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# Lichen diversity in alpine regions of eastern Sikkim with respect to long term monitoring programme of Indian Space Research Organization

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## ABSTRACT

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Alpine region of the Himalaya poses limitations for the growth of plant vegetation due to high wind velocity, high UV radiation, low atmospheric pressure and low precipitation. Lichens are among the few cryptogams adapted to such harsh living conditions and are known to be indicator of climate change. A total of 44 lichen species belonging to 23 genera and 15 families were recorded from three HSP (Highest Summit Point) sites in Kupup (Gnathang), Sikkim. *Cladonia coccifera* (L.) Willd, *Everniastrum cirrhatum* (Fr.) Hale, *Heterodermia diademata* (Taylor) D. D. Awasthi, *Lecanora frimbriatula* Stirt., *Stereocaulon austroindicum* I. M. Lamb, *Umbilicaria vellea* (L.) Ach. Em Frey, *Usnea longissima* Ach. and *Usnea sordida* Mot. were the most common lichen species found at HSP sites. The present baseline information about diversity and abundance of lichen vegetation in the area provides valuable information for conducting long term climate change monitoring programmes in alpine regions of the country. The restricted distribution of certain lichen growth forms further affirms the use of lichens in climate change studies.

**Key-words:** Lichens, alpine region, climate change, eastern Sikkim, Himalaya.

## INTRODUCTION

The alpine ecosystem represents unique composition of species and high degree of taxonomic richness due to its characteristic physico-chemical environment (Körner 2003). Alpine vegetation is well known indicator of climate change and long term monitoring can be useful for predicting prospective changes in future environment. Among the plant vegetation, lichens constitute a very important part of alpine regions. The photosynthetic performances of lichens of alpine regions are reported to be better than those of temperate lichens enabling them to survive in harsh climatic conditions. Lichens show rapid response to climate change. Being swift coloniser that disperses well, lichen species shift from tropical to higher temperate regions due to global warming (Aptroot 2009).

Climatic conditions mark the ranges and distribution of species in an area and thus composition of biome (Box 1981, 1996, Prentice et al. 1992) and changes in climatic conditions are likely to change the distribution of sensitive species. To monitor the effect of climate change on the fragile alpine ecosystem, a world-wide research initiative Global Observation Research Initiative in Alpine Environments (GLORIA) has been established for comparative study of climate change impact on mountain biodiversity (Grabherr et al. 2000, Pauli et al. 2003). Indian Space Research Organization (ISRO) in India has developed monitoring network for Indian Himalaya known as Himalayan Alpine Dynamics Research Initiative (HIMADRI). The programme intends for long term monitoring of ecologically sensitive parameters at benchmark sites in selected areas of Himalaya. Chopta-Tungnath site in the state of Uttarakhand, Aparwat region in Jammu & Kashmir, Roharu area in Shimla district of Himachal Pradesh, Sela Pass in Arunachal Pradesh and Kupup (Gnathang) in Sikkim are selected by ISRO for conducting long term monitoring of vegetation to estimate response of environmental changes on biodiversity. Since lichens are sensitive to environmental changes and have been particularly used as an indicator of ecosystem disturbances (Nordberg & Allard 2002), the distribution pattern of lichen vegetation in an area can be of importance to study the shift in species due to climate change.

The monitoring of lichen communities over time has been used extensively in Europe (van Herk et al. 2002) and in North America (McCune 2000) for predicting response of lichens to warming but no such studies have been reported from Indian Himalaya. The collection of dried plant specimens in museums and live plants in botanic gardens have also been used to track the response of plants to increasing temperatures and helped in predicting the effects of climate change on plants (Miller-Rushing et al. 2004). In the present study, the alpine areas of few sites in Sikkim, lying on the north-eastern Himalaya, have been explored to study the diversity of lichens. In order to understand the effects of climate change in these parts of Himalaya, long term monitoring sites HSP (Highest Summit Point) have been developed in the mountain tops. The abundance of lichen species in HSP has been estimated. Further, the estimation of species community richness in these areas will account for development of strategies for conservation of lichens in mountainous regions.

