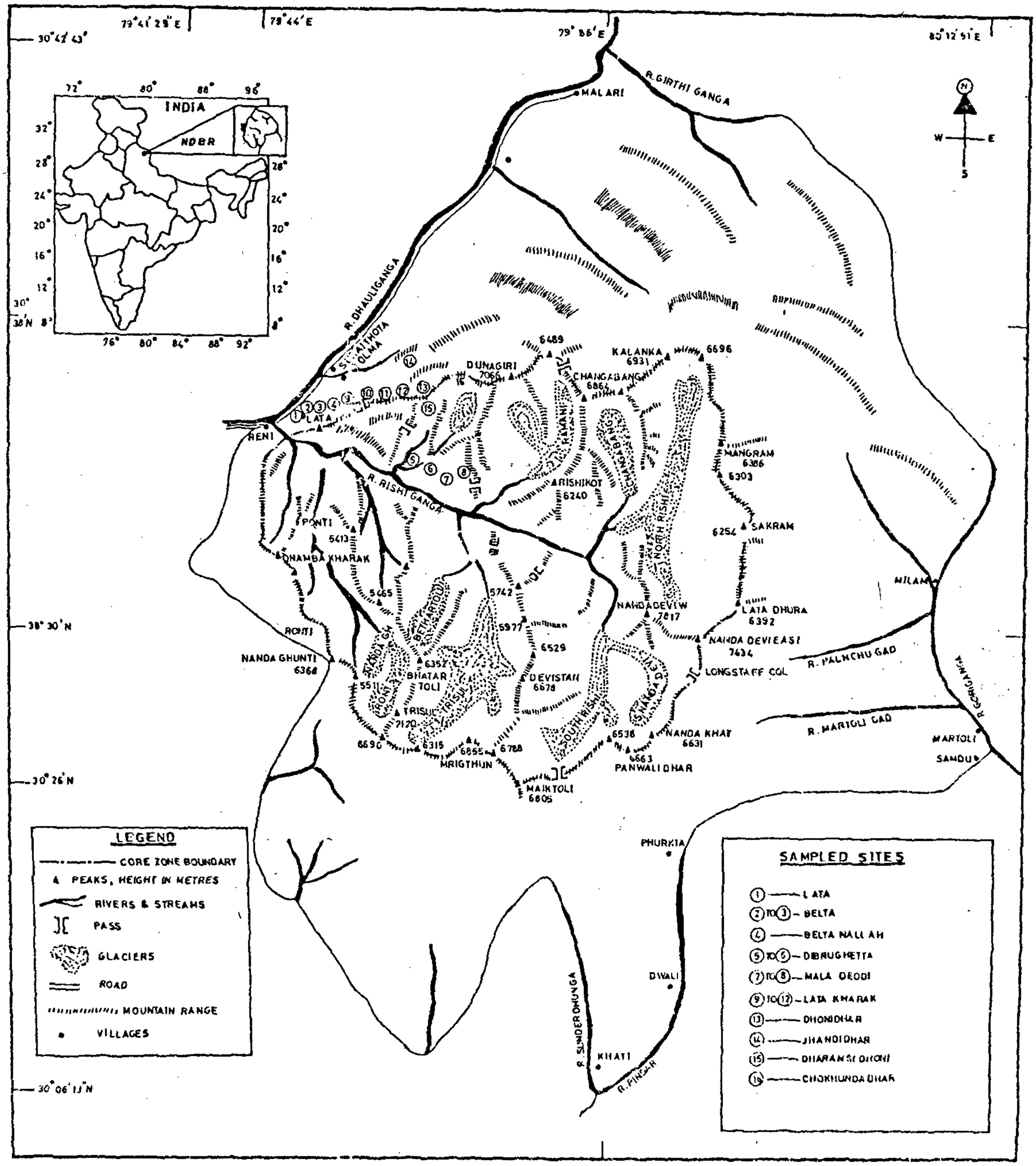

Figure 1. Schematic map of Nanda Devi Biosphere Reserve (scaled map is not available).

Cladonia coniocraea, abundantly encountered macrolichen occurring on soil as well as wood substrates.

Rhizocarpon geographicum, abundantly found microlichen species only grow on rocks.

Lichens of genus *Parmelia* growing on tree trunk bark at 2500 m.

Lichens are the dominant forms of life on the exposed rocks in the higher reaches of Nanda Devi Biosphere Reserve.

Xanthoria elagans, a colourful lichen growing on rocks at 4000 m.

Birch tree supporting a luxuriant growth of longest of lichen thalli of *Usnea longissima*.

to other studies reported from India. Figure 3 shows the patterns of relative abundance of the species showing that most species were encountered in 1 to 4 colonies only. *Cladonia coniocaea* was the most abundant of all the species.

