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Primary Investigation of Lichenized Fungi in and around High-altitude Sacred Wetland Hemkund in Western Himalaya

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ABSTRACT

The present study deciphers the lichen diversity in and around the high-altitude sacred wetland Hemkund in Uttarakhand. The study revealed an occurrence of 90 species of lichens belonging to 45 genera and 18 families. Among the different lichen families of the Hemkund region, Parmeliaceae with 18 species belonging to 13 genera is the dominant, followed by Cladoniaceae with 17 species belonging to 3 genera and Peltigeraceae with 15 species belonging to 4 genera. Among the different growth forms of lichens; foliose comprises the highest number of 49 species, followed by 16 dimorphic lichens taxa. The area exhibits maximum number of rock and soil inhabiting lichens with 39 and 19 spp. Thus, this study reveals the lichens richness in the region providing new insights that can be used as a cumulative indicator of environmental quality, conservation measures and future bio-monitoring studies.

INTRODUCTION

High Altitude Wetlands are extreme ecosystems consisting of water bodies like lakes, ponds and rivers, found at higher altitudes more than 3,000 m. These wetlands are often fed by glaciers or snow from the surrounding mountains and are characterized by adverse climate (ISRO 2012; Chatterjee et al. 2010). Uttarakhand has 118 high-altitude lakes (HAL) and Hemkund is one of them. Hemkund (Snow Lake) is fed by the Hathi Parvat and Sapt Rishi glaciers situated in the Garhwal Himalaya. A small stream called Himganga flows out of this lake. The lake is about 2 km in fringe and its clear, standstill water reflects images of the peaks. Close to the lake is a Gurudwara (Hemkund Sahib) and Laxman temple, which are pilgrimage centre for Sikhs and Hindus from all over the world. The Hemkund Sahib is popular as the highest Gurudwara in the world and is surrounded by a surrealistic landscape made up mostly of rock, ice and devoid of animal or human inhabitation. Hemkund is one of the toughest and steepest terrains, comprises of several treacherous treks. The Abies, dwarf Rhododendron bushes and herbaceous elements such as *Primula, Leontopodium, Meconopsis, Corydalis, Pleurospermum, Saussurea* (Brahma kamal) and *Senecio* with deep roots, cushioned leaves and attractive flowers are common vegetation among the Hemkund.

The cryptogam species can be found in all areas of the world and plays a significant role in an ecosystem (Slack 1988; Berglund and Jonsson 2001; Gignac 2001). The wetland has a highly heterogeneous landscape, ranging from low-lying flats and gentle to steep slopes, unstable glacial moraines, stream banks, forest-meadow edges and snow-bound areas. The Himalayas high altitudinal zone exhibits a great variation in topography, precipitation, floristics, physiognomy of vegetation and palaeohistory (Tambe and Rawat 2011). The area's climate is moist alpine type with short cool summers and long severe winters and inaccessible most of the year. The alpine regions are considered as one of the most distressing environmental settings for various organisms, however, lichens are known to be among the dominating organisms surviving in these habitats (Boustie et al. 2011). The absence of large trees reduces vegetative competition in wetland areas, which allows lichens to grow on all available substrates. Several lichen floristic studies have been carried out in the Garhwal Himalayan region by the various workers (Upreti and Negi 1995; Negi and Gadgil 1996; Joshi et al. 2007; Upreti and Joshi 2010; Rai et al. 2010; Rawat et al. 2010, 2014). However, Hemkund is hitherto not explored so far. Therefore, an effort has been made for the first time to explore the lichen diversity in and around high-altitude wetland Hemkund area.

