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Untangling Quantitative Lichen Diversity in and Around Badrinath Holy Pilgrimage of Western Himalaya, India

Sugam Gupta[1], Omesh Bajpai[2*], Himanshu Rai[3,4], Dalip Kumar Upreti[3], Pradeep Kumar Sharma[1], Rajan Kumar Gupta[4]

[1]Department of Environmental Science
Graphic Era (Deemed to be University), Dehradun, India
[2]Division of Plant Sciences
Plant and Environmental Research Institute (PERI), Kanpur, Uttar Pradesh, India
[3]Lichenology laboratory, Plant Diversity, Systematics and Herbarium Division,
CSIR-National Botanical Research Institute, Lucknow, Uttar Pradesh, India
[4]Department of Botany
Pt. Lalit Mohan, Government P.G. College, Rishikesh, Dehradun, India
[*]Corresponding Author: omeshbajpa@gmail.com

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Abstract
The present study was conducted in the Badrinath holy pilgrimage in Western Himalaya. Lichen collected from seven localities (Badrinath, enroute Bhimpul to Vasudhara, Mana, enroute Vasudhara to Mana, Bhimpul, Vasudhara Glacier and enroute Vasudhara to Bhagirathi Glacier). The highest overall IVI (6.64) was recorded for *Rhizoplaca chrysoleuca*. The maximum number of lichens have been documented in Badrinath locality (139 spp.) while minimum (6) in enroute Vasudhara to Bhagirathi Glacier. The Badrinath has also express maximum 71 site specific species, while the Vasudhara Glacier has only 2 species. The dominance has been computed maximum (0.17) for enroute Vasudhara to Bhagirathi Glacier while, minimum for the Badrinath (0.01). The lowest Simpson Index value (0.83) has been recorded in enroute Vasudhara to Bhagirathi Glacier while the highest (0.99) in Badrinath. The lowest value of Berger-Parker diversity index (0.03), as well as the highest values of Brillouin, Shannon, Menhinick, Margalef and Fisher alpha diversity indices (7.20, 4.78, 8.03, 24.2 and 100.6 respectively) from the Badrinath locality, designates it as a site of highest species diversity. While enroute Vasudhara to Bhagirathi Glacier locality shows the highest value of Berger-Parker diversity index (0.17) as well as the lowest values of Brillouin, Shannon, Menhinick, Margalef and Fisher alpha diversity indices (1.75, 1.79, 0.35, 0.88 and 1.03 respectively). The value of evenness and equitability has been computed maximum (1.00) for enroute Vasudhara to Mana and Vasudhara to Bhagirathi Glacier localities, on the other hand, minimum (0.086 and 0.97 respectively) in the Badrinath.

Keywords- Lichens, Quantitative Ecology, Badrinath, IVI, Alpha Diversity.

1. Introduction

Lichens are self-stable symbiotic association of a fungus and algae and have are distributed worldwide. Due to its unique structure and poikilohydric nature (whose water status differs passively with surrounding environmental conditions) these organism have an ability to grow on various geographical regions from icy areas to hot deserts. Lichens are spread over wide range of habitat from large natural to managed environment systems with their specifically

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preferred substratum. Several macro scale environmental variables such as relative humidity, temperature, precipitation, altitudes etc. influence both taxonomic as well as ecological diversity of lichens worldwide (Ahti, 1966; John and Dale, 1990; Wolf, 1993; Pirintsos et al., 1995; Upreti and Negi, 1998; Vokou et al., 1999; Grytnes et al., 2006; Pinokiyo et al., 2008; Gupta et al., 2014).

The light, water and nutrients, driven by local sources of disturbance, such as road or farms, different land uses or habitat fragmentation are the reasons for the distribution and diversity of lichens in a particular location (Lescia et al., 1991; McCune and Geiser, 1997; Uliczka and Anglestam, 1999; Brunialti and Giordani, 2003). The quantification of lichen diversity can be done by their ecological assessment. For this ecological assessment, numbers of indices have been used from different positions of the globe. An index is usually a count statics that carries information about the population and is generally used to observe the count of individuals of the species (Wilson et al., 1996a, b; Gaines et al., 1999). In general, there are three main categories of measures used to evaluate species diversity (a) species richness indices, which measures the number of species in sample units. (b) species abundance models which have been developed to define the distribution of species abundance (c) indices that are based on the relative abundance of species such as the Shannon and Simpson indices (Magurran, 1988). Alpha diversity is the mean species diversity within a particular area or ecosystem and expressed by several indices such as Dominance, Simpson, Berger-Parker, Brillouin, Shannon, Menhinick, Margalef, Fisher alpha etc. (Gaines et al., 1999).