Niche-width of species computed as Shannon–Wiener index[18] with respect to fine divisions of the substrates (microhabitats) is, as expected, positively correlated with the number of colonies encountered. After correcting for this factor, *Parmelia cirrhata* emerges as a significantly broad niched species while *Dermatocarpon vellerium* and *Umbilicaria indica* as two significantly narrow niched species with respect to their fine microhabitat preference (Figure 4). Nine of the 20 more abundant species occurring in four or more colonies occupy two out of three major substrates, and may therefore be

Table 1. Details of locality, macrohabitat, mesohabitat, major substrates, macrolichen abundance and species richness for the sixteen 50 m × 10 m transects

Locality	Altitude (m)	Macrohabitat	Mesohabitats				Major substrates	No. of colonies	No. of species	Signi-ficance
			Sn	Wn	Slp	Hm				
Lata	2100	Road side scrub and grass	3	3	1	2	Soil, rocks	3	1	
Belta	2500	Kail*-dominated habitat	1	1	2	2	Soil, rocks, wood	20	12	
Belta	2700	Raga*-dominated habitat	1	1	3	2	Soil, rocks, wood	27	21	+
Belta Nallah	2800	Raga*-Bhojpatra*-Thuner* dominant habitat	1	1	3	2	Soil, rocks, wood	12	9	
Dibrughetta	3300	Rocky rivulet bank	2	2	2	3	Soil, rocks	11	6	
Dibrughetta	3400	Raga*-Bhojpatra* dominant habitat	1	1	3	2	Soil, rocks, wood	20	16	+
Mala Deodi	3500	Scruby patch with a Bhojpatra*	1	1	1	2	Soil, rocks, wood	8	5	
Mala Deodi	3500	Grassy patch dotted with Bhojpatra* and shrub	2	2	2	2	Soil, rocks, wood	8	6	
Latakharak	3600	Sholu*-Bhojpatra* dominant habitat	1	1	1	3	Soil, rocks, wood	10	9	+
Latakharak	3700	Angod*-Sholu*-Bhojpatra* dominant habitat	1	1	2	2	Soil, rocks, wood	10	5	
Latakharak	3700	Angod*-dominated habitat	1	1	2	2	Soil, rocks, wood	11	11	+
Latakharak	3700	Takkar*-dominated habitat	2	2	2	2	Soil, rocks, wood	5	5	
Dhonidhar	3800	Alpine pasture	3	3	1	2	Soil, rocks	19	13	+
Jhandidhar	4000	Alpine pasture with morains	3	3	3	2	Soil, rocks	20	11	
Dharansi-Dhoni	4200	Morain-rich alpine pasture	3	3	1	2	Soil, rocks	6	4	
Chokhundadha	4500	Morain-rich alpine pasture	3	3	2	2	Soil, rocks	14	8	

* = Local name.
Botanical names: Kail = *Pinus wallichiana*; Raga = *Abies* sp.; Thuner = *Taxus buccata*; Bhojpatra = *Betula utilis*; Angod = *Rhododendron campanulatum*; Takkar = *Rhododendron anthopogon*; Sholu = *Sorbus foliolosa*.
+ indicates significantly high species richness at 1% level of significance.
1, 2, 3 represent low, moderate and high levels of mesohabitat conditions ranked on ordinal scaling.
Abbreviations: Sn = Exposure to sun; Wn = Exposure to wind; Slp = Habitat slope; Hm = Humidity.

