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Community structure, regeneration potential and future dynamics of natural forest site in part of Nanda Devi Biosphere Reserve, Uttarakhand, India

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Realizing the overarching values of forests and considering their depletion at unprecedented rate, conservation of forests has emerged as the prime objective across the globe. Forest vegetation of Pindari-Sunderdhunga-Kafni (PSK), a protected area, part of Nanda Devi Biosphere Reserve in west Himalaya was analyzed for structure, composition and development of future compositional patterns. Forest vegetation surveys were carried out enumerating ten 10 x 10 m quadrat for tree species in each of 30 forest stand complemented by shrub (five 2 x 2 m quadrat) and herb (ten 1 x 1 m quadrat) surveys within each stand. Floristic richness reveals 332 plant species from 11 representative forest communities. Broadly, the demographic profiles exhibited progressive structures suggesting long term persistence of the communities/species. Differences in regeneration behavior of various species are indicative of future structure and dynamics of the communities. Data sets in the present study established target site in NDBR as potential sites for long-term ecological monitoring under various change scenarios.

Key words: Natural forests, regeneration pattern, population structure, compositional changes.

INTRODUCTION

Forest composition, community structure and diversity patterns are important ecological attributes significantly correlated with prevailing environmental as well as anthropogenic variables (Gairola et al., 2008; Ahmad et al., 2010). Forests are always characterized by their three main life stages called seedling (newly emerged plants), sapling (established plants stands between seedling and tree) and tree (tree undisturbed of micro environmental conditions). The number (density) and type (richness) of trees define the structure and composition of forest (Shankar, 2001; Mishra et al., 2003). Species richness patterns in relation to the environment need to be understood before drawing conclusions on the effect of biodiversity on ecosystem processes. Numerous problems regarding the study of species richness need to be clarified, including the role of disturbance (Huston,

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1994), and the relative importance of biotic versus abiotic factors (Cornell and Lawton, 1992; Austin and Gaywood, 1994). The number of tree individuals at seedling, sapling and tree level reveals population structure and their establishment at seedling and sapling level represent regeneration status (Baduni and Sharma, 2001; Bhandari, 2003). The nature of forest communities depends on the ecological characteristics in sites, species diversity and regeneration status of species (Criddle et al., 2003; Todaria et al., 2010). The tree species strata, that is, seedling, sapling and tree layers of the plant communities that maintain the population structure of forest get affected by micro-environmental factors which vary with seasonal changes (Khumbongmayum et al., 2006; Kharkwal et al., 2009). Environmental variation within a small geographical area makes altitudinal gradients ideal for investigating several ecological and biogeographical hypotheses (Korner, 1998). Hence, it becomes necessary to understand the species richness, population structure, germination and establishment of seedlings and saplings across seasons and altitude for maintenance of forest (Khumbongmayum et al., 2006; Rao, 1988). Complete absence of seedlings and saplings of tree species in a forest indicates poor regeneration, while presence of sufficient number of young individuals in a given species population indicates successful regeneration (Saxena and Singh, 1984). Presence of sufficient number of seedlings, saplings and young trees is greatly influenced by interaction of biotic factors of the environment (Boring et al., 1981; Aksamit and Irving, 1984).

Realizing the overarching values of forests and considering their depletion at unprecedented rate, conservation of forests has emerged as the prime objective. As such, it is globally accepted that the depletion of forests has many ecological, social and economic consequences; one among these is loss of biodiversity (Jha et al., 2000). Forests form the renewable natural resource on earth and occupy very unique position among the various natural resources by supporting life on earth in several ways and providing services that cannot be substituted by any other means.

Since its inception (1988), the diverse ecosystems and their components in Nanda Devi Biosphere Reserve (NDBR) have remained attraction of researches. The representative ecosystems and their components in the reserve have shown evidences of change with time and space. In particular, the variations and changes in plant communities have been reported to be highly dependent on geographical, environmental and anthropogenic factors. Besides, differences in soil parameters, fire intensity, over harvesting and other kinds of disturbances contribute to the variation in vegetation from one stand to another or even within a community. Therefore, the reserve management, most often, looks for authentic and precise information on structure and composition of vegetation so as to address diverse issues of conservation and management at different levels ranging from species and community to landscape level. The forests in NDBR not only form diverse representative ecosystems but also are the home for many rare and endangered species. While the core zone of reserve consists of 10% forests, the buffer zone has nearly 27% area under forests. These frosts help in maintaining rich floral (angiosperms- 699, gymnosperms- 11, pteredophytes- 137, bryophytes- 146, lichens- 77 and fungi- 128 spp.) and faunal (mammals- 29, birds- 243, insects- 229, molluscs- 14, amphibian- 8, annelids- 6, reptiles- 3 and pisces- 1) diversity in the reserve (Rawal and Rawat, 2012). In recognition of its uniqueness, NDBR has been included in World Network of Biosphere Reserves (WNBR) by UNESCO since 2004. Also, the Nanda Devi and the Valley of Flowers National Parks, forming core zone of the reserve, have been inscribed on the World Heritage List by UNESCO under Natural Criteria vii and x.

