

Full Length Research Paper

Enumeration of lichen diversity in Manaslu Conservation Area and Sagarmatha National Park of Nepal

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An extensive research on deciphering lichen diversity in the high Nepalese Himalaya was undertaken in two subsequent years in Manaslu Conservation Area (MCA) and Sagarmatha National Park (SNP). Altogether, 621 specimens were collected from these two regions, viz., 173 from MCA and 448 from SNP, which resulted in the occurrence of a total of 13 species of lichens from MCA (belonging to 4 families) and 69 species belonging to 15 different families from SNP. Among the lichen families reported from these two study sites, family Parmeliaceae (7 and 29 species from MCA and SNP, respectively) was the dominant one followed by Physciaceae (12 species from SNP) and Cladoniaceae (4 and 8 from MCA and SNP, respectively). Thus, this research work, to some extent, reveals the lichens enrichment in the study region, furnishing much new insights that can be used as a composite signal of environmental quality and future bio-monitoring studies.

Key words: Bio-indicators, endemism, geographical gradients, speciation.

INTRODUCTION

Lichens, frequently called 'Jhyau' or 'Tare' in Nepal are classified as a cluster of lower life-form of fungi (dual organisms assumed as a single one) and are formed by an intricate and mutualistic combination of both fungal (mycobiont) and algal (phycobiont/cyanobiont) partners (Sharma, 1995; Shah, 2014). Approximately, about 771 species belonging to 167 genera are known to Nepal as of now, of which more than 50 species are endemic (Baniya et al., 2010). However, current estimation of over 2,000 lichen species belonging to Nepal has now been made (Bhujju et al., 2007), but, lack of adequate knowledge

continues to keep them undocumented. Though, the Nepalese Himalaya possess enormous pristine glories enriched with higher diversity and a very wide range of eco-climatic zones (Dobremez, 1976), most of its regions remained still unexplored. As it is well known that scientific discourse on ecological and biogeographical patterns and theories of species richness may prove an excellent system in bio-monitoring (Körner, 2002), this contemporary study was designed to abridge the existing gap in understanding and elucidating the diversity of lichens in Nepal.

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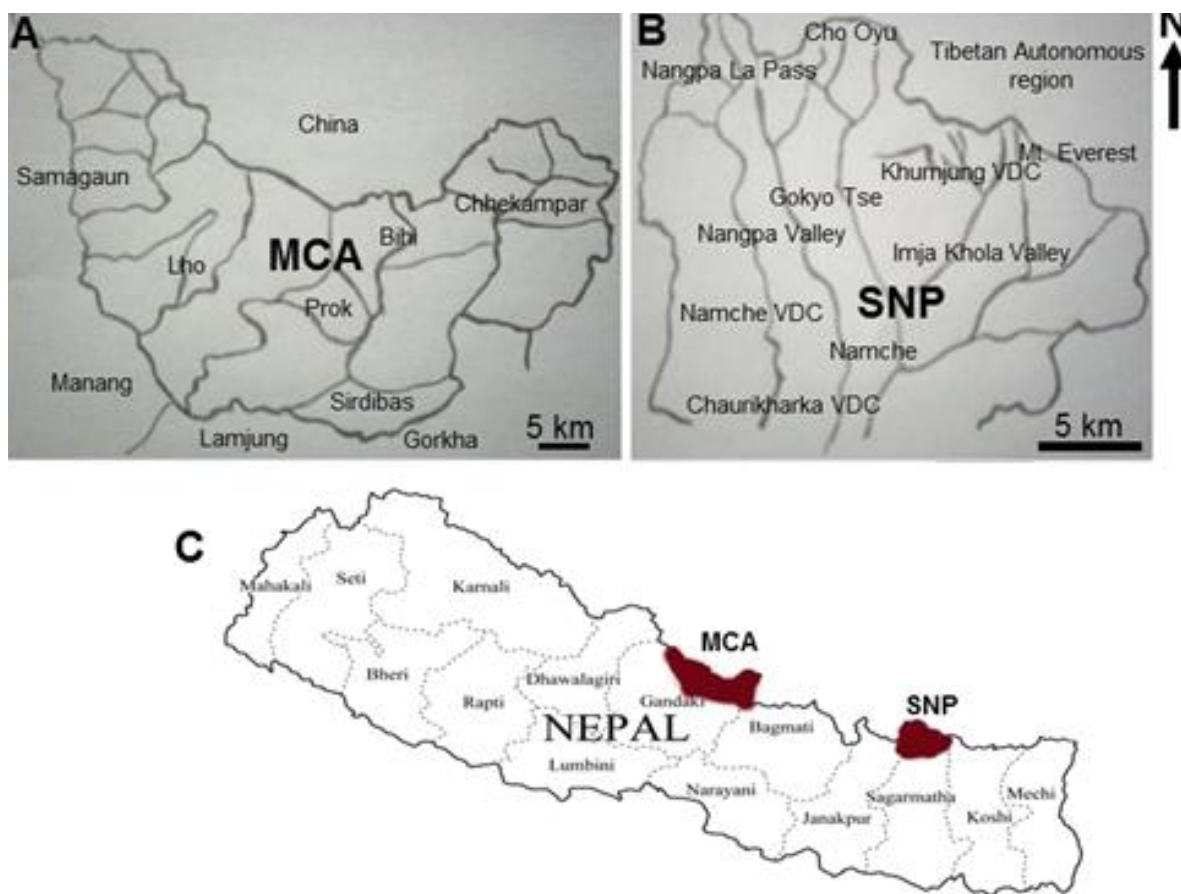


