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RESEARCH ARTICLE

AN INVENTORY OF BIODIVERSITY OF THE ALPINE REGION OF LHONAK VALLEY IN NORTH SIKKIM, INDIA

***Anjana Pradhan, Kusum Gurung and Sanchi Subba**

Sikkim Biodiversity Conservation and Forest Management Project, Forests and Environment Department, Government of Sikkim, Gangtok, India

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ABSTRACT

Rapid Biodiversity Survey assessment was carried out along the sampling path of Lhonak Valley in the north district of Sikkim in October 2018 and a total of 102 floral species were recorded out of which, 81 species were represented by herbs and 21 species by scrubs. These species belonged to 55 genera in total (48 dicots, 4 monocots and 3 gymnosperms) and 33 families (27 dicots, 3 monocots and 3 gymnosperms). Out of the 102 species, 88 were dicots (86.3%), 11 were monocots (10.8%) and only 3 were gymnosperms (2.9%). Asteraceae was the largest family which contributed 11 species followed by Rosaceae (8 species), Gentianaceae (7 species) and Ericaceae and Caryophyllaceae (6 species each). The life-form spectra of the region shows dominance of hemicryptophytes with 43.3% followed by chamaephytes (29.9%), phanaerophytes (13.4%), therophytes (7.2%) and crypotophytic geophytes (6.1%). The high percentage of hemicryptophytes shows the indication of high altitude area and cold climate. The survey also reported the presence of 14 faunal and 21 avi-faunal species through direct and indirect evidences.

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INTRODUCTION

The diversity of plant life is the foundation for terrestrial plants and animals and the habitat in which they live. This diversity of plants together forms a vegetation type of a certain area that defines its own structural and functional aspects of an ecosystem. The diversity of plant life increases ecosystem productivity by promoting soil formation and providing nutrient storage and recycling, stabilizing climate, protecting fresh water resources, and also by providing and protecting a habitat for the wild fauna. Biodiversity assessment of such plant species of an area is important for evaluation and provides a necessary framework for planning and interpreting long-term ecological research. Alexander von Humbolt (1805) began the field studies of vegetation in the early 19th century in plant geography that dealt with the study of spatial distribution of taxa and their evolutionary relationships and has become a novel of the natural sciences (Causton, 1988; Randall, 1978). In recent years, the baseline value of vegetation has become so important that standardized classification of ecological communities using vegetation has been recognized as an essential tool for identification, monitoring and conservation of ecosystems (Grossman *et al*. 1988).

Corresponding author: **Anjana Pradhan,**
Sikkim Biodiversity Conservation and Forest Management Project, Forests and Environment Department, Government of Sikkim, Gangtok, India.

The alpine zone in the Himalaya is lined up as an archipelago on high mountains at the southern periphery of the high central Asia, separated from each other by deeply incised transverse valleys (Miehe, 1997; Tambe & Rawat, 2010). The variation in the topography and climate of the alpine zone of Sikkim Himalaya exhibits a critical repository of biodiversity harbouring great variation in the alpine vegetation of rare and endemic species, hence marking it as a biodiversity hotspot region. As stated by Körner (1999) the alpine flora of Sikkim Himalaya belonged to 60 families and 297 genera (1300 species) which contribute 60% of the total alpine plant families and 10% of all the alpine genera known worldwide (Yasmeen, 2012). The total number of vascular plant species recorded across the alpine zone in Sikkim (1400 ± 75 species) is more than double of that recorded for the European Alps, New Zealand Alps and the Rocky mountains region (600 – 650 species) as reported by Mark & Adams (1973), Hadley (1987) and Ozenda (1993). This observation shows higher speciation rates in the Himalayan alpine genera even though the region is one of the smallest in terms of geographic area with a variation in topography (Yasmeen, 2012). However, as per the literature review of Rawat (2007), the alpine zone of the Western Himalaya (WH) has diverse alpine vegetation record (1800 – 1900 species) as compared to the vegetation of the Eastern Himalaya (EH) with about 1200 species (Tambe & Rawat, 2010). This can be interpreted on the basis of the alpine zone of WH being more extensive in geographical coverage than the alpine zone of the EH.

Also, the reason being that most of the literature available on the alpine vegetation are based on the studies conducted in the WH and Nepal due to easy accessibility as compared to the EH. Hence, limited studies on the EH alpine vegetation is available (Tambe & Rawat, 2010). A number of floristic studies on the alpine regions of KNP has been done where Singh and Sundriyal (2005) reported the occurrence of 202 species of higher plants which belonged to 38 families (90% dicots, 9% monocots and 1% gymnosperms) while Maity and Maiti in 2007 reported 1580 species of vascular plants from KNP including 106 species of Pteridophytes, 11 gymnosperms and 1463 angiosperms (Tambe & Rawat, 2010). Dahal et al. (2017) recorded 151 floral species in the random sampling path of Kyongnosla Alpine Sanctuary (East Sikkim) through Rapid Biodiversity Survey (RBS). Another RBS study by Dahal et al. (2018) recorded 104 floral species belonging to 49 families under 74 genera along the sampling path of Thangu to Lashar Valley. The floristic structure of the Lhonak Valley are quite limited apart from the extensive study on the vegetation and flora of Zemu and Lhonak valley carried out by the two famous botanists, W. W. Smith and G. H. Cave from 1904 to 1911 (Smith and Cave, 1911). They recorded about 855 species of angiosperms out of which 734 species belonged to dicotyledons and 121 species belonged to monocotyledons (Dey, 2017; Smith and Cave, 1911). Very recent study on the diversity of flowering plants of Zemu and Lhonak valley by Sentu Kumar Dey has been documented with 889 species under 347 genera belonging to 89 families (Dey, 2017). Lucksom (2005) states that few new species/taxa have been described from this region. Some species have also been rediscovered after a long gap in this region. Dey and Maity (2015b) rediscovered the long lost species of *Pseudoyoungia simulatrix* (Babc.) D. Maity and Maiti in the Lhonak valley which was first collected in 1909. *Gentiana springateana* D.Maity *sp. nov*., a rare and endemic species of the region, was discovered by Maity (2014) between Kalapatthar and Muguthang (4500 – 4800m) which is supposedly close to the taxon *G. urnula* and *G. phyllocalyx*. This species was encountered in our RBS survey as well. Many species over the past decade and more, have been disappearing and sadly to the extent of extinction due to anthropogenic factors caused by activities like digging of the earth to construct roads for easy accessibility, not to forget the grazing limiting the growth of the natural species, landslides and soil erosion disrupting the regeneration of the species in the habitat.

