Tropical Plant Research
An International Journal
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ISSN (E): 2349 – 1183
ISSN (P): 2349 – 9265
3(2): 396–407, 2016

Research article

Species richness and diversity along the altitudinal gradient in Tungnath, the Himalayan benchmark site of HIMADRI

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Abstract: Alpine ecosystems are likely to show the effects of climate change earlier and more clearly than other ecosystems. The main purpose of the recently launched research initiative, HIMADRI (Himalayan Alpine Dynamics Research Initiative) is the long term monitoring of the ecologically sensitive parameters at benchmark sites selected in various regions of Indian Himalayan Region. The aim of the present study was characterization of one of the HIMADRI benchmark sites (Tungnath, Western Himalaya) and to provide a baseline data about the species richness and diversity along the altitudinal gradient for long monitoring. Four sites were selected along an altitudinal gradient (3200–3600 m asl). A total of 52 plant species belonging to 40 genera and 21 families were reported from the study area during the different seasons of year. Species richness showed a non-significant positive correlation (r=0.53) with altitude but diversity showed a slightly negative correlation (r=-0.05) with it. The reinvestigation of these sites in future (*e.g.* after a decade or more) will help in understanding the effect of climate change in IHR in terms of changes in species composition and diversity or in terms of species shifts from one vegetation zone or/and ecotone to another.

Keywords: Alpine ecosystems - Climate change - Species migration - HIMADRI.

[Cite as: Malik ZA & Nautiyal MC (2016) Species richness and diversity along the altitudinal gradient in Tungnath, the Himalayan benchmark site of HIMADRI. *Tropical Plant Research* 3(2): 396–407]

INTRODUCTION

Altitude and climate are the two main factors that determine the prominent vegetation zones of the mountains that are the most remarkable land forms on earth surface (Malik 2014). The area of mountains where closed canopy forests end and give way to open vegetation is known as the alpine treeline ecotone. 'Alpine' is commonly used in a broad sense for the treeless areas above a low-temperature determined treeline in the high reaches of mountains. The alpines are characterized by scanty rainfall, high wind velocity, low temperature, high intensity of ultraviolet (UV) radiation, blizzards and snow storms (Nautiyal *et al.* 2004). The plants of this zone show some adaptations to these conditions and are generally dwarfed, stunted, woolly or spiny, and develop a mosaic patch of different forms (Walker *et al.* 1994). They possess an early growth initiation with a short vegetative span ranging from several days to a few months (Bowman & Damm 2002). The community as a whole usually exhibits seasonal fluctuations and its structure and composition are strongly influenced by the extent to which periodic phenomena in the individuals are adjusted to each other (Kershaw 1973).

The distribution of plant species within alpine areas is often regulated by climate or climate-influenced ecological factors. Therefore they are considered particularly sensitive to the influence of predicted climatic change (Pauli *et al*. 2007). As a result, alpine ecosystems are likely to show the effects of climate change earlier and more clearly than some other ecosystems (Grabherr 2000). Therefore, long term monitoring programs such as the Global Observation Research Initiative in Alpine Environments (GLORIA) have been established worldwide in different continents (www.gloria.ac.at). This program involves recording information about composition of vascular species and soil temperatures according to a common protocol. This protocol can be

Received: 08 April 2016 Published online: 31 August 2016

used anywhere to examine patterns in species richness and diversity on the mountain peaks along altitudinal gradients and for different aspects (Pauli *et al*. 2004).

Biological diversity includes the richness and evenness (relative abundance) of species amongst and within living organisms and ecological complexes (Polyakov *et al*. 2008). Knowing the species diversity patterns and the vegetation as a whole is fundamental for conservation of natural areas. Species richness and diversity are the simple and easily interpretable indicators of biological diversity. These are ecologically sensitive parameters. The number of species in a particular plant community varies markedly along the altitudinal range of its growth, which depends on a set of complex factors that characterize the habitat of individual species (Malik *et al*. 2014). Slobodkin & Sanders (1969) opine that community is a function of severity, variability and predictability of the environment in which it develops. Therefore, diversity tends to increase as the environment becomes more favourable and more predictable (Putman 1994).The factors such as soil nutrient content, slope, aspect and altitude have been shown to exert an important control on species richness and diversity on a great variety of ecosystems (Kharakwal *et al*. 2005).

The Indian Himalayan Region (IHR) occupies a special place in the mountain ecosystems of the world. Himalayas, world's youngest mountains with diverse vegetation are important locations for research into ecology and biodiversity conservation (Pei 2001). But remoteness, difficult terrain, lack of resources and poor infrastructure are some inherent difficulties that hamper the extent and quality of research in the region (Negi *et al*. 2014). Thus there is a need for urgent attention from all concerned. Keeping in view all the aforesaid facts, recently a multi-site research initiative, HIMADRI (Himalayan Alpine Dynamics Research Initiative) has been launched that works on the protocol of GLORIA. This program, like GLORIA, involves recording information about composition of vascular species and soil temperatures in the alpine regions of IHR. The aim of the present study is to characterize the HIMADRI benchmark site (Tungnath) of Uttarakhand state of IHR on the basis of species richness and diversity of plants along an altitudinal gradient.

MATERIALS AND METHODS

a) Study Area

The study area is being carried out in Tungnath area (N 30°29'–30°30' and E 79°12'–79°13') of Western Himalaya, India. Tungnath forms a part of Kedarnath Wildlife Sanctuary (Fig. 1). It lies in the upper catchment of the Alaknanda and the Mandakini Rivers, two major tributaries of the Ganges.

