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Diversity and regeneration status of tree species in Khokhan Wildlife Sanctuary, north-western Himalaya

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Abstract: The Khokhan Wildlife Sanctuary (KhWLS) located in the Kullu district of northwestern Himalaya and covering an area of 14 km² has not been explored for documenting the structure and composition of vegetation. In this study we examine the site/habitat characteristics, assess the diversity of tree species, delineate forest tree communities, assess the regeneration pattern of tree species, and suggest conservation measures. Sixty-five sites were sampled between 1640 - 2400 m asl and for each site, habitat characteristics, altitude and dominant species were noted. Seventeen forest tree communities were recorded. *Cedrus deodara* community was the most widely distributed followed by *Quercus leucotrichophora*, *Abies pindrow* and *Quercus semecarpifolia* communities. *Cedrus deodara* community had maximum density of trees (1468 Ind ha^{-1}), seedlings (1290 Ind ha^{-1}) and saplings (1172 Ind ha^{-1}), while *Picea smithiana* community recorded the maximum total basal area (186.2 m² ha^{-1}). Of the 17 forest tree communities identified, eight showed maximum regeneration of the dominant species, six showed maximum regeneration of the co-dominant species indicating the possibility of at least partial replacement of the dominant species by the co-dominant species in the future; and three communities showed poor or no regeneration of the dominant species indicating a total replacement of the dominants in the coming years. Long term monitoring of these tree communities for their conservation management is suggested.

Resumen: El Santuario Khokhanpara la Vida Silvestre, localizado en el distrito Kullude los HimalayaNoroccidentales y con una superficie de 14 km², no había sido explorado con el fin de documentar laestructura y la composición de la vegetación. En esteestudiose examinan-lascaracterísticasde sitio/hábitat, se evalúa la diversidadde especies arbóreas, se delimitan las comunidades arbóreas, se evalúa el patrón de regeneraciónde las especies arbóreas y se sugieren medidas deconservación. Se muestrearon 65 sitios entre 1640-2400 m s.n.m. y para cada sitio se anotaron las características del hábitat, la altitud y las especies dominantes. Se registraron 17 comunidades de bosque. La comunidad de *Cedrus deodarafue* la más ampliamente distribuida,seguida por las comunidades de *Quercus leucotrichophora*, *Abies pindrowy Quercus semecarpifolia*. La comunidadde *Cedrus deodaratuvo* la densidad más alta deárboles (1468 ind. ha^{-1}), plántulas (1290 ind. ha^{-1}) y plantas jóvenes (1172 ind. ha^{-1}), mientras que en la comunidad de *Picea smithianase* registró la mayor área basal total (186.2 m² ha^{-1}). De las 17 comunidades de bosque identificadas,ocho mostraron una regeneraciónmáximade la especie dominantey seismostraronuna regeneración máximade las especiescodominantes, lo que indica la posibilidad de que ocurra al menos un reemplazo parcialde la especie dominante por las especies codominantes en el futuro;además, tres comunidades mostraron una regeneración muy pobre o una ausencia total de regeneración de la especie dominante, lo que sugiere que

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habrá un reemplazo total de los dominantes en los años venideros. Se sugiere hacer un monitoreo de largo plazo de estas comunidades arbóreas para su manejo y conservación

Resumo: O santuário de vida selvagem de Khokhan (KhWLS), localizado no distrito de Kullu no noroeste dos Himalaia e cobrindo uma área de 14 km², não tem sido explorado para documentar a estrutura e composição da vegetação. Neste estudo examinámos as características do local / habitat, avaliámos a diversidade de espécies arbóreas, delineámos as comunidades de árvores florestais, avaliámos o padrão de regeneração das espécies arbóreas e sugerimos medidas de conservação. Amostraram-se sessenta e cinco locais entre as altitudes de 1640 - 2400 m tendo-se, para cada local registado as características do habitat, a altitude e as espécies dominantes.Registaram-se dezassete comunidades de árvores florestais. A comunidade de *Cedrus deodarafoi* a mais amplamente distribuído seguida pela de *Quercus leucotrichophora*, *Abies pindrow* e pelas comunidades de *Quercus semecarpifolia.* A comunidade de *Cedrus deodara* apresentou uma densidade máxima de árvores (1468 ha^{-1}), plântulas (1290 ha^{-1}) e árvores juvenis (1172 Ind ha^{-1}), enquanto a comunidade de *Picea smithiana* apresentou a área basal total máxima (186,2 m^2 ha^{-1}). Das 17 comunidades de árvores florestais identificadas, oito mostraram regeneração máxima da espécie dominante, seis mostraram regeneração máxima das espécies codominantes, indicando a possibilidade de, pelo menos no futuro, a substituição parcial da espécie dominante pela espécie codominante, e três comunidades mostraram pouca ou nenhuma regeneração das espécies dominantes indicando uma substituição total das dominantes nos próximos anos. Sugere-se a monitorização de longo prazo das comunidades destas árvores para a gestão dasua conservação.