Though, studies on different aspects of biodiversity have been carried out in NDBR of Himalaya viz. natural resource utilization (Joshi, 2002; Joshi and Samant, 2004; Silori, 2001), ecosystem functions (Adhikari, 1992; Garkoti, 1992, 2008; Singh et al., 1994; Garkoti and Singh, 1995; Gairola, 2005), management and development (Rawal and Rawat, 2012), threat assessment (Kala et al., 1998; Kala, 2005; Joshi, 2002; Joshi and Samant, 2004), ethonobiological enumerations (Joshi et al., 2000; Kala, 2005; Rawat et al., 2013) and floristic analysis (Joshi, 2002; Gairola, 2005; Sekar and Rawat, 2011; Rawat, 2013) but a systematic approach on the population structure and seasonal regeneration pattern of forest communities in NDBR with respect to their long term existence, is still lacking. Under the provision of protected areas, the need for understanding the structure and regeneration pattern in forests have been already emphasized to mitigate the ongoing challenges like overexploitation, deforestation etc., that emerged along with the present changing climate and socio-economic scenario.

Therefore, an understanding of the processes that affect regeneration of forest species is of crucial importance to both ecologists and forest managers in protected areas. Keeping the above in mind, seasonal phytosociological investigations have been carried out in a part of Nanda Devi Biosphere Reserve of Uttarakhand.

MATERIALS AND METHODS

Study area and site selection

The Nanda Devi Biosphere Reserve (NDBR), which forms the extensive study area, was designated as Biosphere Reserve by Government of India on 18th January, 1988. The reserve has a unique combination of diverse ecosystems including traditional agro ecosystems, various types of temperate forests, alpine meadows, glaciers, etc. It represents the west Himalayan highland (2b) province of the biogeographic zone-Himalaya and lies between

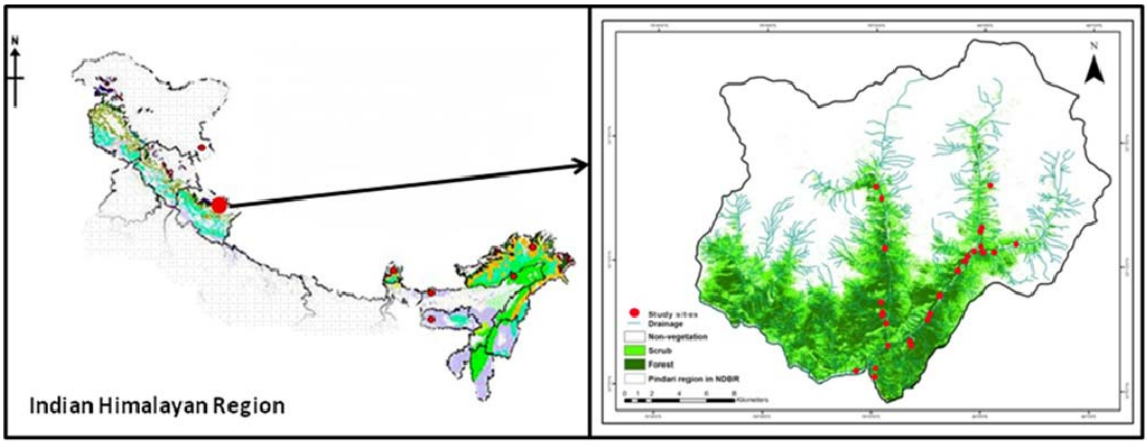

Figure 1. Location of study site of Pindari-Sunderdhunga-Kafni (right) in Nanda Devi Biosphere Reserve, western Himalaya (left).

30°06' and 31°04' north latitude and 79°13' and 80°17' east longitudes (Figure 1), and covers a total of 6,407.03 km^2 (Core zone 712.12 km^2; Buffer zone 5,148.57 km^2, Transition zone 546.34 km^2). One representative sites (Pindari-Sunderdhunga-Kafni: PSK in Kumaun region) in the buffer zone of NDBR formed the intensive study sites. Extensive surveys were conducted during 2008-2012 in these sites.

Sampling and data collection

Attempt was made to reach maximum possibly approachable stands. Standard phytosociological methods were followed to obtain quadrat data (Grieg-Smith, 1957; Misra, 1968; Kershaw, 1973; Muller-Dombois and Ellenberg, 1974; Dhar et al., 1997). In general, from each quadrat, circumference at breast height (CBH at 1.37 m from the ground) of all tree individual was recorded. Based on this information, individuals were considered as tree >31 cm; sapling 11-30 cm; seedling <11 cm CBH. Further, the individuals of tree species were grouped into six arbitrary CBH classes (A: <10; B: 11-30; C: 31-60; D: 61-120; E: >120 cm). The total number of individuals, belonging to each of the above classes, was calculated for each species in individual stand and stand information was pooled to represent community. Size class A and B represented seedlings and saplings, respectively. Other classes (C-E) represented tree classes. Relatively density of species in a particular size class was calculated as a percentage of total number of individuals in all size classes.

The quadrat information was pooled for calculating density, frequency, total basal area and their relative values (Misra, 1968; Muller-Dombois and Ellenberg, 1974). Following Whittaker (1975) and Pielou (1975), species richness was considered simply as the number of species per unit area. Species diversity index was computed using Shannon-Wiener information function (Shannon and Weiner, 1963). Statistical analysis (*t*-test and correlation coefficient (r) and coefficient determination (r^2)) and similarity indices were calculated using SPSS version 16 to determine the relationship between different phytosociological parameters.