Figure 1. Pictures depicting the sampling area. A. Manaslu Conservation Area, B. Sagarmatha National Park, C. Map of Nepal.

MATERIALS AND METHODS

Topography of the sampling areas

The Manaslu Conservation Area (MCA) lying on the lap of Manaslu Himalaya (Figure 1A), is spread in an area of 1,663 km² and has an elevation gradient ranging from 1,400-8,163 m asl. It is bordered by Tibet autonomous region of China to the north and east, while Manang district to the west and Gorkha district to the south. The Sagarmatha National Park (Figure 1B) stretched in an area of 1,148 km² lies in the Solukhumbu district and has an elevation gradient ranging from 2,845-8,848 m asl. The dominant tree vegetation in both the study area comprises of species of *Rhododendron*, *Betula*, *Quercus* and *Juniperus*.

Lichen sampling

The field trips were executed during 2010 (September-October) in Manaslu Conservation Area (MCA; coordinates Table 1), and in 2012 (April-May) in Sagarmatha National Park (SNP; Mount Everest Region; coordinates Table 2). Lichens growing on different substrata were sampled at an elevation above 2,350 m asl. With the special focus made on higher elevations, the sampling of

lichens below 2,300 m asl was not incorporated in the present study. All species of lichens found in the sampling areas were harvested and species that tightly adhered to bark or soil were uprooted with the help of iron scalpels. Immediately after collection, samples were cleansed to eliminate the bark residues and other extraneous materials for their proper identification, followed by storage in air tight zip-lock plastic bags. All specimens were shade dried and the herbaria prepared according to method devised by Nash et al. (1993), was lodged in Nepal Academy of Science and Technology (NAST). All specimens collected were also coded with the British Lichen Society recording code numbers (Coppins, 2002).

The lichen cohort richness patterns in the studied areas were performed at different altitudinal ranges. Random-samplings were performed according to the availability of the lichens and the lichens found were harvested and the geographical co-ordinates and substratum were recorded. The specimens were identified through examination of their morphology, anatomy and habitation as per published floras (Awasthi, 2007).

RESULTS AND DISCUSSION

The two studied areas (Figure 1) possess an ample

Table 1. Diversity of lichens in MCA.