Key words: Conservation, Khokhan Wildlife Sanctuary, diversity, regeneration, species richness, species diversity and structural pattern.

Introduction

The Indian Himalayan Region (IHR) is known for its diverse, unique, natural, and socio-economically important flora and fauna (Samant *et al.* 1998a). This rich biodiversity is being utilized by the inhabitants of the region for medicine, food (wild edible), fodder, fuel, timber, making agriculture tools, religious and various other purposes (Samant & Dhar 1997; Samant *et al.* 1998 a,b). With the increasing human population, the demand for the economically important biodiversity is increasing. Collection of fodder and fuel species from the forests has been identified as one of the chronic problems in the IHR (Samant *et al.* 2000, 2006; Singh 1998). The anthropogenic pressures including heavy grazing coupled with the natural calamities have led to degradation of natural habitats of many species. Such practices are discouraging the moisture loving species and promoting the hardy and spiny species having little value for the society (Samant *et al.* 2000). This loss of biodiversity and changing pattern of vegetation has necessitated assessing the vegetation composition and regeneration pattern of tree species of the region and prioritizing habitats, communities and species for conservation.

The State of Himachal Pradesh (geographical area, 55,673 km²) comprises the part of Trans & northwest Himalaya that supports a unique biodiversity. Of the total geographical area, 66.45 % is under forests. Protected forests comprise 59.3 % and Reserve Forests 3.41 %. The state supports 32 Wildlife Sanctuaries; two National Parks; one Biosphere Reserve. The Kullu district is one of the richest districts in terms of biodiversity, and supports one National Park (i.e., Great Himalayan National Park) and six Wildlife Sanctuaries (i.e., Manali, Kanawar, Khokhan, Kais, Sainj and Tirthan) (Singh *et al.* 1990). Amongst the wildlife sanctuaries, Khokhan Wildlife Sanctuary (KhWLS) is perhaps the richest wildlife sanctuary in terms of biodiversity and falls in a part of Mohal Khad Watershed (Beas River). Present study was conducted in the Khokhan Wildlife Sanctuary (KhWLS) of Kullu district of northwest Himalaya during 2004 - 2005. Khokhan Wildlife Sanctuary was notified vide 70-GP-53/97, dated 26-2-54 under Punjab Birds and Wild Animals Protection Act, 1933. It covers an area of about 14 km². The altitude

ranges between 1500 - 2787 m asl and the area supports diverse habitats, species and communities of the sub-tropical, temperate and sub-alpine zones.

Structural diversity of some parts of the IHR has been evaluated by various workers (Bankoti *et al.* 1992; Bankoti & Tewari 2001; Kalakoti *et al.* 1986; Ralhan *et al.* 1982; Rawal & Pangtey 1994a,b; Rawal *et al.* 1994; Rawat *et al.* 1999, 2001; Samant *et al.* 2000; Saxena *et al.* 1978; Saxena & Singh 1982; Singh 1998; Singh & Singh 1986, 1987; Singh *et al.* 1987; Singh & Singh 1992; Upreti *et al.* 1985; Tewari 1998 etc.). As regards the quantitative assessment of the vegetation in pro-tected areas, studies are available from Nanda Devi Biosphere Reserve, Askot Wildlife Sanctuary, Kedarnath Wildlife Sanctuary, Valley of Flowers National Parks, Mornaula Reserve Forest, etc. (Dhar *et al.* 1997; Joshi 2002; Joshi & Samant 2004; Pant & Samant 2007; Rawal & Pangtey 1994a,b; Rawal *et al.* 1994; Rawat *et al.* 1999, 2001; Samant *et al.* 2000, 2002, Samant & Joshi 2004 etc.) in Uttarakhand and Great Himalayan National Park, Manali Wildlife Sanctuary, Kais Wildlife Sanctuary, Lahaul valley of proposed Cold Desert Biosphere Reserve, Pin Valley National Park, etc. in Himachal Pradesh (Lal 2007; Rana 2007; Rawat & Singh 2006; Singh 1998; Singh 2007; Verma *et al.* 2003). For the whole Himachal Pradesh only a few studies are available on forest diversity including regeneration pattern. Therefore, an attempt has been made to: (i) study the site/ habitat characteristics; (ii) assess the diversity of tree species; (iii) delineate forest tree communities; (iv) assess the regeneration pattern of tree species, and (v) suggest conservation measures.

