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The Potential Contribution of Wildlife Sanctuary to Forest Conservation: A Case Study from Binsar Wildlife Sanctuary

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Abstract: Forest vegetation of a protected area (Binsar Wildlife Sanctuary) in Kumaun region (west Himalaya) was analysed for structure, composition and representativeness across three different altitudinal belts, lower (1,600-1,800 m a.s.l.), middle (1,900-2,100 m a.s.l.) and upper (2,200-2,400 m a.s.l.) during 2009-2011 using standard phytosociological methods. Four aspects (east, west, north and south) in each altitudinal belt were chosen for sampling to depict maximum representation of vegetation in the sanctuary. Population structure and regeneration behaviour was analysed seasonally for two years to show the establishment and growth of tree species. A total of 147 plant species were recorded from the entire region of which 27 tree species were selected for detailed study. Highest number was recorded at upper (18 species), and lowest at lower altitudinal belt (15 species). The relative proportion of species richness showed higher contribution of tree layer at each altitudinal belt. The population structure, based on the number of individuals, revealed a greater proportion of seedling layer at each altitudinal belt. The relative proportion of seedlings increases significantly along altitudinal belts ($p<0.05$) while opposite trends were observed in sapling and tree layers. The density of sapling and seedling species varied non-significantly across seasons ($p>0.05$). The density values decreased in summer and increased during rainy season. As far as the regeneration status is concerned, middle and upper altitudinal belts showed maximum number of species with fair regeneration as compared to lower altitudinal belt. Overall density diameter distribution of tree species showed highest species density and richness in the smallest girth class and decreased in the succeeding girth classes. This study suggests that patterns of regeneration behaviour would determine future structural and compositional changes in the forest communities. It is suggested that the compositional changes vis-à-vis role of 'New' and 'Not regenerating' species need priority attention while initiating conservation activities in the sanctuary. This study calls for exploring other less explored Wildlife Sanctuaries in the Himalaya and across the world, to achieve overall biodiversity status in these protected areas and thus to justify their role in conserving biodiversity in the region.

Keywords: Altitudinal gradient; Population structure; Regeneration status; West Himalaya; Wildlife Sanctuary.

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Introduction

Conservation of the world wild genetic

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resources increasingly depends on a small percentage of land area called protected areas in nature reserves, especially at a time when natural areas are being rapidly depleted (Macdonald et al. 1989). The Protected Areas (PAs) are repositories of biodiversity in a biogeographic unit. They function as a refuge for native plants, animals and micro-organisms and as an outdoor laboratory (Brandt and Rickard 1994). In the concept of protected areas, Wildlife Sanctuaries (WLS) are the protected areas designated to conserve and sustain the biodiversity of the region with a special focus on the wildlife (faunal component of the biodiversity), within which hunting is either or strictly controlled. These representative landscapes harbor rich diversity of both faunal and floral component of biodiversity, thus act as a reservoir of much local biodiversity element (Dhar et al. 1997, 1998). WLS have always been the major source of natural resources like fuel, fodder, medicinal plants, edible fruits (Samant et al. 2006; Majila and Kala 2010; Singh and Rawat 2011) and gene pool of threatened species (Rana and Samant 2010) in west Himalaya. The biological resources make indirect contributions to the welfare and stability of the local environment (Khumbongmayum et al. 2006). Various medicinal plants, fuel, fodder and edible species are found abundantly in WLS and they are the important livelihood options and source of diverse gene pool. As a result, WLS can help in assessing the potential values of forest communities within a conserved area.

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 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 i.e. 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; Kharakwal 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).

Though, studies on different aspects of biodiversity have been carried out in WLS of Himalaya viz. natural resource utilization (Dhar et al. 1998; Samant et al. 2006; Majila and Kala 2010), ecosystem functions (Majila et al. 2005), management and development (Samant et al. 1998), threat assessment (Pant and Samant 2008; Rana and Samant 2010), ethonobiological enumerations (Singh and Rawat 2011) and floristic analysis (Lal and Samant 2010; Samant et al. 1995) but a systematic approach on the population structure and regeneration pattern of forest communities in WLS 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., 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 WLS. Keeping the above in mind, seasonal phytosociological investigations have been carried out in Binsar Wildlife Sanctuary of Uttarakhand.

