Forest Structure, Diversity and Regeneration Pattern Along Altitudinal Gradient in Temperate Zone of Nanda Devi Biosphere Reserve (a World Heritage Site), Western Himalaya, India

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Research

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Abstract

Background

The present study exhibited forest structure, plant species composition and regeneration pattern in temperate zone of Nanda Devi Biosphere Reserve (NDBR), western Himalaya along the different altitudinal gradient (2600 to 3600 m asl). The diverse ecosystems of the NDBR contain a tremendous array of floral and faunal diversity, many of which are rare and endangered species.

Results

A total of 223 species of vascular plants (Angiosperm, Gymnosperm and Pteridophytes) were identified within the study area. Rosaceae (17.69 %) family was exhibited dominant followed by Asteraceae (14.97 %) and Ranunculaceae (12.93 %). Among all the plant species, *Betula utilis* had highest tree density (724 & 324 individuals ha⁻¹ in each site) and contributed maximum dominance of species cover (44 % and 36 %) at Tolma and Ghangaria sites followed by *Pinus wallichiana* (24 %) and *Cedrus deodara* (15 %), respectively. In Ghangaria site, 56 % tree species showed fair regeneration, 22 % good, 11% exhibited poor and remaining (11 %) indicated no regeneration while at Tolma site, 40 % species showed fair regeneration, 40 % good and remaining 20 % no regeneration.

Conclusion

Our results suggest to monitor the change in vegetation structure, species composition and regeneration pattern, we should establish permanent study plots in different forest types located along the elevational gradients for an effective and comprehensive monitoring programme to tracks the response of changing climate at both community and species level. Therefore, it is necessary to development of appropriate weather and meteorological station in this sensitive and ecologically important area for regional projection of micro climatic condition and generation of scientific data on changing vegetation composition and advancement of the native species.

Background

The Himalayas regions most diverse ecosystem on the earth with a variety of plants species, high endemism and forest types due to the wide altitude gradient, topography, soil, climate and geographical location (Mani 1978; Kharkwal 2005; Sharma et al. 2009, 2010a; Chandra et al. 2010; Gairola et al. 2011a). Indian Himalayan region cover about 5 lakh km² (about 16.2% of country's total geographical area) and forms the northern boundary of the country. Himalayan region recognized as one of the hotspots of biodiversity and harbors nearly 8,000 species of flowering plants, of which 25.3% are endemic (Singh and Hajra 1996). Forest structure, species composition and regeneration patterns are most crucial ecological attributes of healthy forest ecosystems which exhibit variations in response to change in climate as well as anthropogenic complexities (Gairola et al. 2008; Krauchi et al. 2000; Dolezal and Srutek 2002). Elevation play major role to determine the structure of vegetation in most mountain of the world (Zhang et al. 2006; McVicar and Korner 2012). However, several studies have been carried out to assess the qualitative and quantitative characters

of the vegetation in Western Himalaya (Saxena and Singh 1982; Rawal and Pangtey 1994; Baduni and Sharma 1996; Dhar et al. 1997; Rawat et al. 2001; Adhikari et al. 2004; Joshi et al. 2004), and other parts of the world (Shaw 1909; Goldsmith and Smith 1926; Griggs 1938; Allen and Walsh 1996; Holtmeier 2003; Schickhoff 2005), mostly revealed hump shaped (high species diversity at middle of gradient) distribution of species (Austrheim 2002; Zhang and Ru 2010). The population structure, characterized by the presence of sufficient population of seedlings, saplings and adults, indicates successful regeneration of forest species (Marks 1974; Vablen et al. 1979; Pritts and Hancock 1983; Saxena et al. 1984; Khan et al. 1987), and the future composition of the forests depends on the potential regenerative status of tree species within a forest stand in space and time (Henle et al., 2004). The studies on forest composition, structure, plant diversity and regeneration of different part of NDBR have been studied but particularly in Ghangaria and Tolma sites of present study has so far not been analysed along altitudinal gradients. The Tolma site is way to approach the core zone of the reserve and old trekking route of the tourist before the notification as reserve. However, the Ghangaria site influenced by the Sikh pilgrims (visited to Hemkund Sahib, sacred place of Sikh community), tourist visited Valley of Flower National Park (another core zone of the reserve) and inhabitants who has constructed permanent and temporary shops, lodges and small hotel and restaurants for income generation during summer season.

The hypothesis of the present study was that: (i) Forest structure, species composition and regeneration status change along the altitudinal gradient up to timberline ecotone (ii) Does altitude influence the species diversity?. To test the hypothesis, the following objectives were envisages: (i) To assess the forest structure, species composition and regeneration status of forest stand along altitudinal gradient. (ii) To assess the physiochemical properties of soil with relation to the forest stand. Therefore, present study expected to provide scientific information and baseline data that can be used for halt the biodiversity and help to develop the effective conservation and management plans for these ecological sensitive ecosystems.

Materials And Methods

Study site

The study was conducted at two different sites of Nanda Devi Biosphere Reserve (NDBR) timberline ecotone viz., (A) Ghangaria and (B) Tolma region (buffer zone), covering an area between 30°16' N to 30° 41' N and 79° 33' E to 79° 44' E with elevation ranges from 2800 m to 3400 m asl in the Central Himalaya. This biosphere reserve was recognized as a World Heritage Site in 1992 and was included in the UNESCO's world network of Biosphere Reserves in 2004. The reserve covers an area of about 5860 km² with two core zones - the Nanda Devi National Park (624.62 sq. km) and the Valley of Flowers National Park (87.50 sq km). There are three seasons-summer (April-June), rainy season (June –September), and winter (October-March), and the average annual rainfall is 928.81 mm. About 47.8 % of the annual rainfall occurs over a short period of two months (July-August) due to the strong influence of the monsoon. The maximum temperature ranges from 11 to 24 °C and the minimum from 3 to 7.5°C (Fig. 1). The altitudinal range of the biosphere reserve varies from 2,100 m asl to 7,817 m asl.