Family	Latin name	Substratum	Co-ordinates		Elevation (m asl)
			Latitude	Longitude	
Parmeliaceae	<i>Hypogymnia physodes</i> (L.) Nyl.	<i>Rhododendron</i> sp.	27°39'15.7" N	85°18'43.4" E	2,859
	<i>Everniastrum nepalense</i> (Taylor) Hale ex Sipman	<i>Malus domestica</i>	27°39'15.7" N	85°18'43.4" E	2,353
	<i>Parmotrema reticulatum</i> (Taylor) M. Choisy	<i>R. campanulatum</i>	27°39'15.7" N	85°18'43.4" E	2,727
	<i>Usnea aciculifera</i> Vain.	<i>Quercus</i> sp.	27°39'15.7" N	85°18'43.4" E	3,115
	<i>Usnea arizonica</i> Mot.	<i>Rhododendron</i> sp.	27°39'15.7" N	85°18'43.4" E	2,829
	<i>Usnea longissima</i> Ach.	<i>Quercus</i> sp.	27°39'15.7" N	85°18'43.4" E	3,079
	<i>Usnea rubicunda</i> Stirt.	<i>R. campanulatum</i>	27°39'15.7" N	85°18'43.4" E	2,927
	Cladoniaceae	<i>Cladonia cristatella</i> Tuck.	<i>Quercus</i> sp.	27°39'15.7" N	85°18'43.4" E
<i>Cladonia cariosa</i> var. <i>cariosa</i> (Ach.) Spreng.		Usually on rocks but sometimes on the trees bark	27°39'15.7" N	85°18'43.4" E	3,115
<i>Cladonia chlorophaea</i> (Flörke ex Sommerf.) Spreng.		<i>R. campanulatum</i>	27°39'15.7" N	85°18'43.4" E	2,833
<i>Cladonia ramulosa</i> (With.) Laundon		Rocks along with mosses	27°39'15.7" N	85°18'43.4" E	2,829
Coccocarpiaceae	<i>Coccocarpia</i> sp.	<i>Malus domestica</i>	27°39'15.7" N	85°18'43.4" E	2,727
Lobariaceae	<i>Lobaria pindarensis</i> Räsänen	Rocks along with mosses	27°39'15.7" N	85°18'43.4" E	2,829

amount of lichens diversity, which are summarized in Tables 1 and 2. Through this discourse, we traced a total of 621 lichens specimen from the studied areas, viz., 173 from MCA and 448 from SNP. Altogether, 13 species of lichens from MCA (lying on 4 families) and 69 different species lying on 15 different families from SNP were identified, among which family Parmeliaceae (7 and 29 species from MCA and SNP, respectively) was largest followed by Physciaceae (12 species from SNP) and Cladoniaceae (4 and 8 from MCA and SNP, respectively) (Figure 2). From the study, the high altitudinal lichens located on the studied areas were *Leptogium indicum* (3,900 m asl) and *Cladonia coniocraea* (3,803 m asl). Lichens enrichment was found to be maximum in the range of 2,800 m asl in MCA, while the species richness were found to be maximum at an elevation of 2,700 m asl in SNP.

Most of the lichen species traced in the present study have previously been reported from the adjacent regions, such as India, Pakistan and Bhutan (Kumar et al., 2011) and also other parts of Nepal (Baniya et al., 2010). Thirty-three percentage of the total lichens reported in the present study were found above the tree line (> 4,300 m asl) of which 53% were endemic. This number seems to be enormous which suggests that the environmental conditions are quite favorable for the luxuriant growth of lichens and the topography and varied altitude somehow

contribute towards rich lichen diversity and endemism in the study sites. But, it would be too early to predict that the results of the present study are somewhat similar to that of Baniya et al. (2010) who traced altogether 525 species of Nepalese lichen distributed between elevations of 200-7,400 m asl and documented 55 species endemic to Nepal, because, in the present study, lichens sampling was done up to the elevation of 4,200 m asl. The members of the *Parmelioid* clade belonging to lichen family Parmeliaceae were dominant in the study sites and are followed by the *Usneoid* clade of the same family. This study corresponds to the findings of Thell et al. (2012) who mentions that the Parmeliaceae is the largest family across the globe and till date includes 79 genera and ca. 2,726 spp. belonging to 5-main clades, viz., *Parmelioid*, *Cetrarioid*, *Usneoid*, *Alectorioid* and *Hypogymnioid*.