1 Methodology

1.1 Study area

In Indian Himalayan Region (IHR), 98 WLS have been identified from 12 states covering 29,143.27 km² geographical areas. Uttarakhand harbours six WLS which constitute about 23% (6,479 km²) of total geographical area covered by Himalayan WLS. Among the six WLS in Uttarakhand, Binsar is one of the important WLS lies between 29°30' to 29°43' N and 79°41' to 79°47' E in Almora district. It covers a total geographical area of 46 km². The entire region is dominated by Oak species with altitude ranges between 1,600 m - 2,400 m a.s.l. Binsar is famous for some very important fauna like Ghoral (*Nemorhaedus goral*), Flying Squirrel (*Petaurista petaurista*), Wild boar (*Sus scrofa*), Black bear (*Selenarctos thibeticus*), Red-billed Blue Magpie (*Urocissa erythrorhyncha*), Kalij pheasant (*Gennaeus hamiltoni*) etc., which are under different threat categories. In addition to the faunal diversity, the sanctuary harbours many important woody and herbaceous plants species. Three main forest types in the sanctuary Oak forests, Oak-Pine forests and Chir-Pine forests provides favourable conditions for the growth of many shade and moist plants like moss, lichens and bryophytes. In the study area, three layers of vertical stratification named 'belt' were observed. In lower belt (1,600 m - 1,800 m), *Pinus roxburghii* was the dominated species with having open canopy, *Quercus leucotrichophora* and *P. roxburghii* both with sparse canopy dominated the middle belt (1,900 m - 2,100 m) and *Q. leucotrichophora* dominated the higher belt (2,200 m - 2,400 m) with relatively close canopy.

1.2 Survey and sampling

Population structure and regeneration behaviour of all the plant communities occurring in Binsar Wildlife Sanctuary (BWLS) was studied during 2009-2011 using quadrate method within three altitudinal belts. For this purpose 120 quadrates of 10 m × 10 m were laid randomly in four aspects in each belt. Number of species in three tree layers (seedling, sapling and tree) in all three belts was recorded. A seasonal investigation on population structure and regeneration behaviour of all tree species in three altitudinal belts was carried out during summer season: May-June, rainy season: mid July to August and winter season: November-December (Negi 1995) in the years 2009 and 2010. Relative, proportion (%) of the different diameter groups/layers, i.e. seedlings, saplings, and trees, to the richness and density in all belts was calculated and figures were drawn. Three dominant species *Quercus leucotricophora, Pinus roxburghii and Rhododendron arboretum* were selected from the three belts for studying detailed population structure to predict the future compositional changes in parent communities.

1.3 Data analysis

Density of all the individuals of seedlings (≤20 cm height and <10 cm girth), saplings (<30 cm girth and >20 cm in height) and trees (≥ 30 cm girth at breast height of 1.37 m) of all the species were determined (Curtis and Mcintosh 1950). Data on tree species richness, population structure and recruitment behaviour were analyzed using MS-Excel. Similarity index (*community coefficient*) of woody species among the three altitudinal belt was calculated using the standard formula (Jaccard 1912).

$$C_j = j/(a+b-j)$$

where j is the number of species common to altitudinal belts, a is the number of species in belt A and b is the number of species in belt B.

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

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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.

2 Results

2.1 Community composition: diversity and distribution pattern

A total of 147 plant species were recorded in BWLS of which 90 species were herbs, 20 were shrubs and 27 were trees. Among them, there are 12 species with edible fruits, 3 species are timber yielding, 26 are good fuel and fodder, 8 have sacred values and 46 are medicinally important. All the tree species are distributed in three belts within a wide altitudinal range of 800 m (1,600 m to 2,400 m). The similarity index (community coefficient) of tree species among the three altitudinal belts is given in Table 1.