Community structure and regeneration patterns

Seasonal investigation (Negi, 1995) on population structure and regeneration behavior of all tree species in PSK site was carried out during summer season: May-June, rainy season: mid July to August and winter season: November-December in the years 2009 and 2010. Eleven representative forest communities were identified for studying detailed population structure to predict the future compositional changes in parent communities.

Regeneration status of species was determined based on population size of seedlings and saplings (Khan et al., 1987; Shankar, 2001; Bhuyan et al., 2003): good regeneration, if seedlings > saplings > trees; fair regeneration, if seedlings > or ≤ saplings ≤ trees; fair regeneration, if the species survives only in sapling stage, but no seedlings (saplings may be <, > or = trees). If a species is present only in tree form, it is considered as not regenerating, while species having no trees but only seedlings is considered as 'new' species.

RESULTS

Site characteristics, floristic diversity and demographic patters

Eleven representative forest communities were distributed between 2025 to 3343 m asl. The community types, site representation and important species (IVI) are presented in Table 1. In general, 332 plant species were recorded from target site in NDBR. Of these, greater proportion (70.8%; 235 spp.) was of herbs. Shrubs constituted 16.3% (54 spp.), and trees 13.0% (43 spp.). Considering various taxonomic groups of the total 332 species in PSK site, 88.9% were angiosperms, 1.2% gymnosperms and 9.9% pteridophytes.

Proportional distribution of individuals in three broad tree strata (tree, sapling and seedling) and life forms (tree, shrubs, and herbs) in the study area and representative sites are depicted in Figure 2. In general, PSK site represented 43 tree species. Representation as compared to total tree species across different strata indicated maximum proportion of trees (93.2%) followed by saplings (81.4%) and seedlings (74.4%). The overall population structure for target sites and the entire reserve have been presented (Figure 3). As reflected, PSK site

Table 1. Site characteristics and dominant species across forest communities in PSK site.

Community types (PSK site)	Altitude (masl)	Slope (°)	No. of stands	Important species (IVI value)
Alnus nepalensis (Utis)	2025	40-45	2	*Alnus nepalensis* (128.2) *Ulmus wallichiana* (32.9)
Mixed Oak- Deciduous	2217	40-55	3	*Quercus floribunda* (79.8) *Aesculus indica* (34.6)
Hippophae salicifolia (Chuck)	2452	5-15	3	*Hippophae salicifolia* (232.0) *Alnus nepalensis* (32.6)
Quercus floribunda (Tilonj Oak)	2504	35-50	4	*Quercus floribunda* (127.1) *Rhododendron arboreum* (42.7)
Quercus semecarpifolia (Kharsu Oak)	2669	35-50	4	*Quercus semecarpifolia* (112.7) *Rhododendron arboreum* (37.9) *Quercus floribunda* (35.3)
Mixed-deciduous	2773	40-55	3	*Acer cappadocicum* (49.4) *Ulmus wallichiana* (28.1) *Rhododendron arboreum* (26.9)
Mixed Silver fir-Oak	2855	30-45	2	*Abies pindrow* (68.5) *Quercus semecarpifolia* (33.8) *Aesculus indica* (30.4)
Mixed Silver fir-Rhododendron-Maple	2860	40-50	3	*Rhododendron barbatum* (74.0) *Abies pindrow* (38.9) *Ilex dipyrena* (27.5)
Abies pindrow (Silver fir)	2970	60-65	2	*Abies pindrow* (99.9) *Rhododendron barbatum* (47.6) *Betula utilis* (44.0)
Mixed Birch-Silver fir	3238	50-60	2	*Betula utilis* (126.4) *Abies pindrow* (67.9) *Taxus wallichiana* (32.6)
Betula utilis (Birch)	3343	50-65	2	*Betula utilis* (183.4) *Euonymous fimbriatus* (29.1) *Rhododendron campanulatum* (20.8)

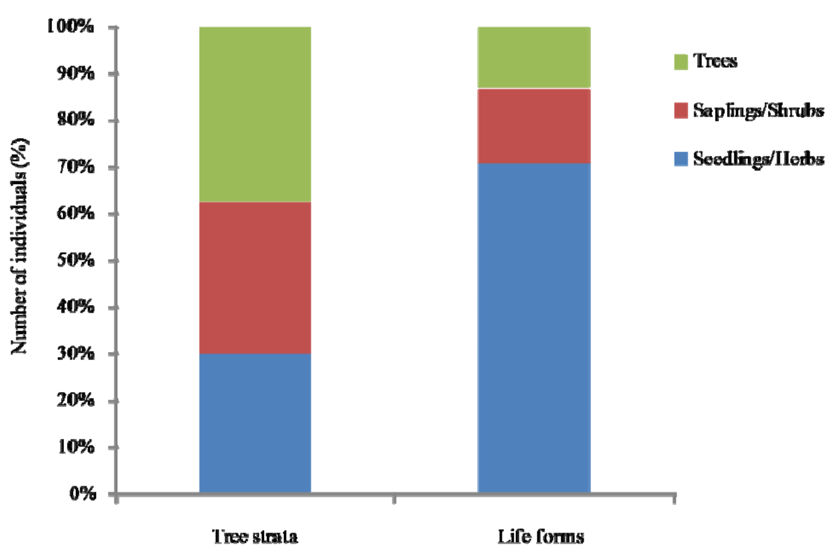

Figure 2. Proportional distribution of species richness across different tree strata and life forms in PSK site in NDBR.