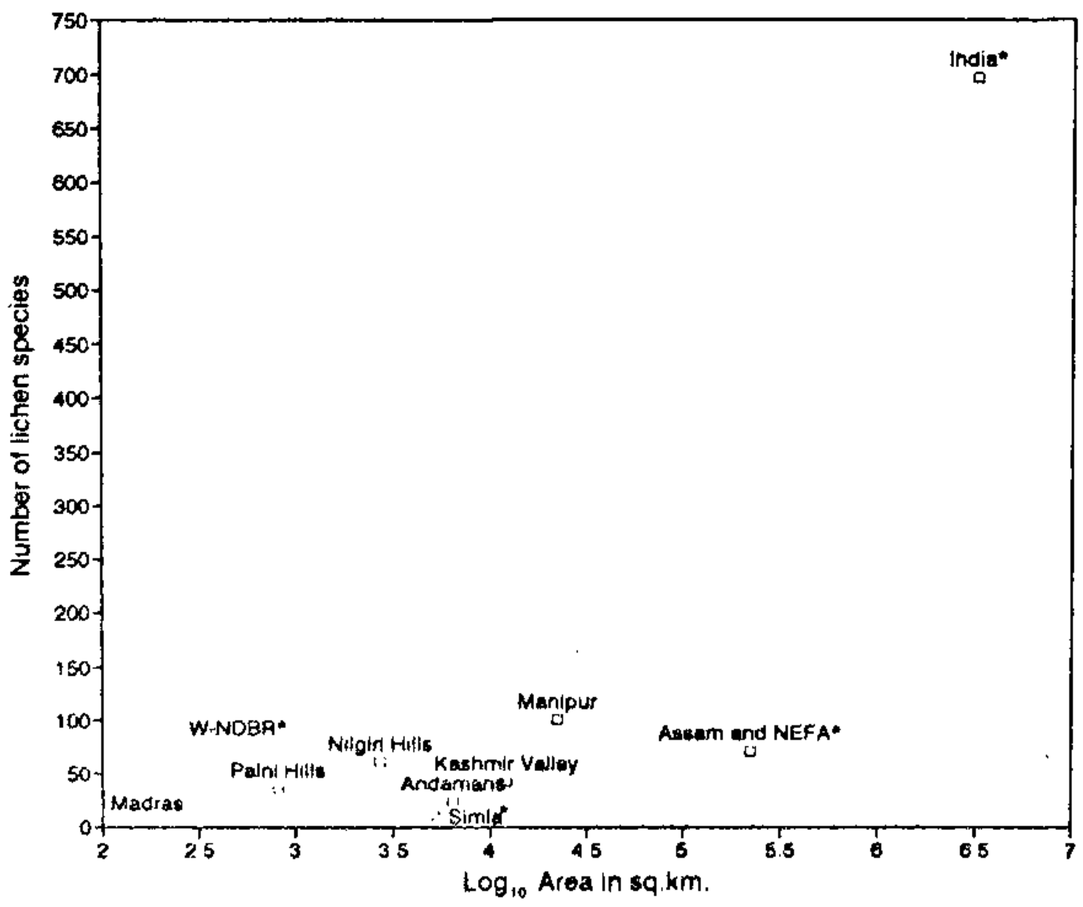

Figure 2. Levels of lichen species richness in the study area (W-NDBR*) with 8 other investigations in different parts of India. *, indicates macrolichen species richness; microlichens have also been included in other studies.

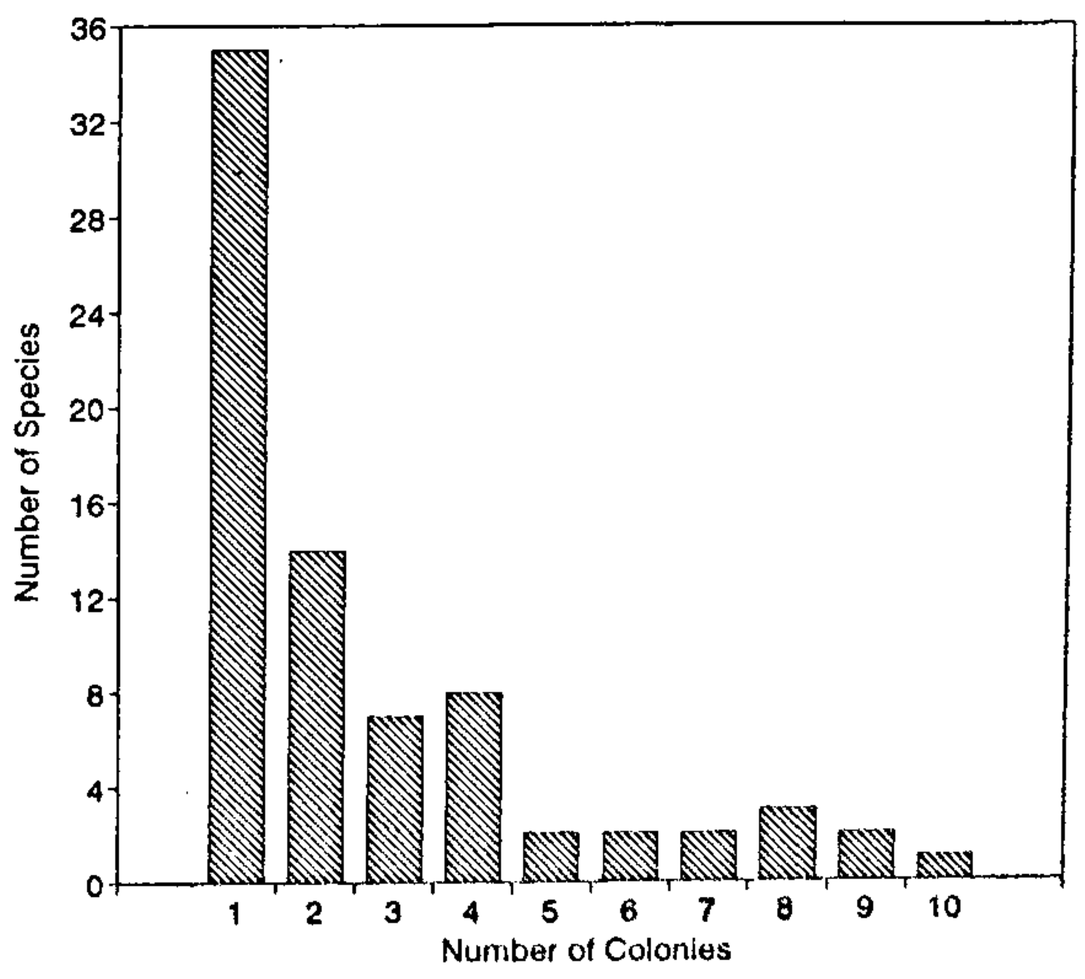

Figure 3. Distribution of relative abundance of 76 species of macrolichens making up a total of 204 colonies over 8000 sq m sampled.