In Indian scenario, few studies on the ecology of lichens are available (Negi, 2000; Pinokiyo et al., 2008). However, we concentrate on the Badrinath holy pilgrimage, almost no such study has been reported till date. Thus, the present study was conducted for untangling the quantitative lichen diversity in the Badrinath holy pilgrimage. The ecological parameters such as frequency, density, IVI and species richness (Alfa diversity) were studied in the seven selected localities *i.e.* Badrinath (BNT), enroute Bhimpul to Vasudhara (BHM–VSD), Mana (MAN), enroute Vasudhara to Mana (VSD–MAN), Bhimpul (BHM), Vasudhara Glacier (VSDGl) and enroute Vasudhara–Bhagirathi Glacier (VSD–BhGl).

2. Material and Methods

2.1 Study Area

The study area is positioned in the north-west extreme at an elevation of 3000 – 4000m of Chamoli district in the state of Uttarakhand. Seven major sites of Badrinath, Mana, Bhimpul, Bhimpul to Vasudhara, Vasudhara to Mana, Vasudhara to Bhagirathi Glacier and Vasudhara Glacier (Figure 1).

2.2 Data Collection and Analysis

The lichens were collected from all the available substrates. All the necessary information such as altitude, substrate, growth form, and habitat was noted. Identification process was

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further followed by morphology, anatomy and chemical tests following standard protocols (Magnusson, 1929; Awasthi, 1991; Orange et al., 2010; Nash et al., 2002; Divakar and Upreti, 2005; Awasthi, 2007; Upreti and Divakar, 2008; Elix, 2014). The voucher specimens with details of locality, date of collection and substratum were deposited at the Lichen herbarium (LWG), National Botanical Research Institute, Lucknow.

Ecological parameters were estimated to measure the frequency (F%) and density (D) followed by their relative values, Relative Frequency (RF) and Relative Density (RD). The relative values of the frequency (RF) and density (RD) are used to calculate Important value Index (IVI) following Pinokiyo et al. (2008). The IVI values were further used to calculate different alpha diversity indices by using PAST (Paleontological Statistics) to analyse the different indices of species diversity (Bajpai et al., 2015).

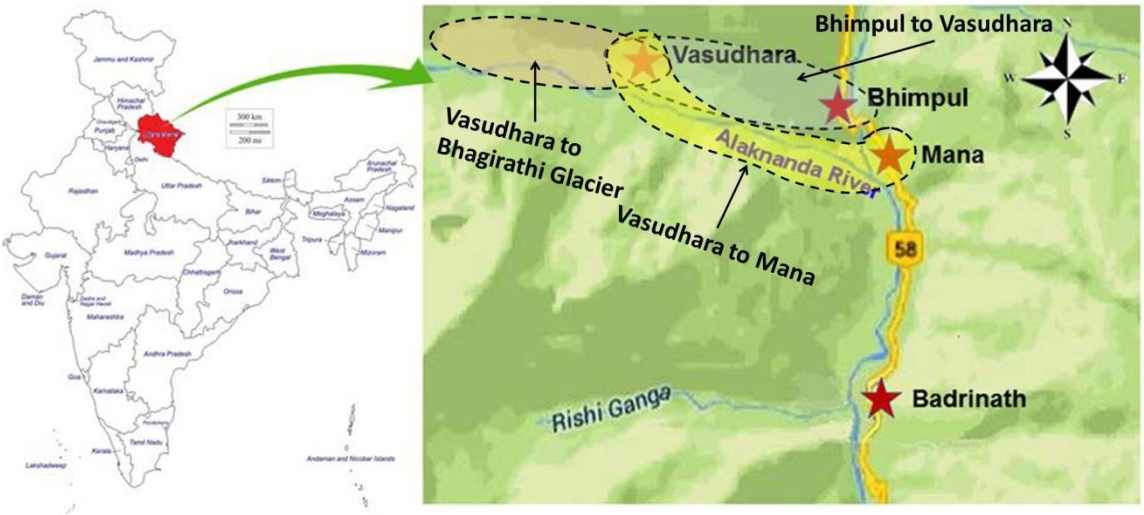

Figure 1. Locations of study site (Badrinath Holy Pilgrimage)

3. Results and Discussion

3.1 Important Value Index (IVI)

The value of Important value index in overall study area showed that *Rhizoplaca chrysoleuca* have highest IVI value (6.64) followed by *Flavoparmelia caperata* (6.25), *Cladonia pyxidata* (5.86) and *Lecanora muralis* (4.69), whereas *Peltigera pratextata*, *Phaeophyscia hispidula* and *Xanthparmelia terricola* have IVI value 3.91 for each; *Acarospora fusca*, *Rhizocarpon geographicum*, *Xanthoparmelia bellatula*, *Xanthoria candelaria* and *Xanthoria elegans* have IVI value 3.52 for each; *Rhizocarpon disporum* have IVI value 3.13 and so on (Table 1). From the above observations results, it is clear that *Rhizoplaca chrysoleuca*, *Flavoparmelia caperata* and *Lecanora muralis* are the most abundant species in the study area.