## MATERIAL AND METHODS

**Study area:** Sikkim is the smallest north-eastern state of India occupying an area of 7096 km$^2$. Of this, 3033 km$^2$ is covered by forest providing excellent climatic conditions for the growth of lichens. To understand the effect of climate change in alpine lichen ecosystem of Himalaya, long term monitoring sites designated as HSP (Highest Summit Point) were established at mountain tops in Kupup (Gnathang), Sikkim. Three HSP sites, viz. HSP-1 (altitude 4003 m, Lat. 27°17'51.3"N, Long. 88°50'09.0"E), HSP-2 (altitude 3957 m, Lat. 27°17'43.3"N, Long.

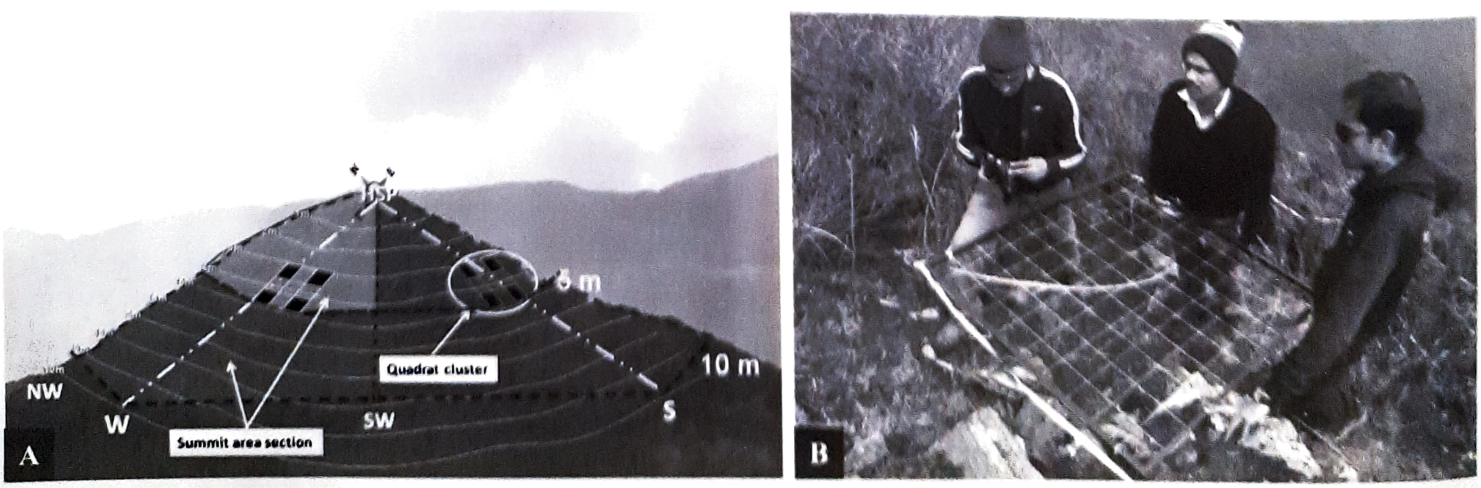


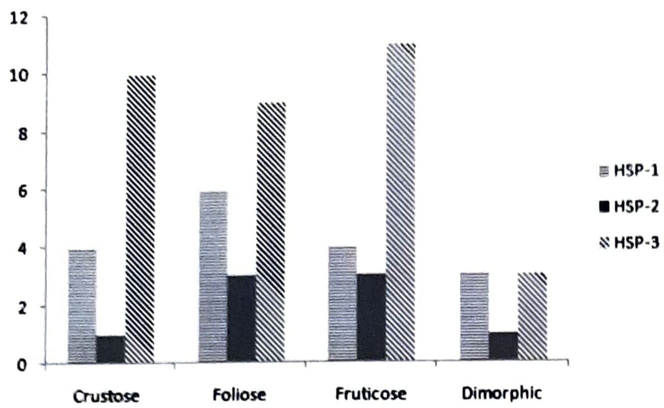

**Figure 1.** A. Oblique view with contour lines and actual plot settings in Kupup, Sikkim. B. Scholars placing Quadrates at submit area sections (SAS).