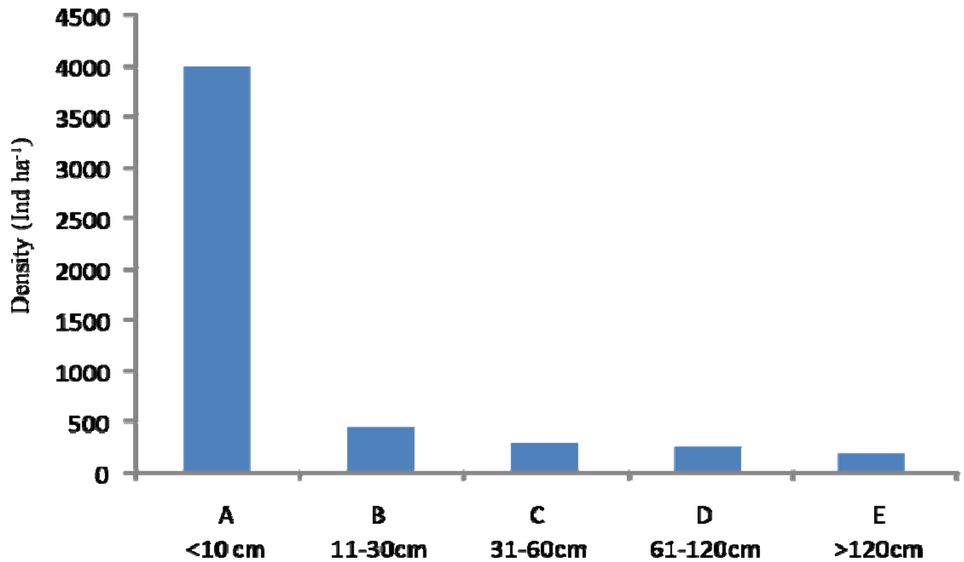

Figure 3. Mean density-diameter distribution of trees in PSK site.

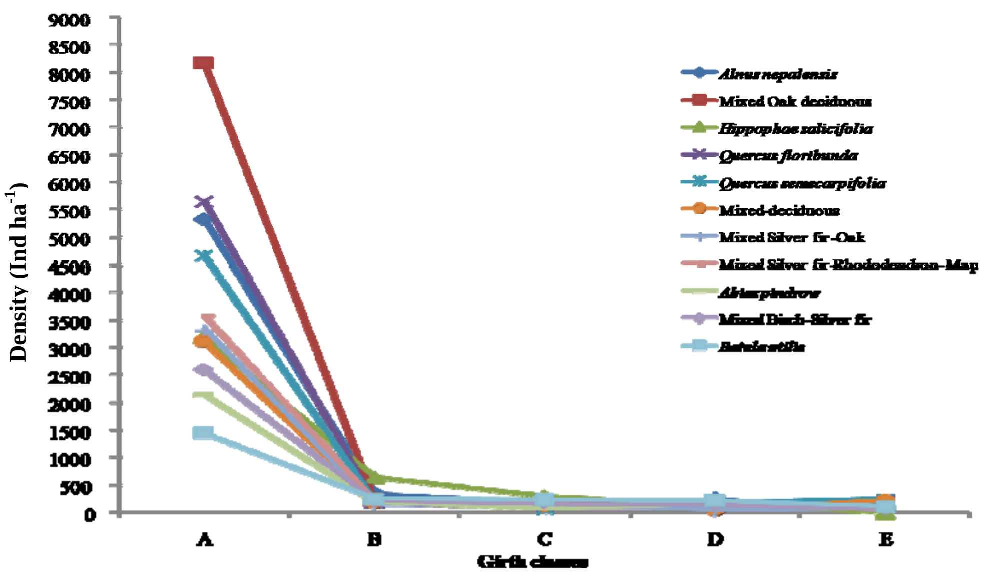

Figure 4. Density-diameter distribution of trees in different forest communities in PSK site.

has considerably larger number of individuals in seedling stage and more gradual decline of individuals towards higher tree size classes. The profile of demography for different forests in PSK site exhibited more or less similar patterns (Figure 4).

Community diversity and distribution pattern

Detailed quantitative ecological parameters in different forest communities are presented in Table 2. Considering the forest composition, tree species richness was highest in *Quercus semecarpifolia* and Mixed Silver fir-Oak communities (23 spp. each) and minimum in *Hippophae salisifolia* community (4 spp.). Sapling species richness peaked in *Q. floribunda* (18 spp.) followed by Mixed deciduous and Mixed Silver fir-Oak communities (15 spp. each). Lowest richness was recorded in *H. salicifolia* community (3 spp.). Species richness at seedling stage was maximum in *Quercus floribunda* (19 spp.) followed by *Quercus semecarpifolia* and MIXED deciduous community (16 spp. each) and lowest in *H. salicifolia* and *Betula utilis* communities (5 spp. each). The details of species richness in different tree layers and across

Table 2. Quantitative ecological parameters in different forest communities in PSK site.