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Table 1. Lichen species from different locations of the study site with the values of iimportant value index (IVI)

S.N.	Name of Species	Over all	BNT	BHM–VSD	MAN	VSD–MAN	BHM	VSDGl	VSD–BhGl
1	*Acarospora angolensis*	0.39	0.00	0.00	3.28	0.00	0.00	0.00	0.00
2	*Acarospora badiofusca*	0.78	1.35	0.00	0.00	0.00	0.00	0.00	0.00
3	*Acarospora bullata*	1.17	0.00	0.00	6.56	0.00	8.70	0.00	0.00
4	*Acarospora carnegiei*	0.39	0.00	0.00	0.00	0.00	8.70	0.00	0.00
5	*Acarospora fusca*	3.52	4.71	0.00	6.56	0.00	0.00	0.00	0.00
6	*Acarospora fuscata*	0.39	0.00	0.00	3.28	0.00	0.00	0.00	0.00
7	*Acarospora saxicola*	1.17	0.67	0.00	6.56	0.00	0.00	0.00	0.00
8	*Acarospora scabra*	0.39	0.00	0.00	3.28	0.00	0.00	0.00	0.00
9	*Acarospora smaragdula*	1.95	2.02	2.35	0.00	6.90	0.00	0.00	0.00
10	*Acarospora socialis*	0.39	0.00	0.00	0.00	0.00	8.70	0.00	0.00
11	*Acarospora strigata*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
12	*Aspicilia almorensis*	1.95	2.02	0.00	6.56	0.00	0.00	0.00	0.00
13	*Aspicilia caesiocinerea*	0.78	0.00	0.00	0.00	0.00	17.39	0.00	0.00
14	*Aspicilia calcarea*	1.17	0.00	2.35	3.28	0.00	8.70	0.00	0.00
15	*Aspicilia griseocinerea*	0.78	1.35	0.00	0.00	0.00	0.00	0.00	0.00
16	*Aspicilia maculata*	2.73	1.35	2.35	6.56	6.90	8.70	0.00	0.00
17	*Bryoria asiatica*	0.39	0.00	0.00	0.00	6.90	0.00	0.00	0.00
18	*Bryoria nepalensis*	0.39	0.00	0.00	0.00	0.00	0.00	0.00	33.33
19	*Buellia aethalea*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
20	*Buellia asterella*	0.39	0.00	0.00	0.00	6.90	0.00	0.00	0.00
21	*Caloplaca flavovirescens*	0.39	0.00	0.00	3.28	0.00	0.00	0.00	0.00
22	*Caloplaca lithophila*	0.78	0.00	2.35	3.28	0.00	0.00	0.00	0.00
23	*Caloplaca subsoluta*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
24	*Caloplaca variabilis*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
25	*Candelaria concolor*	2.73	1.35	7.06	3.28	0.00	8.70	0.00	0.00
26	*Candelaria indica*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
27	*Candelariella aurella*	1.17	1.35	2.35	0.00	0.00	0.00	0.00	0.00
28	*Candelariella grimmiae*	0.39	0.00	0.00	0.00	6.90	0.00	0.00	0.00
29	*Candelariella vitellina*	0.39	0.00	0.00	3.28	0.00	0.00	0.00	0.00
30	*Canomaculina subtinctoria*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
31	*Catapyrenium cinereum*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
32	*Cetraria laevigata*	0.39	0.00	0.00	0.00	6.90	0.00	0.00	0.00
33	*Cetraria nigricans*	1.56	1.35	2.35	0.00	6.90	0.00	0.00	0.00
34	*Cetrelia cetrarioides*	0.39	0.00	2.35	0.00	0.00	0.00	0.00	0.00
35	*Cladia aggregata*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
36	*Cladonia borealis*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
37	*Cladonia cartilaginea*	0.78	1.35	0.00	0.00	0.00	0.00	0.00	0.00
38	*Cladonia chlorophaea*	1.17	2.02	0.00	0.00	0.00	0.00	0.00	0.00
39	*Cladonia coniocraea*	1.17	1.35	2.35	0.00	0.00	0.00	0.00	0.00
40	*Cladonia corymbescens*	0.39	0.00	0.00	0.00	0.00	0.00	18.18	0.00
41	*Cladonia fimbriata*	1.95	1.35	4.71	0.00	0.00	0.00	18.18	0.00
42	*Cladonia furcata*	0.78	0.67	0.00	0.00	6.90	0.00	0.00	0.00
43	*Cladonia macroceras*	0.39	0.00	0.00	0.00	0.00	0.00	0.00	33.33
44	*Cladonia mongolica*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
45	*Cladonia ochrochlora*	1.17	1.35	2.35	0.00	0.00	0.00	0.00	0.00
46	*Cladonia pyxidata*	5.86	7.41	4.71	0.00	6.90	0.00	18.18	0.00
47	*Cladonia rei*	0.39	0.00	2.35	0.00	0.00	0.00	0.00	0.00
48	*Cladonia subsquamosa*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
49	*Claonia pocillum*	0.78	1.35	0.00	0.00	0.00	0.00	0.00	0.00
50	*Dermatocarpon miniatum*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
51	*Dermatocarpon vellereum*	1.95	1.35	0.00	6.56	0.00	8.70	0.00	0.00
52	*Dimelaena oreina*	1.17	0.00	2.35	3.28	0.00	8.70	0.00	0.00
53	*Diploschistes gypsaceus*	0.78	1.35	0.00	0.00	0.00	0.00	0.00	0.00
54	*Diploschistes muscorum*	2.34	2.02	4.71	0.00	0.00	8.70	0.00	0.00
55	*Diploschistes rampoddensis*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00