88°49'57.9"E) and HSP-3 (altitude 3707 m, 27°17'26.0"N, Long. 88°50'02.0"E), are established. The spectra of commonly occurring lichens in the area will be generated through remote sensing and will be simulated to study the response of species in alpine region due to change in climatic conditions.

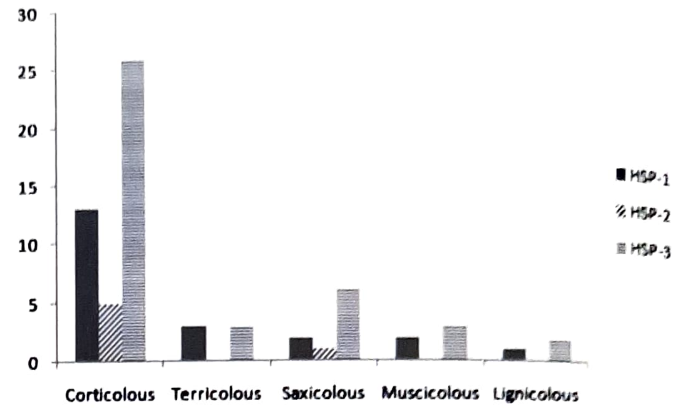
**Lichen collection and identification:** More than 100 lichen specimens were collected from three HSP sites (HSP-1, HSP-2 and HSP-3) in Kupup during the month of April 2014. Four 3m × 3m quadrate clusters in all four main compass directions were laid (Figure 1A). The quadrates were further divided into 1m × 1m permanent quadrate arranged within the four corners of the former quadrate. The resulting 16 quadrate areas were surveyed for lichens at 3, 5 and 10 metres distance (called summit area section, SAS)

**Table 1. Lichen species collected from selected sites in Kupup, Sikkim. Cr= Crustose, Fo= Foliose, Fr= Fruticose, Dm= Dimorphic; S= Saxicolous, C= Corticolous, L= Lignicolous, M= Muscicolous, T= Terricolous.**