Table 2. Occurrence of macrolichens with respect to 41 microhabitats

Major substrates	Finer divisions of the substrates (Microhabitats)	No. of transects in which present	No. of colonies encountered	No. of species
Rock	Rock	11	48	16
Soil	Humus-rich soil	5	11	7
	Humus-rich soil on rock	2	4	4
	Humus-rich soil on dead wood log of *Rhododendron campanulatum*	1	1	1
	Black soil	2	10	5
	Black soil on rock	5	12	9
	Sandy soil on rock	2	5	5
	Red soil	5	2	2
	Moss bed on black soil on rock	2	8	7
	Moss bed on black soil	2	2	2
Wood	Tree trunk bark of *Abies pindrow*	2	15	14
	Tree trunk bark of *Cedrus deodara*	1	1	1
	Tree trunk bark of *Cupressus torulosa*	1	1	1
	Tree trunk bark of *Pinus wallichiana*	1	5	4
	Tree trunk bark of *Taxus buccata*	1	1	1
	Tree trunk bark of *Betula utilis*	4	7	6
	Tree trunk bark of *Rhododendron campanulatum*	1	2	2
	Standing dead tree trunk bark of *Rhododendron campanulatum*	1	1	1
	Tree trunk bark of *Sorbus foliolosa*	1	1	1
	Lower branches of *Abies pindrow*	2	6	4
	Lower branches of *Cedrus deodara*	1	1	1
	Lower branches of *Pinus wallichiana*	1	6	3
	Lower branches of *Taxus buccata*	1	1	1
	Lower branches of *Betula utilis*	2	6	3
	Lower branches of *Sorbus foliolosa*	3	4	3
	Lower branches of *Rosa macrophylla*	1	1	1
	Fallen dead branch of *Abies pindrow*	1	1	1
	Fallen dead branch of *Cedrus deodara*	1	1	1
	Fallen dead branch of *Cupressus torulosa*	1	2	2
	Fallen dead branch of *Pinus wallichiana*	1	3	2
	Fallen dead branch of *Betula utilis*	3	5	3
	Fallen dead branch of *Sorbus foliolosa*	1	1	1
	Fallen dead branch of *Vibernum cotinifolium*	1	1	1
	Fallen dead branch of *Populus ciliata*	1	1	1
	Fallen dead branch of *Salix lindleyana*	1	1	1
	Dead wood log of *Abies pindrow*	2	14	9
	Dead wood log of *Taxus buccata*	1	3	2
	Dead wood log of *Betula utilis*	2	5	2
	Dead wood of log of *Rhododendron campanulatum*	1	2	2
	Standing dead tree trunk bark of *Cedrus deodara*	1	1	1
	Burnt wood log of *Pinus wallichiana*	1	1	1

considered as broad niched in this context. These include, *Stereocaulon foliolosum*, *Stereocaulon glareosum*, *Cladonia coccifera*, *Phaeophyscia hispidula*, *Cladonia coniocraea*, *Ramalina pollinaria*, *Menegazzia terebrata*, *Ramalina roesleri* and *Cladonia rangiformis*.

Species diversity

Table 2 provides details of the 16 sites in terms of macrohabitat type, altitude, mesohabitats and major substrates. The species richness or α-diversity of these sites was compared through rarefaction[19]. On this basis we can assign significantly high levels of species richness at 1% level to 5 sites, viz. Belta at 2700 m, Dibrughetta at 3400 m, Latakharak at 3600 m and 3700 m and Dhonidhar at 3800 m. Notably enough, four of these species-rich sites harbour all the three major types of substrates.

Species turnover or β-diversity defined as unshared species as a proportion of total species at any two different sites is another component of species diversity[20]. This is equivalent to 1-Jaccard co-efficient of similarity employed in the complete linkage dendrogram[21] of Figure 5. It is evident that turnover increases with altitudinal difference. Although microhabitats and mesohabitat conditions at the lowest altitudinal site were similar with alpine meadows, this site separates out because of a distinctive species composition. This may be attributed to the substantial altitudinal difference coupled to human disturbance and air pollution on the road side. The three transects at the same altitude of 3700 m varied in species composition, presumably because of differences in macrohabitat and mesohabitat conditions (Table 1).

Table 3. Macrolichen species, with abbreviated family name in brackets, of western parts of Nanda Devi Biosphere Reserve, arranged in order of decreasing abundance on the three major substrate types, viz. rock, soil and wood