Methods

Identification and selection of transects, sites and habitats

Sites were selected on accessible aspects along transects between 1640 - 2400 m asl. The habitats were identified based on physical characteristics and dominance of species. Sites having closed forest canopy with high soil humus and moisture contents were considered as moist habitats. The sites experiencing high anthropogenic pressures were considered as degraded habitats.

Survey, sampling, identification and analysis of data

The field surveys and vegetation sampling were conducted during 2004 to 2005 within the selected sites. For tree layer, in each site, a plot of 50 x 50 m was laid. Trees, saplings and seedlings were sampled by ten randomly placed 10 x 10 m quadrats. The size and number of quadrats were determined following Misra (1968) and Kershaw (1973). For the collection of data from these quadrats standard ecological methods (Curtis & McIntosh 1950; Kershaw 1973; Muller-Dombois & Ellenberge 1974) were followed. From each site, samples of each species were collected and identified with the help of various floras and research papers (Aswal & Mehrotra 1994; Collett 1902; Choudhery & Wadhwa 1984; Dhaliwal & Sharma 1999; Singh & Rawat 2000).

For trees, basal area (BA) and Importance Value Index (IVI) were computed. IVI was calculated as the sum of relative frequency, relative density and relative basal area. Communities were named based on the IVI of species. The abundance data of different sites within the identified communities were pooled to get averages for density, BA and IVI. If a species contributed ≥ 50 % of the total IVI in a particular site/habitat that site was considered a single species dominated community and if < 50 % of the total IVI, a mixed community.

Species diversity

Species richness is the total number of species in a particular community. Shanon Wiener Information Statistic (H′) (Shannon & Weaver 1963) was used to represent species diversity.

Results

Site and habitat characteristics

Total 65 sites representing four major habitats and six aspects were selected and sampled. Maximum sites (56) were represented by shady moist habitat, followed by exposed (4), riverine (3) and degraded (2) habitats. Twenty-three sites were represented in northwest aspect, 17 on southwest, 10 each on northeast and west, 4 on east and 1 on north aspect. The slope varied from 50 - 60°. Site/ habitat characteristics, dominant species, altitude, slope and aspect for KhWLS are presented in Appendix Table 1.

Community diversity and distribution pattern

Seventeen forest communities were identified between 1640 - 2400 m. The community types, altitudinal distribution, sites and habitat representation and major tree associates are presented in Table 1. Among the communities, *C. deodara* community represented the maximum number of sites

Table 1. Community types, their distribution and characteristics in the Khokhan Wildlife Sanctuary.

Community type	Altitude/Altitudinal range (m)	Habitat (s)	Slope (^{0})	Density (Ind ha $^{-1}$)			TBA (m^2 ha^{-1})	IVI of Dominant spp
				Trees	Seedlings	Saplings		
A. pindrow	1860 - 2380	SM	10 - 40	1146	911	913	106.2	91.8
A. pindrow-C. deodara mixed	2100 - 2220	SM	15 - 35	1170	455	920	157.6	127
A. indica	1820 - 2280	SM	15 - 35	1137	510	650	68.6	186
C. deodara	1800 - 2400	SM, R	5 - 60	1468	1290	1172	124.5	116
J. regia	2207 - 2320	SM	20	710	145	180	17.7	156
P. odoratissima	1700 - 2140	SM	5 - 35	570	340	200	99.5	146
P. duthiei-Q. floribunda mixed	2220	SM	35	1232	807	623	125.8	150
P. smithiana	2250 - 2340	SM	20 - 35	818	747	753	186.2	88
P. smithiana-C. deodara-Q. leucotrichophora mixed	1940	SM	25	907	617	496	86.5	60
P. wallichiana	1740 - 2380	E, D	25 - 65	550	240	230	174.2	118
P. ciliata	2320	E	20	750	550	410	9.6	75
Q. floribunda	1790 - 2140	SM	25 - 35	1120	506	543	131.1	120
Q. glauca	1660	R	40	460	440	340	47.5	75
Q. leucotrichophora	1820 - 2100	SM, D	15 - 45	1218	560	595	104.9	70
Q. semecarpifolia	2200 - 2320	SM	15 - 45	1014	697	730	178.7	85
Q. semecarpifolia –A. pindrow mixed	1940	SM	25	887	762	802	77.4	50
R. arboreum	1640	R	40	1020	430	260	37.0	43

Abbreviations used : SM = Shady Moist; R = Riverine; E = Exposed; D = Degraded; TBA = Total basal area; and IVI = Importance Value Index.