Community types (PSK site)	Species richness			Species density (Ind ha^{-1})			Species diversity		
	Seedling	Sapling	Tree	Seedling	Sapling	Tree	Seedling	Sapling	Tree
Alnus nepalensis	9	9	14	5325± 878	345 ± 53	460± 49	2.20 ± 0.3	2.38 ± 0.3	2.38 ± 0.2
Mixed Oak deciduous	13	12	21	8170± 3012	233 ± 33	480 ± 50	2.28 ± 0.2	2.66 ± 0.1	3.37 ± 0.1
Hippophae salicifolia	5	3	4	3167 ± 609	633 ± 179	423 ± 174	0.70 ± 0.2	0.64 ± 0.3	0.73 ± 0.1
Quercus floribunda	19	18	20	5650 ± 1613	170 ± 27	378 ± 40	2.46 ± 0.4	2.48 ± 0.1	2.84 ± 0.2
Quercus semecarpifolia	16	14	23	4663 ± 819	200 ± 37	473 ± 42	2.27 ± 0.3	2.10 ± 0.3	2.73 ± 0.4
Mixed-deciduous	16	15	21	3117 ± 348	197 ± 41	407 ± 73	2.34 ± 0.3	2.47 ± 0.2	3.31 ± 0.1
Mixed Silver fir-Oak	9	13	21	3325 ± 469	145 ± 12	260 ± 16	2.27 ± 0.1	2.39 ± 0.1	3.20 ± 0.1
Mixed Silver fir-Rhododendron-Maple	14	15	23	3583 ± 866	200 ± 26	367 ± 39	2.51 ± 0.1	2.67 ± 0.3	3.22 ± 0.3
Abies pindrow	9	10	17	2150 ± 653	190 ± 8	320 ± 49	2.08 ± 0.4	2.55 ± 0.1	2.71 ± 0.2
Mixed Birch-Silver fir	9	11	10	2600 ± 694	210 ± 0	355 ± 102	2.49 ± 0.3	2.64 ± 0.1	2.02 ± 0.1
Betula utilis	5	6	8	1450 ± 531	235 ± 20	535 ± 116	1.50 ± 0.1	1.81 ± 0.3	1.55 ± 0.2

communities are presented.

The tree density ranged from 260 (Mixed Silver fir-Oak community) to 535 ind ha^{-1} in *B. utilis* community. In the case of saplings, maximum density was recorded in *H. salicifolia* community (633 ind ha^{-1}) and minimum in Mixed Silever fir-Oak community (145 ind ha^{-1}). Seedling density, however, peaked in Mixed Oak deciduous community (8170 ind ha^{-1}) followed by *Q. floribunda* (5650 ind ha^{-1}) and *Alnus nepalensis* community (5325 ind ha^{-1}). The minimum seedling density was recorded in *B. utilis* community (1450 ind ha^{-1}).

While considering the diversity index, highest value for tree layer was in the case of Mixed Oak deciduous community (3.37) followed by Mixed deciduous (3.31) and Mixed Silver fir-Rhododendron-Maple community (3.22). Whereas, Mixed Silver fir-Rhododendron-Maple community (2.67) followed by Mixed Oak deciduous (2.66) and Mixed Birch-Silver fir community (2.64) showed highest values in sapling layer. Mixed Silver fir-Rhododendron-Maple community (2.51) also peaked for seedling diversity followed by Mixed Birch-Silver fir (2.49) and *Q. floribunda* community (2.46). *H. salicifolia* community invariably had lowest diversity values across three tree strata (tree - 0.73, sapling - 0.64, seedling - 0.70).

Regeneration status and seasonal behavior

In the target site, out of the 43 tree species, 16.3% showed good, 46.5% fair, 25.6% no, 7.0% poor regeneration and remaining 4.7% were represented only by seedlings and saplings (Table 3). ANOVA based analysis revealed uneven variation in density values across the seasons (Figure 5). Starting from summer (2009), a significant (p>0.05) increase in the number of seedlings was observed with onset of rainy season (2009).

Afterward, the seedling density gradually decreased in winter (2009) and summer (2010) and increased significantly in the next rainy season (2010). In the year 2009, the average seedling density was measured about 2,867 ind ha^{-1} in summer that reached 3,491 ind ha^{-1} in the rainy season. In winter 2009, gradual decrease in seedling density (3,182 ind ha^{-1}) was recorded. Similar trends were observed in 2010. A linear regression line showed gradual but non-significant (p>0.05) increase in seedling density across the years.

The growth and establishment of seedling is irrespective of the altitude (Figure 6). *A. nepalensis* and mixed oak deciduous in lower altitudinal zone, Abies-Rhododendron-Maple in mid altitudinal zone and *B. utilis* in high altitude zone showed remarkable regeneration and seedling establishment.

DISCUSSION

Compositional diversity

Considering the floristic richness of representative

Table 3. Density and regeneration status in different forest communities in PSK site.