At high elevation, lichens of either in foliose or fruticose forms are found and they exhibit maximum species diversity value (Sipman, 1989), while crustose forms of lichens prevail greatly in lower altitude. The ubiquitous lichen species tend to establish and colonize early on every microhabitat occupying a larger chunk of area (Rose and Wolseley, 1984). The diversity of the epiphytic lichens may vary with tree species, age of the tree, bark pH and tree health status (Herk, 2001; Hauck and Runge, 2002; Nascimbene et al., 2013). However, actual

Table 2. Diversity of lichens in SNP.

Family	Latin name	Substratum	Locality	Co-ordinates		Elevation (m asl)
				Latitude	Longitude	
Collemaaceae	<i>Leptogium trichophorum</i> Müll. Arg.	Rock	Chhuthawa	27°44'32.6" N	86°42'47.8" E	2,672
	<i>Leptogium delavayi</i> Hue	<i>R. campylocarpum</i> and other trees	Phakding	27°45'20.4" N	86°42'37.1" E	2,729
	<i>Leptogium adpressum</i> Nyl.	Trees bark	Chhuthawa	27°44'05.8" N	86°42'43.6" E	2,566
	<i>Leptogium indicum</i> D.D. Awasthi & Akhatar	<i>Rhododendron</i> sp.	Near Khunde	27°48'56.4" N	86°42'36.6" E	3,900
	<i>Leptogium lacerum</i> (Sw.) Gray	<i>Malus</i> sp.	Ghat	27°43'59.8" N	86°42'46.3" E	2,750
Cladoniaceae	<i>Cladonia cariosa</i> var. <i>cariosa</i> (Ach.) Spreng.	Usually in rocks, but sometimes on the trees bark	Kyanjuma	27°48'58.3" N	86°43'50.6" E	3,583
	<i>Cladonia chlorophaea</i> (Flörke ex Sommerf.) Spreng.	Rocks	Near Larza	27°47'09.7" N	86°43'17" E	2,860
	<i>Cladonia portentosa</i> (Dufour) Coem.	<i>Quercus</i> sp.	Jorsalle	27°46'50.4" N	86°43'19" E	2,994
	<i>Cladonia coniocraea</i> (Flörke) Spreng.	On roots of woods and tree bases, rarely on bare soil	Syanboche	27°48'45.2" N	86°42'38.9" E	3,803
	<i>Cladonia cristatella</i> Tuck.	<i>Malus</i> sp., <i>Rhododendron</i> sp.	Larza bridge	27°47'24" N	86°43'03.8" E	2,910
	<i>Cladonia ramulosa</i> (With.) J.R. Laundon	Rocks along with mosses	Phakding	27°45'20.4" N	86°42'37.1" E	2,728
	<i>Cladonia rangiferina</i> (L.) Weber ex F.H. Wigg.	<i>Rhododendron</i> sp.	Toktok	27°45'21.3" N	86°42'36.3" E	2,710
	<i>Cladonia rangiformis</i> Hoffm.	Rocks	Jorsalle	27°46'28.7" N	86°43'19" E	2,812
	<i>Anzia colpodes</i> (Ach.) Stizenb.	Trees bark	Toktok	27°45'20.4" N	86°42'37.1" E	2,729
	<i>Bulbothrix</i> sp.	Trees bark	Near Phakding	27°44'05.8" N	86°42'46.6" E	2,566
Parmeliaceae	<i>Canoparmelia texana</i> (Tuck.) Elix & Hale	Rocks and barely on barks	Chhuthawa	27°44'56.2" N	86°42'44.6" E	2,687
	<i>Cetraria</i> sp.	Rocks	Syanboche to Khunde	27°48'57" N	86°42'36" E	3,850
	<i>Everniastrum nepalense</i> (Taylor) Hale ex Shipman	<i>R. arboretum</i> and other trees	Kyanjuma	27°48'58.3" N	86°43'50.6" E	3,583
	<i>Flavoparmelia caperata</i> (L.) Hale	Trees bark	Ghat	27°42'49.7" N	86°42'50.9" E	2,614
	<i>Flavoparmelia soledians</i> (Nyl.) Hale	Rocks	Larza bridge	27°47'22.9" N	86°43'07.1" E	3,123
	<i>Hypogymnia</i> sp.	Trees bark	Phakding	27°44'05.8" N	86°42'46.6" E	2,566
	<i>Parmelaria thomsonii</i> (Stirt.) D.D. Awasthi.	<i>Malus domestica</i>	Manjo	27°46'10.9" N	86°43'25.7" E	2,810
	<i>Parmelia nepalensis</i> Taylor	Trees bark	Manjo	27°44'03.5" N	86°42'42.6" E	2,860
	<i>Parmelia nilgherrensis</i> Nyl.	<i>Quercus</i> sp.	Mislung	27°47'56.8" N	86°42'47.4" E	3,340
	<i>Parmelia reticulata</i> Taylor	Trees bark	Khunde	27°49'09.6" N	86°42'29.2" E	4,110