Species {family}	No. of transects in which present	Altitude (× 100 m range)	Rock (1) No. of colonies	Soil (9) No. of colonies	Soil (9) No. of fine micro-habitats	Wood (31) No. of colonies	Wood (31) No. of fine micro-habitats
Dermatocarpon vellereum Zschacke {Ver}⁻	3	21–40	9				
Umbilicaria indica Frey {Umb}⁻	2	37–38	8				
Rhizoplaca chrysoleuca (Smith) Zopf. {Lec.}	1	45	3				
Ramalina himalayensis Ras. {Ram}	1	38	3				
Parmelia sorediosa Almb. {Par}	1	38	1				
Nephroma spl {Nep}	1	40	1				
Leptogium furfuraceum (Harm.) Seirk {Col}	1	35	1				
Phaeophyscia constipata (Norrlin in Nyl.) Moberg {Phy}	1	35	1				
Xanthoria elagans (Link.) Th. Fr. {Tel}	1	40	1				
Stereocaulon cf. *coniophyllum* Lamb. {Ste}	1	38	1				
Stereocaulon foliolosum Nyl.⁺⁺	5	33–45	7	1	1		
Stereocaulon glareosum (Sav.) *Magnusson* {Ste}⁺⁺	5	37–45	4	3	2		
Cladonia coccifera (L.) Wild {Cla}⁺⁺	3	37–40	1	5	2		
Phaeophyscia hispidula (Ach.) Essl. {Phy}⁺⁺	4	33–38	2	2	2		
Thamnolia vermicularis (Swartz) Ach. {Sip}	4	35–40		8	5		
Cladonia pyxidata (L.) Hoffm. {Cla}	4	33–45		5	4		
Cladonia ramulosa (With.) Laudon {Cla}	4	34–40		4	3		
Cladonia fimbriata (L.) Fr. {Cla}	3	28–37		3	2		
Peltigera venosa (L.) Hoffm. {Pel}	1	35		2	2		
Peltigera polydactyla (Necker) Hoffm. {Pel}	2	25–36		2	2		
Cetraria everniella (Nyl.) Krempelh. {Par}	2	42–45		2	2		
Cladonia furcata (Huds.) Schrader {Cla}	2	37		2	1		
Cetraria islandica (L.) Ach. {Par}	1	45		1	1		
Heterodermia dissecta var. *koyana* Kurok. {Phy}	1	33		1	1		
Cladonia rangiferina (L.) Wigg. {Cla}	1	40		1	1		
Cladonia squamosa (Scop.) Hoffm. {Cla}	1	40		1	1		
Peltigera praetextata (Florke ex Sommerf.) Zopt. {Pel}	1	38		1	1		
Cladonia crispata (Ach.) Flotow {Cla}	1	38		1	1		
Cladonia coniocraea (Florke) Sprengel {Cla}⁺⁺	6	27–37		3	3	7	2
Ramalina pollinaria (Westr.) Ach. {Ram}⁺⁺	2	33–34	3			1	1
Menegazzia terebrata (Hoffm.) Massal. {Par}⁺⁺	2	27–28	2			2	1
Ramalina roesleri (Hochst. in Schaerer) Hue {Ram}⁺	2	27–34		1	1	3	2
Cladonia rangiformis Hoffm. {Cla}⁺⁺	2	27–40		3	1	1	1
Cladonia chlorophaea (Florke) Sprengel {Cla}	2	37–38		1	1	1	1
Heterodermia speciosa (Wulfen) Trevisan {Phy}	2	27–33		1	1	1	1
Usnea longissima Ach. {Usn}	5	27–37				9	5
Ramalina sinensis Jatta {Ram}	4	25–37				7	4
Lobaria retigera (Bory) Trevisan {Lob}	3	27–34				6	4
Parmelia cirrhata Fr. {Par}⁺	3	25–28				5	5
Cetaria laureri Krempelh. {Par}	2	25–27				4	3
Parmelia flaventior Stirton {Par}	3	25–34				4	4
Heterodermia leucomela (L.) Poelt {Phy}	2	25–27				3	2
Parmelia nepalensis Taylor {Par}	3	27–36				3	3
Usnea subfloridana Stirton {Usn}	1	35				3	1
Usnea subsordida Striton {Usn}	1	25				2	1
Pseudocyphellaria intricata (Delise) Vainio {Sti}	2	27–28				2	1
Usnea orientalis Mot. {Usn}	1	25				2	2
Ramalina taitensis Nyl. {Ram}	1	25				2	1
Sticta praetextata (Ras.) Awas. in M. Josh & Awasthi {Sti}	2	28–34				2	2
Parmelia praesorediosa Nyl. {Par}	2	34–36				2	2
Cetraria pallescens Schaerer in Moritzi {Par}	2	25–36				2	2
Ramalina spl of G. Pant {Ram}	2	25–27				2	2
Parmelia mussooriensis Awasthi {Par}	1	27				1	1
Lobaria isidiosa (Miill. Arg.) Vainio {Lob}	1	37				1	1
Sticta nylanderiana Zahibr. {Sti}	1	34				1	1
Cetraria pinastri (Scop.) Gray {Par}	1	37				1	1
Peltigera spl {Pel}	1	27				1	1
Parmelia infumata Nyl. {Par}	1	28				1	1
Heterodermia diademata (Taylor) Awasthi {Phy}	1	27				1	1
Parmelia exasperatula Nyl. {Par}	1	27				1	1
Cetrelia braunsiana (Miill Arg.) Culb. & Culb. {Par}	1	27				1	1
Parmelia xantholepis Mont & Bosch in Jungh. {Par}	1	34				1	1
Parmelia crenata Kurok. in Hale & Kurok. {Par}	1	34				1	1

Table 3. (*Contd*)