Species	No. of individuals ha^{-1}			
	Seedling	Sapling	Tree	Status
Abies pindrow	2937.5	109.2	297.5	Fair
A. spectabilis	-	5.0	10.0	No
Acer acuminatum	362.5	35.0	49.2	Fair
A. caesium	545.8	33.3	61.7	Fair
A. cappadocicum	1916.7	120.8	165.8	Fair
Aesculus indica	-	7.5	101.7	No
Alnus nepalensis	1970.8	220.0	274.2	Fair
Betula alnoides	1029.2	23.3	84.2	Fair
Betula utilis	1125.0	185.0	570.0	Fair
Buxus wallichiana	58.3	10.0	-	New
Carpinus viminea	154.2	14.2	66.7	Fair
Celtis australis	-	-	10.0	No
Cornus macrophylla	-	3.3	45.0	No
Corylus jacquemontii	50.0	10.0	33.3	Poor
Elaeagnus parvifolia	-	-	10.0	No
Euonymus fimbriatus	675.0	83.3	115.0	Fair
Eurya acuminate	-	5.0	-	No
Fraxinus micrantha	-	-	35.8	No
Hippophae salicifolia	3654.8	546.7	346.7	Good
Ilex dipyrena	1941.7	118.3	102.5	Good
Juglans regia	16.7	-	42.5	Poor
Lyonia ovalifolia	1170.8	51.7	124.2	Fair
Mahonia borealis	33.3	-	5.0	Poor
Meliosma dilleniaefolia	287.5	34.2	31.7	Good
Neolitsea pallens	3929.2	126.7	123.3	Good
Prunus cornuta	-	-	35.0	No
Pyrus lanata	387.5	12.5	37.5	Fair
Pyrus pahsia	12.5	6.7	-	New
P. vestita	83.3	5.0	61.7	Poor
Quercus floribunda	6037.5	64.2	287.5	Fair
Q. incana	-	-	11.7	No
Q. semecarpifolia	3037.5	19.2	194.2	Fair
Rhododendron arboretum	5820.8	272.5	310.0	Fair
R. barbatum	4887.5	225.8	267.5	Fair
R. campanulatum	650.0	53.3	65.0	Fair
Rhus punjabensis	-	-	2.5	No
Salix daphnoides	628.6	70.0	96.7	Fair
Symplocos chinensis	258.3	49.2	70.8	Fair
S. ramosissima	-	3.3	33.3	No
Syringa emodi	183.3	32.5	8.3	Good
Taxus wallichiana	912.5	116.7	114.2	Good
Ulmus wallichiana	633.3	35.8	152.5	Fair
Viburnum nervosum	487.5	64.2	2.5	Good

site, the PSK site with over 332 plant species emerged as more species rich and representative as compared to other sites in NDBR (Rawat, 2013). This can be attributed to the existence of more diverse and broadleaf forest communities (11 forest communities). In general, PSK site has 72% coverage of broadleaf dominated forests and nearly 28% conifer dominated ones, which is much higher than any other site in NDBR (Joshi, 2002; Joshi

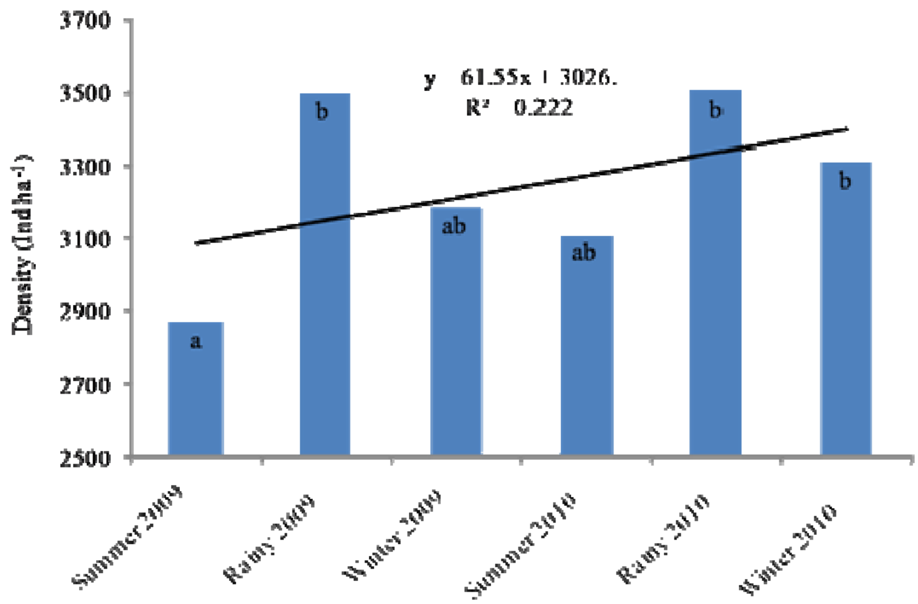

Figure 5. Average seasonal recruitment pattern in the entire forest communities. ANOVA was applied against the average density; same letters denote non-significant difference.