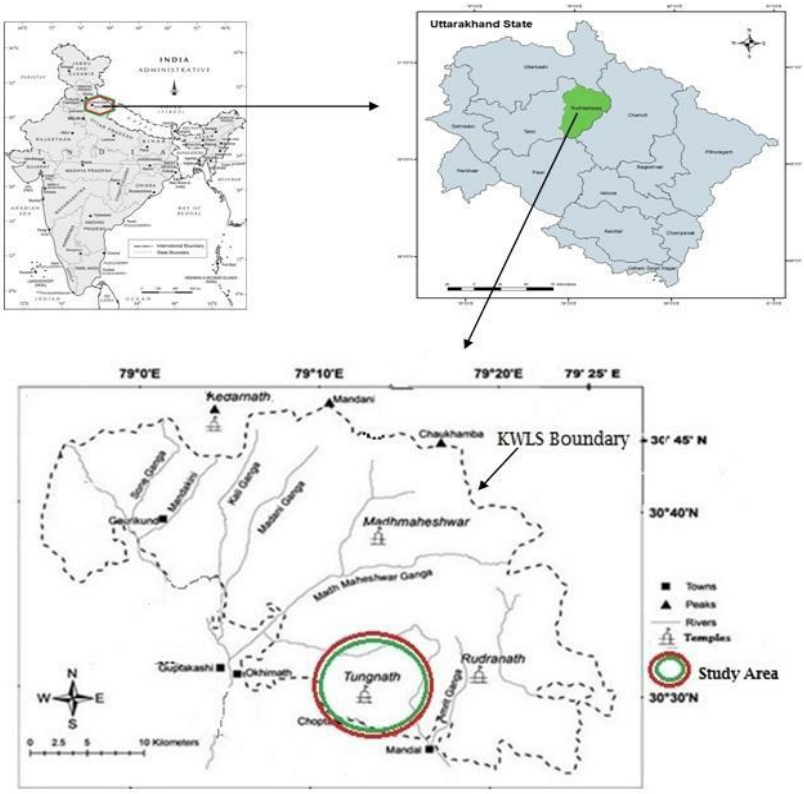

Figure 1. Map showing the location of study area (Tungnath).

Geology, soil and climate

The rocks around Tungnath are mainly mylonitized gneisses, augen gneisses, schists and granites constituting munsiari formation (Agarwala 1973). The weathering bedrocks, that provide the bulk of the loose material in these mountains, are crystalline and metamorphic; with sedimentary deposits of Paleozoic age (Gupta 1964). The soil texture is sandy loam, light grey to brown in colour and acidic in nature with a pH range between 4 and 5 (Rai *et al*. 2012a). Meadows with deep soil cover are seen in northern aspects, while the southern faces generally have large rock spurs and crevices and are either barren or have a few lithophytes. Four distinct seasons are observed in the study area *viz.*, short summer (May–June), Monsoon (July–mid September) and autumn (mid-September–October) and long winter (November–April). The snow cover lasts for about 4–5 months and melts during April–May that marks the arrival of favourable conditions for plant growth. The growth period lasts for about 5–7 months only. Mean Annual temperature at the timberline ecotone (3300 m) ranged between -8.91 (January) and +25.6°C (May) with an average of 6.65±0.68°C. Mean temperature of the warmest month was 12.56±1.23°C, in July (Fig. 2). Annual precipitation was 2410.5±432.2 mm, of which 89.5%, recorded during June–September (Adhikari *et al*. 2011).

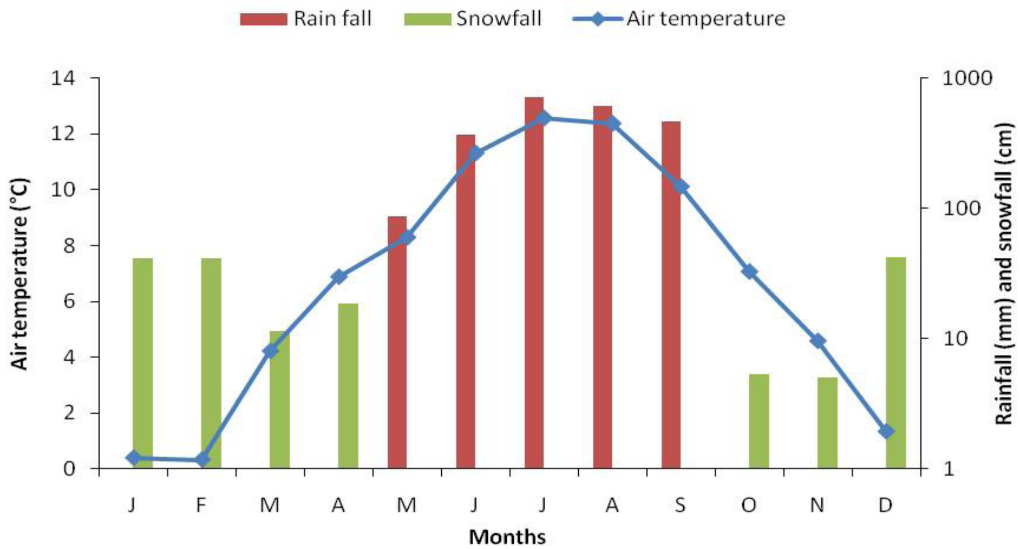

Figure 2. Mean air temperature, rainfall and snowfall at timberline ecotone in the study area during 2008-2010 (Courtesy: Rai*et al*. 2012a).