Table 2. Contd.

Family	Latin name	Substratum	Locality	Co-ordinates		Elevation (m asl)
				Latitude	Longitude	
Parmeliaceae	<i>Parmelia sancti-angelii</i> Lynge	Trees bark	Namche	27°48'45.1" N	86°42'38.7" E	3,450
	<i>Parmelia squarrosa</i> Hale	Tree barks	Larza bridge	27°47'22.9" N	86°43'07.1" E	3,123
	<i>Parmelia stuppea</i> Taylor	Trees bark	Chhuthawa	27°43'44.5" N	86°42'48.3" E	2,600
	<i>Parmelia sulcata</i> Taylor	Trees bark	Thamu	27°49'16.1" N	86°40'52.4" E	3,450
	<i>Parmelia wallichiana</i> Taylor	<i>Malus domestica</i>	These	27°48'54.5" N	86°41'11" E	3,480
	<i>Parmotrema</i> sp.	Trees bark	Benkar	27°45'41.6" N	86°42'45.7" E	2,757
	<i>Parmotrema tinctorum</i> (Delise ex Nyl.) Hale	Trees bark	Phurte	27°48'45.8" N	86°41'31.1" E	3,400
	<i>Pseudevernia furfuracea</i> (L.) Zopf	Trees bark	Jorsalle	27°46'50.4" N	86°43'19" E	2,993
	<i>Punctelia borrieri</i> (Sm.) Krog	Trees Bark	Phakding	27°45'55.7" N	86°43'23.3" E	2,809
	<i>Punctelia subrudecta</i> (Nyl.) Krog	Tree bark	Manjo	27°46'10.9" N	86°43'25.7" E	2,810
	<i>Usnea aciculifera</i> Vain.	<i>Quercus</i> sp.	Toktok	27°45'20.4" N	86°42'37.1" E	2,729
	<i>Usnea longissima</i> Ach.	Trees bark	Phakding	27°44'05.8" N	86°42'46.6" E	2,566
	<i>Usnea orientalis</i> Motyka	Trees and sometimes on rocks	Chhuthawa	27°44'56.2" N	86°42'44.6" E	2,687
	<i>Usnea rubicunda</i> Stirt.	Trees bark	Benkar	27°45'41.6" N	86°42'45.7" E	2,757
	<i>Usnea</i> sp.	Trees bark	Manjo	27°46'10.9" N	86°43'25.7" E	2,810
	<i>Usnea trichodeoides</i> Motyka	<i>Betula</i> sp.	Mislung	27°47'52" N	86°42'41.5" E	3,477
	<i>Xanthoparmelia stenophylla</i> (Ach.) Ahti & D. Hawksw	Tree barks and rocks	Benkar	27°45'41.6" N	86°42'45.7" E	2,757
Gyalectaceae	<i>Pachyphiale himalayensis</i> Vezda & Poelt	<i>Malus domestica</i>	Kyanjuma	27°48'58.3" N	86°43'50.6" E	3,583
Caliciaceae	<i>Dirinaria confluens</i> (Fr.) D.D. Awasthi	Trees bark	Kyanjuma	27°48'58.3" N	86°43'50.6" E	3,583
Coccocarpiaceae	<i>Coccocarpia</i> sp.	<i>Malus</i> sp.	Ghat	27°42'49.7" N	86°42'50.9" E	2,613
Lecanoraceae	<i>Lecanora himalayae</i> Poelt	<i>Malus domestica</i>	Toktok	27°45'06.4" N	86°42'37.4" E	2,743
Graphidaceae	<i>Phaeographina nepalensis</i> D.D. Awasthi & Kam. P. Singh	Moist soil and rocks	Phakding	27°45'20.4" N	86°42'37.1" E	2,728