In this paper, the floral diversity of the alpine region of Lhonak Valley in North Sikkim has been documented along the sampling path of the valley during the survey with the purpose of preparing baseline information on key biological elements in the alpine zone for long-term monitoring and evaluation of the impacts of changes in the forest and biodiversity management.

Study Area Rapid Biodiversity Survey: The study was conducted in Lhonak Valley along the sampling path from Kalapatthar – Muguthang – 20R – Zanak 2 – Lhonak. The study area covered the altitudinal gradient from 4501m to 5092m asl lying between 27°51′44.14″N – 27°57′24.3″N latitude and 88°20′54.03″E – 88°34′38.2″E longitude. A total of 29 plots were laid in the valley (covering compartments Lachen 23 – 29) of approximate area 0.29Ha (Figure 1). It falls under the jurisdiction of Thangu Block in Lachen Range of north district of Sikkim. The survey was carried out in October – November, 2018 (Annexure I).

Lhonak is exposed to the valley of Goma Chu originating from the Lhonak glacier that runs across the valley to join Zema Chu that originates from Zemu glacier (Johnson *et al*. 2006). This high altitude valley lying behind the alpine forest of the north extending above 4500m asl is a Trans-Himalayan eco-region in proximate with the Tibetan Plateau (Anonymous, 2003). Lhonak Chu and other numerous tributaries flow down towards the south-east and ultimately meet with the River Teesta. The region is accessible from Thangu via the high and treacherous Lungnak La standing at almost 5000m asl beyond which lies an unexplored Lhonak Valley extending from Muguthang to Lhonak Lake. The Lhonak Valley is one of the sparsely populated regions in the extreme part of North Sikkim and is called the home of the Herdsmen with only about seven *Dokpa* (graziers) families or the Tibetan nomads who graze yak in a rotational system governed by traditional laws (Lachungpa, 2009). The climate is extremely cold and dry characterised by alpine scrubs with scarce and scattered patches of vegetation. The wettest month witnesses heaviest rainfall in June – July while it is moderate in April and October (Dey, 2017). The Valley is a typical dry alpine forest (4501m - 5092m) characterized by dwarf scrubs of Rhododendron and Juniper. The floristic species of this alpine zone are adapted to withstand the extremes of cold and shows remarkable vegetation of endemic, rare and important medicinal plants. The terrain is typically a cold desert with high snow mountains, glaciers, lakes and vast valleys with grasses, sedges, cushionoid vegetation, lichens and associated fauna. Most of the vegetation is composed of thorny and cushion plants and xerophytes among the grasses, sedges and medicinal herbs supporting a host of fauna and avi-fauna. The Valley is an Important Bird and Biodiversity Area with IBA Site Code of IN-SK-06 and IBA Criteria of A1 (Threatened species), A2 (Endemic Bird Area-133: Tibetan Plateau) and A3 (Biome 5: Eurasian High Montane; Biome 7: Sino-Himalayan Temperate Forest) (Lachungpa, 2009).

METHODOLOGY

Vegetation Sampling and Collection of Data: Inventory and monitoring of the biodiversity of the alpine region of Lhonak Valley were done using Rapid Biodiversity Survey technique. Prior to the field visit, a base map was prepared using the Geographic Information System (GIS) in the GIS laboratory of the Department for supplementary information of the reserve forest and its adjoining areas showing drainages, rivers, roads and villages. Forest cover map was also prepared highlighting the forest types and its density. Literature review was also done to have a general idea about the biodiversity of the area, and a checklist for both flora and fauna was prepared to confirm their presence in the study area. In alpine grassland, repeated quadrats of 1m x 1m at an interval of 5 m along a 50 m line transect at each site (8 quadrats) was laid for the species present in an area. However, such transects may vary in length depending on the site feasibility. In case of alpine with shrubs/scrubs, a plot size of 5m x 5m was laid along 50m distance. Placing quadrats next to each other limits the independence of the data derived from each quadrat and placing quadrats at least 5m apart ensures independence of most data derived from nearby quadrats (Johnson *et al*. 2006). The study was conducted covering the feasible compartments by laying 29 random sampling plots as per the vegetation variation and forest type and preparing an inventory for the same (Figure 2).

Fauna: Presence and relative abundance of most of the small and large fauna species was evaluated using methods that rely on indirect evidence such as animal burrows/holes, dung, pellets, scats, feeding signs, tracks, nests, digging and antler thrashing. The birds were also inventoried along the sampling paths.

RESULTS

Vegetation composition along the sampling path: The alpine forest of the sampling path of Lhonak valley occurs in between the altitudes of 4501m – 5092m and is a typical dry alpine forest characterized by dwarf scrubs of Rhododendron and Juniper. The inner basin of the valley (4531m – 4994m) is dominated by dwarf Rhododendron scrubs of *Rhododendron anthopogon*, *R. campanulatum* subsp. *aeruginosum*, *R. nivale* and *R. setosum* found in association with shrubby species of *Berberis angulosa*, *Salix lindleyana* and *Lonicera* sp. The vegetation is practically of scattered scrubs and often barren mostly composed of stunted thorny and cushion plants, grasses, sedges and medicinal herbs supporting a host of fauna and avi-fauna. Erect and stunted scrubs of *Juniperus indica* is also widely available in the lower reaches of the valley (4511 – 4592m) in association with *Geranium polyanthes*, *G. donianum*, *Pleurospermum hookeri*, *Poa* and *Bistorta* species. Scrubs of *Cotoneaster microphyllus* and *Myricaria rosea* are seen stretching across the floor. Most of the ground is bare but patches of herbaceous species belonging to genera like *Anaphalis xylorhiza, Aster flaccidus, Cremanthodium oblongatum, Cyananthus incanus, Delphinium, Dracocephallum, Gentiana, Gentianella, Juncus himalensis, Kobresia, Koenigia islandica, Leontopodium, Oxytropis, Ranunculus, Rheum, Rhodiola, Taraxacum* and *Sedum* are irregularly distributed. *Cassiope fastigata* starts to appear only after 4760m elevation gradient growing in association with *Gentiana ornata and G*. micans. The gymnospermous *Ephedra gerardiana* is also commonly seen along the route above 4685m. *Saussurea simpsoniana*, *Rheum nobile, Saxifraga* and *Meconopsis* species are some of the herbs seen on the rocky scree slopes towards the Lake.