Vegetation sampling

Vegetation analysis was carried out by using stratified random design sampling at two sites of timberline area in NDBR. A total of 146 plots (73 in each site) of 10 m × 10 m were laid randomly between 2600 m asl to 3600 m asl for enumeration of tree species. Each plot (10×10 m) was further subdivided into 5 m × 5 m sub-plots for enumeration of shrub and saplings, and 1m × 1m for seedlings and herb species (Misra 1968). The vegetation data were quantitatively analyzed for abundance, density and frequency according to Curtis and McIntosh (1950) and Misra (1968). The relative values were summed up to represent important value index (IVI) given by Curtis (1959). The diversity index (H') was computed by using Shannon-Weaver information Index (Shannon and Weaver, 1949). The regeneration status of dominant tree species was assessed based on the proportional distribution of density of individuals in each seedling, sapling and adult tree). The regeneration status of tree was considered **“good”** when seedling density > sapling density > adult tree density, **“fair”** when seedling density > sapling density ≤ adult density, **“poor”** when the species survived in only the sapling stage but not in the seedling stage, **“none”**, for species with no sapling or seedling stages but present as adult trees, and **“new”** when adults of a species were absent but sapling and/or seedling stage(s) were present (Shankar 2001; Paul 2008).

Physiochemical properties of soil

The soil analysis of different aspect of the study area was conducted to determine the physiochemical characteristics of soil at different altitude gradient. The moisture percentage, water holding capacity (%) and texture of soil was determined as the methods described by Misra (1968). Soil pH (1:2.5, soil: water) was used to measure with the help of dynamic digital pH meter. Soil organic carbon (%) was determined by Walkley and Black's rapid titration method (Walkley and Black 1934). Total N was determined using the micro-Kjeldahl approach, exchangeable phosphorus (P) and available potassium (K) was determined by (Jackson 1958).

Statistical analysis

The abundance data were statistically analyzed for mean, standard deviation, correlation, ANOVA and t-test using Microsoft Office, 2007.

Result

Floral diversity

A total of 223 species of vascular plants (angiosperm, gymnosperm and pteridophytes) were identified within the study area. These species belong to 57 families and 165 genera. Of these, 46 families and 151 genera belonging to angiosperm, 4 families and 5 genera of gymnosperms and 7 families and 9 genera of pteridophytes were found at both study sites between 3000–3600 m asl. Among the flowering plants (angiosperms and gymnosperms), the percent proportion of the life forms recorded as 4.6% trees, 18.77% shrubs and remaining 76.63% were herbs and forbs. Rosaceae (17.69%) family was exhibited dominant followed by Asteraceae (14.97%), Ranunculaceae (12.93%), Lamiaceae and Poaceae (7.48% each). (Table 1).

Table 1
Distribution of families in study areas

Families	No. of genera		No. of species		Species %		Total species occurrence
	Ghangaria Site	Tolma Site	Ghangaria Site	Tolma Site	Ghangaria Site	Tolma Site	
Angiosperms							
<i>Ranunculaceae</i>	6	3	9	10	6.12	6.80	12.93
<i>Berberidaceae</i>	1	1	3	2	2.04	1.36	3.40
<i>Podophyllaceae</i>	1	1	1	1	0.68	0.68	1.36
<i>Papaveraceae</i>	1	1	1	1	0.68	0.68	1.36
<i>Brassicaceae</i>	1	1	1	2	0.68	1.36	2.04
<i>Violaceae</i>	1	1	1	1	0.68	0.68	1.36
<i>Polyglaceae</i>	1	1	1	1	0.68	0.68	1.36
<i>Caryophyllaceae</i>	1	2	1	4	0.68	2.72	3.40
<i>Geraniaceae</i>	1	0	3	0	2.04	0.00	2.04
<i>Balsaminaceae</i>	1	0	2	0	1.36	0.00	1.36
<i>Aceracear</i>	1	1	2	1	1.36	0.68	2.04
<i>Fabaceae</i>	2	3	5	3	3.40	2.04	5.44
<i>Rosaceae</i>	5	6	16	10	10.88	6.80	17.69
<i>Saxifragaceae</i>	2	1	4	2	2.72	1.36	4.08
<i>Grossulariaceae</i>	0	1	0	4	0.00	2.72	2.72
<i>Crassulaceae</i>	0	2	0	6	0.00	4.08	4.08
<i>Onagraceae</i>	1	1	2	1	1.36	0.68	2.04
<i>Apiaceae</i>	3	3	5	3	3.40	2.04	5.44
<i>Caprifoliaceae</i>	0	2	0	2	0.00	1.36	1.36
<i>Rubiaceae</i>	1	0	2	0	1.36	0.00	1.36
<i>Valerianaceae</i>	1	1	1	1	0.68	0.68	1.36
<i>Dipsacaceae</i>	0	1	0	2	0.00	1.36	1.36
<i>Asteraceae</i>	8	6	13	9	8.84	6.12	14.97
<i>Campanulaceae</i>	1	1	2	2	1.36	1.36	2.72
<i>Ericaceae</i>	2	1	3	2	2.04	1.36	3.40