| S. No. | Lichen species | Family | Sikkim | | | Growth form | Substrate |
|---|---|---|---|---|---|---|---|
| | | | Kupup, Gnathang (HSP-1) | Kupup, Gnathang (HSP-2) | Kupup, Gnathang (HSP-3) | | |
| 1. | *Anisomeridium tuckeri* (R. C. Harris) R. C. Harris | Monoblastiaceae | + | - | - | Cr | C |
| 2. | *Bryoria asiatica* (Du Rietz) Brodo & Hawksw. | Parmeliaceae | + | + | + | Fr | C |
| 3. | *Bryoria himalayana* (Mont.) Brodo & Hawksw. | Parmeliaceae | + | - | + | Fr | C/S |
| 4. | *Bryoria levis* D. D. Awasthi | Parmeliaceae | - | - | + | Fr | C |
| 5. | *Candelariella aurella* (Hoffm.) Zahlbr. | Candelariaceae | - | + | - | Cr | C |
| 6. | *Cetrelia cetrarioides* (Del. Ex Duby) W. Culb. & C. Culb. | Parmeliaceae | + | - | + | Fo | C |
| 7. | *Cladonia coccifera* (L.) Willd | Cladoniaceae | + | - | - | Dm | L/M/T |
| 8. | *Cladonia furcata* (Huds.) Schrad. | Cladoniaceae | - | | + | Dm | M/T |
| 9. | *Everniastrum cirrhatum* (Fr.) Hale | Parmeliaceae | + | + | + | Fo | C |
| 10. | *Everniastrum nepalense* (Taylor) Hale | Parmeliaceae | - | - | + | Fo | C |
| 11. | *Heterodermia diademata* (Taylor) D. D. Awasthi | Physciaceae | + | + | + | Fo | C |
| 12. | *Heterodermia hypoleuca* (Ach.) Trevis. | Physciaceae | - | + | - | Fo | C |
| 13. | *Hypogymnia vittata* (Ach.) Parrique | Parmeliaceae | - | - | + | Fo | L/M |
| 14. | *Lecanora albella* (pears.) Ach. | Lecanoraceae | - | - | + | Cr | C |
| 15. | *Lecanora flavidofusca* Mull. Arg. | Lecanoraceae | + | - | - | Cr | C |
| 16. | *Lecanora frimbriatula* Stirt. | Lecanoraceae | - | - | + | Cr | C |
| 17. | *Lecanora helva* Stizenb. | Lecanoraceae | - | - | + | Cr | C |
| 18. | *Lecanora pulicaris* (Pers.) Ach. | Lecanoraceae | + | - | - | Cr | C |
| 19. | *Lecanora queenslandica* Knight | Lecanoraceae | - | - | + | Cr | C |
| 20. | *Lobaria kurokawae* Yoshim. | Lobariaceae | + | - | - | Fo | C |
| 21. | *Lobaria pindarensis* Rasanen | Lobariaceae | + | - | - | Fo | C |
| 22. | *Lobaria retigera* (Bory.) Trevisan | Lobariaceae | - | - | + | Fo | C/M |
| 23. | *Myelochroa subaurulenta* (Nyl.) Elix & Hale | Parmeliaceae | - | - | + | Fo | C |
| 24. | *Ochrolechia rosella* (Mull. Arg.) Vers. | Ochrolechiaceae | - | - | + | Cr | C |
| 25. | *Ochrolechia yasudae* Vain. | Ochrolechiaceae | - | - | + | Cr | C |
| 26. | *Parmotrema thomsonii* (Stirt.) A. Crespo, Divakar & Elix | Parmeliaceae | + | - | + | Fo | C |
| 27. | *Peltigera polydactylon* (Neck.) Hoffm. | Peltigeraceae | + | - | - | Fo | C/M |
| 28. | *Pertusaria leioplacella* Nyl. | Pertusariaceae | - | - | + | Cr | C |
| 29. | *Pertusaria melastomella* Nyl. | Pertusariaceae | - | - | + | Cr | C |
| 30. | *Pertusaria multipuncta* (Turner.) Nyl. | Pertusariaceae | + | - | - | Cr | C |
| 31. | *Platismatia erosa* W. Culb. & C. Culb. | Parmeliaceae | - | - | + | Fo | C |
| 32. | *Porpidia macrocarpa* (DC.) Hertil Knoph in Hertil | Porpidiaceae | - | - | + | Cr | C |
| 33. | *Ramalina pollinaria* (Westr.) Ach. | Ramalinaceae | - | - | + | Fr | S |
| 34. | *Ramalina roesleri* (Hochst.) Hue | Ramalinaceae | - | - | + | Fr | C |
| 35. | *Rhizocarpon geographicum* (L.) DC in Lam. & DC | Rhizocarpaceae | - | - | + | Cr | C |
| 36. | *Stereocaulon alpinum* Laurer | Stereocaulaceae | + | - | - | Dm | S |
| 37. | *Stereocaulon austroindicum* I. M. Lamb | Stereocaulaceae | - | + | + | Dm | T |
| 38. | *Stereocaulon foliolosum* Nyl. | Stereocaulaceae | - | - | + | Dm | S/T |
| 39. | *Umbilicaria vellea* (L.) Ach. Em Frey | Umbilicariaceae | + | + | + | Fo | S/T |
| 40. | *Usnea bornmuelleri* J. Steiner | Parmeliaceae | - | - | + | Fr | S |
| 41. | *Usnea longissima* Ach. | Parmeliaceae | - | - | + | Fr | C |
| 42. | *Usnea sordida* Mot. | Parmeliaceae | + | + | + | Fr | C |
| 43. | *Usnea subfloridana* Stirt. | Parmeliaceae | - | - | + | Fr | C |
| 44. | *Usnea thomsonii* Stirt. | Parmeliaceae | - | - | + | Fr | C |
| 45. | **Total** | | **17** | **08** | **33** | | |