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56	*Diploschistes scruposus*	1.17	1.35	0.00	0.00	0.00	8.70	0.00	0.00
57	*Endocarpon rosettum*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
58	*Endocarpon subrosettum*	1.17	1.35	0.00	3.28	0.00	0.00	0.00	0.00
59	*Evernia mesomorpha*	0.39	0.00	0.00	0.00	6.90	0.00	0.00	0.00
60	*Everniastrum cirrhatum*	0.78	1.35	0.00	0.00	0.00	0.00	0.00	0.00
61	*Flavoparmelia caperata*	6.25	7.41	7.06	0.00	0.00	8.70	0.00	33.33
62	*Flavopunctelia flaventior*	1.17	1.35	0.00	0.00	6.90	0.00	0.00	0.00
63	*Fuscopannaria saltuensis*	0.39	0.00	0.00	0.00	6.90	0.00	0.00	0.00
64	*Heterodermia boryi*	0.39	0.00	2.35	0.00	0.00	0.00	0.00	0.00
65	*Heterodermia diademata*	0.78	0.67	0.00	3.28	0.00	0.00	0.00	0.00
66	*Heterodermia galactophylla*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
67	*Heterodermia hypocaesia*	0.78	1.35	0.00	0.00	0.00	0.00	0.00	0.00
68	*Heterodermia japonica*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
69	*Heterodermia leucomelos*	0.78	0.67	0.00	0.00	6.90	0.00	0.00	0.00
70	*Heterodermia microphylla*	0.39	0.00	2.35	0.00	0.00	0.00	0.00	0.00
71	*Heterodermia pseudospeciosa*	1.17	0.67	4.71	0.00	0.00	0.00	0.00	0.00
72	*Heterodermia speciosa*	1.56	0.67	0.00	3.28	6.90	8.70	0.00	0.00
73	*Lasallia pertusa*	1.17	1.35	0.00	0.00	6.90	0.00	0.00	0.00
74	*Lasallia pustulata*	2.34	1.35	4.71	3.28	0.00	0.00	18.18	0.00
75	*Lecanora frustulosa*	0.78	0.67	2.35	0.00	0.00	0.00	0.00	0.00
76	*Lecanora garovaglii*	1.17	0.67	4.71	0.00	0.00	0.00	0.00	0.00
77	*Lecanora luteomarginata*	0.39	0.00	2.35	0.00	0.00	0.00	0.00	0.00
78	*Lecanora muralis*	4.69	4.71	4.71	9.84	0.00	0.00	0.00	0.00
79	*Lecanora muralis* var. *dubyi*	0.39	0.00	2.35	0.00	0.00	0.00	0.00	0.00
80	*Lecanora phaedrophthalma*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
81	*Lecanora pseudistera*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
82	*Lecidea confluens*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
83	*Lecidea lapicida*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
84	*Lecidea plana*	0.39	0.00	0.00	0.00	0.00	8.70	0.00	0.00
85	*Lecidella alaiensis*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
86	*Lecidella carpathica*	0.78	0.67	0.00	3.28	0.00	0.00	0.00	0.00
87	*Lecidella stigmatea*	0.39	0.00	0.00	3.28	0.00	0.00	0.00	0.00
88	*Lepraria lobifans*	0.78	0.00	0.00	6.56	0.00	0.00	0.00	0.00
89	*Leptogium burnetiae*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
90	*Lichinella cribellifera*	2.34	3.37	2.35	0.00	0.00	0.00	0.00	0.00
91	*Lobaria kurokawae*	0.78	1.35	0.00	0.00	0.00	0.00	0.00	0.00
92	*Lobothallia alphoplaca*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
93	*Lobothallia praeradiosa*	1.95	1.35	2.35	3.28	6.90	0.00	0.00	0.00
94	*Lobothallia radiosa*	0.39	0.00	0.00	3.28	0.00	0.00	0.00	0.00
95	*Melaneia tominii*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
96	*Melanelia disjuncta*	0.39	0.00	2.35	0.00	0.00	0.00	0.00	0.00
97	*Melanelia panniformis*	0.39	0.00	0.00	0.00	6.90	0.00	0.00	0.00
98	*Melanelixia villosella*	0.39	0.00	0.00	0.00	6.90	0.00	0.00	0.00
99	*Melanohalea exasperatula*	0.39	0.00	2.35	0.00	0.00	0.00	0.00	0.00
100	*Melanohalea infumata*	0.78	1.35	0.00	0.00	0.00	0.00	0.00	0.00
101	*Mycobilimbia hunana*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
102	*Nephroma helveticum*	0.39	0.00	0.00	0.00	6.90	0.00	0.00	0.00
103	*Nephroma parile*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
104	*Normandina pulchella*	0.39	0.00	2.35	0.00	0.00	0.00	0.00	0.00
105	*Parmelia saxatilis*	1.56	2.69	0.00	0.00	0.00	0.00	0.00	0.00
106	*Parmelia squarrosa*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
107	*Parmelia sulcata*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
108	*Parmelina tiliacea*	0.39	0.00	0.00	0.00	6.90	0.00	0.00	0.00
109	*Parmotrema praesorediosum*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
110	*Peltigera canina*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
111	*Peltigera collina*	0.78	1.35	0.00	0.00	0.00	0.00	0.00	0.00
112	*Peltigera didactyla*	0.78	1.35	0.00	0.00	0.00	0.00	0.00	0.00
113	*Peltigera elisabethae*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
114	*Peltigera horizontalis*	1.17	2.02	0.00	0.00	0.00	0.00	0.00	0.00