Families	No. of genera		No. of species		Species %		Total species occurrence
	Ghangaria Site	Tolma Site	Ghangaria Site	Tolma Site	Ghangaria Site	Tolma Site	
<i>Primulaceae</i>	1	1	3	3	2.04	2.04	4.08
<i>Gentianaceae</i>	3	2	5	3	3.40	2.04	5.44
<i>Boraginaceae</i>	2	2	2	2	1.36	1.36	2.72
<i>Cuscutaceae</i>	0	1	0	1	0.00	0.68	0.68
<i>Scrophulariaceae</i>	3	2	4	3	2.72	2.04	4.76
<i>Lamiaceae</i>	5	4	5	6	3.40	4.08	7.48
<i>Plantaginaceae</i>	0	1	0	1	0.00	0.68	0.68
<i>Chenopodiaceae</i>	1	1	1	1	0.68	0.68	1.36
<i>Polygonaceae</i>	2	2	4	6	2.72	4.08	6.80
<i>Thymelaeaceae</i>	1	0	1	0	0.68	0.00	0.68
<i>Euphorbiaceae</i>	1	1	1	1	0.68	0.68	1.36
<i>Urticaceae</i>	0	1	0	2	0.00	1.36	1.36
<i>Betulaceae</i>	1	1	1	1	0.68	0.68	1.36
<i>Salicaceae</i>	2	1	4	2	2.72	1.36	4.08
<i>Orchidaceae</i>	4	2	5	2	3.40	1.36	4.76
<i>Alliaceae</i>	1	0	3	0	2.04	0.00	2.04
<i>Liliaceae</i>	4	3	6	4	4.08	2.72	6.80
<i>Juncaceae</i>	0	1	0	2	0.00	1.36	1.36
<i>Araceae</i>	1	0	3	0	2.04	0.00	2.04
<i>Cyperaceae</i>	1	0	3	0	2.04	0.00	2.04
<i>Poaceae</i>	2	5	5	6	3.40	4.08	7.48
Gymnosperms							
<i>Ephedraceae</i>	1	1	1	2	0.68	1.36	2.04
<i>Cupressaceae</i>	1	1	3	2	2.04	1.36	3.40
<i>Taxaceae</i>	1	1	1	1	0.68	0.68	1.36
<i>Pinaceae</i>	2	2	2	3	1.36	2.04	3.40
Pteridophytes							

Families	No. of genera		No. of species		Species %		Total species occurrence
	Ghangaria Site	Tolma Site	Ghangaria Site	Tolma Site	Ghangaria Site	Tolma Site	
<i>Osmundaceae</i>	1	1	1	1	0.68	0.68	1.36
<i>Polypodiaceae</i>	2	3	2	3	1.36	2.04	3.40
<i>Cryptogrammaceae</i>	1	1	2	1	1.36	0.68	2.04
<i>Adiantaceae</i>	1	1	1	1	0.68	0.68	1.36
<i>Aspleniaceae</i>	0	1	0	2	0.00	1.36	1.36
<i>Athyriaceae</i>	0	2	0	2	0.00	1.36	1.36
<i>Dryopteridaceae</i>	0	1	0	3	0.00	2.04	2.04
					100	100	

Species richness and diversity

The total species richness (tree and shrub) was found higher in Ghangaria as compared to the Tolma site. Most of the tree and shrub species were common at both the sites thus, resulting 90% similarity in tree layer and 60% similarity in shrub layer. Diversity index values were obtained slightly higher at Ghangaria site (7.9) as compared to Tolma site (7.84). However, the concentration of dominance (CD) particularly for the tree, sapling & seedling layer was found higher at Tolma site as compared to Ghangaria site, whereas, shrub layer showed higher CD at Ghangaria site (Table 2).

Table 2

Diversity Index (H') and concentration of dominance (CD) for tree, sapling, seedling and shrub in Ghangaria and Tolma forest area of NDBR.

Site	Parameters	Forest strata	Diversity	Dominant tree species
Ghangaria site (GS)	H'	Tree	1.93	<i>Betula utilis</i> , <i>Cedrus deodar</i> , <i>Abies pindrow</i> , <i>Taxus baccata</i> , <i>Acer caesium</i> , <i>Salix sikkimensis</i> , <i>Rhododendron campanulatum</i>
		Sapling	1.99	
		Seedling	1.99	
		Shrub	1.99	
		Total	7.9	
	CD	Tree	0.18	
		Sapling	0.16	
		Seedling	0.15	
		Shrub	0.17	
		Total	0.66	
Tolma site (TS)	H'	Tree	1.65	<i>Betula utilis</i> , <i>Abies pindrow</i> , <i>Pinus wallichiana</i> , <i>Salix sikkimensis</i> , <i>Cedrus deodar</i> , <i>Populus ciliata</i> , <i>Picea smithiana</i> , <i>Acer caesium</i>
		Sapling	1.87	
		Seedling	1.77	
		Shrub	2.55	
		Total	7.84	
	CD	Tree	0.26	
		Sapling	0.2	
		Seedling	0.22	
		Shrub	0.08	
		Total	0.76	

Population structure

The total tree density ($1632 \text{ trees ha}^{-1}$) and total basal area ($67.39 \text{ m}^2 \text{ ha}^{-1}$) was recorded higher in Tolma site as compared to the Ghangaria site. Among the total tree density maximum ($724 \text{ trees ha}^{-1}$) was recorded for *Betula utilis* with highest IVI (114.35) at the same site. The *Cedrus deodara* was found an important co-dominant tree species (IVI 63.43) at Ghangaria site and *Pinus wallichiana* (IVI 70.84) and *Abies pindrow* (IVI 58.42) at Tolma site, respectively (Table 3). The higher seedling density was recorded for *R. campanulatum* ($320 \text{ sapling ha}^{-1}$) followed by *Betula utilis* ($232 \text{ sapling ha}^{-1}$) at Ghangaria site, while at

Tolma site, higher density was found for *Betula utilis* (544 sapling ha⁻¹) and *Salix sikkimensis* (268 sapling ha⁻¹). *Abies pindrow* was another associate species exhibited higher sapling density at both sites (168 sapling ha⁻¹ and 244 sapling ha⁻¹ each site). In the seedling stratum, the maximum total density was recorded at Tolma site (2328 seedling ha⁻¹) as compared to the Ghangaria site (2032 seedling ha⁻¹). Among the species, higher seedling density was recorded for *Betula utilis* at both the sites (920 seedling ha⁻¹ and 456 seedling ha⁻¹ each site) followed by *Rhododendron campanulatum* (428 seedling ha⁻¹) and *Abies pindrow* (364 seedling ha⁻¹). (Table 5).