The valley also harbours the two rarely found high medicinal herbs of *Rheum nobile* and *Saussurea obvallata*. Commonly called Rhubarb or Sikkim Sundari (*Rheum nobile*) was first named by Joseph Hooker (Nicholis, 2013). *Saussurea obvallata*, an extremely rare plant native to the Himalayas is identified as endangered due to anthropogenic pressure by extraction of the plant. In the present study, this plant was observed only at the stretch of Kalapatthar and must be conserved for future as these plants may become extinct in that area. This plant was also recorded from Tholung – Kisong sampling path (Bharat *et al*. 2015; Pradhan & Lachungpa 2015), Kyongnosla Alpine Sanctuary (Dahal *et al*. 2018) and Tamze Valley through RBS study (Dahal *et al*. 2018). Cushion plants such as *Androsace tapete, Arenaria ciliolata, A. edgeworthiana* and *Saxifraga* species are commonly seen across the valley forming mats on the ground. While *Arenaria bryophylla* and A. *polytrichoides* are found along 4511m to 5000m on rocky stony slopes, *A. ciliolata* and A. *edgeworthiana* are largely seen across the sandy slopes along 4300m to 5092m in the valley. *Saxifraga andersonii*, S. *jacquemontiana* and S. *punctulata* are other cushion-forming herbs of the valley. The higher elevation of the alpine highlands ranging from 4554m to 5130m (along 20R to Lhonak) is a barren rocky area with plants forming dense clumps of scrubby *Salix lindleyana*, *Potentilla fruticosa* var. *arbuscula, Myricaria rosea* and *Hippophae tibetana*. *Hippophae tibetana*, a high-valued medicinal scrub is distributed along the gradient 4653m – 4761m in association with *Salix lindleyana* which was previously recorded to be associated with *Rhododendron nivale* in the valley between Kambochen and Lhonak at elevation ranging from 4600m to 4900m (Carpenter *et al*. 1994). However, the last mention of this species was recorded in Lhonak Valley by Smith and Cave (1911), Dey (2017) and in Flora of Bhutan by Grierson and Long (1911). Due to its availability only in this region so far, this species requires location survey. The plant is locally known as Tarwa whose leaves are used to make tea. The tender branches, leaves and fruits contain bioactive compounds which are used to produce oil which is used as an ointment for treating burns. The fruit has high quality medicinal uses in the treatment of cardiac disorders, radiation injury and intestinal diseases.

Floristic Structure: During the survey, a total of 102 species were recorded out of which, 81 species were represented by herbs and 21 species by scrubs (Annexure II). These species belonged to 55 genera in total (48 dicots, 4 monocots and 3 gymnosperms) and 33 families (27 dicots, 3 monocots and 3 gymnosperms) as given in Table 1. Out of the 102 species, 88 were dicots (86.3%), 11 were monocots (10.8%) and only 3 were gymnosperms (2.9%; Table 1). The prominent genera were *Arenaria*, *Gentiana, Juniperus, Kobresia, Potentilla*, *Rhododendron* (5 species each) and *Saxifraga* (4 species). The gymnosperms recorded in the area were the stunted *Juniperus indica, Ephedra gerardiana* and *Lycopodium* species which clearly indicate the occurrence of typical alpine vegetation. The most dominant families in the study area belonged to Compositae (11 species), Rosaceae (8 species), Gentianaceae (7 species), Ericaceae and Caryophyllaceae (6 species each) (Figure 3).

Life-form Spectra: According to Raunkier's life-form classification (1934), vascular plants are classified into 5 major groups namely the phanerophytes, chamaephytes, hemicryptophytes, cryptophytes (geophytes, helophytes and hydrophytes) and therophytes based on the position of the perennating buds in relation to the soil surface. In the present study, all of these five life-forms were present where hemicryptophytes (43.3%) representing the herbaceous perennial plants was the dominant life-form spectra. This was followed by chamaephytes (29.9%) representing the low-growing creeping plants or woody perennial plants and cushionoids. While phanaerophytes (13.4%), therophytes (7.2%) and cryptophytic geophytes (6.1%) also formed the life-form spectra in the study area representing the other herbaceous flora (Figure 4).

Faunal and Avi-Faunal Diversity: The present study site also recorded 14 faunal and 21 avi-faunal species some of which were directly sighted and others reported in the area. Some of the commonly encountered avi-faunal species in the complex were Warbler, Male Guldenstadt's Redstart, Female Guldenstadt's Redstart, Robin Accentor, Yellow-billed Chough, Red-billed Chough and Large-billed crow. Lhonak Valley is the only known breeding area in the Eastern Himalayas of the Black-necked Crane (Lachungpa, 2009). Mammalian fauna reported in the area are Kiang, Snow Leopard, Tibetan Wolf, Tibetan Fox, Woolly Hare, etc. Himalayan Marmots are frequently seen along the valley making huge burrows and feeding on the ground vegetation especially the grasses.