Forest types and vegetation

According to Champion and Seth's (1968) classification the study area falls in sub-alpine forest and alpine scrubs. The description of the vegetation types of the area is as under:

Sub-alpine forest: The sub alpine forest is formed by *Abies* spp., *Betula utilis*, *Quercus semecarpifolia*, *Acer* spp., *Sorbus* sp. etc. Shrub layer is represented by *Rhododendron campanulatum*, *R. barbatum*, *Viburnum* spp., *Rosa sericea*, *Rubus niveus*, *Salix* sp. etc. Herb layer is represented *Trachydium roylei*, *Rumex nepalensis*, *Persicaria wallichii*, *Thamnocalamus spathiflorus* etc.

Timberline ecotone: Timberline in the study area ranges between 3250–3350 m which is formed by *Betula utilis* and *Abies spectabilis* in the north to north-west facing slopes, while south to south west facing slopes dominated by *Q. semecarpifolia* and *R. arboreum* (Rai *et al.* 2012b). In the steep rocky slopes timberline is dominated by climatically modified dwarf and stunted individuals of *R. arboreum*, which grow very slowly in harsh climatic conditions. Other major shrub species in this zone are *Lonicera* spp., *Rubus niveus*, *Salix denticulata*, *Rosa sericea*, *Berberis jaeschkeana* and *Viburnum grandiflorum*, while in drier slopes and rocky outcrops *Cotoneaster microphylla* and *Juniperus indica*. *Cypripedium elegans*, *C. cordigerum*, *Neottia pinetorum* and *Platanthera leptocaulon* are some rare orchid taxa of the area which are mainly recorded at timberline zone (Rai *et al*. 2012b). Beyond timberline ecotone other two species of *Rhododendron viz.*, *R. anthopogon* and *R. lepidotum* form the community and provide micro-habitat to several other herbaceous species.

Krummholz layer: The '*krummholz*' layer under the tree canopy is formed by *Rhododendron campanulatum*, a dominant shrub species of this region.

Alpine meadow and scrubs: The ground layer vegetation consists of cushionoid herb, grasses and sedges. The herbaceous flora is represented by *Ascomastylis elata*, *Anaphalis* spp., *Anemone* spp., *Bistorta* spp., *Carex inanis, Danthonia cachemyriana, Gaultheris trichophylla, Trachydium roylei, Sibbaldia cuneata, Tanacetum longifolium*etc.

b) *Methodology*

For the present study, four sites were selected along an altitudinal gradient (3200–3600 m asl). The details of the selected sites are given in the table 1. Field expeditions were made to the selected sites during June, August and October months of 2014 for vegetation analysis. At each altitudinal zone, a 3m × 3m quadrat cluster was marked permanently during the first visit in the month of June 2014. Each quadrat cluster consists of nine 1m × 1m quadrats. Vegetation analysis was carried out thrice during 2014 in the four corner quadrats to study the variation of species richness and diversity throughout the year.

Table 1. Characteristics of the study area.

Site Code	Altitude (m)	Vegetation Zone/Ecotone	Geographic co-ordinates
TUN 1a	3236	Sub-Alpine	N 30° 29.723'; E 079° 12.970'
TUN 1	3330	Timberline-Alpine Ecotone	N 30° 29.600'; E 079° 12.985'
TUN 2a	3455	Ecotone between tree line and alpine zone	N 30° 29.449'; E 079° 13.173'
TUN 2	3555	Upper Alpine Zone	N 30° 29.350' ; E 079°13.242'

Species Richness was simply taken as a count of total number of species in a particular vegetation zone. The index of diversity was calculated after Shannon & Wiener (1949). If pi is the proportion of individuals (from the sample total) of species *i.e.* then diversity (H’) is,

$$H' = -\sum_{i=1}^{s} (pi)(\ln pi)$$

Simpson’s Index (D) was calculated following Simpson (1949). It measures the probability that two individuals randomly selected from a sample will belong to the same species.

$$D = \sum_{i=1}^{s} P_i^{\,2}$$

Simpson’s diversity index (SDI) was calculated by using following formula (Simpson 1949):

SDI=1-D

Where, D is the Simpson’s index. SDI represents the probability that two individuals randomly selected from a sample will belong to different species. Its value ranges between 0 and 1.

Equitability (Ep) or Evenness Index was calculated following Pielou (1975):

$$Ep = \frac{\overline{H}}{\overline{H}\max}$$

Where, $\overline{H}$ = Shannon-Wiener Diversity Index; $\overline{H}\max = \ln S$; lnS = natural log of S.

Beta Diversity (β-Div) was calculated as per following formula given by Whittaker (1972):

$$\beta - \mathrm{Div} = \frac{Sc}{S}$$

Where, β-Div = Beta Diversity; Sc is the total number of species occurring in a set of samples counting each species only once whether or not it occur more than once and S is the average number of species per individual sample.

Sorenson Similarity Index (I_S) of similarity (in percentage) between forest sites was calculated following Sorenson (1948):

$$I_S = \frac{2C}{A + B} \times 100$$

Where, I_S= Sorenson Index of Similarity; C= Species common to both comparable sites; A= Total number of species in site A; B= Total number of species in site B.