MATERIALS AND METHODS

The study was carried out in high altitude sacred wetland area of Hemkund of Western Himalaya, situated in Chamoli district, Uttarakhand (Fig. 1 & 2). More than 150 specimens of lichens were collected in June 2017 from the different available substrates like soil, rock, bark, twigs etc. The area belongs to the alpine region and the altitude ranges from 3200-4400 m. The specimens were identified based on their morphology, anatomy and chemistry. The morphology and anatomy of the lichen specimens were examined by using a NIKON SMZ 1500 and a NIKON ECLIPSE 80i microscope. The chemistry of all the specimens were performed by both colour spot tests (K, C, KC and Pd) followed by thin layer chromatographic (TLC) methods (Culberson and Kristinsson, 1972; Elix, 2014).

The identified characteristics were confirmed with the help of the literature of Awasthi (1991, 2007), Divakar and Upreti (2005). The systematic arrangement follows the latest classification system (Wijayawardene et al. 2010). The specimens are deposited in the herbarium of Ajrekar Mycological Herbarium (AMH) of Agharkar Research Institute, Pune.

Results and discussion

The high-altitude lakes apart from their ecological significance play crucial role in biodiversity, wildlife habitat and socio-economic aspects (ISRO 2011). The lichens embrace a very significant part of cryptogrammic vegetation in alpine habitats of the Himalayas (Upreti 1998). The area has comprised of 90 lichens species belonging to 45 genera and 18 families (Table 1), growing luxuriantly and flourished well in Hemkund on various substrates (Fig. 3).

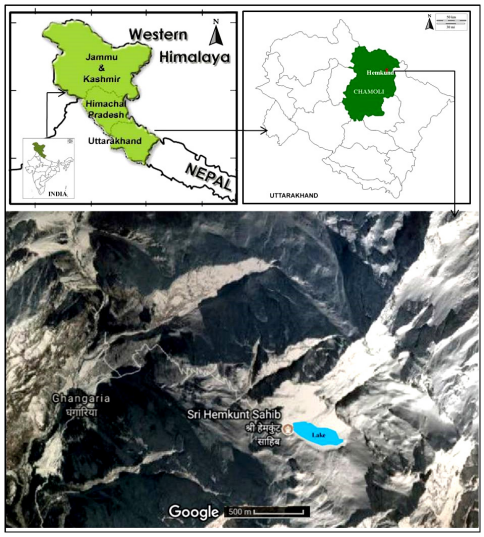

Fig.1. Map represents the study area

Amongst 18 lichen families revealed in the area *Parmeliaceae* dominates with 18 species followed by *Cladoniaceae* with 17 species, *Peltigeraceae* (15 spp.) and *Physciaceae* by 6 species (Fig. 4). The data further indicates that most common lichen genera of the area is *Cladonia* with 11 species, *Peltigera* with 8 species, *Stereocaulon* with 5 species and *Lobaria* with 4 species.

The peculiar symbiotic association in lichens enables them to survive the harsh environment of alpine Himalaya. This adaptation flexibility has resulted in very high diversity of growth and habitat subsets in alpine lichens (Rai et al 2010). Although foliose growth forms were most dominant (49 spp.), it is followed by secondary dominance of dimorphic (16 spp.), crustose (12 spp.), fruticose and squamulose with 6 species each of growth forms (Fig. 5). The increase in lichen diversity with increasing altitudes and their preference to rock and soil habitat can be attributed to the favorable environmental conditions such as temperature, rainfall and substrate. It can be concluded that the diversity of lichens was strongly influenced by the ecological conditions. The region is deprived of taller trees, so major growth of lichens was recorded on soil and rocks. In the present study the saxicolous lichens exhibit maximum diversity represented by 39 species followed by terricolous with 19 species, ramicolous and corticolous lichens with 8

Fig. 2. Some common lichens in and around Hemkund area growing on different substrates a. collection of lichens b. *Porpidia* sp. c. *Physconia* sp. d. *Stereocaulon* sp. e. *Cladonia pyxidata* f. *Peltigera praetextata* g. rock covered with *Dermatocarpon* and *Umbilicaria* h. *Aspicilia calcarea* and *Dermatocarpon miniatum* i. twig covered with *Parmotrema praesorediosum* and *Physcia* sp. j. *Parmotrema reticulatum*

and 4 species, respectively. However, some of the species exhibited shared substrates in the combination of rock/soil (11 spp), twig/rock (2 spp), bark/ twig (4 spp) and bark/ rock (2 spp) (Fig.6).