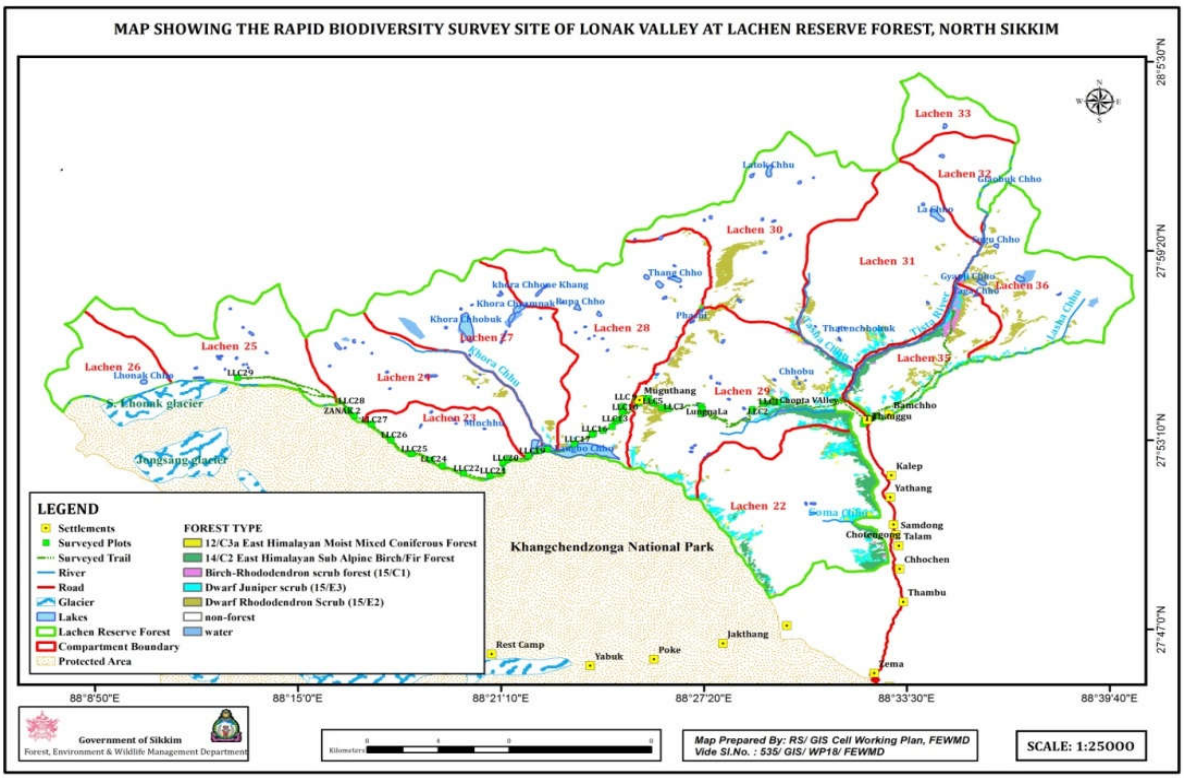

Figure 1. Map showing the survey plots along the sampling path of Lhonak Valley in North Sikkim

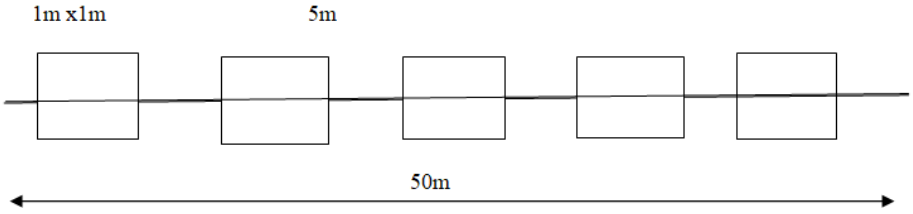

Figure 2. Repeated quadrat for alpine grassland

Table 1. Diversity of floral species recorded along the sampling path of Lhonak Valley

Plant Group	Species	%	Genera	%	Family	%
Dicotyledons	88 (20 scrubs and 68 herbs)	86.3	48	87.3	27	81.8
Monocotyledons	11 (all herbs)	10.8	4	7.3	3	9.1
Gymnosperms	3 (2 herbs and 1 scrub)	2.9	3	5.5	3	9.1
TOTAL	102	100.0	55	100.0	33	100.0

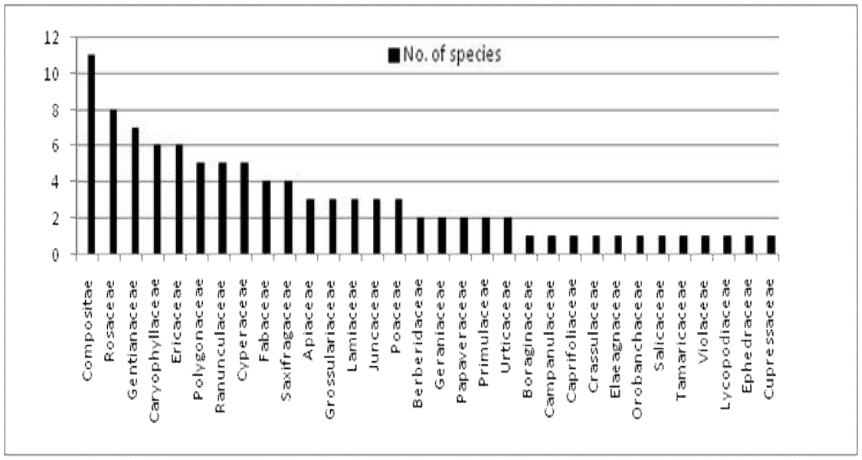

Figure 3. Major families of plant species encountered in the sampling path of alpine region of Lhonak Valley

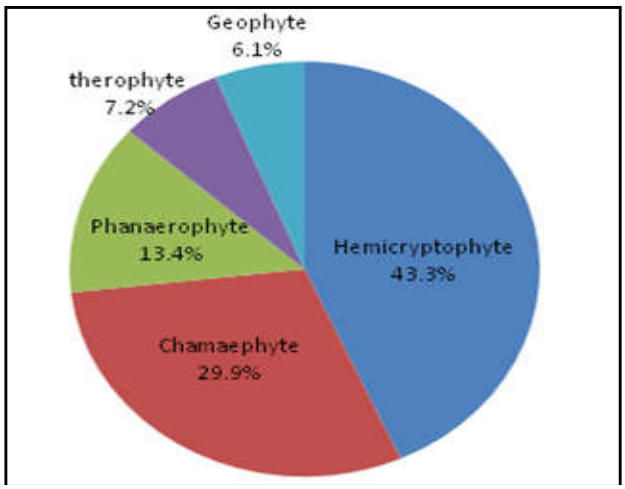

Figure 4. Life-form spectra of alpine plants of Lhonak Valley

Snow Toad, the highest altitude amphibian is reported in almost all lakes and water bodies of the Goma Chu Valley (Lachungpa, 2009). Blue Sheep (Ban bakhra) is another group of mammal seen in the valley.