**Text-figure 1.** Different lichen growth forms at three HSP sites in Kupup (Gnathang), Sikkim.




**Text-figure 2.** Substrate specificity of different lichens present at three HSP sites in Kupup (Gnathang), Sikkim.

down the slope of mountains in four directions as shown in Figure 1B. The collected lichen specimens were identified morpho-anatomically using Leica S8APO stereo zoom microscope and Leica DM 500 micro-system. The chemistry of specimens were also analysed using spot tests and thin layer chromatography (TLC) (Orange et al. 2001) in solvent system A (180 ml toluene: 60 ml 1, 4 dioxane: 8 ml acetic acid). Spot tests were performed with reagents K, P and C. The relevant keys and monographs (Awasthi 1991, Awasthi 2007, Divakar & Upreti 2005) were also used for authentic identification.

## RESULTS AND DISCUSSION

The study area enumerates occurrence of 44 species of lichens belonging to 23 genera and 15 families (Table 1). Among the different localities, HSP-3 was found to be the richest site in terms of lichen diversity represented by 19 genera and 33 species followed by HSP-1 and HSP-2 (Table 2). HSP-1 site represented 13 genera and 17 species whereas HSP-2 site has 7 genera and 8 species. The most dominant family of lichens in all the HSP sites was Parmeliaceae with the highest number of species in HSP-3. Cladoniaceae, Lecanoraceae and Lobariaceae were dominant followed by Parmeliaceae in HSP-1. Physciaceae was the second dominant family in HSP-2 whereas Lecanoraceae dominated HSP-3 after family Parmeliaceae. The areas explored were situated at higher temperate to alpine altitudes and exhibited dominance of *Abies* spp., *Alnus nepalensis* D. Don, *Betula utilis* D. Don and *Rhododendron* spp., which provide suitable habitat for corticolous lichens. Dwarf bushes of *Berberis* and *Juniperus* were restricted in higher alpine regions also provides excellent substrate for many lichen taxa.

**Table 2. Number of genera and species of lichens found in three HSP sites in Kupup (Gnathang), Sikkim.**

| S. No. | Family | HSP-1 | | HSP-2 | | HSP-3 | |
|---|---|---|---|---|---|---|---|
| | | Genera | Species | Genera | Species | Genera | Species |
| 1 | Candelariaceae | 0 | 0 | 1 | 1 | 0 | 0 |
| 2 | Cladoniaceae | 1 | 2 | 0 | 0 | 1 | 1 |
| 3 | Lecanoraceae | 1 | 2 | 0 | 0 | 1 | 4 |
| 4 | Lobariaceae | 1 | 2 | 0 | 0 | 1 | 1 |
| 5 | Monoblastiaceae | 1 | 1 | 0 | 0 | 0 | 0 |
| 6 | Ochrolechiaceae | 0 | 0 | 0 | 0 | 1 | 2 |
| 7 | Parmeliaceae | 4 | 5 | 3 | 3 | 8 | 15 |
| 8 | Peltigeraceae | 1 | 1 | 0 | 0 | 0 | 0 |
| 9 | Pertusariaceae | 1 | 1 | 0 | 0 | 1 | 2 |
| 10 | Physciaceae | 1 | 1 | 1 | 2 | 1 | 1 |
| 11 | Porpidiaceae | 0 | 0 | 0 | 0 | 1 | 1 |
| 12 | Ramalinaceae | 0 | 0 | 0 | 0 | 1 | 2 |
| 13 | Rhizocarpaceae | 0 | 0 | 0 | 0 | 1 | 1 |
| 14 | Stereocaulaceae | 1 | 1 | 1 | 1 | 1 | 2 |
| 15 | Umbilicariaceae | 1 | 1 | 1 | 1 | 1 | 1 |
| | **Total** | **13** | **17** | **7** | **8** | **19** | **33** |

The higher altitude (3800-4000 m) sites exhibit poor lichen diversity than the sites at lower altitudes (3200-3500 m). Dimorphic forms (*Cladonia* spp. and *Stereocaulon* spp.) dominate the higher altitudes while leafy foliose forms dominate the lower altitudes (Text-figure 1, Table 3). The probable reason for dominance of members dimorphic lichen families Cladoniaceae and Stereocaulaceae in higher altitudes may be due their ability to tolerate acidic pH and frigid temperature together their cushion forming habitat. The sites also exhibit luxuriant growth of fruticose forms. The reasons for luxuriant growth of fruitcose lichen in the area may be due to their shrubby or pendent habit which enables