Table 3
Phytosociological parameters of tree species around timberline zone of NDBR.

Tree species	Ghangaria site			Tolma site		
	Density trees ha ⁻¹	TBC m ² ha ⁻¹	IVI	Density trees ha ⁻¹	TBC m ² ha ⁻¹	IVI
<i>Betula utilis</i>	368	6.7	85.68	724	12.8	114.35
<i>Abies pindrow</i>	128	4.8	48.70	248	41.3	58.42
<i>Cedrus deodara</i>	156	8.5	63.43	44	0.45	7.20
<i>Pinus wallichiana</i>	-	-	-	384	11.9	70.83
<i>Taxus baccata</i>	132	3.2	38.93	60	0.19	11.51
<i>Acer caesium</i>	80	0.1	22.64	20	0.04	5.84
<i>Sorbus foliolosa</i>	36	0.2	10.23	-	-	-
<i>Rhododendron campanulatum</i>	44	0.3	12.33	-	-	-
<i>Salix sikkimensis</i>	20	0.3	5.690	68	0.2	12.63
<i>Populus ciliata</i>	-	-	-	60	0.36	13.73
<i>Picea smithiana</i>	-	-	-	24	0.11	5.44
<i>Prunus cornuta</i>	52	1.0	12.33	-	-	-
Total	10.16	25.18	300	16.32	67.39	300

In the shrub layer *Ribes alpestre* (396 individuals ha⁻¹), *Origanum vulgure* (332 individuals ha⁻¹), *Spiraea bella* (224 individuals ha⁻¹), *Polygonum polystachyum* (176 individuals ha⁻¹), and *Rosa webbiana* (132 individuals ha⁻¹) showed higher density at the Ghangaria site, while at Tolma, highest density was represented by *Berberis jaschiana* (228 individuals ha⁻¹) followed by *Salix sikkimensis* (176 individuals ha⁻¹), *Indigofera heterantha* (152 individuals ha⁻¹) and *Sorbus microphylla* (120 individuals ha⁻¹) (Table 4). In the herbaceous layer at Ghangaria site, the dominant species were found in following sequence *Fragaria nubicola* (844 individuals ha⁻¹) > *Oxalis corniculata* (812 individuals ha⁻¹) > *Geranium wallichianum* (780

individuals ha^{-1}) > *Anaphalis triplinervis* (736 individuals ha^{-1}) > *Impatiens sulcata* (364 individuals ha^{-1}). The other co-dominant species were recorded includes *Potentilla atrisanguinea*, *Fragaria nubicola*, *Anemone obtusifolia*, *Ligularia amplexicaulis*, *Origanum vulgare*, *Senecio graciliflorus*, etc. However, Tolma site exhibited maximum density for *Geranium himalayense* (1384 individuals ha^{-1}), followed by *Oxalis corcunata* (792 individuals ha^{-1}) and *Fragaria nubicola* (756 individuals ha^{-1}) and minimum was found for *Angelica glauca* (48 individuals ha^{-1}), *Bergenia ciliata* (112 individuals ha^{-1}), and *Malaxis muscifera* (140 individuals ha^{-1}). Some other important associated prominent species found in the area were *Bergenia starchy*, *Bistorta affinis*, *Geum elatum*, *Impatiens devendrae*, *Taraxacum officinale*, *Origanum vulgare* etc.

Table 4
Phytosociological parameters of shrub species around timberline zone of NDBR.

Species	Ghangaria site			Tolma site			
	Density	Ind. ha ⁻¹	A/F ratio	IVI	Density	A/F ratio	IVI
					Ind. ha ⁻¹		
<i>Astragalus chlorostachys</i>	-	-	-	-	108	0.421	11.96
<i>Berberis aristata</i>	-	-	-	-	60	0.234	8.81
<i>Berberis jaeschkeana</i>	72	0.18	14.36	228	0.291	23.49	
<i>Colquhounia coccinea</i>	-	-	-	-	88	0.22	11.87
<i>Elsholtzia fruticosa</i>	-	-	-	-	88	0.22	11.87
<i>Fren spp</i>	80	1.25	9.5	-	-	-	-
<i>Indigofera heterantha</i>	-	-	-	-	152	0.38	16.07
<i>Lonicera microphylla</i>	64	0.44	10.15	-	-	-	-
<i>Origanum vulgure</i>	332	0.32	38.88	-	-	-	-
<i>Prinspia utilis</i>	64	0.25	11.96	88	0.22	11.87	
<i>Polygonum polystachyum</i>	176	0.13	22.64	-	-	-	-
<i>Ribies alpester</i>	396	0.31	35.39	92	0.159	13.35	
<i>Rosa microphylla</i>	80	0.1	14.59	112	0.143	15.886	
<i>Rosa webbiana</i>	132	0.23	14.58	-	-	-	-
<i>Rosa serica</i>	-	-	-	80	0.139	12.56	
<i>Rubus niveus</i>	-	-	-	56	0.072	12.21	
<i>Sorbus microphylla</i>	112	0.14	11.94	120	0.092	18.84	
<i>Sorbaria tomentosa</i>	32	0.13	9.62	76	0.132	12.30	
<i>Spiraea bella</i>	224	0.22	7.46	-	-	-	-
<i>salix lindleyana</i>	-	-	-	176	0.306	18.86	
Total	1364	3.35	200	1524	3.029	200	

Regeneration potential

In all 12 tree species were found along an elevational gradient between 3000–3600 m asl at both buffer areas of NDBR. Among all these tree species, 56% showed fair regeneration, 22% showed good regeneration, 11% exhibited poor and remaining (11%) indicated no regeneration at Ghangaria site; while at Tolma site,

40% species showed fair regeneration, 40% had good regeneration and remaining 20% exhibited no regeneration. In Ghangaria site two species viz., *Salix sikkimensis* and *Rhododendron campanulatum* showed good regeneration as both the species represented by good number of seedlings and saplings. However, about 5 plant species showed fair regeneration those includes *Betula utilis*, *Abies pindrow*, *Taxus baccata*, *Cedrus deodara* and *Sorbus tomentosa*, whereas species such as *Acer caesium* showed poor regeneration and *Prunus cornuta* exhibited no regenerating. In Tolma forest site, about 4 species (viz., *Salix sikkimensis*, *Populus ciliata*, *Taxus baccata* and *Cedrus deodara*) showed good regeneration (Table 5).