DISCUSSION

The present study reveals that the surveyed area harbours 102 floral species contributing to the rich biodiversity. The presence of high herbaceous plants (81 nos.) and relatively less scrubs (21 nos.) and no tree stratum indicates the region being high altitude. As the elevation increases, the temperature decreases and the vegetation variation is observed. Out of the 102 species, 88 were dicots (86.3%), 11 were monocots (10.8%) and only 3 were gymnosperms (2.9%). Dicots were the dominant plant types with 86.3% which shows similar result from the alpine region of Khangchendzonga Biosphere Reserve (KBR) where 89.6% were dicots and 9.4% were monocots (Singh & Sundriyal, 2005). The presence of only 3 gymnosperms indicates the occurrence of typical alpine vegetation. The most dominant families in the study area belonged to Asteraceae (11 species), Rosaceae (8 species), Gentianaceae (7 species), Ericaceae and Caryophyllaceae (6 species each). The species of these families were more in number than other species belonging to other families. This also indicates that these species are better in adapting the cold environment of such high altitude.

In the present study, Raunkier's five major life-forms were present where 43.3% of hemicryptophytes representing the herbaceous perennial plants showed dominance followed by chamaephytes (29.9%) representing the low-growing creeping plants or woody perennial plants and cushionoids. The percentage of hemicryptophytes (43.3%) in the surveyed site was higher than that reported for the alpine vegetation of the KBR in Sikkim Himalaya as reported by Singh & Sundriyal (2005). This analysis is supported by various reports of Yasmeen (2012) who also stated similar observation in the alpine region of Sikkim Himalaya. The prevalence of hemicryptophytes at the highest elevations has also been reported from other mountains in Central Asia of Hindu Kush (Agakhanyantz & Breckle, 1995) and Nanga Parbat (Dickore & Nusser, 2000). The chamaephyte percentage was, however, comparatively lower (29.9%) than that recorded for the KBR with more than 50% of chamaephytic plants but much higher than the normal Raunkier's spectrum (9%) (Singh & Sundriyal, 2005). Rawat and Adhikari (2005) also reported highest life-form spectrum of hemicryptophytes (57%) followed by chamaephytes (24%) in the Tso Kar basin of Changthang Plateau. The prevalence of such high percentage of hemicryptophytes and the presence of chamaephytes in the alpine region indicates the flora of the region to be that of alpine steppe. Even though trees are absent at such high alpine region there is a presence of woody shrubs and scrubs representing phanaerophytes (13.4) across the sampling path from 4501m to 4994m asl. This report is slightly more than that reported for the KBR (12.4%; Singh & Sundriyal, 2005). The low percentage of geophytes (6.1%) in the region indicates that the presence of rhizomatous plants is less than the presence of woody and herbaceous perennials. It can be concluded that the life-form spectrum in Lhonak valley portrays alpine steppe vegetation due to the high percentage of hemicryptophytes and presence of chamaephytes, phanaerophytes, geophytes and therophytes. These life forms signify the structural diversity of the forest and its ecology.

Conclusion

The valley is found to constitute a habitat suitable for both flora and fauna of alpine steppe. The vegetation of this highland is a home to several globally threatened species as well as high value medicinal plants such as *Ephedra gerardiana*, *Rheum nobile, Saussurea abvallata, S. simpsoniana,* etc. that are naturally available in this valley. But these high altitude plants are under threat due to the natural and anthropogenic disturbances and require attention. This high altitude valley is inhabited by the Tibetan nomads, Defence personnel of Army and ITBP (Indo-Tibet Border Police). The Lhonak Lake is highly prone to landslide events which may be triggered by heavy rain, seismic activity, and fluctuating permafrost condition in moraines. This may also damage the biodiversity of the area if the disaster occurs. Hence, a constant monitoring has to be done as precaution measure to check the control of GLOF.

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Annexure I. Site characteristics of the sampling path along Lhonak Valley in North Sikkim