**Table 3. The most common lichen species found at the three HSP sites in Kupup (Gnathang), Sikkim.**

| S. No. | Highest Summit Point (HSP) in Kupup, Gnathang | Submit area sections (SAS) | Common lichen species found |
|---|---|---|---|
| 1. | HSP-1 | 3 m | *Cladonia coccifera* (L.) Willd, *Cladonia furcata* (Huds.) Schrad., *Stereocaulon alpinum* Laurer. |
| | | 5 m | *Cladonia coccifera* (L.) Willd, *Everniastrum cirrhatum* (Fr.) Hale, *Umbilicaria vellea* (L.) Ach. Em Frey, *Usnea sordida* Mot. |
| | | 10 m | *Bryoria asiatica* (Du Rietz) Brodo & Hawksw., *Heterodermia diademata* (Taylor) D. D. Awasthi, *Parmotrema thomsonii* (Stirt.) A. Crespo, Divakar & Elix, *Peltigera polydactylon* (Neck.) Hoffm. |
| 2. | HSP-2 | 3 m | *Candelariella aurella* (Hoffm.) Zahlbr., *Stereocaulon austroindicum* I. M. Lamb |
| | | 5 m | *Everniastrum cirrhatum* (Fr.) Hale, *Heterodermia diademata* (Taylor) D. D. Awasthi |
| | | 10 m | *Heterodermia hypoleuca* (Ach.) Trevis., *Umbilicaria vellea* (L.) Ach. Em Frey. |
| 3. | HSP-3 | 3 m | *Rhizocarpon geographicum* (L.) DC in Lam. & DC, *Stereocaulon austroindicum* I. M. Lamb, *Stereocaulon foliolosum* Nyl. |
| | | 5 m | *Cladonia coccifera* (L.) Willd, *Everniastrum cirrhatum* (Fr.) Hale, *Lecanora frimbriatula* Stirt., *Usnea longissima* Ach. |
| | | 10 m | *Lobaria retigera* (Bory.) Trevisan, *Lecanora frimbriatula* Stirt., *Parmotrema thomsonii* (Stirt.) A. Crespo, Divakar & Elix, *Ramalina roesleri* (Hochst.) Hue., *Usnea thomsonii* Stirt. |

them to utilize more light than the foliose lichens having flat habit (Gausalaa et al. 2009). Further, high surface area to volume ratio of fruticose lichens also helps them to absorb more moisture from atmosphere than flat forms (Purvis 2000).

Most of the lichens preferred bark of trees as suitable substrate in all the three HSP sites (Text-figure 2). At HSP-1 site, soil was the preferred substrate after bark over rock and mosses. Lignicolous lichens were least in both HSP-1and HSP-3 sites. The HSP-2 site is unique in having corticolous and saxicolous lichens while rock inhabiting lichens were dominant at HSP-3.

## CONCLUSION

With the increase in global mean temperature over the last few centuries, the distribution of lichen species have changed. Lichens respond to global warming by shifting to the areas with appropriate growing conditions. The alpine habitats are ideal environment to study climatic influences (Körner 2002). According to Walther et al. (2005), alpine plants facing climate change might follow three response strategies: they persist in modified climatic conditions; migrate to a habitat with more favourable conditions; or die off. Long term vegetation comparison suggested that species shift to a habitat with more favourable climatic conditions with changing climate. The present data indicates that certain lichen growth forms exhibit their restricted distribution within quadrates. Regular monitoring of these species through remote sensing will help to know about the shift of species in future in response to change in climatic conditions of the area.

The shift in distribution of lichen species as consequence of climate change poses threat to the alpine species due to habitat loss. Alpine habitats are hot spots for endemic species and their decline will result into huge loss to the biodiversity. Hence, inventories of lichen biodiversity in alpine regions should be developed. Such inventories can help to establish conservational strategies for lichens so as to maintain ecosystem dynamics and functions.

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