The highest similarity index value was recorded between lower and middle belts in tree (0.47) and sapling (0.75) layers. In seedling layer, highest similarity (0.87) value was recorded between middle and upper belts. In tree layer, eight species viz., *Quercus leucotrichophora*, *Rhododendron arboeum*, *Lyonia ovalifolia*, *Cornus macrophylla*, *Alnus nepalensis*, *Myrica esculenta* were common to all three belts. Six and eight species were common to sapling and seedling layers respectively. The lower altitudinal belt was dominated by *Pinus roxburghii* (145 ind ha^{-1}). In middle belt, *Q. leucotricophora* (168 ind ha^{-1}) and *Pinus roxburghii* (108 ind ha^{-1}) were found dominant species. Upper belt was dominated by *Q. leucotricophora* (210 ind ha^{-1}). The total density per hectare of all seedlings, saplings and trees taken together ranged from 2425±40.1 in the lower belt to 3240±36.2 ind ha^{-1} in upper belt (Figure 1).

2.2 Species richness, density and population structure

Out of the total 27 species found in BWLS, highest number (18 species) of tree species was recorded from upper belt. Middle altitudinal zone contributed maximum number of saplings (12 species) and seedlings (14 species) species. Minimum number of seedlings (10 species), saplings (9 species) and trees (13 species) species was found in lower belt. Altitudinal belt-wise analysis revealed decreasing trend of relative proportion of total species from lower (13 species: 48.1%) to upper (18 species: 66.6%) belt. The total 27 species were presented in tree layer while 51.8% of them recorded in seedlings and sapling layers each. However, the relative proportion of species at different altitudinal belts and tree layers did not show marked variation (Figure 2). Further, girth class wise analysis showed that species richness in tree layer consistently decreased with increase in girth from 31 cm - 60 cm to > 90 cm in almost all three altitudinal belts (Figure 3). The species

Table 1 Similarity index (*community coefficient*) of different tree species strata among different altitudinal belts in Binsar Wildlife Sanctuary

Sacred groves		Lower	Middle	Upper
Tree layer	Lower	1.00	0.47	0.29
	Middle		1.00	0.38
	Higher			1.00
Sapling layer	Lower	1.00	0.75	0.43
	Middle		1.00	0.64
	Higher			1.00
Seedling layer	Lower	1.00	0.71	0.57
	Middle		1.00	0.86
	Higher			1.00

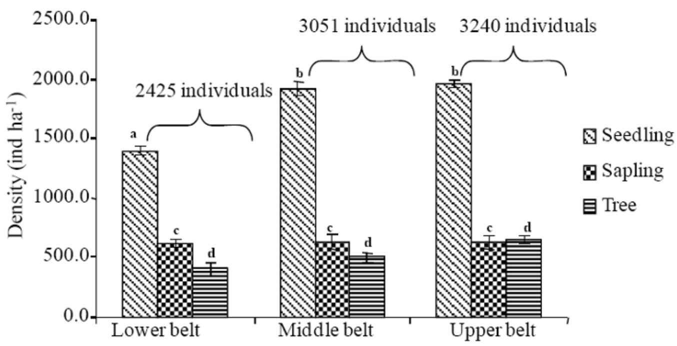

Figure 1 Population structure of seedlings, saplings and trees species in three altitudinal belts in Binsar Wildlife Sanctuary. Total density in each stratum is given at the top of corresponding bars. Note: Same letters denote non-significant difference; a, b used for seedling; c for sapling; d for tree.

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richness was found maximum in lower girth class (31 cm - 60 cm) and minimum in higher girth class (>90 cm) in all three belts.

A total of average 2,905 ind ha^{-1} were recorded in all three layers in BWLS. Average seedlings (1,760 ind ha^{-1}) shared 60.6% of the total density. The share of average trees (17.8%) and saplings (21.6%) was almost similar. Belt wise analysis revealed maximum contribution of seedling layer to the total density in all three belts. Lower altitudinal belt showed significant difference in seedling density with middle and upper belts ($p<0.05$). It ranged from 1,400 ind ha^{-1} (57.7%) in lower belt to 1,960 ind ha^{-1} (60.5%) in upper belt. Sapling and tree layers did not show marked variation ($p>0.05$) in relative proportion across belt (Figure 1). The density in tree layer decreased across increasing girth classes except for upper belt. Lower girth class (31 cm - 60 cm) contributed maximum (60.3%) density at lower and middle (45.3%) belts respectively (Figure 3a, 2b). In upper belt, maximum (53.8%) density was added by girth class 61 cm - 90 cm (Figure 3c).