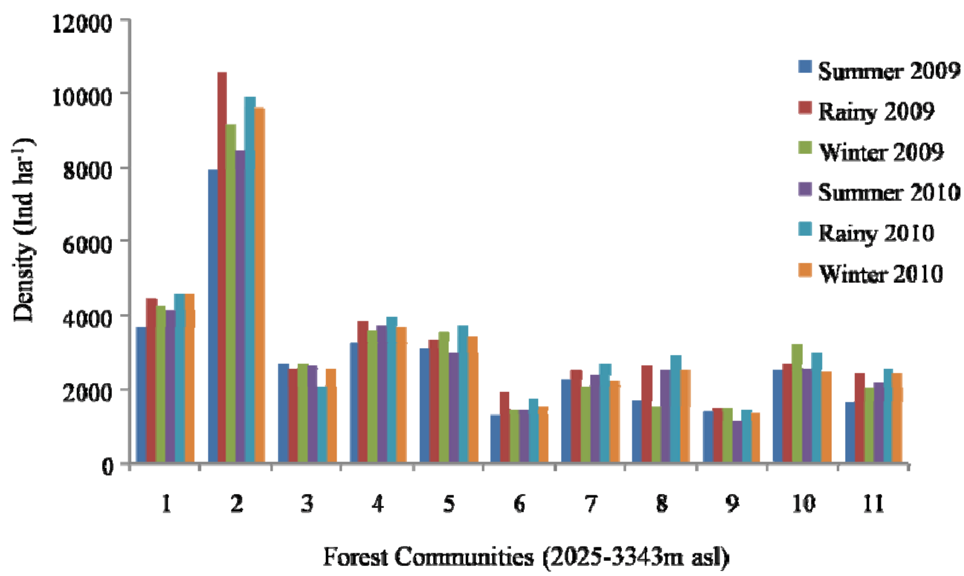

Figure 6. Seasonal recruitment patterns in different forest communities in PSK site in NDBR. [1. *Alnus nepalensis*; 2. Mixed Oak-deciduous; 3. *Hippophae salicifolia*; 4. *Quercus floribunda*; 5. *Quercus semecarpifolia*; 6. Mixed-deciduous; 7. Mixed Silver fir-Oak; 8. Mixed Silver fir-Rhododendron-Maple; 9. *Abies pindrow*; 10. Mixed Birch-Silver fir; 11. *Betula utilis*].

and Samant, 2004; Rawat, 2013). The explanations for this lies in the fact that PSK site supports more mesic (moist) conditions. In general, coniferous communities are broadly reported to be species poor as compared to broadleaf communities (Singh and Singh, 1992).

The mean tree density (260-535 ind ha^{-1}) was comparable to the values (320-1670 ind ha^{-1}) reported in earlier studies pertaining to low and high altitude forests of west Himalaya (Bankoti, 1990; Joshi and Samant, 2004; Gairola et al., 2008; Garkoti, 2008). The density values closely corresponded with the values (270-610 ind ha^{-1}) recorded from the same region two decade ago (Bankoti, 1990), however, these values fall in lower range of values reported for the region (Zobel and Singh, 1997).

The mean values range for seedling density (1450-8170 ind ha^{-1}) was considerably higher as compared to earlier reports for high altitude forest in similar areas (Bankoti, 1990; Joshi, 2002; Joshi and Samant, 2004). The range of mean sapling density (145-633 ind ha^{-1}) falls within the lower range (40-6667 ind ha^{-1}) reported earlier (Bankoti, 1990; Joshi, 2002; Joshi and Samant, 2004; Gairola et al., 2008).

Current state of tree species richness (4-23 species) was comparable to earlier reports (24-42 species) from high altitude forests of the region. Similarly, the diversity values (0.73-3.37) are within the reported range (0.45-3.29) from the region (Bankoti, 1990; Adhikari et al., 1991; Joshi, 2002; Gairola, 2005; Gairola et al., 2008). The trends of species richness and diversity indicate forests in mid to higher altitudes are more diverse than the lower altitude forests in the west Himalaya.

Current demographic profiles

The size class distribution gives a demographic profile of the region which may indicate future prospects of target communities (Gairola, 2005). In general, the forest communities showed greater accumulation of individual in seedlings and a significant decline towards sapling and tree size classes. This structure reveals that the conversion from seedling to sapling is not proportional. This can be explained on account of greater mortality of seedlings due to severe winters. Similar conclusions have been drawn by other workers elsewhere (Khumbongmayum et al., 2006).

Further, large scale extraction of biomass, particularly of selected species, has also been reported to bring in structural changes in plant communities in the region and elsewhere (Thadani and Ashton, 1995; Singh et al., 1997; Spurr and Barnes, 1980; Cairns and Moen, 2004; Shrestha et al., 2007). As such, disturbances have been observed to exert profound effect on forest development, since they alter vegetation and release growing space, making it available for other species to occupy (Oliver and Larson, 1990; Mishra et al., 2003; Mishra et al., 2004; Gairola et al., 2008). The lower density of the higher girth classes of trees in the region, as compared to intermediate or lower girth classes, can be attributed to the relatively high mortality of large canopy trees (Goff et al., 1975; Lorimer et al., 2001).

Seasonal regeneration pattern

While considering the demographic profile, greater accumulation of seedlings can be attributed to occasional mast seedling and recruitment for some dominant species (*Q. floribunda, Q. semecarpifolia*). However, the long-term persistence of such recruits was later confirmed by two years seasonal investigation on seedling survival patterns. Therefore, if this trend continues, the forest communities are likely to have increased dominance of such species.