Parmotrema, Hypotrachyna, Flavoparmelia and *Flavopunctelia* are common epiphytic lichen genera growing in the area. The clefts and undersides of large rocks along the trekking sides provide wet and moist conditions for numerous soil loving dimorphic species of *Cladonia* and *Stereocaulon*. Some crustose and squamulose species of genera *Acarospora, Aspicilia, Lecanora, Lobothallia, Omphalodina* and *Rhizocarpon* also found growing abundantly on the exposed rock surface in steep alpine meadows.

Frequently appearing foliose and fruticose lichen species from the area were *Cladonia borealis* S. Stenroos,

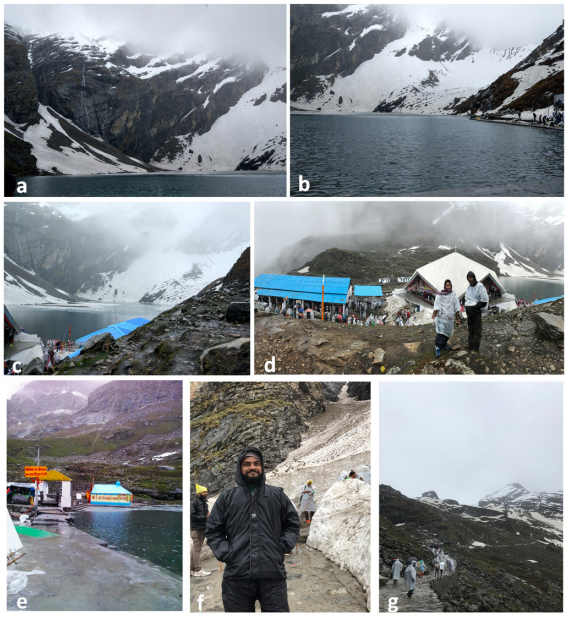

Fig. 3. Study area a-c. Hemkund Lake d. Hemkund Sahib e. Laxman temple f-g. Trek covered with snow