The population structure of three dominant tree species in the associated belt showed that seedlings constituted maximum proportion in all three belts i.e., 54.3% of the total density (1,698 in ha^{-1}) in lower belt; 62.7% (total density 2,213 ind ha^{-1}) in middle and 58.9% (total density 1,616 ind ha^{-1}) in upper belt. Considering seedling contribution, *Q. leucotricophora* dominates all three belts (Figure 4). Saplings and trees represent maximum individuals of *Q. leucotricophora* in middle and upper belts and of *P. roxburghii* in the lower belt. *R. arboretum* has showed its presence abundantly in all three altitudinal belts also in all three species strata (seedling, sapling and tree) followed by *Q. leucotricophora* and *P. roxburghii*. However, individuals of *P. roxburghii* were completely absent in upper belt. Belt-wise analysis showed decreasing proportion of species from seedling layer to tree layer at each belt except in the

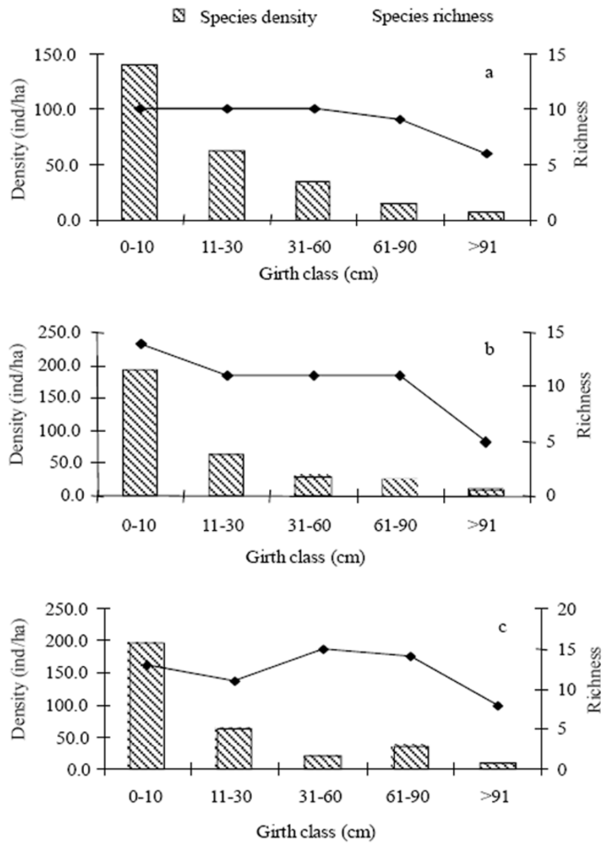

Figure 3 Girth class wise species density and species richness of tree species in Binsar Wildlife Sanctuary. (a) Lower belt; (b) Middle belt; (c) Upper belt

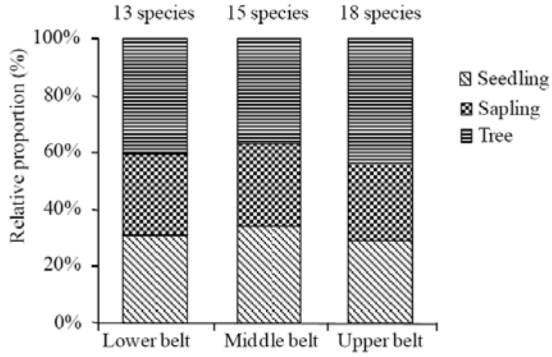

Figure 2 Relative proportion of seedlings, saplings and trees species in three altitudinal belts in Binsar Wildlife Sanctuary. Total number of species is given at the top of corresponding bars