Species (family)	No. of transects in which present	Altitude (× 100 m range)	Rock (1) No. of colonies	Soil (9)		Wood (31)	
				No. of colonies	No. of fine micro-habitats	No. of colonies	No. of fine micro-habitats
Cladonia submultiformis Asah. {Cla}	1	36				1	1
Cladonia cornuta (L.) Hoffm. {Cla}	1	37				1	1
Usnea baileyi (Stirton) Zahlbr. {Usn}	1	34				1	1
Parmelia austrosinensis Zahlbr. {Par}	1	37				1	1
Lobaria pseudopulmonaria Gyelnik {Lob}	1	37				1	1
Evernia mesomorpha Nyl. {Usn}	1	27				1	1
Usnea sp1 {Usn}	1	35				1	1
Cetrelia olivetorum (Nyl.) Culb. & Culb. {Par}	1	34				1	1
Heterodermia isidiophora (Vainio) Awasthi {Phy}	1	34				1	1
Candelaria concolor (Dicks) B. Stein {Can}	1	37				1	1
Usnea sp2 {Usn}	1	25				1	1
Usnea rubicunda Stirton {Usn}	1	27				1	1
Hypogymnia vittata (Ach.) Parr. {Hyp}	1	37				1	1

'+' indicates significantly broad and '–' indicates narrow niche with respect to fine microhabitat preference.
'++' indicates broad niched with respect to their occurrence on the major substrates.
Full names of families: {Can}, Candelariaceae; {Cla}, Cladoniaceae; {Col}, Collemataceae; {Hyp}, Hypogymniaceae; {Lec}, Lecanoraceae; {Lob}, Lobariaceae; {Nep}, Nephromataceae; {Par}, Parmeliaceae; {Pel}, Peltigeraceae; {Phy}, Physciaceae; {Ram}, Ramalinaceae; {Sip}, Siphulaceae; {Ste}, Steriocaulaceae; {Sti}, Stictaceae; {Tel}, Teloschistaceae; {Umb}, Umbilicariaceae; {Usn}, Usneaceae; {Ver}, Verrucariaceae.

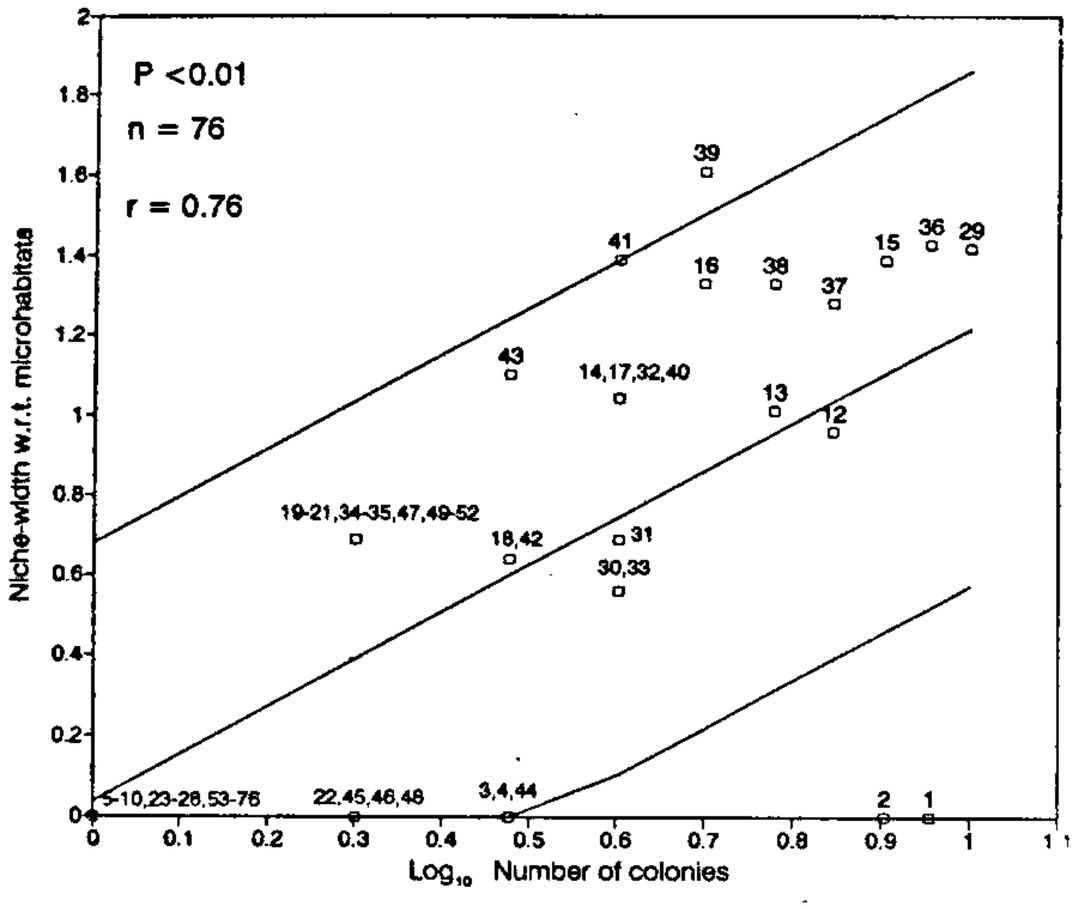

Figure 4. Relationship between the number of colonies encountered and the niche-width of the species with respect to microhabitat usage. The graph also shows the fitted regression line and lines representing confidence intervals at $P < 0.01$. The numbers correspond to the order in which species are listed in Table 3, indicating that *Parmelia cirrhata* has significantly broaden niche and *Umbilicaria indica* and *Dermatocarpon vellereum* have significantly narrow niche-width.