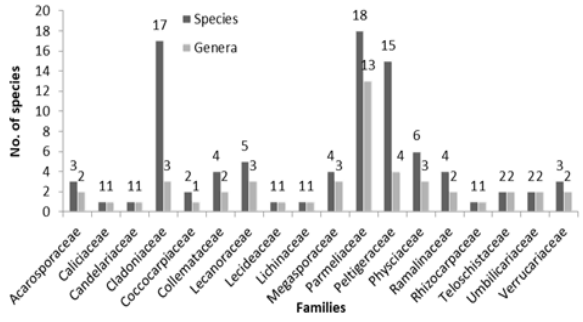

Fig.4. Genera and species composition of lichen families in Hemkund area

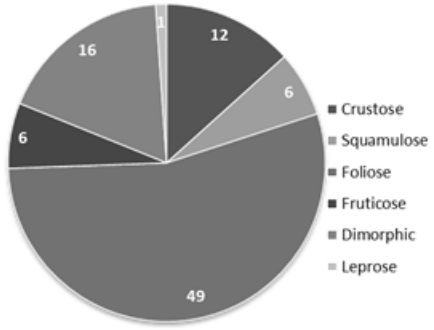

Fig. 5. Different lichen growth forms in study area

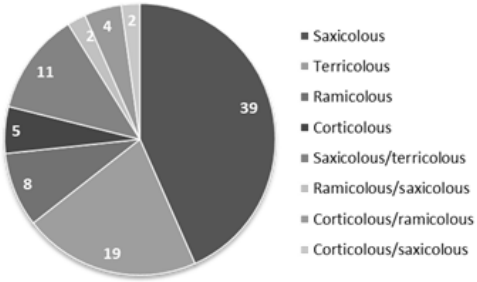

Fig. 6. Substrate diversity of lichens growing in study area

Cladonia corymbescens Nyl. ex Leight., *Cladonia furcata* (Huds.) Schrad., *Leptogium burnetiae* Dodge, *Lobaria retigera* (Bory) Trevis., *Flavoparmelia caperata* (L.) Hale, *Flavopunctelia flaventior* (Stirton) Hale, *Melanelixia vilosella* (Essl.) O. Blanco Crespo, Divakar, Essl. D. Hawksw., *Peltigera polydactylon* (Neck.) Hoffm. Var. *polydactylon, Peltigera praetextata* (Flörke) Zopf, *Stereocaulon foliolosum* var. *foliolosum* Nyl. and *Stereocaulon myriocarpum* Th. Fr.

Hemkund area, due to its sacred Gurudwara and temple, is an attraction for pilgrimage; hence, it is under greater anthropogenic stress in terms of tourist flow. The conservation of high-altitude wetlands and lakes in the Himalayas poses an immense challenge (Gujja 2007). Due to the rising threats such as unfettered tourism and its associated issues, there is an imperative need to conserve these wetland areas. Proper management planning must involve the local communities and the concerned stakeholders.

The lichens offer a means to date chronological, naturally-occurring incidents, as they are long-lived, have a relatively slow radial growth rate, and have different species-specific tolerances to inundation (Benedict 2009). The lichens can be used as a hydrology indicator (Hull, 2011), so this preliminary study gives an ultimate outcome regarding the richness of the biodiversity of the wetland

Table 1: Lichens diversity in and around Hemkund area along with their availability on various substrates.

S. No.	*Lichen family/species name*	*Growth Forms*	*Habit*
	ACAROSPORACEAE		
1	*Acarospora fusca* de Lesd.	Crustose	Saxicolous
2	*A. schleicheri* (Ach.) A. Massal.	Crustose	Saxicolous
3	*Myriospora smaragdula* (Wahlenb. ex Ach.) Nägeli ex Uloth	Crustose	Saxicolous
	CALICIACEAE		
4	*Buellia* sp.	Crustose	Saxicolous
	CANDELARIACEAE		
5	*Candelaria* sp.	Foliose	Saxicolous
	CLADONIACEAE		
6	*Cladonia borealis* S. Stenroos	Dimorphic	Terricolous
7	*Cladonia corniculata* Ahti & Kashiw.	Dimorphic	Terricolous
8	*Cladonia corymbescens* Nyl. ex Leight.	Dimorphic	Saxicolous/Terricolous
9	*Cladonia fenestralis* Nuno	Dimorphic	Terricolous
10	*Cladonia furcata* (Huds.) Schrad.	Dimorphic	Saxicolous/Terricolous
11	*Cladonia laii* S. Stenroos	Dimorphic	Terricolous
12	*Cladonia pocillum* (Ach.) Grognot	Dimorphic	Terricolous
13	*Cladonia pyxidata* (L.) Hoffm.	Dimorphic	Saxicolous/Terricolous
14	*Cladonia rangiferina* (L.) F.H. Wigg.	Dimorphic	Saxicolous/Terricolous
15	*Cladonia squamosa* Hoffm.	Dimorphic	Terricolous
16	*Cladonia subulata* (L.) F.H. Wigg.	Dimorphic	Terricolous
17	*Lepraria lobificans* Nyl.	Leprose	Saxicolous
18	*Stereocaulon foliolosum* var. *foliolosum* Nyl.	Dimorphic	Saxicolous/Terricolous
19	*Stereocaulon foliolosum* var. *strictum* (C. Bab.) I.M. Lamb	Dimorphic	Saxicolous/Terricolous
20	*Stereocaulon myriocarpum* Th. Fr.	Dimorphic	Saxicolous/Terricolous
21	*Stereocaulon piluliferum* Th. Fr.	Dimorphic	Saxicolous
22	*Stereocaulon himalayense* D.D. Awasthi & I.M. Lamb	Dimorphic	Saxicolous/Terricolous
	COCCOCARPIACEAE		
23	*Coccocarpia erythroxyli* (Spreng.) Swinsc. & Krog	Foliose	Saxicolous
24	*Coccocarpia palmicola* (Spreng.) Arv. & D.J. Galloway	Foliose	Saxicolous
	COLLEMATACEAE		
25	*Collema subflaccidum* Degel.	Foliose	Terricolous
26	*Leptogium burnetiae* Dodge	Foliose	Terricolous
27	*Leptogium cyanescens* (Rabenh.) Körb.	Foliose	Saxicolous
28	*Leptogium saturninum* (Dickson) Nyl.	Foliose	Saxicolous
	LECANORACEAE		
29	*Lecanora albescens* (Hoffm.) Flörke	Crustose	Saxicolous
30	*Lecanora* sp.	Crustose	Corticolous/Ramicolous
31	*Protoparmeliopsis garovaglii* (Körb.) Arup, Zhao Xin & Lumbsch	Squamulose	Saxicolous
32	*Protoparmeliopsis muralis* (Schreb.) M. Choisy	Squamulose	Saxicolous