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115	*Peltigera lepidophora*	0.78	1.35	0.00	0.00	0.00	0.00	0.00	0.00
116	*Peltigera malacea*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
117	*Peltigera membranacea*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
118	*Peltigera pindarensis*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
119	*Peltigera praetextata*	3.91	5.39	4.71	0.00	0.00	0.00	0.00	0.00
120	*Peltigera rufescens*	1.56	2.02	2.35	0.00	0.00	0.00	0.00	0.00
121	*Peltula patellata*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
122	*Pertusaria leucosora*	0.39	0.00	0.00	3.28	0.00	0.00	0.00	0.00
123	*Petigera polydactylon*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
124	*Phaeophyscia ciliata*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
125	*Phaeophyscia constipata*	1.95	2.02	2.35	3.28	0.00	0.00	0.00	0.00
126	*Phaeophyscia hispidula*	3.91	3.37	2.35	6.56	6.90	8.70	0.00	0.00
127	*Phaeophyscia orbicularis*	1.17	0.67	0.00	3.28	0.00	8.70	0.00	0.00
128	*Phaeophyscia primaria*	2.73	4.04	2.35	0.00	0.00	0.00	0.00	0.00
129	*Phaeophyscia pyrrhophora*	1.17	2.02	0.00	0.00	0.00	0.00	0.00	0.00
130	*Physcia albinea*	0.78	0.67	2.35	0.00	0.00	0.00	0.00	0.00
131	*Physcia biziana*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
132	*Physcia caesia*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
133	*Physcia gomukhensis*	2.73	3.37	2.35	3.28	0.00	0.00	0.00	0.00
134	*Physcia leptalea*	0.78	1.35	0.00	0.00	0.00	0.00	0.00	0.00
135	*Physconia detersa*	1.56	0.67	4.71	0.00	6.90	0.00	0.00	0.00
136	*Physconia enteroxantha*	1.17	1.35	0.00	0.00	0.00	8.70	0.00	0.00
137	*Physconia grisea*	0.78	0.67	0.00	0.00	0.00	8.70	0.00	0.00
138	*Physconia muscigena*	1.95	2.02	2.35	0.00	6.90	0.00	0.00	0.00
139	*Pleopsidium flavum*	0.78	1.35	0.00	0.00	0.00	0.00	0.00	0.00
140	*Porpidia albocoerulescens*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
141	*Porpidia crustulata*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
142	*Punctelia borreri*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
143	*Punctelia rudecta*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
144	*punctelia subrudecta*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
145	*Ramalina intermedia*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
146	*Ramalina sinensis*	1.17	0.67	4.71	0.00	0.00	0.00	0.00	0.00
147	*Remototrachyna awasthii*	0.78	0.67	2.35	0.00	0.00	0.00	0.00	0.00
148	*Remototrachyna flexilis*	0.39	0.00	2.35	0.00	0.00	0.00	0.00	0.00
149	*Remototrachyna incognita*	0.39	0.00	2.35	0.00	0.00	0.00	0.00	0.00
150	*Rhizocarpon badioatrum*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
151	*Rhizocarpon disporum*	3.13	4.04	2.35	0.00	0.00	8.70	0.00	0.00
152	*Rhizocarpon geographicum*	3.52	3.37	2.35	6.56	6.90	0.00	0.00	0.00
153	*Rhizocarpon macrosporum*	1.17	1.35	0.00	3.28	0.00	0.00	0.00	0.00
154	*Rhizocarpon sublucidum*	0.78	1.35	0.00	0.00	0.00	0.00	0.00	0.00
155	*Rhizoplaca chrysoleuca*	6.64	6.06	11.76	3.28	6.90	8.70	0.00	0.00
156	*Rinodina megaspora*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
157	*Sarcogyne privigna*	0.78	0.00	2.35	3.28	0.00	0.00	0.00	0.00
158	*Stereocaulon alpinum*	0.78	0.67	2.35	0.00	0.00	0.00	0.00	0.00
159	*Stereocaulon foliolosum*	1.95	2.02	2.35	0.00	6.90	0.00	0.00	0.00
160	*Stereocaulon myriocarpum*	1.95	2.69	0.00	0.00	0.00	0.00	0.00	33.33
161	*Tephromela khatiensis*	0.39	0.00	0.00	3.28	0.00	0.00	0.00	0.00
162	*Thamnolia vermicularis* var. *vermicularis*	0.39	0.00	0.00	0.00	0.00	0.00	18.18	0.00
163	*Thamnolia vermicularis* var. *subuliformis*	0.39	0.00	0.00	0.00	0.00	0.00	0.00	33.33
164	*Toninia tristis* ssp. *asiae centralis*	1.17	1.35	0.00	0.00	6.90	0.00	0.00	0.00
165	*Toninia tristis* ssp. *scholanderi*	0.78	0.67	0.00	0.00	0.00	0.00	18.18	0.00
166	*Umbilicaria indica*	1.17	1.35	0.00	0.00	0.00	0.00	18.18	0.00
167	*Umbilicaria vellea*	1.56	1.35	0.00	0.00	6.90	0.00	18.18	0.00
168	*Usnea orientalis*	0.39	0.00	2.35	0.00	0.00	0.00	0.00	0.00
169	*Usnea perplexans*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
170	*Usnea pseudosinensis*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
171	*Usnea subflorida*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00