Site Code	Latitude (N)	Longitude (E)	Elevation (m)	Slope Aspect	Slope Angle (°)	Forest Type	Area name
LLC 1	27°53′51.13″	88°28′40.94″	4518	NW	mild	Dry alpine forest	Kalapatthar
LLC 2	27°53′37.09″	88°28′02.15″	4752	NW	mild	Dry alpine forest	Ginghanu
LLC 3	27°54′03.12″	88°27′29.27″	4994	NE	mild	Dwarf Rhododendron scrub	Below Shiv Mandir
LLC 4	27°54′22.81″	88°25′48.16″	4612	NW	mild	Dwarf Rhododendron scrub	Below Lungnak La
LLC 5	27°54′11.51″	88°24′56.91″	4556	NW	mild	Dry alpine forest	Muguthang
LLC 6	27°54′05.59″	88°24′59.84″	4550	NW	mild	Dwarf Juniper scrub	Muguthang
LLC 7	27°53′49.34″	88°25′03.59″	4545	SW	mild	Dwarf Rhododendron scrub	Muguthang
LLC 8	27°53′42.20″	88°25′01.52″	4547	SW	10%	Dwarf Rhododendron scrub	Muguthang
LLC 9	27°53′33.10″	88°24′58.13″	4531	NW	mild	Dwarf Rhododendron scrub	Muguthang
LLC 10	27°54′05.12″	88°24′51.27″	4555	N	10%	Dwarf Juniper scrub	Muguthang
LLC 11	27°53′50.06″	88°24′46.15″	4545	N	mild	Dwarf Juniper scrub	Muguthang
LLC 12	27°53′36.19″	88°24′33.87″	4553	NW	mild	Dwarf Juniper scrub	Thaplay
LLC 13	27°53′28.66″	88°24′16.37″	4511	NW	mild	Dwarf Juniper scrub	Thaplay
LLC 14	27°53′28.87″	88°23′59.04″	4592	NW	mild	Dwarf Juniper scrub	Thaplay Thang Maidan
LLC 15	27°53′02.57″	88°23′24.20″	4501	NE	mild	Dwarf Rhododendron scrub	Phukcha
LLC 16	27°52′50.64″	88°22′34.43″	4517	NE	mild	Dwarf Rhododendron scrub	Goma Chu
LLC 17	27°52′44.16″	88°22′19.35″	4529	SE	mild	Dwarf Rhododendron scrub	Dolma Sampa
LLC 18	27°52′35.13″	88°22′02.00″	4554	NE	15%	Non forest (meadow)	20R
LLC 19	27°52′14.35″	88°21′18.78″	4701	NE	10%	Non forest (meadow)	Cherup
LLC 20	27°51′44.14″	88°20′54.03″	4653	NE	mild	Non forest (meadow)	Cherup
LLC 21	27°51′59.22″	88°19′59.09″	4685	NE	15%	Non forest (meadow)	Rassam
LLC 22	27°52′12.84″	88°19′19.17″	4705	NE	mild	Non forest (meadow)	Tompeng Goma
LLC 23	27°52′20.67″	88°18′55.34″	4733	N	mild	Non forest (meadow)	
LLC 25	27°52′42.44″	88°18′09.91″	4761	N	mild	Non forest (meadow)	Thukchu
LLC 24	27°52′34.65″	88°18′22.30″	4756	N	mild	Non forest (meadow)	Zanak 2
LLC 26	27°52′32.81″	88°19′11.30″	4855	N	mild	Non forest (meadow)	
LLC 27	27°52′21.81″	88°21′12.89″	4689	N	mild	Non forest (meadow)	
LLC 28	27°52′42.93″	88°18′09.14″	4765	N	mild	Non forest (meadow)	After Zanak 2
LLC 29	27°54′50.32″	88°13′30.11″	5130	N	mild	Non forest (meadow)	Near Lhonak lake

Annexure II. Checklist of floral species recorded along the sampling path of Lhonak Valley, North Sikkim

S. No	Family	Botanical Name	Elevation Gradient	Plant Group		Life Form	Habit
1	Apiaceae	*Cortia depressa* (D.Don) C.Norman	3600--4800	Angiosperm	Dicotyledon	Chamaephyte	Herb
2	Apiaceae	*Pleurospermum hookeri* C.B.Clarke	2700--5400	Angiosperm	Dicotyledon	Hemicryptophyte	Herb
3	Apiaceae	*Pleurospermum stellatum* (D. Don) Benth. ex C.B. Clarke	ca. 4517	Angiosperm	Dicotyledon	Hemicryptophyte	Herb
4	Asteraceae	*Anaphalis contorta* (D.Don) Hook.f.	3800--5000	Angiosperm	Dicotyledon	Therophyte	Herb
5	Asteraceae	*Anaphalis xylorhiza* Sch.Bip. Ex Hook.f.	3800--5000	Angiosperm	Dicotyledon	Therophyte	Herb
6	Berberidaceae	*Berberis angulosa* Wall. ex Hook.f. & Thomson	3400--4500	Angiosperm	Dicotyledon	Phanaerophyte	Scrub
7	Berberidaceae	*Berberis mucrifolia* Ahrendt	4500--4555	Angiosperm	Dicotyledon	Phanaerophyte	Scrub
8	Boraginaceae	*Chionocharis hookeri* (C.B.Clarke) I.M.Johnst.	3500-5000	Angiosperm	Dicotyledon	Chamaephyte	Herb
9	Boraginaceae	*Onosma hookeri* C.B. Clarke	3000--4700	Angiosperm	Dicotyledon	Chamaephyte	Herb