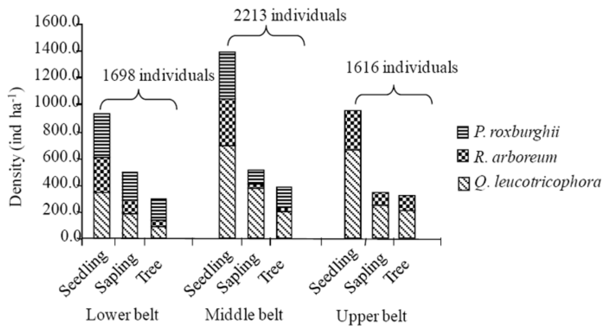

Figure 4 Population structure of selected trees species; *Q. leucotricophora*, *R. arboreum* and *P. roxburghii* in Binsar Wildlife Sanctuary. Total density in each stratum is given at the top of corresponding bars

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middle belt (seedling>sapling<tree). In lower belt, *P. roxburghii* constituted about 39.3% of the total density (1,698 ind ha^{-1}). Middle and higher belts were dominated by *Q. leucotricophora* in terms of maximum species density which has contributed 56.3% (total density 2,213 ind ha^{-1}) in middle and 68.5% (total density 1616 ind ha^{-1}) in higher belt (Figure 4).

2.3 Regeneration status and seasonal behaviour

In lower altitudinal belt, out of the 15 species, 33% showed good regeneration pattern, 20% fair, 33% no regeneration and remaining 14% were represented only by seedlings and saplings. Middle belt has lowest number of species which are regenerating 'good' (11%). Out of 18 species, 7(38%) showed fair regeneration, 4(23%) and 1(5%) species exhibited no and poor regeneration respectively. New species constituted 23% (4 species) of the total species. Among the total 18 species in higher belt, 4 (23%) species showed good regeneration, 6(33%) and 2 (11%) were regenerating fair and poor respectively. Six species (33%) were recorded not regenerating. No 'new' species was recorded in upper belt (Table 2).

Seasonal behaviour of recruitment showed marked but non-significant (p>0.05) variation in density in seedling layer. Starting from summer, a gradual increase in the number of seedlings was observed with onset of rainy season. Afterward, decrease in the seedling density was observed in winter which gradually increased in next summer. In the year 2010, the seedling density was measured about 1,640 ind ha^{-1} in summer that reached 1,760 ind ha^{-1} in rainy season. In winter 2009, gradual decrease in seedling density (1,720 ind ha^{-1}) was recorded. Similar trends were observed in 2010. The growth and establishment of seedling is highly affected in the lower altitudinal belt as compare to the middle and upper altitudinal belts (Figure 5a). Sapling population showed maximum establishment in middle belt (Figure 5b). Fluctuations in establishment of saplings in lower and upper belts were observed in 2009, which, later in 2010 became stable. Overall, no noticeable variation (p>0.05) was observed in sapling establishment across seasons.

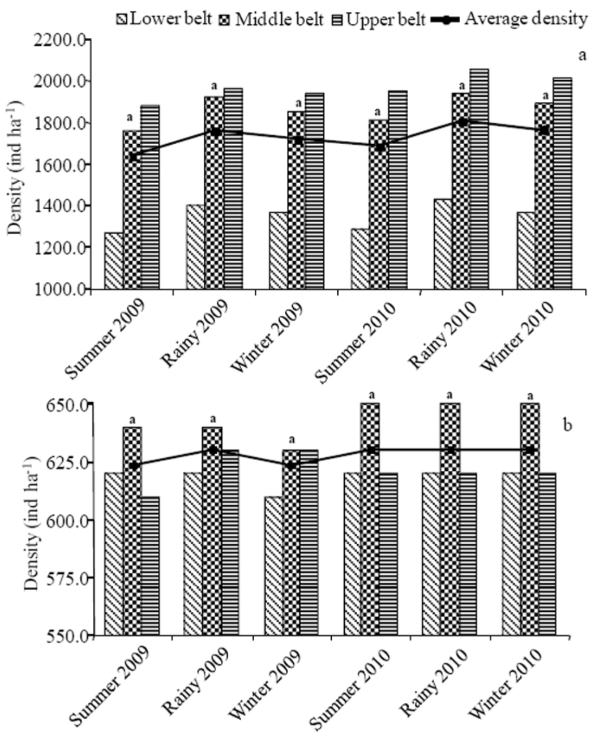

Figure 5 Seasonal population structure of; (a) seedlings, and (b) saplings in Binsar Wildlife Sanctuary. Note: The *T-test* was applied against the average density; same letters denote non-significant difference