RESULTS

A total of 52 plant species belonging to 40 genera and 21 families were reported from the study area during the whole year (Table 2). Rosaceae with highest number of species (8) emerged as the dominant family, followed by Asteraceae (7), Rananculaceae (5), and so on (Fig. 3). About 48% of the families were represented by a single species.

Table 2. Occurrence of species during different seasons of the year. (+ is presence and – is absence)

Species	Jun	Aug	Oct	Species	Jun	Aug	Oct
Ascomastylis elata	+	+	+	*Polygonatum verticillatum*	-	+	+
Anaphalis cuneifolia	-	+	+	*Polygonum vaccinifolium*	-	+	-
Anaphalis royleana	+	+	+	*Potentella atrosanguinea*	+	-	-
Anemone obustiloba	+	-	-	*Potentella microphylla*	+	+	+
Anemone rivularis	+	-	-	*Potentella polyphylla*	+	+	+
Bistorta amplexicaulis	+	+	+	*Potentilla leuconata*	+	-	-
Bistorta macrophylla	+	+	+	*Polygonatum vaccinifolium*	_	+	+
Bupleurum longicaule	-	+	+	*Primula denticula*	+	+	+
Carex inanis	+	+	+	*Rananculus hirtulus*	+	-	-
Clematis montana	+	+	+	*Rhododendron anthopogon*	+	+	+
Cyananthus lobatus	-	+	-	*Rhododendron campanulatum*	+	+	+
Danthonia cachemyriana	+	+	+	*Rubus niveus*	+	+	+
Euphraisa himailica	-	+	-	*Salix lindleyana*	-	+	-
Gaultheria trichophylla	+	+	+	*Salvia hians*	-	+	-
Gentiana pedicillata	+	-	-	*Saussurea taraxacifolia*	+	+	+
Geranium wallichianum	+	+	+	*Senecio graciliflorus*	-	+	-
Goodyera fusca	-	+	-	*Sibbaldia cuneata*	+	+	+
Goodyera repens	+	+	+	*Smilacina purpurea*	+	+	-
Jurinea macrocephala	-	+	+	*Stachys melissifolia*	-	+	-
Myriactis javanica	-	+	-	*Swertia ciliate*	-	+	+
Oxygraphis polypetalla	+	+	+	*Swertia speciosa*	+	+	+
Parnassia laxmannii	-	+	-	*Tanacetum longifolium*	+	+	+
Parnassia nubicola	-	+	+	*Taraxacum officinale*	-	+	+
Parochaetus communis	+	+	+	*Trachydium roylei*	+	+	+
Pedicularis pectinata	+	+	-	*Viola biflora*	+	+	-
Plantago brachyphylla	+	+	+	*Viola canescens*	+	+	-

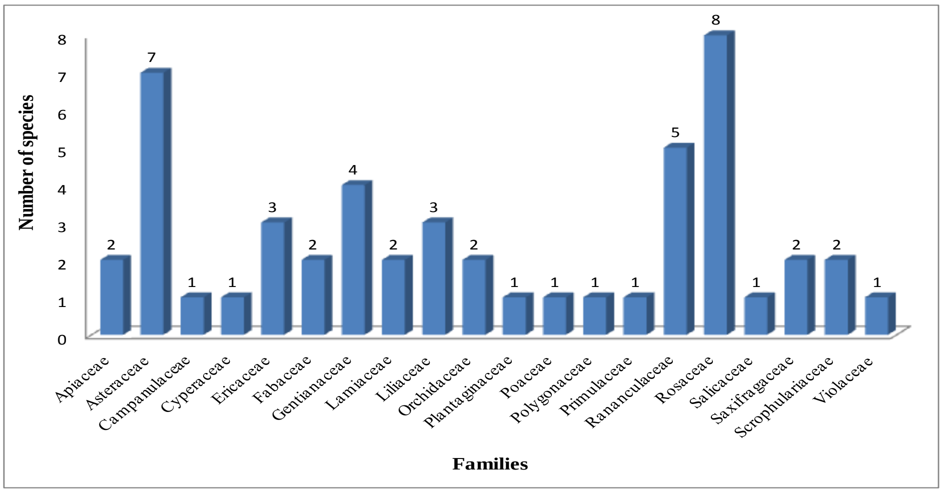

Figure 3. Number of species in different plant families of the study area.

Species richness and diversity patterns

The number of species (SR) and diversity varied during different seasons of the year (Table 3). A total of 52 plant species were reported in the study area during different visits. Maximum species (46) were reported in the month of August, followed by 34 in June and 32 in October (Table 2). In the month of June maximum number of species (21) were reported from TUN 2a (ecotone between tree line and alpine zone, 3455 m asl) while minimum species richness (18) was reported from TUN 1a (sub-alpine zone, 3236 m asl). During the month of August, the SR varied from 21 (TUN 2a, 3455 m asl) to 24 (TUN 2, 3555 m asl), while during the month of

October, SR varied from 12 (TUN 1a, 3236 m asl) to 21 (TUN 1, 3330 m asl). During all these seasons, the SR did not follow any definite trend along the altitudinal gradient. SR first increased from lower altitude (sub alpine) to mid altitude and then decreased (Fig. 4).