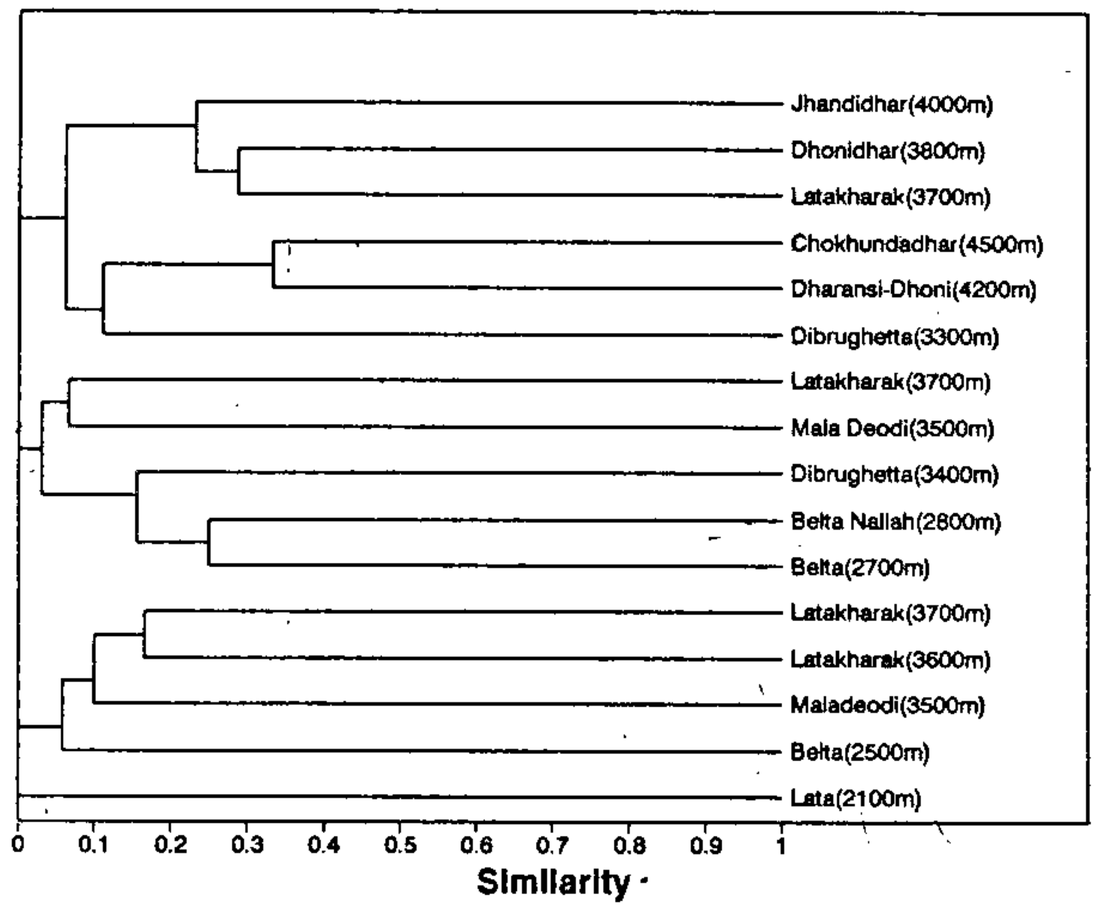

Figure 5. Complete linkage dendrogram of 16 sites based on Jaccard's co-efficient of similarity with respect to composition of species.

Niche-overlap

Niche-overlap with respect to microhabitat usage was computed based on Pianka's measure of niche-overlap[22]. Figure 6 based on complete linkage analysis[21] depicts the clustering of 20 species occurring in four or more colonies with respect to their preference for the 41 microhabitats. The species tend to cluster with respect to the major substrates which are evidently critical in determining the distribution of macrolichen species.

Microhabitat preference

Although woody microhabitats were restricted to 10 out of 16 transects, a majority of the species were found to be favouring wood. Figure 7 is a Venn diagram of microhabitat preference of 20 more abundant as well as 76 total species. These bring out the importance of woody microhabitats in promoting lichen species diver-