Table 5

Regeneration status (density ha⁻¹) of trees species around Ghangaria and Tolma sites, NDBR.

Dominant tree species	Ghangaria site				Tolma site			
	Tree	Sapling	Seedling	Status	Tree	Sapling	Seedling	Status
<i>Betula utilis</i>	484	232	456	F	852	544	920	F
<i>Abies pindrow</i>	192	168	340	F	392	244	364	F
<i>Salix sikkimensis</i>	76	148	196	G	68	268	344	G
<i>Pinus wallichiana</i>	-	-	-	SA	464	100	200	F
<i>Acer caesium</i>	80	156	104	P	20	68	-	NR
<i>Populus ciliata</i>	-	-	-	SA	60	80	100	G
<i>Taxus baccata</i>	196	164	300	F	60	68	176	G
<i>Picea smithiana</i>	-	-	-	SA	24	-	-	NR
<i>Cedrus deodara</i>	180	60	100	F	44	96	104	G
<i>Rhododendron campanulatum</i>	172	320	428	G	108	56	120	F
<i>Sorbus tomentosa</i>	36	140	108	F	-	-	-	SA
<i>Prunus cornuta</i>	52	-	-	NR	-	-	-	SA
Total	1468	1388	2032		2092	1524	2328	
Note: F = Fair regeneration; G = Good regeneration; P = Poor regeneration; NR = No regeneration; SA = Species absent.								

Soil characteristics

Soil water holding capacity (49.94 ± 5.63) and moisture content (60.43 ± 9.71) was found higher in N-aspect as compared to S-aspect at Tolma site. However, Ghangaria site also exhibit higher WHC (33.50 ± 4.54) for N-aspect while soil moisture showed maximum (63.77 ± 4.77) in S-aspect. Tolma site revealed maximum bulk density for S-aspect (0.91 ± 0.10) as compared to N-aspect while Ghangaria site ranged between 1.03 g cm^3 to 1.06 gcm^3 in S and N-aspect, respectively. As far as soil structure concerned sand was the prime

constituent of the soil in both aspect and sites, however decreasing trend was observed in silt proportion with increasing altitudinal. The soil pH ranged between 6.54 to 6.77 and 6.28 to 6.94 in Tolma and Ghangaria site, respectively. The availability of phosphorus (0.11 ± 0.01), potassium (1.32 ± 0.56), total organic carbon (1.04 ± 0.30) and organic matter (1.79 ± 0.52) was found maximum in S-aspect whereas nitrogen concentration (0.170 ± 0.07) recorded higher at N-aspect of Tolma site, whereas phosphorus concentration revealed almost similar value (0.09 ± 0.01) for both aspect while the potassium (1.33 ± 0.27) was recorded higher in N aspect. The total nitrogen value (0.218 ± 0.06), total organic carbon (1.06 ± 0.25) and organic matter (1.82 ± 0.44) showed highest in S-aspect at Ghangaria site.

Statistical analysis

The species richness was observed decreased with increasing elevational gradient showed significant relationship ($R^2 = 0.826$, $p < 0.003$), whereas Simpson's Index of Dominance and the altitude demonstrates a positive quadrature relation ($R^2 = 0.326$, $p < 0.066$). Both forest sites, revealing declining trend among the Shannone Weiner Diversity Index ($R^2 = 0.434$, $p < 0.026$) and the Shannon Index of species evenness ($R^2 = 0.243$, $p < 0.069$) with the increasing altitudinal gradient.

Discussion

The community structure and regeneration status of the plant species could be predicted from the relative proportion of seedlings, saplings and adults in the total populations of different species. The present study exhibit the regeneration of the dominant species was quite moderate except for the *Betula utilis* and *Rhododendron campanulatum*. The higher seedling and sapling density of *Betula utilis* along the timberline is predicted better growth, survival and the advancement, but negligible in the near settlement and highly disturb area (Rai et al. 2012). The population structure of the forest in the present study reveals that dominant species of the buffer zone of NDBR are distributed in all the life stage classes. However, the percentage density declines progressively from seedling to adult tree stages along the altitudinal gradient up to the upper timberline. Among the plant species, *Betula utilis* had highest tree density ($724 \& 324 \text{ trees ha}^{-1}$), contributed 44% and 36% of the total population at Tolma and Ghangaria sites followed by *Pinus wallichiana* (24%) and *Cedrus deodara* (15%), respectively. The average total basal area was recorded $2.77 \text{ m}^2 \text{ ha}^{-1}$ at Ghangaria and $7.48 \text{ m}^2 \text{ ha}^{-1}$ at Tolma site. The study also reveals that shrubs and herbs density was found higher in the Ghangaria site where anthropogenic disturbance was lower than Tolma site of buffer zone. Besides, both the study areas showed a good number of seedling and sapling population. Among the tree species, higher density was represented by *Betula utilis* at both the sites with maximum density ($2476 \text{ trees ha}^{-1}$) were recorded at Tolma site and lower for *Viburnum* spp ($100 \text{ trees ha}^{-1}$) followed by *Prunus cornuta* (50 trees ha^{-1}). Some species viz., *Populus ciliata*, *Picea smithiana* and *Pinus wallichiana* were not found at Ghangaria site but present at Tolma site (Table 1). Regeneration of both forests sites although showed progressive, but it was found better in Tolma site because of high density of seedlings and saplings. Human presence for pilgrimage and nature tourism and livestock grazing, along with cutting, lopping, and debarking of trees and extraction of other bio-resources such as medicinal plants which might have affected the regeneration of species at Ghangaria site.