Further, the seasonal recruitment patterns suggest that the regenerating species are now established and if this trend continues, the forest communities will sustain long in future. The overall population structure of tree species reveals that seedlings populations dominate tree populations and the fluctuation in population density in various seasons is related to the prevailing environmental factors. Germination of freshly dispersed seeds is high for most of the species during the rainy season, which is the wettest season. Lieberman and Li (1992) and Swaine et al. (1990) have observed similar patterns in tropical dry forest at Pinkwae, Ghana. Adverse effects of soil moisture stress and unfavorable temperature on survival of plant species may be responsible for reduction of seedling population during winter season (Perira and Kozlowski, 1977; Schulte and Marshall, 1983; Khumbongmayum et al., 2006). The gradual decrease in recruitments in summer season can be attributed to the anthropogenic pressure in form of lopping and grazing. Evolutionary history of grazing and environmental moisture or primary productivity interacts in determining species adaptations for tolerance or avoidance of herbivores and in community responses to grazing (Milchunas and Lauenroth, 1993). The average of fluctuations in recruitment density across altitude and seasons revealed established regeneration.

Expected changes in forests vis- a-vis representativeness

Broadly, the demographic profiles exhibited progressive structures suggesting long term persistence of the communities/species in these sites. However, diverse trends of density and richness of recruits helps us to depict the status of species in different forest communities (Khan et al., 1987; Shankar, 2001; Bhuyan et al., 2003). In this respect, following patterns across recruitment layers are noticeable for different communities:

Sapling layer

1. Communities having high representation of dominant species: *Alnus nepaensis, H. salicifolia,* Mixed deciduous, Mixed Silver fir-Rhododendron-Maple, *B. utilis* communities.
2. Communities having high representation of co-dominant species: Mixed Birch-Silver fir
3. Communities having poor representation of dominant species but highest of co-dominant species: *Q. floribunda, Q. semecarpifolia* communities.

4. Communities having poor representation of dominant and co-dominant species and high representation of other species: Mixed Oak deciduous**,** Mixed Silver fir-Oak communities.

Seedling layer

1. Communities having high seedling representation of dominant species: Mixed Oak deciduous, *H. salicifolia, Q. floribunda, Q. semecarpifolia,* Mixed Oak deciduous, Mixed Silver fir-Oak, Mixed Silver fir-Rhododendron-Maple, *Abies pindrow, B. utilis* communities.
2. Communities having sufficient representation of both dominant and co-dominant species, and accompanied by high representation of other species as well: Mixed Birch-Silver fir community.

Therefore, based on above trends of seedlings and saplings, various combinations and trends of communities can be drawn. For example, (i) the communities with greater representation of dominant species in both seedling and sapling stage would suggest further strengthening of dominant species; (ii) the communities with greater representation of both dominant and co-dominant in sapling and seedling layers would indicate the composition remains unchanged in future; (iii) the communities having greater proportion of seedling and saplings of co-dominant would indicate possible dominance of such species in future; (iv) the communities having greater representation of seedlings and saplings of the species other than the dominants and the co-dominants would indicate likely future changes in composition of target communities.

The demographic profiles of some of the dominant and some relatively less prominent tree species definitely require attention. For example, in the case of two dominant species, *Q. floribunda* and *Q. semecarpifolia*, in spite of their greater seedling numbers both were less prominently represented in sapling layer. Certain relatively less prominent species like *Celtis australis, Elaeagnus parvifolia, Fraxinus micrantha, Prunus cornuta, Quercus incana* and *Rhus punjabensis* were, however, represented only in tree layer suggesting that these species are not properly regenerating through near past and in the present. Therefore, long-term persistence of such species is in question. Besides, *Abies spectabilis, Aesculus indica, Symplocos ramosissima* with representation only in tree and sapling class and *Cornus macrophylla, Juglans regia, Mahonia borealis, Viburnum nervosum* in tree and seedling class only would require attention. On the contrary, species like *Buxus wallichiana, Pyrus pahsia, Eurya acuminata* having individuals in sapling and seedling class only indicated their recent introduction in respective communities.

Differences in regeneration behavior of various species are indicative of future structure and dynamics of the communities under natural circumstances. Present study reveals good regeneration and exemplifies regeneration of tree species which is largely dependent on the prevailing environmental factors and anthropogenic threat, and if the existing ecological factors are not jeopardized, the future maintenance of the tree species in PSK site in NDBR will be sustained. However, presence of 'new' and 'not regenerating' species must be taken into consideration at the time of development of policies and plan for proper conservation and management of respective forest communities.

Conclusion

1. The data sets available, and generated through this study, provide enough bases for establishing PSK site in NDBR as potential sites for long-term ecological monitoring under various change scenarios.
2. Comparatively, the PSK site of the reserve supported greater diversity of plant communities and species as compared to other sites in the reserve.
3. Communities in target site broadly exhibited progressive demographic profiles which suggested long-term persistence of communities. However, unusually greater accumulation of seedling in PSK site with indications of successful establishment is indicative of possible changes in composition of communities in this site. Also, various community specific patterns of demography were revealed.
4. Assessment and analysis of changes in structure and composition of different forest types provides baseline data for developing priorities for conservation of other representative landscapes in the reserve as well as in the Himalaya.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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