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172	*Usnea subfloridana*	1.17	1.35	2.35	0.00	0.00	0.00	0.00	0.00
173	*Verrucaria acrotella*	0.78	0.67	0.00	3.28	0.00	0.00	0.00	0.00
174	*Verrucaria compacta*	0.78	1.35	0.00	0.00	0.00	0.00	0.00	0.00
175	*Xanthoparmelia australasica*	0.78	0.67	0.00	3.28	0.00	0.00	0.00	0.00
176	*Xanthoparmelia bellatula*	3.52	2.02	9.41	6.56	0.00	0.00	0.00	0.00
177	*Xanthoparmelia congensis*	0.39	0.00	0.00	3.28	0.00	0.00	0.00	0.00
178	*Xanthoparmelia coreana*	0.39	0.67	0.00	0.00	0.00	0.00	0.00	0.00
179	*Xanthoparmelia mexicana*	2.73	2.02	7.06	3.28	0.00	0.00	0.00	0.00
180	*Xanthoparmelia stenophylla*	2.73	2.02	0.00	6.56	0.00	0.00	36.36	0.00
181	*Xanthoparmelia terricola*	3.91	2.69	11.76	0.00	0.00	0.00	0.00	33.33
182	*Xanthoparmelia tinctina*	0.78	0.67	0.00	3.28	0.00	0.00	0.00	0.00
183	*Xanthoria candelaria*	3.52	4.04	4.71	3.28	0.00	0.00	0.00	0.00
184	*Xanthoria elegans*	3.52	2.69	4.71	3.28	6.90	8.70	0.00	0.00
185	*Xanthoria fallax*	0.39	0.00	0.00	3.28	0.00	0.00	0.00	0.00
186	*Xanthoria sorediata*	2.73	2.02	0.00	6.56	0.00	8.70	18.18	0.00
187	*Xanthoria ulophyllodes*	2.34	3.37	0.00	3.28	0.00	0.00	0.00	0.00
Total		**200.00**	**200.00**	**200.00**	**200.00**	**200.00**	**200.00**	**200.00**	**200.00**