33	*Omphalodina chrysoleuca* (Sm.) S.Y. Kondr., Lőkös & Farkas	Squamulose	Saxicolous
	LECIDEACEAE		
34	*Porpidia macrocarpa* (DC) Hertel & Knoph	Crustose	Saxicolous
	LICHINACEAE		
35	*Lichinella* sp.	Foliose	Saxicolous
	MEGASPORACEAE		
36	*Circinaria calcarea* (L.) A. Nordin, Savić & Tibell	Crustose	Saxicolous
37	*Aspicilia dwaliensis* Räsänen	Crustose	Saxicolous
38	*Lobothallia alphoplaca* (Wahlenb. ex Ach.) Hafellner	Squamulose	Saxicolous
39	*Lobothallia praeradiosa* (Nyl.) Hafellner	Squamulose	Saxicolous
	PARMELIACEAE		
40	*Cetrelia cetrarioides* (Delise ex Duby) W.L. Culb. & C.F. Culb.	Foliose	Saxicolous
41	*Cetrelia olivetorum* (Nyl.) W.L. Culb. & C.F. Culb.	Foliose	Corticolous/Saxicolous
42	*Dolichousnea longissima* (Ach.) Articus	Fruticose	Corticolous/Ramicolous
43	*Hypotrachyna cirrhata* (Fr.) Divakar, A. Crespo, Sipman, Elix & Lumbsch	Foliose	Ramicolous
44	*Flavoparmelia caperata* (L.) Hale	Foliose	Corticolous/Ramicolous
45	*Flavopunctelia flaventior* (Stirt.) Hale	Foliose	Corticolous/Ramicolous
46	*Melanelia hepatizon* (Ach.) A. Thell	Foliose	Saxicolous
47	*Melanelixia villosella* (Essl.) O. Blanco Crespo, Divakar, Essl. & D. Hawksw.	Foliose	Saxicolous
48	*Menegazzia terebrata* (Hoffm.) A. Massal.	Foliose	Corticolous
49	*Nephromopsis laii* (A. Thell & Randlane) Saag & A.Thell	Foliose	Ramicolous
50	*Nephromopsis nephromoides* (Nyl.) Ahti & Randlane	Foliose	Ramicolous
51	*Nephromopsis pallescens* (Schaer.) Park	Foliose	Ramicolous
52	*Parmotrema praesorediosum* (Nyl.) Hale	Foliose	Ramicolous
53	*Parmotrema reticulatum* (Taylor) M. Choisy	Foliose	Saxicolous
54	*Punctelia borreri* (Sm.) Krog	Foliose	Ramicolous
55	*Usnea himalayana* C. Bab.	Fruticose	Ramicolous/Saxicolous
56	*Usnea orientalis* Motyka	Fruticose	Corticolous
57	*Xanthoparmelia terricola* Hale, Nash & Elix	Foliose	Terricolous
	PELTIGERACEAE		
58	*Lobaria kurokawae* Yoshim.	Foliose	Saxicolous
59	*Lobaria pindarensis* Räsänen	Foliose	Saxicolous
60	*Lobaria pseudopulmonaria* Gyeln.	Foliose	Saxicolous
61	*Lobaria retigera* (Bory) Trevis.	Foliose	Saxicolous/Terricolous
62	*Dendriscosticta platyphylla* (Trevis.) B. Moncada & Lücking	Foliose	Corticolous /Saxicolous
63	*Dendriscosticta praetextata* (Räsänen) B. Moncada & Lücking	Foliose	Corticolous
64	*Nephroma helveticum* Ach.	Foliose	Terricolous
65	*Peltigera canina* (L.) Willd.	Foliose	Terricolous
66	*Peltigera didactyla* (With.) J.R. Laundon	Foliose	Terricolous
67	*Peltigera horizontalis* (Huds.) Baumg.	Foliose	Saxicolous/Terricolous