3 Discussions

3.1 Community composition and girth class wise species richness and density

Forests of humid east and dry west Himalaya are represented in the study area. *Pinus roxburghii* and *Quercus* species are typical west Himalayan elements and oak forest (*Quercus leucotrichophora, Q. glauca* and *Q. lanuginosa*) as found in present case are widely distributed in the west with higher concentrations in central Himalaya (Singh et al. 1984; Singh and Singh 1986). In our study, *Q. leucotircophora* was abundantly found at 1,900 m - 2,400 m as compared to 1,200 m - 2,300 m by Singh and Singh 1986; 1,700 - 2,100 m by Singh et al. 1994; 1,800 m - 2,300 m by Hussain et al. 2000, 2008. Chir pine forest exhibited the elevational zone 1,600 m - 1,800 m as compared to 400 m - 2,300 m by Sahni 1990; 700 m - 1,000 m by Brown et al. 2011. The sanctuary includes forests of both

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Table 2 Density and regeneration status of different species in three altitudinal belts in Binsar Wildlife Sanctuary (BWLS)

Species	Lower belt (1,600 m - 1,800 m)				Middle belt (1,900 m - 2,100 m)				Upper belt (2,200 m - 2,400 m)			
	No. of individuals/ha				No. of individuals/ ha				No. of individuals/ ha			
	SE	SA	Tree	Status	SE	SA	Tree	Status	SE	SA	Tree	Status
Quercus leucotrichophora A. Camus.	353	183	93	Good	700	378	168	Good	653	245	210	Good
Rhododendron arboeum Smith.	260	103	38	Good	338	30	43	Fair	300	98	110	Fair
Lyonia ovalifolia (Wall.) Drude.	148	15	30	Fair	180	23	38	Fair	30	45	43	Poor
Cornus macrophylla Wall.	25	8	8	Fair	50	5	10	Fair	88	10	10	Fair
Alnus nepalensis D. Don	115	60	20	Good	10	10	8	Fair	5	55	20	Poor
Myrica esculenta Buch-Ham. Ex. D. Don	118	30	28	Good	138	53	20	Good	50	60	3	Fair
Pinus roxburghii Sargent	313	210	145	Good	350	98	108	Fair	-	-	-	-
Illex dipyrena Wall.	5	7	-	New	35	8	5	Fair	78	-	13	Fair
Persea duthiei (King ex Hook, f.) Koot.	5	-	-	New	15	10	10	Fair	100	30	13	Good
Litsea umbrosa Nees.	-	-	-	-	83	5	3	New	100	36	13	Good
Quercus floribunda Render.	-	-	-	-	5	-	-	New	497	36	165	Fair
Euonymus pendulus Wall.	-	-	-		-	-	-	-	-	-	10	No
Acer oblongum Wall, ex DC.	60	5	3	Fair	8	5	5	Poor	-	-	-	-
Ficus nemoralis Wall, ex Miq.	-	-	3	No	-	-	5	No	-	-	-	-
Cornus capitata Wall.	-	-	5	No	-	-	-	-	-	-	-	-
Picea smithianan (Wall.) Boiss.	-	-	5	No	-	-	-	-	-	-	3	No
Daphniphyllum himalayense (Benth.) Muell.-Arg.	-	-	-	-	-	-	10	No	-	-	-	-
Castenopsis tribuloides (J.E. Sm.) A. DC.	-	-	-	-	-	-	5	No	-	-	-	-
Symplocos ramosissima Wall, ex G. Don	-	-	-	-	-	-	-	-	-	-	5	No
Meliosma pungens (Wall, ex W. & A.) Walp.	-	-	-	-	-	-	5	No	-	-	-	
Symplocos chinensis (Lour.) Drace.	-	-	-	-	7	-	-	New	30	10	5	Good
Betula alnoides Buch.-Ham. ex D. Don	-	-	-	-	3	7	-	New	30	5	5	Fair
Eurya acuminata DC.	-	-	-	-	-	-	-	-	-	-	20	No
Quercus lanuginosa D. Don	-	-	3	No	-	-	-	-	-	-	-	-
Quercus glauca Thunb.	-	-	3	No	-	-	-	-	-	-	-	-
Acer cappadocicum Gled.	-	-	-	-	-	-	-	-	-	-	3	No
Fraxinus micrantha Lingetsh.	-	-	-	-	-	-	-	-	-	-	3	No