Note: BNT = Badrinath, BHM–VSD = Bhimpul to Vasudhara, MAN = Mana, VSD–MAN = Vasudhara to Mana, BHM = Bhimpul, VSDGl = Vasudhara Glacier, VSD–BhGl = Vasudhara–Bhagirathi Glacier.

3.2 Species Richness (Alpha Diversity)

The number of lichen species has been found the maximum in Badrinath locality (139 spp.) followed by enroute Bhimpul to Vasudhara (56) and Mana (47); on the other hand, the minimum number of species (6) have been reported from enroute Vasudhara to Bhagirathi Glacier (Table 2). The Badrinath locality shows maximum lichen species diversity by having 71 site specific species which are present here only, while the Vasudhara Glacier has only 2 species (*i.e. Cladonia corymbescens* and *Thamnolia vermicularis* var. *vermicularis*) (Table 2).

The dominance has been computed maximum (0.17) for enroute Vasudhara to Bhagirathi Glacier which clearly indicates its lowest heterogeneity in the lichen distribution and it has been also supported by the lowest Simpson Index value (0.83). The minimum dominance has been computed for the Badrinath (0.01) with the highest value of Simpson Index (0.99) and points toward its highest heterogeneous nature for lichen distribution. When we see the values of dominance along with the Simpson Index, we found that enroute Bhimpul to Vasudhara and Mana localities also shows the heterogeneous distribution of lichen species in these localities (Table 2).

The lowest value of Berger-Parker diversity index (0.03), as well as the highest values of Brillouin, Shannon, Menhinick, Margalef and Fisher alpha diversity indices (7.20, 4.78, 8.03, 24.2 and 100.6 respectively) from the Badrinath, designates it as a site of highest species diversity. While enroute Vasudhara to Bhagirathi Glacier shows the highest value of Berger-Parker diversity index (0.17) as well as the lowest values of Brillouin, Shannon, Menhinick, Margalef and Fisher alpha diversity indices (1.75, 1.79, 0.35, 0.88 and 1.03 respectively) because of lower species diversity of lichens (Figure 2; Table 2).

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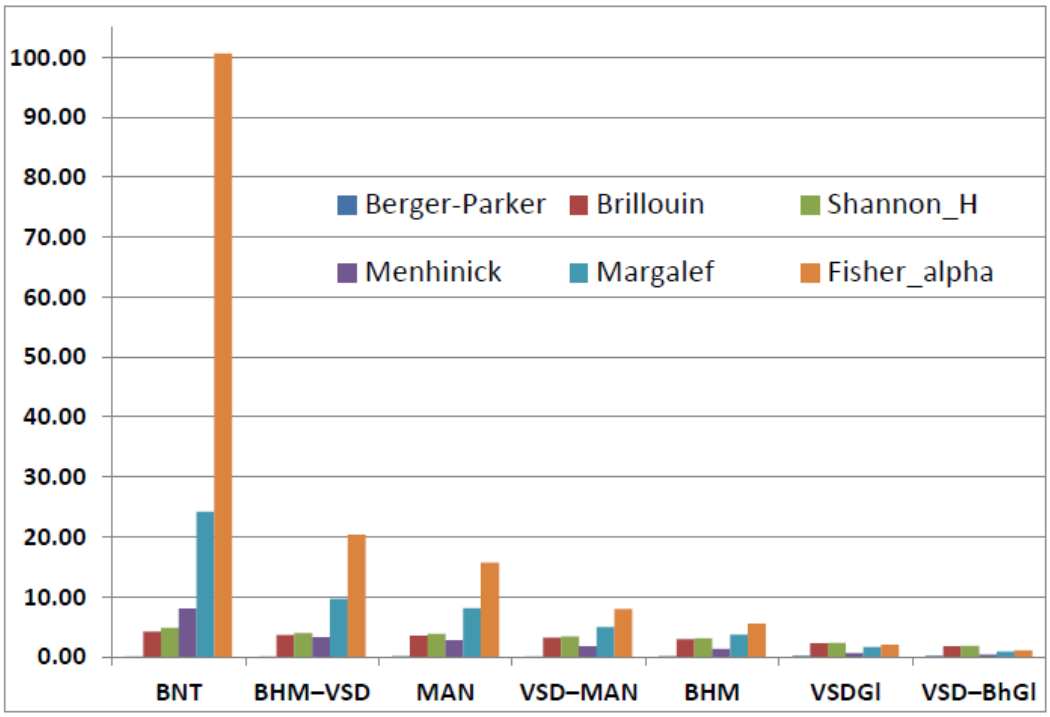