mapping of lichens render difficulties at times. More often, the seemingly chaotic mingling of lichen species provides falsification to their actual identification and classification. Moreover, the implication of the molecular tools for their actual identification at the genomic level is needed, which decreases the falsified misinterpretations

regarding the taxonomic classification. Thus, on such prevailing scenario, scarce ongoing effort to document the lichen population in Nepal is below the threshold, and hence species identification via molecular studies may prove to be an effective milestone to know more about this charismatic group of organism in Himalayan

Table 2. Contd.

Family	Latin name	Substratum	Locality	Co-ordinates		Elevation (m asl)
				Latitude	Longitude	
Physciaceae	<i>Heterodermia corallophora</i> (Taylor) Skorepa	Trees barks	Toktok	27°45'21.3" N	86°42'36.3" E	2,710
	<i>Heterodermia diademata</i> (Taylor) D.D. Awasthi	Trees bark	Chhuthawa	27°43' 44.5" N	86°42'48.3" E	2,600
	<i>Heterodermia dissecta</i> (Kurok.) D.D. Awasthi	Several trees	Phakding	27°45'55.7" N	86°43'23.3" E	2,809
	<i>Heterodermia incana</i> (Stirt.) D.D. Awasthi	Trees barks	Chhuthawa	27°44'25.8" N	86°42'43.6" E	2,566
	<i>Heterodermia leucomela</i> (L.) Poelt	Trees bark	Chhuthawa	27°44'05.8" N	86°42'43.6" E	2,567
	<i>Heterodermia pseudospeciosa</i> (Kurok) W. Culb.	Rocks	Benkar	27°45'41.6" N	86°42'45.7" E	2,757
	<i>Heterodermia punctifera</i> (Kurok.) D.D. Awasthi	<i>R. arboretum</i> and on rocks along with mosses	Jorsalle	27°46'28.7" N	86°43'19" E	2,812
	<i>Heterodermia</i> sp.	Barks and sometimes on rocks	Chhuthawa	27°44'25.8" N	86°42'43.6" E	2,566
	<i>Heterodermia upretti</i>	Rocks and barks of several trees	Jorsalle	27°46'46.6" N	86°43'17.8" E	3,111
	<i>Phaeophyscia hispidula</i> (Ach.) Essl.	<i>Rhododendron</i> sp.	Mislung	27°47'56.8" N	86°42'47.4" E	3,340
Ramalinaceae	<i>Physcia caesia</i> (Hoffm.) Fűrnr.	Trees bark	Phakding	27°44'56.2" N	86°42'44.6" E	2,688
	<i>Physconia enteroxantha</i> (Nyl.) Poelt	Tree barks and on rocks	Phakding	27°44'05.8" N	86°42'46.6" E	2,566
	<i>Ramalina fraxinea</i> (L.) Ach.	Trees bark	Mislung	27°47'52" N	86°42'41.5" E	3,477
	<i>Ramalina sinensis</i> Jatta	<i>Betula</i> sp.	Jorsalle	27°46'50.4" N	86°43'19" E	2,993
Peltigeraceae	<i>Ramalina</i> sp.	Trees bark	Ghat	27°42'49.7" N	86°42'50.9" E	2,614
	<i>Ramalina usnea</i> (L.) R.H. Howe	Rocks along with some mosses	Syanboche	27°48'45.2" N	86°42'38.9" E	3,803
Stereocaulaceae	<i>Peltigera polydactyla</i> (Neck.) Hoffm.	Rocks, barks and rarely on soil	Toktok	27°45'06.4" N	86°42'37.4" E	2,741
Chrysothricaceae	<i>Stereocaulon coniophyllum</i> Lamb	Rocks and soil	Larza bridge	27°47'22.9" N	86°43'07.1" E	3,123
Lecideaceae	<i>Chrysothrix chlorina</i> (Ach.) J.R. Laundon	Rocks and soil	Jorsalle	27°46'46.6" N	86°43'17.8" E	3,111
Lobariaceae	<i>Lecidea khumbuensis</i> Hertel	<i>R. hogsonii</i>	Manjo	27°47'11.3" N	86°43'13.2" E	2,960
Lobariaceae	<i>Lobaria amplissima</i> (Scop.) Forssell	On overhangs of siliceous rocks	Toktok	27°45'06.4" N	86°42'37.4" E	2,741
	<i>Lobaria pindarensis</i> Räsänen	<i>R. hogsonii</i>	Manjo	27°47'11.3" N	86°43'13.2" E	2,960