10	Campanulaceae	*Cyananthus incanus* Hook.f. & Thomson	ca. 4550	Angiosperm	Dicotyledon	Chamaephyte	Herb
11	Caprifoliaceae	*Lonicera* sp.	4550 above	Angiosperm	Dicotyledon	Chamaephyte	Scrub
12	Caryophyllaceae	*Arenaria bryophylla* Fernald	4300--6180	Angiosperm	Dicotyledon	Chamaephyte	Herb
13	Caryophyllaceae	*Arenaria ciliolata* Edgew. & Hook.f.	4000--4600	Angiosperm	Dicotyledon	Chamaephyte	Herb
14	Caryophyllaceae	*Arenaria edgeworthiana* Majumdar	3500--5300	Angiosperm	Dicotyledon	Chamaephyte	Herb
15	Caryophyllaceae	*Arenaria polytrichoides* Edgew.	4300-5500	Angiosperm	Dicotyledon	Chamaephyte	Herb
16	Caryophyllaceae	*Arenaria* sp.	ca. 4500	Angiosperm	Dicotyledon	Chamaephyte	Herb
17	Caryophyllaceae	*Silene setisperma* Majumdar	ca. 4553	Angiosperm	Dicotyledon	Chamaephyte	Herb
18	Compositae	*Artemisia campbellii* Hook.f. & Thomson ex C.B.Clarke	3800-5200	Angiosperm	Dicotyledon	Chamaephyte	subshrub/scrub
19	Compositae	*Artemisia* sp.	ca. 4756	Angiosperm	Dicotyledon	Hemicryptophyte	Herb
20	Compositae	*Artemisia vulgaris* L.	ca. 4300	Angiosperm	Dicotyledon	Hemicryptophyte	Herb
21	Compositae	*Artemisia wallichiana*		Angiosperm	Dicotyledon	Hemicryptophyte	Herb
22	Compositae	*Aster flaccidus* Bunge	ca. 4545m	Angiosperm	Dicotyledon	Therophyte	Herb
23	Compositae	*Cremanthodium oblongatum* C.B. Clarke	3600--5000	Angiosperm	Dicotyledon	Therophyte	Herb
24	Compositae	*Leontopodium* sp.	ca. 4540 above	Angiosperm	Dicotyledon	Chamaephyte	Herb
25	Compositae	*Saussurea gossypiphora* D.Don	4300--5600	Angiosperm	Dicotyledon	Chamaephyte	Herb
26	Compositae	*Saussurea obvallata* (DC.) Edgew.	3700—4600	Angiosperm	Dicotyledon	Chamaephyte	Herb
27	Compositae	*Saussurea simpsoniana* (Fielding & Gardner) Lipsch.	3800--5600	Angiosperm	Dicotyledon	Chamaephyte	Herb
28	Compositae	*Taraxacum eriopodum* (D.Don) DC.	4531--4556m	Angiosperm	Dicotyledon	Hemicryptophyte	Herb
29	Crassulaceae	*Rhodiola* sp.	ca. 4733	Angiosperm	Dicotyledon	Chamaephyte	Herb
30	Cupressaceae	*Juniperus indica* Bertol.	3600--4800	Gymnosperm		Phanaerophyte	Scrub
31	Cyperaceae	*Kobresia duthiei* C.B .Clarke	3600--4600	Angiosperm	Monocotyledon	Hemicryptophyte	Herb
32	Cyperaceae	*Kobresia nepalensis* (Nees) Kuik	3600--4601	Angiosperm	Monocotyledon	Hemicryptophyte	Herb
33	Cyperaceae	*Kobresia pygmaea* C.B .Clarke	3100--5600	Angiosperm	Monocotyledon	Hemicryptophyte	Herb
34	Cyperaceae	*Kobresia schoenoides* (C.A.Mey.) Steud.	3800--4600	Angiosperm	Monocotyledon	Hemicryptophyte	Herb
35	Cyperaceae	*Kobresia* sp.	ca. 4600	Angiosperm	Monocotyledon	Hemicryptophyte	Herb
36	Elaeagnaceae	*Hippophae tibetana* Schltdl.	ca. 4685--4761	Angiosperm	Dicotyledon	Chamaephyte	Scrub
37	Ephedraceae	*Ephedra gerardiana* Wall. ex Stapf	4550 above	Gymnosperm		Chamaephyte	Herb
38	Ericaceae	*Cassiope fastigiata* (Wall.) D.Don	2800--4500	Angiosperm	Dicotyledon	Chamaephyte	Scrub
39	Ericaceae	*Rhododendron anthopogon* D. Don	3000--4800	Angiosperm	Dicotyledon	Phanaerophyte	Scrub
40	Ericaceae	*Rhododendron campanulatum* subsp *aeruginosum* Hook.f.	3000--4400	Angiosperm	Dicotyledon	Phanaerophyte	Scrub
41	Ericaceae	*Rhododendron lepidotum* Wall. ex G.Don	2500--5000	Angiosperm	Dicotyledon	Phanaerophyte	Scrub
42	Ericaceae	*Rhododendron nivale* Hook. f.	4500--5500	Angiosperm	Dicotyledon	Phanaerophyte	Scrub
43	Ericaceae	*Rhododendron setosum* D. Don	3600--4800	Angiosperm	Dicotyledon	Phanaerophyte	Scrub
44	Fabaceae	*Astragalus* sp.	ca. 4500 above	Angiosperm	Dicotyledon	Chamaephyte	Herb
45	Fabaceae	*Oxytropis* sp.	4550m above	Angiosperm	Dicotyledon	Hemicryptophyte	Herb