The present study showed huge variation in the density, basal area and species diversity in temperate forest ecosystem due to the topography, altitudinal variation, forest type and micro climatic conditions (Table 6.). The species richness reported in the present study higher and nearby than result observed (species = 75; tree = 3; shrub = 12; herb = 60) from Kedarnath wildlife sanctuary, Western Himalaya, Uttarakhand (Rai et al. 2012); in temperate forest of Dudhatoli Garhwal Himalaya (species 268); in temperate forest of Azad Kashmir (species 200) and Naran Valley of Pakistan (species 198). However, the species richness value lower than the moist temperate forest of Mandal-Chopta (species 300), Garhwal Himalaya, Uttarakhand (Gairola et al. 2010) and in temperate forest NDBR (species 451), Western Himalaya, India (Rawat et al. 2015). Rosaceae (17.69 %), Asteraceae (14.97%), Ranunculaceae (12.93%), Lamiaceae and Poaceae (7.48 each), Liliaceae and Polygonaceae (6.80 each) were the most dominant species families in temperate forests of Western Himalaya. Similarly, Asteraceae and Lamiaceae have been reported as dominant families in temperate forests of India and elsewhere (Gairola et al., 2010, Saima et al., 2010, Khan et al., 2012, Sharma et al., 2013). Shaheen et al (2011a) also reported that Asteraceae (19%), Poaceae (13%), Ranunculaceae (11%), Rosaceae (8%), and Saxifragaceae (8%) were dominant families in western Himalayas, northern Pakistan. Dar et al (2012) also reported Asteraceae (260 species), Poaceae (160 species), Brassicaceae (115 species), Rosaceae (98 species), and Lamiaceae (88 species) were the major species families in Kashmir Himalaya. Hooker (1906) stated Orchidaceae, Fabaceae, Poaceae, Rubiaceae, Euphorbiaceae, Acanthaceae, Asteraceae, Cyperaceae, Lamiaceae, and Utricaceae as the diverse families of India. Therefore, the result of study also explicit that across various temperate forests of the world having a close similarity is an evident at the families' level. Maximum shrub density was recorded for *Ribes alpester* and *Berberis jaeschkeana* while minimum observed for *Sorbaria tomentosa* and *Rubus niveus* in Ghangaria and Tolma site, respectively. The dominant herbaceous species followed the sequence i.e., *Fragaria nubicola* > *Oxalis corniculata* > *Geranium wallichianum* > *Anaphalis triplinervis* > *Impatiens sulcata* in Ghangaria site. However, *Geranium himalayense* was recorded dominant species with *Oxalis corniculata* and *Fragaria nubicola* as co-dominant species at Tolma site.

Table 6
Comparisons of phytosociological attributes and species richness of different temperate forest of the present and previous study.

Forest type	Region/locality	Elevation (m. asl.)	Total area sampled	Density (D)	Basal Area (BA)	Species richness	Source
Temperate forests	Kashmir Himalaya, India	1,550-3,250	111 (.25 ha)	103-1,201	19.4–51.9	177 = 14T + 17S + 146H	Dar et al. 2016
Temperate forests	Changbai Mountains, China	750-2,100	68 (0.04 ha)	-	-	213 = 37 ^T + 32 ^S + 144 ^H	Bai et al. 2011
Sub-alpine region	Garhwal Himalaya, India	2,200-3,000	20 (50 × 50 m) 50 ha	-	-	90	Bisht and Bhat 2013
Temperate Deciduous forest	Denmark	-	50 ha	770	30.7	165	Borchsenius et al. 2004
Sub tropical to warm temperate	Central Himalaya	1,300-1,750	40 (0.01 ha)	540–1630	25-47.2	-	Chaturvedi & Singh 1987
Tropical semi evergreen	Manipur Northeast, India	-	20 (0.01 ha each)	10–675	-	123 = 17 ^T + 36 ^S + 70 ^H	Devi and Yadava 2006
Abies pindow	Pithoragarh, Kumaun Himalaya	3100	3 (0.5 ha)	660	78.90	-	Dhar et al. 1997
Moist temperate forest	Mandal-CHopta, Garhwal Himalaya, Uttarakhand, India	1500–3000	NA	-	-	338	Gairola et al. 2010
Moist temperate forest	Western Himalaya Garhwal, Uttarakhand India	2400–2850	NA	380-1,180	41.25–86.56	65	Gairola et al. 2011a
Moist temperate forest	Western Himalaya, India	1500–2500	NA	990-1,470	35.08–84.25	125	Gairola et al. 2011b