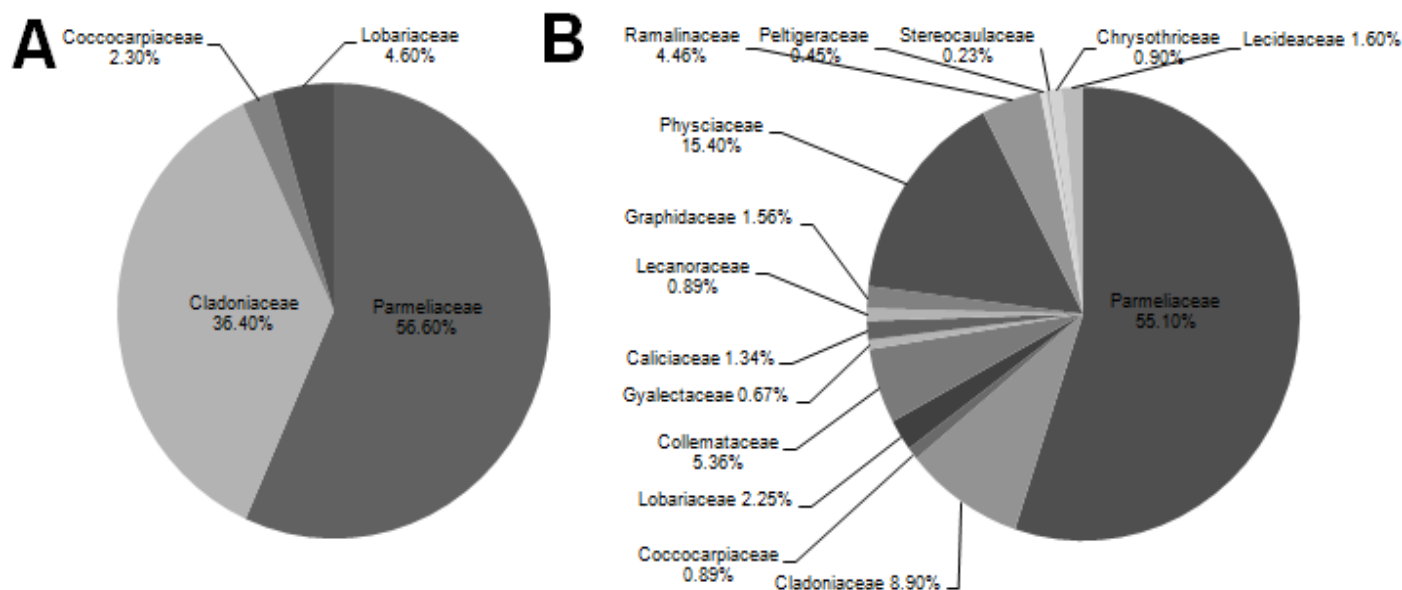


Figure 2. Frequency distribution of the lichen families in the studied areas, A. Lichens found in MCA, B. Lichens found in SNP.

ecozone.

Conclusion

The Nepalese Himalayas still harbors clusters of lichens that are not well-identified, so this study furnishes a preliminary finding about the diversity of lichens in some new localities of Nepal which may somehow be helpful in developing a general framework on the exploration of lichens in other regions of Nepal, and also to conduct future bio-monitoring studies by utilizing this baseline data.

Conflict of interests

The author declares there is no conflict of interest whatsoever.

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