Continue ……..

46	Fabaceae	*Oxytropis tatarica* Baker	4500 above	Angiosperm	Dicotyledon	Hemicryptophyte	Herb
47	Fumariaceae	*Corydalis* sp.	ca. 4800	Angiosperm	Dicotyledon	Chamaephyte	Herb
48	Gentianaceae	*Gentiana carinata* (D.Don) Griseb.	3000--4300	Angiosperm	Dicotyledon	Chamaephyte	Herb
49	Gentianaceae	*Gentiana micans* C.B.Clarke	ca. 4500	Angiosperm	Dicotyledon	Chamaephyte	Herb
50	Gentianaceae	*Gentiana ornata* (D.Don) Wall. ex Griseb.	3400--5500	Angiosperm	Dicotyledon	Chamaephyte	Herb
51	Gentianaceae	*Gentiana robusta* King ex Hook.f.	ca. 4592	Angiosperm	Dicotyledon	Chamaephyte	Herb
52	Gentianaceae	*Gentiana springateana* D.Maity *sp. nov.*	4500-4800	Angiosperm	Dicotyledon	Chamaephyte	Herb
53	Gentianaceae	*Gentiana tubiflora* (G.Don) Griseb.	4545	Angiosperm	Dicotyledon	Chamaephyte	Herb
54	Gentianaceae	*Gentianella* sp.	ca. 4500	Angiosperm	Dicotyledon	Chamaephyte	Herb
55	Geraniaceae	*Geranium donianum* Sweet	ca. 4994m	Angiosperm	Dicotyledon	Therophyte	Herb
56	Geraniaceae	*Geranium polyanthes* Edgew. & Hook.f.	ca. 4994m	Angiosperm	Dicotyledon	Therophyte	Herb
57	Grossulariaceae	*Ribes himalense* Royle ex Decne.	1500--4200	Angiosperm	Dicotyledon	Phanaerophyte	Scrub
58	Grossulariaceae	*Ribes orientale* Desf.	4550	Angiosperm	Dicotyledon	Phanaerophyte	Scrub
59	Grossulariaceae	*Ribes takare* D. Don	ca. 4553	Angiosperm	Dicotyledon	Phanaerophyte	Scrub
60	Juncaceae	*Juncus himalensis* Klotzsch	3000--5000	Angiosperm	Monocotyledon	Hemicryptophyte	Herb
61	Juncaceae	*Juncus* sp.	4500	Angiosperm	Monocotyledon	Hemicryptophyte	Herb
62	Lamiaceae	*Dracocephalum heterophyllum* Benth.	3000--5000	Angiosperm	Dicotyledon	Therophyte	Herb
63	Lamiaceae	*Elsholtzia* sp.	ca. 4556	Angiosperm	Dicotyledon	Hemicryptophyte	Herb
64	Lamiaceae	*Phlomoides rotata* (Benth. ex Hook.f.) Mathiesen	3800--6102	Angiosperm	Dicotyledon	Chamaephyte	Herb
65	Leguminosae	*Thermopsis barbata* Benth.	2700 -4500	Angiosperm	Dicotyledon	Hemicryptophyte	Herb
66	Liliaceae	*Aletris pauciflora (Klotzsch) Hand.--Mazz.*	3000--4300	Angiosperm	Monocotyledon	Hemicryptophyte	Herb
67	Lycopodiaceae	*Lycopodium* sp.	ca. 4592	Gymnosperm		Hemicryptophyte	Herb
68	Papaveraceae	*Meconopsis bella* Prain	3600--5400	Angiosperm	Dicotyledon	Chamaephyte	Herb
69	Papaveraceae	*Meconopsis* sp.	3600--5400	Angiosperm	Dicotyledon	Chamaephyte	Herb
70	Poaceae	*Eragrostis* sp.	4500	Angiosperm	Monocotyledon	Hemicryptophyte	Herb
71	Poaceae	*Poa* sp.	4500	Angiosperm	Monocotyledon	Hemicryptophyte	Herb
72	Polygonaceae	*Bistorta affinis* (D.Don) Greene	4000--4900	Angiosperm	Dicotyledon	Hemicryptophyte	Herb
73	Polygonaceae	*Koenigia islandica* L.	2000--4900	Angiosperm	Dicotyledon	Hemicryptophyte	Herb
74	Polygonaceae	*Oxyria digyna* (L.) Hill	2400--5000	Angiosperm	Dicotyledon	Chamaephyte	Herb
75	Polygonaceae	*Persicaria vivipara* (L.) Ronse Decr.	3300--5501	Angiosperm	Dicotyledon	Hemicryptophyte	Herb
76	Polygonaceae	*Rheum nobile* Hook. f. & Thoms.	3600--4500	Angiosperm	Dicotyledon	Geophyte	Herb
77	Polygonaceae	*Rheum spiciforme* Royle	ca. 4701	Angiosperm	Dicotyledon	Geophyte	Herb
78	Primulaceae	*Androsace selago* Hook. f. & Thomson ex Klatt	3600--5000	Angiosperm	Dicotyledon	Chamaephyte	Herb
79	Primulaceae	*Androsace tapete* Maxim.	3800-5500	Angiosperm	Dicotyledon	Chamaephyte	Herb
80	Ranunculaceae	*Delphinium caeruleum* Jacquem. ex Cambess.	ca. 4556	Angiosperm	Dicotyledon	Hemicryptophyte	Herb
81	Ranunculaceae	*Delphinium nepalense* Kitam. & Tamura	4685	Angiosperm	Dicotyledon	Hemicryptophyte	Herb
82	Ranunculaceae	*Ranunculus hirtellus* Royle.	2800--5500	Angiosperm	Dicotyledon	Chamaephyte	Herb
83	Ranunculaceae	*Ranunculus membranaceus* Royle	2700--5000	Angiosperm	Dicotyledon	Chamaephyte	Herb
84	Ranunculaceae	*Ranunculus* sp.	4556m	Angiosperm	Dicotyledon	Chamaephyte	Herb
85	Rosaceae	*Acomastylis elata* var. *elata* Wall. ex G.Don	3500--5400	Angiosperm	Dicotyledon	Geophyte	Herb
86	Rosaceae	*Cotoneaster microphyllus* Wall. ex Lindl.	2000--5400	Angiosperm	Dicotyledon	Hemicryptophyte	Scrub
87	Rosaceae	*Fragaria nubicola* (Lindl. ex Hook.f.) Lacaita	1800--3800	Angiosperm	Dicotyledon	Hemicryptophyte	Herb
88	Rosaceae	*Geum elatum* Wall.	3500--5400	Angiosperm	Dicotyledon	Chamaephyte	Herb
89	Rosaceae	*Potentila arbuscula* D.Don	2500--5500	Angiosperm	Dicotyledon	Phanaerophyte	Scrub
90	Rosaceae	*Potentilla argyrophylla* Wall. ex Lehm.	3700--4000	Angiosperm	Dicotyledon	Phanaerophyte	Herb

91	Rosaceae	*Potentilla fruticosa* var. *arbuscula*	2400--5500	Angiosperm	Dicotyledon	Phanaerophyte	Scrub
92	Rosaceae	*Potentilla peduncularis* D.Don	3000--4500	Angiosperm	Dicotyledon	Hemicryptophyte	Herb
93	Salicaceae	*Salix lindleyana* Wall. ex Andersson	above 4000m	Angiosperm	Dicotyledon	Phanaerophyte	Shrub
94	Saxifragaceae	*Saxifraga andersonii* Engl.	4100-4700	Angiosperm	Dicotyledon	Chamaephyte	Herb
95	Saxifragaceae	*Saxifraga jacquemontiana* Decne.	4000-5200	Angiosperm	Dicotyledon	Chamaephyte	Herb
96	Saxifragaceae	*Saxifraga punctulata* Engl.	ca. 4765	Angiosperm	Dicotyledon	Chamaephyte	Herb
97	Saxifragaceae	*Saxifraga* sp.		Angiosperm	Dicotyledon	Chamaephyte	Herb
98	Scrophulariaceae	*Pedicularis megalantha* D.Don	2300--4300	Angiosperm	Dicotyledon	Chamaephyte	Herb
99	Tamaricaceae	*Myricaria rosea* W.W. Sm.	3000--4500	Angiosperm	Dicotyledon	Chamaephyte	Scrub
100	Urticaceae	*Urtica dioica* L.	4556	Angiosperm	Dicotyledon	Cryptophyte	Herb
101	Urticaceae	*Urtica hyperborea* Jacquem. ex Wedd.	3000--6000	Angiosperm	Dicotyledon	Cryptophyte	Herb
102	Violaceae	*Viola biflora* L.	2500--4301	Angiosperm	Dicotyledon	Hemicryptophyte	Herb

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