Forest type	Region/locality	Elevation (m. asl.)	Total area sampled	Density (D)	Basal Area (BA)	Species richness	Source
Temperate forest	Mandal-CHOpta, Garhwal Himalaya, Uttarakhand, India	1,500-2,850	NA	380-1,390	32.77–86.56	-	Gairola et al. 2012
Temperate forest	Northeast Spain	1500–2200	329	-	-	9	Gracia et al. 2007
Dry forest	Miombo, Zambia	1,292–1300	24 (0.25 ha)	308–736	5.6–27.5	83	Kalaba et al 2013
Temperate forest	Naran Valley, Pakistan	2,450–4100	144 (0.25 ha)	-	-	198 = 12 ^T + 20 ^S + 166 ^H	Khan et al. 2011
Community temperate forest	Dolpha Mid-west, Nepal	1,900–2700	20 (0.01 ha)	2,090-2100	90.07-151.98	98	Kunwar & Sharma 2004
Temperate forest	Manang, Central Nepal	3,000–4,000	80 (0.01 ha)	-	-	168	Panthi et al.2007
Temperate forest	Arunachal Pradesh, India	350–700	60 (0.01 ha)	550–860	19.61–78.32	128 = 41 ^T + 22 ^S + 65 ^H	Rana and Gairola 2009
Temperate forest	Garhwal Himalaya, India	500–6940	20 (0.01 ha)	1,090-1980	20.97–40.19	8–19	Raturi 2012
Wet temperate forest	Abottabad, Pakistan	800–2500	NA	-	-	167	Saima et al. 2010
Temperate forest	Kumaun Himalaya	1280–2227	48 (0.01 ha)	-	-	7–21	Saxena & Singh 1984
Temperate forest	Central Himalaya, India	1400–2700	60 (0.01 ha)	20–170	-	116 = 16 ^T + 35 ^S + 65 ^H	Semwal et al.2010
Temperate forest	Western Himalaya, northern Pakistan	> 3300	30 (0.01 ha)	-	-	83	Shaheen et al. 2011a
Temperate alpine pasture	Western Himalaya, Pakistan	2600–3500	20.5 ha	-	-	69	Shaheen et al. 2011b

Forest type	Region/locality	Elevation (m. asl.)	Total area sampled	Density (D)	Basal Area (BA)	Species richness	Source
Moist temperate forest	Western Himalaya, Kashmir	1700–2600	180 (900 m ² each)	90–227	42.32–105.29	122	Shaheen et al. 2012
Moist temperate forest	Dudhatoli Garhwal Himalaya	1800–3000	NA	-	-	268	Sharma et al. 2013
Alpine zone	Northwest Yunnan, China	3800–5200	70 (0.036)	-	-	369	Sherman et al. 2012
Temperate forest	Shimla, Himachal Pradesh, India	1650–2295	36 (0.01 ha)	4,217–7765	18.49–52.54	55 = 6 ^T + 14 ^S + 35 ^H	Singh & Gupta 2009
Temperate: Evergreen deciduous & coniferous	Mt. Emei, Sichuen, China	680–3099	10 (0.02–0.04)	-	-	122	Tang & Ohsawa 1997
Temperate forest	Azad Kashmir, Pakistan	-	70 (0.01 ha)	-	-	200	Tanvir et al. 2014
Temperate forest	Baihua Mountain, China	750–2043	61 (0.02 ha)	-	-	71	Zhang et al. 2013

Table 7
Over all physiochemical properties of Tolma and Ghangaria sites.

Parameter	Ghangaria site		Tolma site	
	N aspect	South aspect	N aspect	South aspect
Sand (%)	63.98 ± 8.27	46.88 ± 2.70	60.11 ± 4.13	64.99 ± 3.95
Silt (%)	50.4 ± 5.45	34.65 ± 2.71	33.01 ± 4.11	27.20 ± 3.16
Clay (%)	0.88 ± 0.06	0.87 ± 0.12	6.88 ± 2.80	7.82 ± 1.41
Moisture (%)	57.41 ± 3.27	63.77 ± 4.77	60.43 ± 9.71	46.49 ± 3.85
WHC (%)	33.50 ± 4.54	28.70 ± 3.35	49.94 ± 5.63	40.58 ± 6.91
bD (g cm ⁻³)	1.06 ± 1.71	1.03 ± 3.29	0.85 ± 0.13	0.91 ± 0.10
pH	6.94 ± 0.15	6.28 ± 0.22	6.77 ± 0.30	6.54 ± 0.37
P (%)	0.09 ± 0.01	0.09 ± 0.02	0.09 ± 0.02	0.11 ± 0.01
K (%)	1.33 ± 0.27	1.23 ± 0.69	1.32 ± 0.56	1.47 ± 0.72
N (%)	0.141 ± 0.05	0.218 ± 0.06	0.170 ± 0.07	0.105 ± 0.02
SOC (%)	0.89 ± 0.11	1.06 ± 0.25	0.94 ± 0.15	1.04 ± 0.30
OM (%)	1.54 ± 0.20	1.82 ± 0.44	1.62 ± 0.25	1.79 ± 0.52

In the correlation analysis, we found significant positive correlation among the variables in Ghangaria and Tolma site. The PCA ordination of Ghangaria site and Tolma site showed no relation of *Acer caesium* and *Salix sikkimensis* with any variable of the F1 and F2 which is indicated as supplementary variable, respectively (Figs. 2 and 3). In the context of frequency, seedling, sapling and tree of S-aspect were highly correlated with seedling, sapling and trees of N-aspects at both sites of the reserve (significant at $p \leq 0.05$) (Tables 8 and 9).

Table 8

Correlation matrix of floristic composition on the basis of frequency indicator at Ghangaria site, NDBR.

Variables	NT	NSA	NSE	ST	SSA	SSE
NT	1	0.932*	0.943*	0.786*	0.727*	0.766*
NSA		1	0.935*	0.578	0.650*	0.744*
NSE			1	0.667*	0.610	0.712*
ST				1	0.722*	0.757*
SSA					1	0.843*
SSE						1
*. Correlation is significant at the 0.05 level (2-tailed).						
NT = North Tree; NSA = North Sapling; NSE = North seedling; ST = South Tree; SSA = South Sapling; SSE = South seedling						

Table 9

Correlation matrix of floristic composition on the basis of frequency indicator at Tolma site, NDBR.