Table 3. Variation of ecological attributes in the study area during different seasons

		June				August				October			
Site	**Altitude**	**H'**	***J'**	**SID**	**β-Div**	**H'**	**J'**	**SID**	**β-Div**	**H'**	**J'**	**SID**	**β-Div**
TUN 1a	3236 m	1.09	0.37	0.27	0.59	2.63	0.85	0.65	0.67	1.23	0.49	0.38	0.66
TUN 1	3330 m	2.80	0.90	0.89	0.73	2.51	0.77	0.87	0.74	2.55	0.83	0.86	0.72
TUN 2a	3453 m	2.02	0.66	0.69	0.73	2.09	0.67	0.78	0.88	1.96	0.69	0.61	0.86
TUN 2	3475 m	1.77	0.59	0.67	0.80	1.89	0.59	0.62	0.66	1.45	0.50	0.74	0.77
	Average	**1.92**	**0.63**	**0.63**	**0.71**	**2.28**	**0.72**	**0.73**	**0.74**	**1.79**	**0.62**	**0.64**	**0.75**

Note: *J'= Species evenness, SDI= Simpson's Diversity Index, β-Div= Beta Diversity.

Table 4. Diversity and dominance of plant species in TUN 1a during different seasons.

Species	**June, 2014**		**August, 2014**		**October, 2014**	
	***H'**	***SI**	**H'**	**SI**	**H'**	**SI**
Anemone rivularis	-0.023	0.000	-0.076	0.0003	-	-
Bistorta amplexicaulis	-0.048	0.0002	-0.171	0.006	-0.105	0.002
Bistorta macrophylla	-	-	-0.125	0.001	-	-
Clematis montana	-0.111	0.001	-0.075	0.0008	-	-
Danthonia cahemyriana	-0.060	0.0002	-0.088	0.001	-0.110	0.005
Geranium wallichianum	-0.051	0.0001	-0.117	0.002	-0.146	0.002
Goodyera repens	-	-	-0.074	0.0003	-0.036	0.0001
Myriactis javanica	-	-	-0.185	0.004	-	-
Parochaetus communis	-0.025	0.000	-0.056	0.0002	-	-
Polygonum vaccinifolium	-0.032	0.0001	-0.087	0.0016	-	-
Potentella atrosanguinea	-0.079	0.0004	-0.274	0.019	-0.097	0.0007
Potentella polyphylla	-0.050	0.0001	-0.127	0.005	-0.157	0.021
Potentilla leuconata	-0.028	0.000	-0.088	0.0006	-0.042	0.000
Primula denticulata	-0.025	0.000	-0.088	0.001	-0.052	0.0003
R. campanulatum	-0.137	0.720	-0.253	0.311	-0.179	0.596
Rubus niveus	-0.064	0.0005	-0.132	0.003	-0.111	0.001
Salvia hians	-	-	-	-	-0.036	0.000
Senecio graciliflorus	-	-	-0.160	0.003	-	-
Smilacina purpurea	-0.085	0.0005	-0.044	0.0002	-	-
Stachys melissifolia	-	-	-0.031	0.000	-	-
Swertia speciosa	-0.158	0.011	-0.190	0.018	-0.158	0.005
Viola biflora	-0.021	0.000	-0.086	0.003	-	-
Viola canescens	-0.045	0.0001	-0.097	0.0013	-	-

Note: *H= Shannon Wiener's Diversity, SI= Simpsons Index.

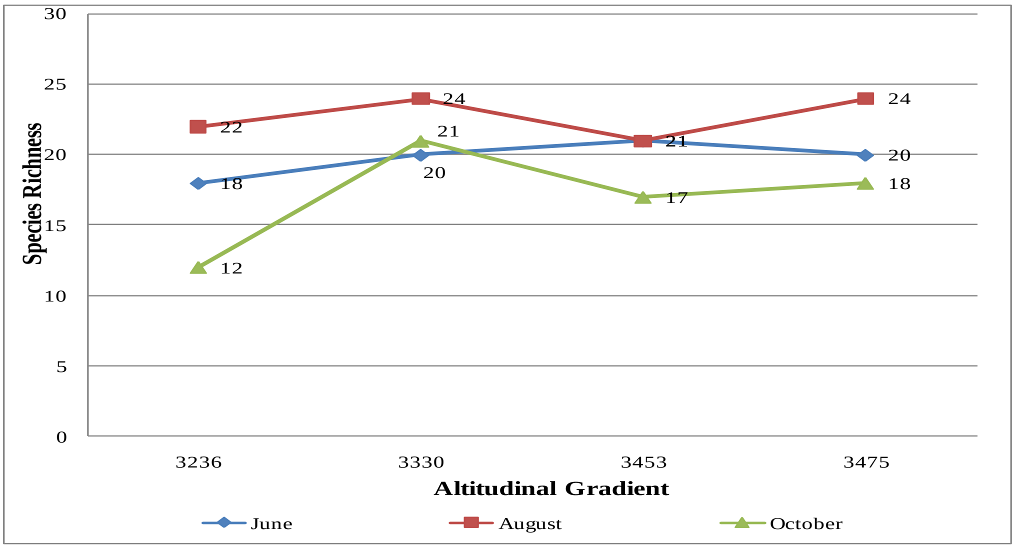

Figure 4. SR variation along the altitudinal gradient during different seasons.

Table 5. Diversity and dominance of plant species in TUN 1 during different seasons.