SE= Seedling; SA= Sapling

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pioneer and climax stages, *Pinus roxburghii* are an early successional species and oak a climatic climax for the region (Champion and Seth 1968; Singh et al. 1987). The importance of forest types found in present study has already been described for Himalayan region in last few years (Negi et al. 2012). Oak species plays a vital role not only in soil and water conservation but also contribute significantly to the sustenance of rural ecosystems. The wood is used as fuel and for making agricultural tools, leaves as green fodder and leaf litter as cattle bedding. Therefore, they have been exploited indiscriminately (Troup 1921; Purohit et al. 2002). Similarly, Chir pine forests provide a variety of ecosystem services to surrounding inhabitants (Semwal and Mehta 1996; Maikhuri et al. 2000; Kala 2004) as well as high level of revenue to the government.

An analysis of population structure of woody species in WLS based on the girth classes revealed majority of tree species showed reduced abundance from lower to higher girth classes. There was a gradual decrease in species richness and density with increase in girth class in lower and middle belt. Such trends have been reported earlier by Majila and Kala (2010) in the study area. The increased density in girth class 61 cm - 90 cm in upper belt could be attributed to the presence of high number of mature individuals of *Q. leucotricophora* and *Q. floribunda*. On the other side, the minimum density value in girth class 31 cm - 60 cm can be due to the coexistence of maximum number of species.

3.2 Population structure and regeneration behaviour of tree species

Population structure studies along altitudinal gradients of a mountain would be helpful in understanding the influences of environmental factors on the regeneration of natural forests (Wang et al. 2004). The overall population structure of woody species showed highest contribution of seedlings to the total density in all three belts followed by saplings and trees. This indicates good regeneration of tree species in BWLS (Khan et al. 1987; Shankar 2001; Bhuyan et al. 2003) and the future communities may be sustained for a long time period. In general, regeneration of species is affected by anthropogenic factors (Khan and Tripathi 1989; Barik et al. 1996; Sukumar et al. 1998) and natural phenomena (Welden et al. 1991). With an exception of tree layer, maximum sapling and seedling species holding good density value were recorded in middle belt. High occurrence of 'new' species may be due to the invasion through dispersal from adjacent areas and favourable habitat and environmental condition stimulated their establishment and growth. In view of this, the middle belt may be considered as most representative for long term monitoring of ecosystem elements in BWLS. The reduced species richness and density at lower belt could be due to the ecological nature of pine species of not allowing other broadleaf species to replace it (Singh et al. 1984). Canopy structure helps to promote seedling germination through changes in environmental conditions on the florets floor (Espelta et al. 1995). Complete absence of *P. roxburghii* and *Q. floribunda* species in upper and lower belts respectively, could be attributed to their poor regeneration and establishment in unfavorable canopies. The greater number of seedlings and saplings similar in composition with respective overstories suggests long term sustainability of the forests in BWLS. *P. roxburghii*, possesses higher number of seedlings in lower belt also extended in middle belt suggests expansion of this species in the region. The highest seedling density followed by good number of saplings of *Q. leucotricophora* in pine dominating forest in lower belt may be ascribed to the availability of microsites (Espelta et al. 1995; Khumbongmayum et al. 2006). Tripathi and Khan (1990) stated that microsite characteristics of forest floor and micro-environmental conditions under the forest canopy also influence the regeneration of trees by seeds. The low sapling population of *R. arboreum* despite of presence of high number of seedlings in middle and upper belt may be attributed to the adverse impact of micro-environmental factors prevalent during sapling growth (Khumbongmayum et al. 2006). Moreover, close canopy and insufficient light intensity along with thick litter layer at the ground surface may reduce the establishment capacity of Rhododendron seedlings and saplings (Facelli and Pickett 1991). Good regeneration of few other species in oak dominated belts is

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important to consider for future compositional changes.