Variables	NT	NSA	NSE	ST	SSA	SSE
NT	1	0.897*	0.866*	0.802*	0.809*	0.636*
NSA		1	0.921*	0.861*	0.818*	0.707*
NSE			1	0.881*	0.863*	0.798*
ST				1	0.935*	0.831*
SSA					1	0.946*
SSE						1
* Correlation is significant at the 0.05 level (2-tailed).						
NT=North Tree; NSA=North Sapling; NSE= North seedling; ST= South Tree; SSA= South Sapling; SSE= South seedling						

Soil characteristics may severely influence the vegetation, while vegetation structure and composition also affect the soil properties. Selective absorption of nutrient element by different tree species and their capacity to return nutrients to the soil bring about changes in soil properties (Singh et al. 1986). The soil texture is an important factor which indicates how well a particular texture can hold the water. Values of the water holding capacity varied from $28.70 \pm 3.35\%$ to $33.50 \pm 4.54\%$ and $40.58 \pm 6.92\%$ to $49.94 \pm 5.63\%$ at Tolma and Ghangaria site, respectively. The values for water holding capacity in the present study are in the line of values reported earlier by various workers from the temperate region of Garhwal Himalaya (Sharma et al.

2010, and Nazir et al. 2009). The overall water holding capacity increased with increasing clay content in the soil while where sand proportion was lesser, water holding capacity of the soil was low. The calculated values for moisture content ranged between 46.49 ± 3.85 to 63.77 ± 4.77 were slightly higher than values reported by Khera et al. (2001) for Kumaun Himalaya and Nazir (2009) for Garhwal Himalaya. Clay, silt and sand contents in the soil of the studied sites ranged from $0.87 \pm 0.12\%$ to $0.88 \pm 0.06\%$, $34.65 \pm 2.71\%$ to 50.4 ± 5.45 and $46.88 \pm 2.70\%$ to $63.98 \pm 8.27\%$ for Ghangaria site, whereas Tolma site exhibits $6.88 \pm 2.80\%$ to $7.82 \pm 1.41\%$, $27.20 \pm 3.16\%$ to $33.01 \pm 4.11\%$ and $60.11 \pm 4.13\%$ to $64.99 \pm 3.95\%$, respectively. The soil was recorded slightly acidic in nature as indicated the range between 6.28 to 6.94 and 6.54 to 6.77 at Tolma and Ghangaria site. In general, pH values for the N-aspect were higher compared to contrasting S-aspect, which could be attributed to the coniferous leaf litters, and stone rocks and more precipitation. Soil phosphorus content among all the stands was found in decreasing order with the soil depth. The phosphorus content ranged between $0.09 \pm 0.02\%$ to 0.11 ± 0.01 at both site. Values for available K observed between $1.23 \pm 0.69\%$ and $1.33 \pm 0.27\%$ at Ghangaria site, while Tolma site showed range between $1.32 \pm 0.56\%$ and $1.47 \pm 0.72\%$. Soil nitrogen ranged was found between 0.170 ± 0.07 and $0.218 \pm 0.06\%$ at both sites. The values of total N in the present study are higher than the values recorded by Khera et al. (2001), Srivastava et al. (2005), and Semwal (2006), Pandey et al. (2001), Sharma et al. (2010a), Thadani and Ashton (1995), Nazir (2009), and Sharma et al. (2010c). This could be attributed to higher water holding capacity and heavy litter and humus accumulation in the upper layers of forest soil. The present results revealed that soil carbon (0.89 ± 0.11 to $1.06 \pm 0.25\%$) and organic matter (1.54 ± 0.20 to $1.82 \pm 0.44\%$) has increased with increasing altitude and similar findings were reported in earlier study from mountain terrain by various workers (Trumbore et al. 1996; Garten et al. 1999; and Bolstad and Vose 2001). Hence, increasing trends of soil organic matter (%) with increasing altitude may be due to the constant carbon inputs and decreasing rate of carbon loss at different altitude (Table 7).

The study revealed that intense recruitment of seedling and sapling of *Betula utilis* and *Rhododendron campanulatum* along the altitudinal gradient up to the upper timberline may be due to the more favorable climatic conditions for growth during past decades, and/or to land use changes in the high-altitude regions projected the great potential for future vegetation advancement. This study also exhibited the continuous decrease in the diameter (CBH) of trees and augmentation of sapling and seedlings of *Betula utilis* and *Rhododendron campanulatum* along an altitudinal gradient is clear indication that these species may move upward to the higher altitude. With increased global warming, the vegetation of high altitude areas would be expected to advance upwards, but yet the changes observed in both study areas have been limited to enhance the recruitment and growth of species rather than vegetation advancement. However, to confirm the shifting of vegetation in NDBR, the long-term studies are required through establishment of permanent plots with manual as well as automatic weather data recording set ups. The upper limit of survival of the plant species is still unknown from these areas since no long term scientific data available on one hand and at the same time as the region has been under high anthropogenic pressure during recent past.

Conclusion

Our results suggest to monitor the change in vegetation structure, species composition and regeneration pattern, we should establish permanent study plots in different forest types located along the elevational

gradients for an effective and comprehensive monitoring programme to tracks the response of changing climate at both community and species level. In addition, many important tree species of the reserve have already been listed in the rare and endangered categories, i.e., *Taxus baccata*, *Juniperus* spp. and *Betula utilis*. These species are over exploited, legally or illegally, to a great extent and increased rates of destruction and the influence of a changing climate have made the situation worse. Therefore, it is necessary to development of appropriate weather and meteorological station in this sensitive and ecologically important area for regional projection of micro climatic condition and generation of scientific data on changing vegetation composition and advancement of the native species.

Declarations

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Authors Contribution

A. M. is first or primary author of the manuscript who developed the research concept and collecting and analyzing the data set. R.K.M. and S.S.B. was the supervisor of the research concept. He provided technical editing and critical suggestion to shape of the manuscript.

Conflict of interest

All the authors declare no “**conflict of interest**” in the present Manuscript.

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Figures

Figure 1

The annual rainfall occurs over a short period of two months (July-August) due to the strong influence of the monsoon. The maximum temperature ranges from 11 to 24 0C and the minimum from 3 to 7.50C

Ghangaria site

Tolma site

Figure 2

Positive correlation among the variables in Ghangaria and Tolma site.