Plant species	June, 2014		August, 2014		October, 2014	
	H'	SI*	H'	SI	H'	SI
Acomastylis elata	-0.223	0.010	-0.214	0.008	-0.208	0.008
Anaphalis cuneifolia	-	-	-0.011	0.000	-0.026	0.000
Anaphalis royleana	-0.084	0.0006	-0.066	0.0004	-0.087	0.0008
Anemone obustiloba	-0.002	0.000	-	-	-	-
Anemone rivularis	-0.017	0.000	-	-	-	-
Bistorta macrophylla	-0.241	0.012	-0.077	0.0005	-0.019	0.000
Bupleurum longicaule	-	-	-0.013	0.000	-0.012	0.000
Carex inanis	-0.133	0.002	-0.134	0.002	-0.151	0.002
Danthonia cachemyriana	-0.176	0.004	-0.193	0.006	-0.185	0.005
Gaultheria trichophylla	-0.197	0.007	-0.189	0.005	-0.213	0.01
Gentiana pedicillata	-0.0002	0.000	-	-	-	-
Geranium wallichianum	-	-	-0.006	0.000	-	-
Goodyera repens	-	-	-0.006	0.000	-0.016	0.000
Oxygraphis polypetalla	-0.142	0.002	-0.237	0.014	-0.203	0.008
Parnassia nubicola	-	-	-0.004	0.000	-	-
Pedicularis pectinata	-0.07	0.0006	-0.018	0.000	-	-
Plantago brachyphylla	-0.243	0.013	-0.285	0.026	-0.238	0.012
Polygonum vaccinifolium	-0.017	0.000	-0.011	0.000	-0.07	0.0006
Potentella polyphylla	-0.09	0.001	-	-	-0.105	0.001
Potentilla atrosanguinea	-0.08	0.001	-0.016	0.000	-0.031	0.000
Potentilla microphylla	-	-	-0.007	0.000	-	-
Potentilla polyphylla	-	-	-0.111	0.0015	-	-
Primula denticulata	-0.017	0.000	-0.017	0.000	-0.036	0.000
Rhododendron campanulatum	-0.289	0.024	-0.312	0.034	-0.258	0.015
Saussurea taraxacifolia	-0.058	0.0004	-0.013	0.000	-0.022	0.000
Sibbaldia cuneata	-0.239	0.014	-0.258	0.023	-0.232	0.013
Swertia ciliata	-	-	-0.0002	0.000	-0.008	0.000
Taraxacum officinale	-0.165	0.003	-	-	-0.095	0.0007
Trachydium roylei	-0.273	0.029	-0.298	0.033	-0.329	0.073
Viola biflora	-0.032	0.000	-0.012	0.000	-	-

Note: *H= Shannon Wiener's Diversity, SI= Simpsons Index.

TUN 1a (Sub-alpine Zone): SR ranged from 12 (October) to 22 (August). Shannon-Wiener's diversity index (H') varied from 1.09 (June) to 2.63 (August). Species evenness ranged from 0.37 (June) to 0.85 (August). Simpson's Index of Diversity (SID) varied from 0.27 (June) to 0.65 (August) (Fig. 4). β-diversity varied from 0.59 in June to 0.67 in August (Table 3). Details of Shannon-Wiener's diversity and Simpson's index of individual species of TUN 1a in different seasons is given in table 4.

TUN 1 (Timberline-Alpine Ecotone): SR ranged from 20 (June) to 24 (August). Diversity index (H') varied from 2.51 (August) to 2.80 (June) (Fig. 4). Species evenness ranged from 0.77 (August) to 0.90 (June). SID varied from 0.86 (Oct) to 0.89 (June). B-diversity varied from 0.72 in October to 0.74 in August (Table 3). Details of Shannon-Wiener's diversity and Simpson's index of individual species of TUN 1in different seasons is given in table 5.

TUN 2a (Treeline-Alpine Zone Ecotone): SR ranged from 17 (Oct) to 21 (June and August). Diversity index (H') varied from 1.96 (October) to 2.09 (August). Species evenness ranged from 0.66 (June) to 0.69 (Oct). SID varied from 0.61 (Oct) to 0.78 (August). β-diversity varied from 0.73 in June to 0.88 in August (Table 3). Details of Shannon-Wiener's diversity and Simpson's index of individual species of TUN 2a in different seasons is given in table 6.

TUN 2 (Upper Alpine Zone): SR ranged from 18 (Oct) to 24 (August). Diversity index (H') varied from 1.45 (Oct) to 1.89 (August). Species evenness ranged from 0.50 (October) to 0.59 (June & August). SID varied from 0.62 (August) to 0.74 (October). β-diversity varied from 0.66 in August to 0.80 in June (Table 3). Details of

Shannon-Wiener's diversity and Simpson's index of individual species of TUN 2 in different seasons is given in table 7.

Table 6. Diversity and dominance of plant species in TUN 2a during different seasons.