(19), followed by *Q. leucotrichophora* (7 sites), *A. pindrow* (6), *Q. semecarpifolia* (5), *Pinus wallichiana* and *Persea odoratissima* (4 sites, each). *C. deodara, P. odoratissima, P. wallichiana*, *Quercus floribunda*, *A. pindrow* and *Q. leucotrichophora* communities showed a relatively wide altitudinal range.

Species richness

Total 28 tree species were recorded. The tree species richness was highest in *C. deodara* and *P. odoratissima* communities (17, each), followed by *Aesculus indica* (12) and *A. pindrow*, *Picea smithiana*, *Q. leucotrichophora* and *Q. semecarpifolia* (11 each) communities, whereas the species richness of seedlings was highest in *C. deodara* community (17), followed by *A. pindrow-C. deodara* mixed and *Q. leucotrichophora* (10, each), communities. Sapling species richness was highest in *C. deodara* community (17), followed by *Q. leucotrichophora* (11) and *A. pindrow* and *Q. semecarpifolia* (10, each) communities.

Structural pattern

The altitudinal range, habitat (s), slope, density of trees, saplings and seedlings, TBA (total basal area) and IVI of dominant tree species of communities are presented in Table 1. The total tree density ranged from 460 - 1468 Ind ha^{-1} and TBA, 9.6 - 186 m^2 ha^{-1}. Total sapling density ranged from 180 - 1172 Ind ha^{-1} and total seedling density 145 - 1290 Ind ha^{-1}.

Species diversity (H′)

Species diversity (H′) for trees ranged from 0.74 - 2.66, seedlings, 0.65 - 2.57 and saplings, 0.59 - 2.57 (Table 2). The diversity of trees was highest in *P. odoratissima* community, followed by *C. deodara*,

Table 2. Species diversity (H′) of different communities in the Khokhan Wildlife Sanctuary.

Community type	Species diversity		
	Trees	Saplings	Seedlings
A. pindrow	2.23	2.21	1.97
A. pindrow-C. deodara mixed	1.94	1.95	1.99
A. indica	2.37	2.02	1.71
C. deodara	2.46	2.57	2.57
J. regia	0.74	0.59	0.65
P. odoratissima	2.66	2.01	1.99
P. duthiei-Q. floribunda mixed	1.46	1.05	1.29
P. smithiana	2.26	2.14	2.14
P. smithiana-C. deodara-Q. leucotrichophora mixed	1.87	1.41	1.67
P. wallichiana	1.79	1.66	1.53
P. ciliata	0.99	1.02	1.08
Q. semecarpifolia	2.17	2.16	2.08
Q. floribunda	2.00	1.99	2.01
Q. glauca	1.47	1.09	1.42
Q. leucotrichophora	2.26	2.23	2.17
Q. semecarpifolia-A. pindrow mixed	1.46	1.50	1.70
R. arboreum	1.82	1.07	1.30

A. indica and *Q. leucotrichophora* and *P. smithiana*, communities. The diversity of seedlings and saplings was highest in *C. deodara* community, followed by *Q. leucotrichophora P. smithiana* and *A. pindrow* communities.

Regeneration status

The regeneration status of tree species in the indentified communities has been presented in Figs. 1 to 3. Based on the regeneration status i.e., proportion of saplings and seedlings in the population, the identified communities have been categorized as follows :

(i) *Communities having highest regeneration of the dominant species particularly in the sapling layer*

The communities of this category were *P. odoratissima, P. wallichiana, Q. glauca, Q. leucotrichophora, R. arboreum, P. smithiana-C. deodara-Q. leucotrichophora* mixed, A. *pindrow-C. deodara* mixed and *P. smithiana* (Fig. 1 A-H).