Figure 2. Different diversity indices for seven selected localities of Badrinath Holy Pilgrimage (BNT = Badrinath, BHM–VSD = Bhimpul to Vasudhara, MAN = Mana, VSD–MAN = Vasudhara to Mana, BHM = Bhimpul, VSDGl = Vasudhara Glacier, VSD–BhGl = Vasudhara–Bhagirathi Glacier)

The value of evenness and equitability has been computed maximum (1.00 in both) for enroute Vasudhara to Mana and Vasudhara to Bhagirathi Glacier localities, indicate the more evenly distribution of lichen species in these localities. On the other hand, in the Badrinath locality, the evenness and equitability have been found minimum as 0.086 and 0.97 respectively, where lichen species are less evenly distributed (Table 2).

Table 2. Ecological inventory of different locations of the study site

	BNT	BHM–VSD	MAN	VSD–MAN	BHM	VSDGl	VSD–BhGl
Number of species	139	56	47	29	22	10	6
Site specific species	71	12	11	10	4	2	3
Dominance_D	0.01	0.02	0.02	0.03	0.05	0.11	0.17
Simpson_1-D	0.99	0.98	0.98	0.97	0.95	0.89	0.83
Berger-Parker	0.03	0.04	0.06	0.04	0.09	0.16	0.17
Brillouin	4.20	3.62	3.50	3.17	2.90	2.20	1.75
Shannon_H	4.78	3.93	3.78	3.36	3.05	2.28	1.79
Menhinick	8.03	3.23	2.71	1.67	1.27	0.58	0.35
Margalef	24.2	9.64	8.07	4.91	3.68	1.58	0.88
Fisher_alpha	100.6	20.3	15.64	7.92	5.47	1.99	1.06
Evenness_e^H/S	0.86	0.91	0.93	1.00	0.96	0.97	1.00
Equitability_J	0.97	0.98	0.98	1.00	0.99	0.99	1.00

Note: BNT = Badrinath, BHM–VSD = Bhimpul to Vasudhara, MAN = Mana, VSD–MAN = Vasudhara to Mana, BHM = Bhimpul, VSDGl = Vasudhara Glacier, VSD–BhGl = Vasudhara–Bhagirathi Glacier.

Among the different sites, the *Rhizoplaca chrysoleuca* showed the maximum frequency and density in the area. Species richness in the form of Alpha diversity within a site is significant parameters of biodiversity that have a wide application such as environmental monitoring and Conservation assessment (Magurran, 1988; Pressey et al., 1994; Negi, 1999). As Badrinath located in alpine region of the Himalayas, it have stressed climatology *i.e.* higher environmental lapse rate, high wind velocity, high UV radiation, low atmosphere pressure, exposure regime and delimiting nutrient support and comparatively simple ecosystems (Rai et al., 2010; Gupta et al., 2014) that's why this locality bears the good lichen species richness in relation to other localities studied. The difference in species richness and diversity between all the sites can be best defined by habitat quality in Gupta et al. (2016).

4. Conclusion

On the basis of the findings of the present study, it may be concluded that the Badrinath locality bears the maximum 39 lichen species with 71 site specific species. This locality also shows the minimum dominance (0.01) as well as highest value of Simpson Index (0.99), which clearly indicates the presence of highest heterogeneous nature for lichens. On another hand, Vasudhara and Bhagirathi Glacier showed the least number of species. This quantitative assessment of lichen diversity can be further used in the identification of consequences of the allogeneic activities on the diversity and distribution of lichens.

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