Plant Species	June, 2014		August, 2014		October, 2014	
	H	SI	H	SI	H	SI
Acomastylis elata	-0.239	0.018	-0.213	0.009	-0.213	0.011
Anaphalis cuneifolia	-	-	-0.011	0.000	-	-
Anaphalis royleana	-0.111	0.001	-0.094	0.0006	-0.095	0.001
Bistorta amplexicaulis	-0.053	0.0001	-	-	-	-
Bistorta macrophylla	-0.201	0.008	-0.121	0.001	-0.046	0.000
Carex inanis	-0.076	0.0006	-0.156	0.004	-0.157	0.003
Danthonia cachemyriana	-0.127	0.0051	-0.093	0.001	-0.101	0.001
Euphraisa himailica	-	-	-0.006	0.000	-	-
Gaultheria trichophylla	-0.013	0.000	-0.052	0.0002	-0.139	0.002
Gentiana pedicillata	-0.037	0.0001	-	-	-	-
Jurinea macrocephala	-	-	-0.076	0.0003	-	-
Oxygraphis polypetalla	-0.138	0.002	-0.277	0.024	-0.224	0.023
Parnassia laxmannii	-	-	-0.016	0.000	-	-
Parnassia nubicola	-	-	-0.011	0.000	-	-
Pedicularis pectinata	-0.084	0.0005	-0.032	0.000	-0.043	0.0002
Plantago brachyphylla	-0.125	0.002	-0.149	0.003	-0.121	0.002
Potentilla atrosanguinea	-0.011	0.000	-0.018	0.000	-	-
Potentilla leuconata	-	-	-0.013	0.000	-0.015	0.000
Potentilla microphylla	-0.040	0.000	-	-	-	-
Potentilla polyphylla	-0.058	0.0004	-0.072	0.0003	-0.060	0.0002
Rananculus hirtulus	-0.009	0.000	-	-	-	-
Saussurea taraxacifolia	-0.097	0.001	-0.033	0.000	-0.065	0.0003
Sibbaldia cuneata	-0.09	0.0006	-0.093	0.0009	-0.143	0.002
Swertia ciliata	-	-	-	-	-0.007	0.000
Tanacetum longifolium	-0.149	0.003	-0.153	0.005	-0.114	0.001
Taraxacum officinale	-0.020	0.000	-	-	-0.077	0.0008
Trachydium roylei	-0.321	0.265	-0.363	0.169	-0.339	0.209
Viola biflora	-0.014	0.000	-0.0329	0.000	-	-

Note: *H= Shannon Wiener's Diversity, SI= Simpsons Index.

A t-test showed significant differences in diversity (t=6.12-8.20, df= 32-46, p=0.000) at 95% confidence level along the altitudinal gradient. Similar significant differences are shown during different seasons of the year (t= 5.47-11.18, df=33-46, p=0.000).SR showed a non-significant positive correlation (r= 0.53) with altitude but diversity showed a slightly negative correlation (r= -0.05) with it. This means the species evenness decreased or concentration of dominance increased with increase in altitude.

Table 7. Diversity and dominance of plant species in TUN 2 during different seasons.

Plant Species	June, 2014		August, 2014		October, 2014	
	H	SI	H	SI	H	SI
Acomastylis elata	-0.2071	0.012	-0.233	0.000	-0.240	0.018
Anaphalis cuneifolia	-	-	-0.029	0.000	-0.022	0.000
Anaphalis royleana	-0.104	0.0026	-0.049	0.0001	-0.057	0.0002
Bistorta amplexicaulis	-	-	-0.027	0.000	-	-
Bistorta macrophylla	-0.099	0.001	-0.040	0.0001	-0.026	0.000
Bupleurum longicaule	-	-	-0.0009	0.000	-	-
Carex inanis	-0.098	0.0013	-0.090	0.0009	-0.087	0.001
Cyananthus lobatus	-	-	-0.366	0.109	-	-
Danthonia cachemyriana	-0.114	0.002	-0.126	0.002	-0.146	0.004
Euphraisa himailica	-	-	-0.003	0.000	-	-
Gentiana pedicillata	-0.015	0.000	-	-	-	-
Goodyera fusca	-	-	-	-	-0.002	0.000
Jurinea macrocephala	-	-	-0.021	0.000	-	-
Oxygraphis polypetalla	-0.14	0.005	-0.089	0.0009	-0.106	0.002
Parnassia nubicola	-	-	-0.0313	0.000	-	-
Pedicularis pectinata	-0.02	0.000	-0.010	0.000	-0.0072	0.000

Plantago brachyphylla	-0.021	0.000	-	-	-	-
Potentella microphylla	-	-	-0.026	0.000	-	-
Potentella polyphylla	-0.014	0.000	-0.008	0.000	-0.031	0.000
Potentilla leuconata	-0.017	0.000	-	-	-0.019	0.000
Rananculus hirtulus	-0.02	0.000	-	-	-	-
R. anthopogon	-0.261	0.202	-0.198	0.090	-0.199	0.115
Salix lindleyana	-0.122	0.002	-0.015	0.000	-	-
Saussurea taraxacifolia	-0.027	0.000	-0.008	0.000	-0.029	0.000
Sibbaldia cuneata	-0.034	0.000	-0.080	0.0004	-0.032	0.000
Stachys melissifolia	-	-	-0.015	0.000	-	-
Swertia ciliata	-	-	-	-	-0.020	0.000
Tanacetum longifolium	-0.061	0.0002	-0.099	0.0012	-0.065	0.0008
Taraxacum officinale	-0.045	0.0003	-	-	-0.037	0.0001
Trachydium roylei	-0.327	0.099	-0.304	0.244	-0.320	0.249
Viola biflora	-0.014	0.000	-0.019	0.000	-	-

Note: *H= Shannon Wiener's Diversity, SI= Simpsons Index.