(ii) *Communities having sufficient regeneration of the dominant species but highest regeneration of the co-dominant species particularly in the sapling layer*

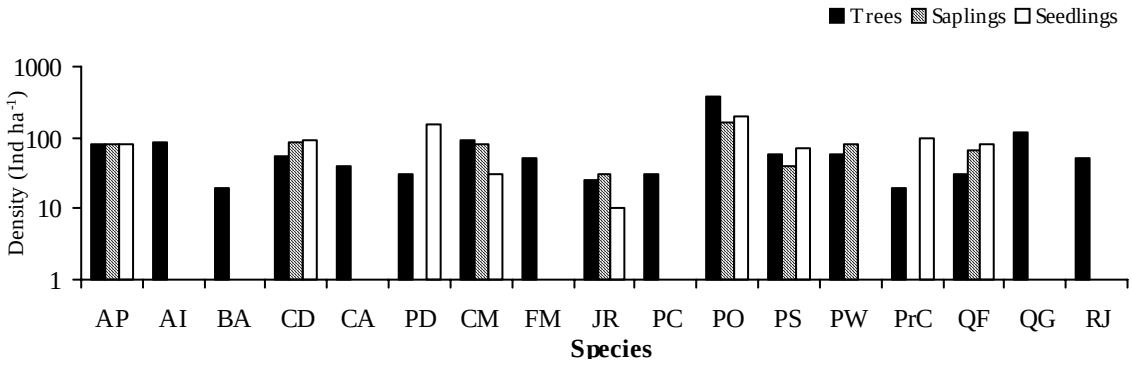
The communities of this category were *A. pindrow, A. indica, C. deodara, Q. semecarpifolia-A. pindrow* mixed, *Q. floribunda* and *Q. semecarpifolia* (Fig. 2 I-N).

(iii) *Communities having poor or no regeneration of the dominant species*

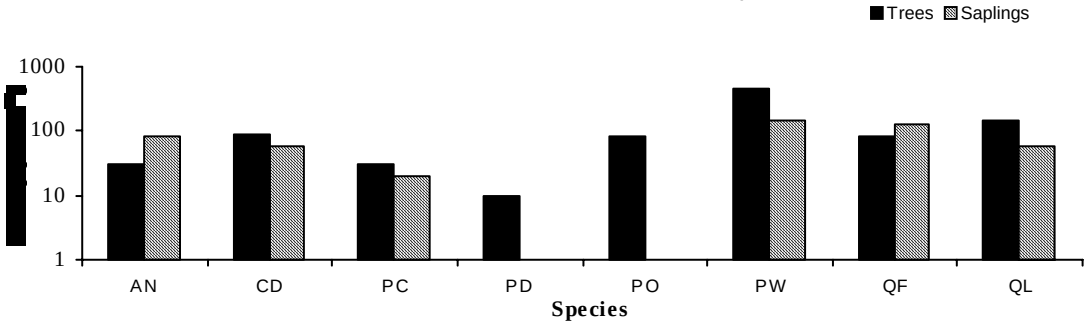
The communities of this category were *J. regia, P. ciliata* and *P. duthiei-Q. floribunda* mixed (Fig. 3 O-Q).

Discussion

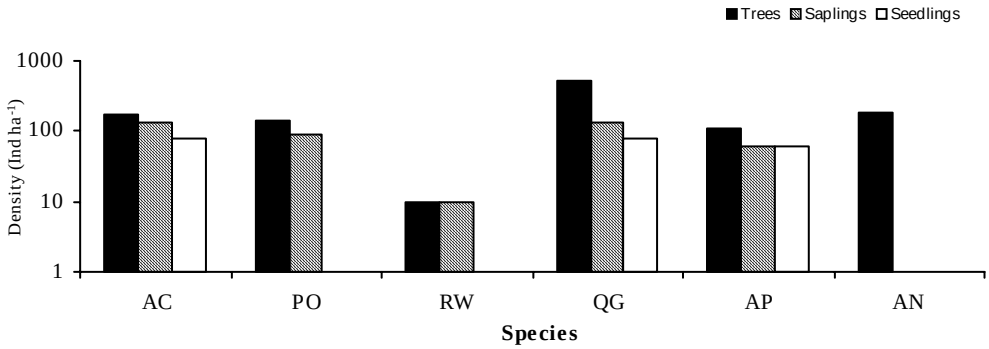
Majority of the protected areas of IHR are unexplored or under-explored (Dhar *et al.* 1997; Samant *et al.* 2002; Singh & Rawat 2000). For the proper management of protected areas, however, base line information on biodiversity is required. Seventeen forest communities were identified between 1640 - 2400 m in the KhWLS. Occurrence of 17 forest communities within a small altitudinal range indicated the presence of diverse habitats supporting an equally diverse vegetation. Total 28 tree species were recorded. This is comparable with the richness of trees reported from temperate and sub-alpine forests of the IHR (Adhikari *et al.* 1991; Bankoti *et al.* 1992; Dhar *et al.* 1997; Rawal *et al.* 1994; Samant *et al.* 2002). Tree species richness was within the range 9 - 28 reported for the sub-tropical and temperate regions (Rawat 2001; Upreti *et al.* 1985). The high richness of trees may be due to suitable edaphic and climatic factors.