68	*Peltigera malacea* (Ach.) Funck.	Foliose	Terricolous
69	*Peltigera polydactylon* var. *polydactylon* (Neck.) Hoffm.	Foliose	Terricolous
70	*Peltigera polydactylon* var. *pruinosa* Gyeln.	Foliose	Saxicolous/Terricolous
71	*Peltigera praetextata* (Flörke) Zopf	Foliose	Terricolous
72	*Peltigera rufescens* (Weiss.) Humb.	Foliose	Terricolous
	PHYSCIACEAE		
73	*Phaeophyscia constipata* (Norrl. & Nyl.) Moberg	Foliose	Terricolous
74	*Phaeophyscia orbicularis* (Neck.) Moberg	Foliose	Saxicolous
75	*Physcia caesia* (Hoffm.) Fürnr.	Foliose	Saxicolous
76	*Physcia* sp.	Foliose	Corticolous
77	*Physconia detersa* (Nyl.) Poelt	Foliose	Saxicolous
78	*Physconia muscigena* (Ach.) Poelt	Foliose	Terricolous
	RAMALINACEAE		
79	*Phyllopsora* sp.	Squamulose	Corticolous
80	*Ramalina himalayensis* Räsänen	Fruticose	Ramicolous/Saxicolous
81	*Ramalina roesleri* (Hochst.) Hue	Fruticose	Ramicolous
82	*Ramalina conduplicans* Vain.	Fruticose	Ramicolous
	RHIZOCARPACEAE		
83	*Rhizocarpon geographicum* (L.) DC.	Crustose	Saxicolous
	TELOSCHISTACEAE		
84	*Caloplaca* sp.	Crustose	Saxicolous
85	*Rusavskia elegans* (Link) S. Y. Kondr. & Kärnefelt	Foliose	Saxicolous
	UMBILICARIACEAE		
86	*Lasallia pustulata* (L.) Mérat	Foliose	Saxicolous
87	*Umbilicaria indica* Frey	Foliose	Saxicolous
	VERRUCARIACEAE		
88	*Dermatocarpon vellereum* Zschacke	Foliose	Saxicolous
89	*Dermatocarpon miniatum* (L.) W. Mann.	Foliose	Saxicolous
90	*Verrucaria acrotella* Ach.	Crustose	Saxicolous

area and its hydrological studies. The composition of the lichen species found during the field sampling indicates that the area contains a rich and diverse assemblage of biodiversity including some valuable medicinal species. The present number of lichen species, their distribution will act as baseline data to carry out other (biomonitoring, glacier retreat, conservation of fragile ecosystem, etc.) studies from the area in the future.

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