Similarity Index: The similarity of any two communities depends on the number of species common to both of them. Sorenson's similarity index showed that the similarity varied not only among the sites but also with the seasons (Table 8). Highest similarity index (87.17%) was found between the two upper sites *viz.,* TUN 2 and TUN 2a during the month of June, while lowest value for the similarity index (15.38 %) was recorded between TUN 1a and TUN 2 during the same month (Table 8).

Table 8. Sorenson's similarity index (%) for the studied sites during different seasons of the year.

	June 2014			
	TUN 1	**TUN 1a**	**TUN 2**	**TUN 2a**
TUN 1	100	-	-	-
TUN 1a	29.26	100	-	-
TUN 2	71.42	15.38	100	-
TUN 2a	76.19	20.51	87.17	100
	August 2014			
	TUN 1	**TUN 1a**	**TUN 2**	**TUN 2a**
TUN 1	100	-	-	-
TUN 1a	33.33	100	-	-
TUN 2	61.22	17.78	100	-
TUN 2a	72.34	69.77	86.36	100
	October 2014			
	TUN 1	**TUN 1a**	**TUN 2**	**TUN 2a**
TUN 1	100	-	-	-
TUN 1a	30.3	100	-	-
TUN 2	61.53	20	100	-
TUN 2a	63.15	20.68	85.71	100

DISCUSSION

The alpine regions are particularly appropriate for a large-scale network to determine the effects of global processes such as climate change (Pauli *et al.* 2004). The main purpose of the recently launched research initiative, HIMADRI, is the long term monitoring of the ecologically sensitive parameters at benchmark sites selected in various regions of IHR. The aim of the present study was the characterization of one of the HIMADRI benchmark sites (Tungnath, Uttarakhand Himalaya) and to provide a baseline data about the species richness and diversity along the altitudinal gradient for long monitoring. The reinvestigation of these sites in future (*e.g.* after a decade or more) will help in understanding the effect of climate change in IHR in terms of changes in species composition and diversity or in terms of species shifts from one vegetation zone or/and ecotone to another. The average species diversity of 1.79–2.28 recorded in the present study is comparable to the results of previous similar investigations in different Himalayan regions *i.e.* 2.39–4.63 in the Uttarakhand Himalaya (Nautiyal & Gaur 1999), 1.44 to 2.48 from Sikkim Himalaya (Tambe & Rawat 2010), 1.02–2.17 in Rama Valley Pakistan (Shaheen *et al.* 2011a) and 3.13 from Western Himalayan Alpine Pastures of Kashmir, Pakistan (Shaheen *et al.* 2011 b). The Evenness (J') and Simpson's diversity index (SDI) varied from 0.62 to

0.72 and 0.63 to 0.73, respectively. These values are comparable to some of the recent studies *viz.*, Tambe & Rawat 2010 (Sikkim Himalaya) and Shaheen *et al.*2011a (Pakistan Himalaya).

Maximum number of species was reported during the months of August and June because these are the months of peak growth for most of the species of this region. Plant growth in alpine region starts with onset of summer and snow melting. The growth activity increases with increase in temperature and moisture.

A gradual monotonic decrease in species richness with increasing altitude is considered a general pattern (Stevens 1992). But in the present study, the SR did not follow this rule strictly. Neither, it followed any definite trend along the altitudinal gradient. However, it showed a non-significant positive correlation (r= 0.53) with the altitude. Rahbek (1995) made a critical review on species richness patterns in relation to altitude viewed that approximately half of the studies detected a mild-peak in species richness. Grytnes & Vetaas (2002) have also reviewed these aspects in Nepalese Himalaya. In the present study, SR first increased from lower altitude (sub alpine) to mid altitude and then again decreased (Fig. 5). Similar types of results have been reported by Pickering *et al.* (2008) and Shaheen *et al.* (2011a) from Australia and Pakistan respectively. Minimum SR was reported from lowest site (TUN 1a, 3236 m asl) that forms the sub-alpine vegetation zone of the study area. This region is very dense and dominated by *Rhododendron campanulatum* and *Abies pindrow.* Due to this dense vegetation, ground flora is poorly represented. But beyond the tree line, the SR first increased in '*timberline-alpine ecotone'* and then again decreased in *'treeline-alpine ecotone'* (Fig. 5). Alpine communities lack the ultra-dominant tree cover which allows the herbs and grasses to flourish freely. Changes in altitude play an important role in the composition of plant communities. Altitude itself represents a complex combination of related climatic variables closely correlated with numerous other environmental properties *viz.*, soil texture, nutrients and substrate stability (Ramsay & Oxley 1997). Within one altitude the community composition is affected by many co-factors like topography, aspect, slope and soil type. A negative correlation was observed between diversity and altitude. Similar results were reported by Shaheen *et al.* (2011b) form alpine pastures of Pakistan Himalaya. The similarity in species composition and community structure decreased with increasing distance among sites, indicating high beta diversity in the area (Table 8).

Grazing activity is prevalent throughout the study area except for the sub alpine region. It is recommended that grazing practices in these fragile alpine communities should be very limited and controlled. Himalayan pastures have been a victim of severe human exploitation from centuries (Miller 1997). The degraded vegetation is further not allowed to repair itself by harsh climatic conditions and very short growing period. It requires immediate attention of monitoring authorities as well as to create awareness among locals about sustainable utilization and conservation of alpine pastures to maintain ecosystem balance.

ACKNOWLEDGEMENT

The work has been funded by Space Application Centre (SAC), ISRO Ahmadabad which is greatly acknowledged.

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