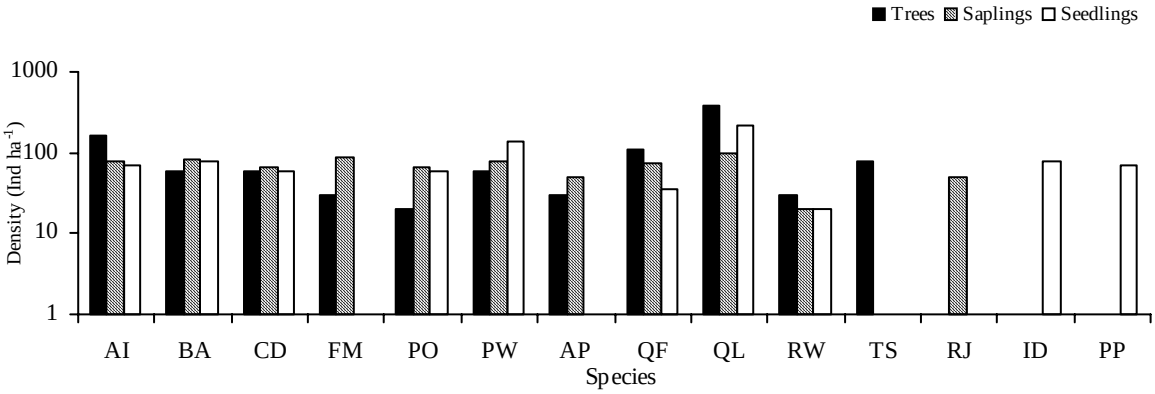
A. *Persea odoratissima* community



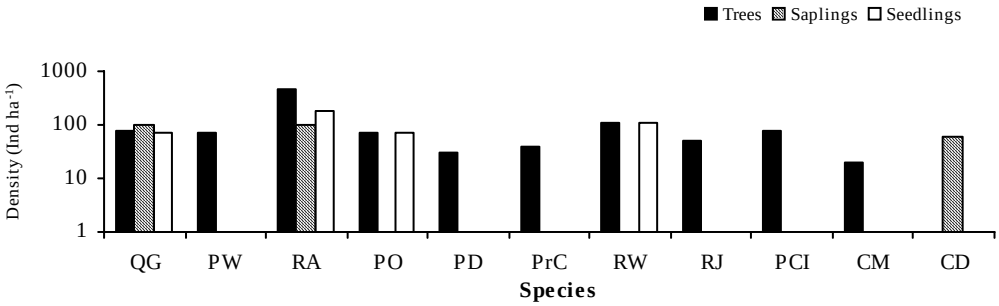
B. *Pinus wallichiana* community



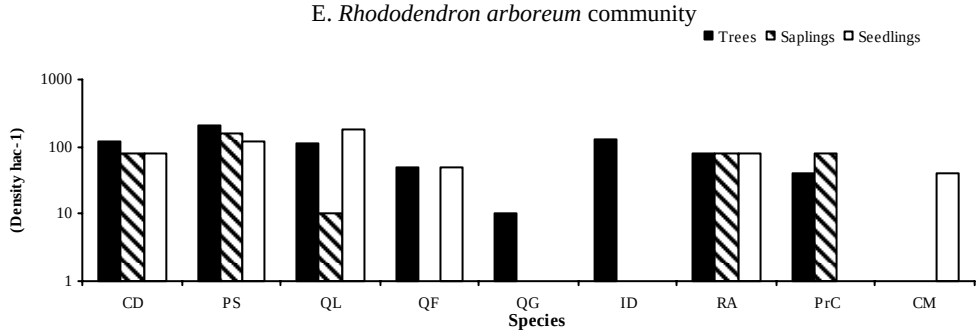
C. *Quercus glauca* community



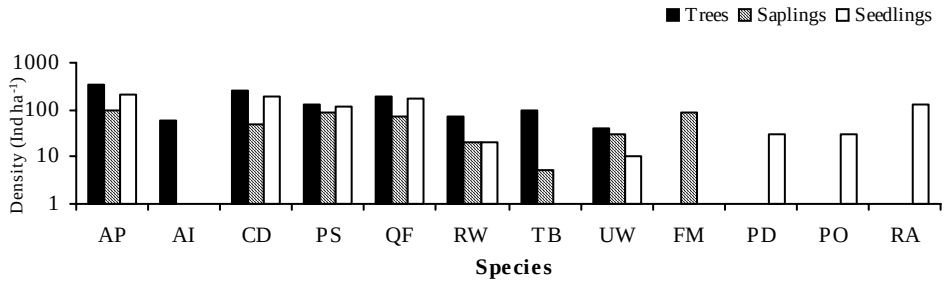