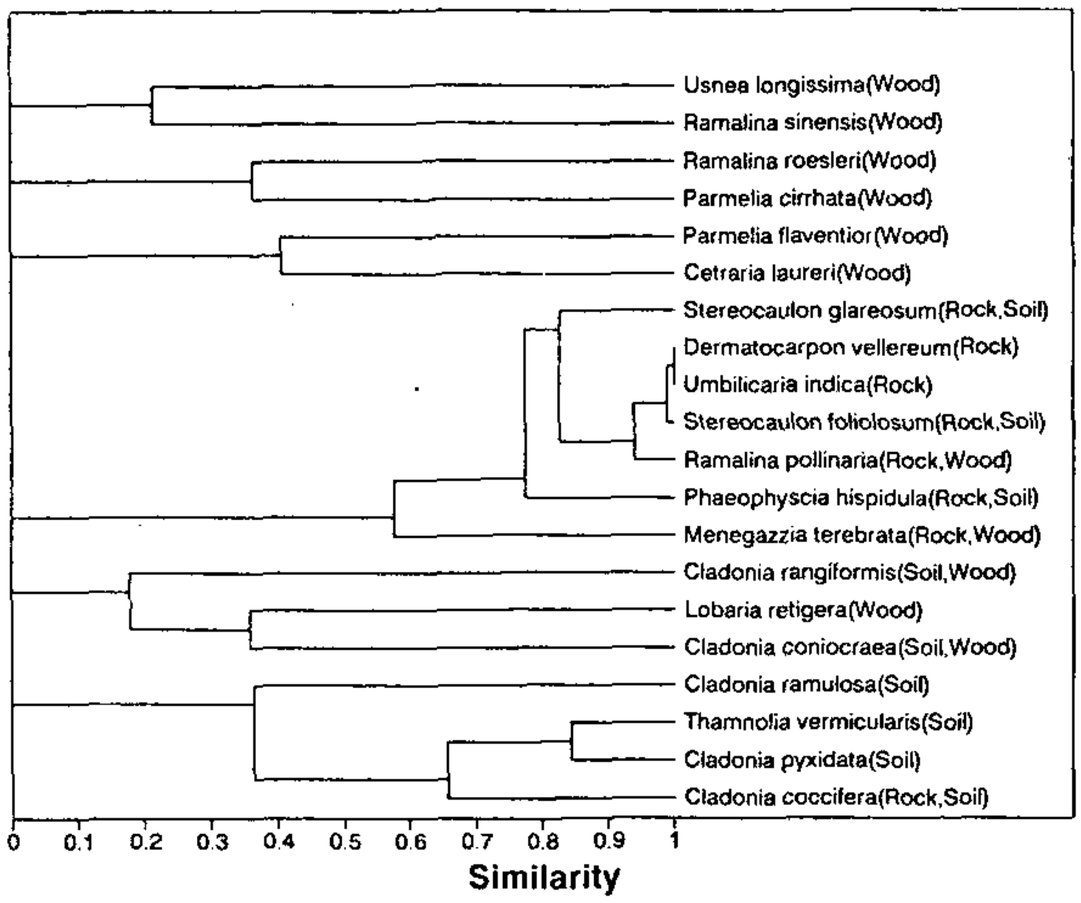

Figure 6. Complete linkage dendrogram for 20 species occurring in 4 or more colonies based on Pianka's measure of niche-overlap with respect to microhabitat usage.

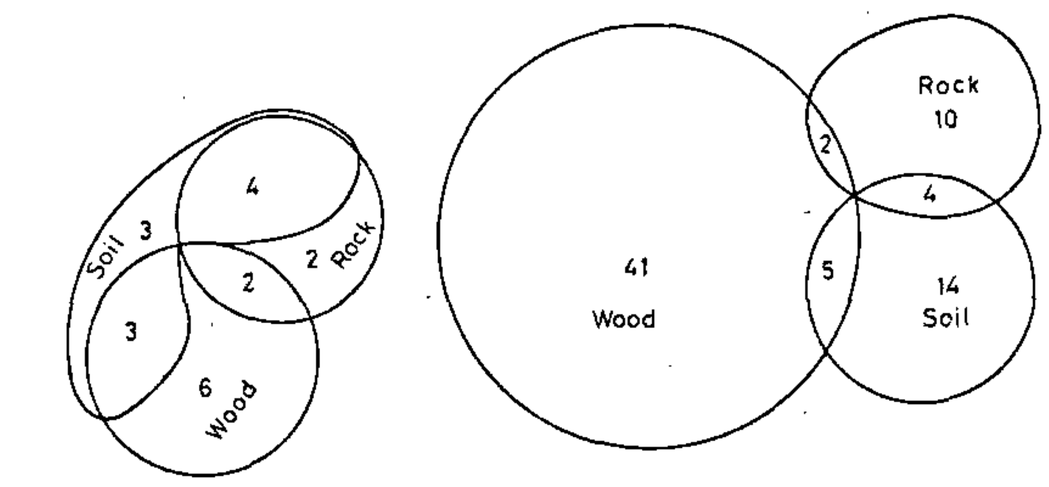

Figure 7. Venn diagram of distribution of a total 76 and of 20 more abundant macrolichen species on the three major substrates.

sity. However there are a number of species confined to soil and rocks as well.

Conservation implications

Deforestation, excessive fuelwood collection and fire[23], all adversely affecting wood loving species of lichens appear to be major threats to the rich macrolichen flora of the Himalayas. Although firm evidence is lacking, it is also possible that the ban on summer grazing in the alpine meadows of NDBR may be adversely affecting macrolichen diversity, since this cessation of grazing has led to spread of weedy species like *Rumex nepalensis* and *Phlomis bracteata* and shrinkage of soil microhabitats of the lichens. The rich macrolichen flora of Himalayas could play an important economic role as well. Species of *Ramalina*, *Parmelia*, *Usnea* and *Evernia* are a source of essential oils widely used in health care and perfumery industry[7]. Lichen thalli, a rich source of nitrogen[24], has promise as a source of organic manure, although today it is being wasted along with fire wood.

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