Seasonal variations in the population structure of tree species in the three belts may be attributed to the differences in their habitat and prevailing micro-environmental factors. 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 unfavourable 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 (Hunt 2001). 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 belts and seasons revealed stable regeneration. Forests in BWLS showed increased regeneration and exhibited good proportion of 'new' species facilitated by the dispersal from nearby forests and prevalence of favourable conditions for germination.

3.3 Expected changes in forests vis- a-vis representativeness

Except *Pinus roxburghii*, the availability of 6 major species based on the density, dominated along a wide altitudinal gradient of 800 m suggested the long-term persistent of forests in BWLS. The expanding population of native *Pinus roxburghii* poses a serious threat to native oak (Quercus) forests of the study area as reported in other parts of Himalaya (Singh and Singh 1987). The inherent capacity of *P. roxburghii* to immobilize available nitrogen from soil is believed to prevent re-invasion of high nitrogen demanding broad leaved species (Singh et al. 1984). Expansion of *P. roxburghii* at recruitment level may provide habitats for proliferation of non-natives herbs (Dhar et al. 1997) in future. The expected compositional changes in *Q. leucotricophora* forest are associated with biomass destruction (Dhar et al. 1997). Large scale extraction of selected species also causes structural change in plant communities (Spurr and Barnes 1980). Disturbances have a 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). Accompanying frequent reproduction and expanding populations of two co-dominant native species, *R. arboretum* and *Lyonia ovalifolia*, result in structural/compositional changes as predicted in Askot Wildlife Sanctuary (Dhar et al. 1997). This phenomenon will help in the expansion of few less preferred natives in the tree layer and non-native herbaceous species. Further, climate is the strongest driver of spatial variation in tree growth, and climate change may therefore have large consequences for forest productivity and compositional changes (Toledo et al. 2011). However, in absence of above mentioned possibilities and any catastrophic events the saplings of dominant species in all three belts will gradually form future crown.

The distribution of tree species in different canopy and altitudes indicates that temperature and moisture are favourable for diversification. Differences in regeneration behaviour of various species would determine future structure and dynamics of the communities under natural circumstances.

Present study reveals good regeneration and exemplifies regeneration of tree species 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 BWLS will be sustained. However, presence of 'new' and 'not regenerating' species must be taken into consideration for predicting future compositional changes.

4 Conclusion

Besides, limitations of our data sets and interpretations, we feel that the results are strong enough to explore the status of BWLS in terms of vegetation dynamics. Keeping the above in mind, this study calls for detailed floristic studies in other unexplored protected landscapes of the Himalaya, so that overall biodiversity status in protected areas can be achieved and the potential role of these conservation sites in harbouring and maintaining rich biodiversity can be highlighted. To achieve the above goal, there is a need to carry out strong research and incorporation of positive management options in policy planning as follows:

(1) There is a need to highlight such conservation sites which are meant to conserve a particular biodiversity component i.e., WLS are mainly designated to conserve a specialized fauna but these sites are equally important with respect to floral diversity as both the component of biodiversity are linked strongly to each other.

(2) Availability of most of the representative forest types in the study area suggests its conservation value. The sanctuary supports a rich diversity of high biological value animals, sensitive plants and wild useful plants.

(3) Establishment of permanent plots in selected sites is necessary to examine the existing plant species and their regeneration pattern to assess the long-term sustainability of biodiversity components in such protected areas.

(4) The present study, therefore, emphasizes on the need for considering the approach of the present study both in research and management of Himalayan forests so as to demonstrate the importance of such protected areas particularly of west Himalaya.

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