D. *Quercus leucotrichophora* community



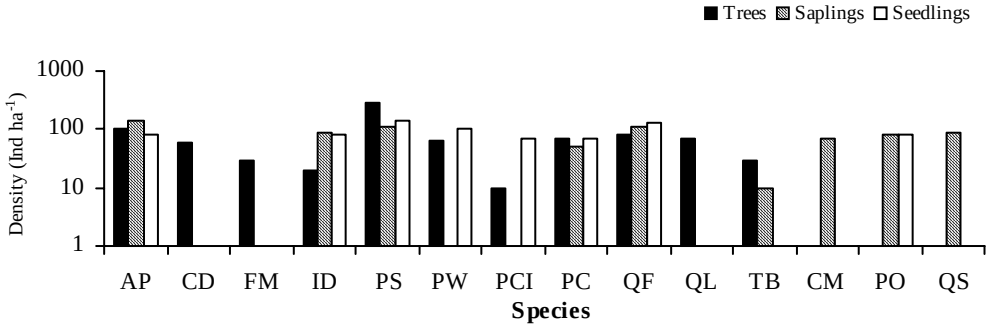
E. *Rhododendron arboreum* community



F. *Picea smithiana-Cedrus deodara-Quercus leucotrichophora* mixed community



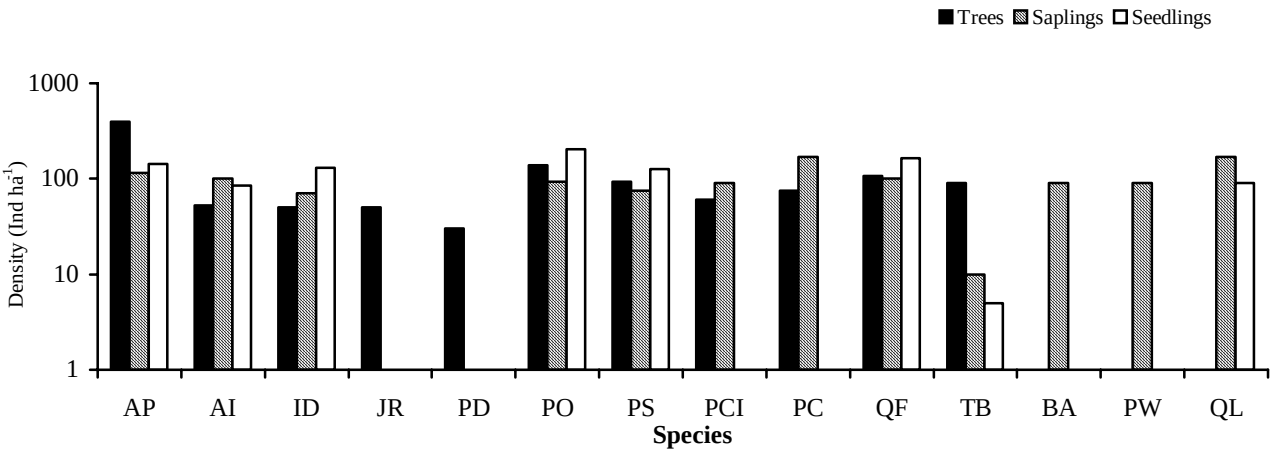
G. *Abies pindrow-Cedrus deodara* mixed community



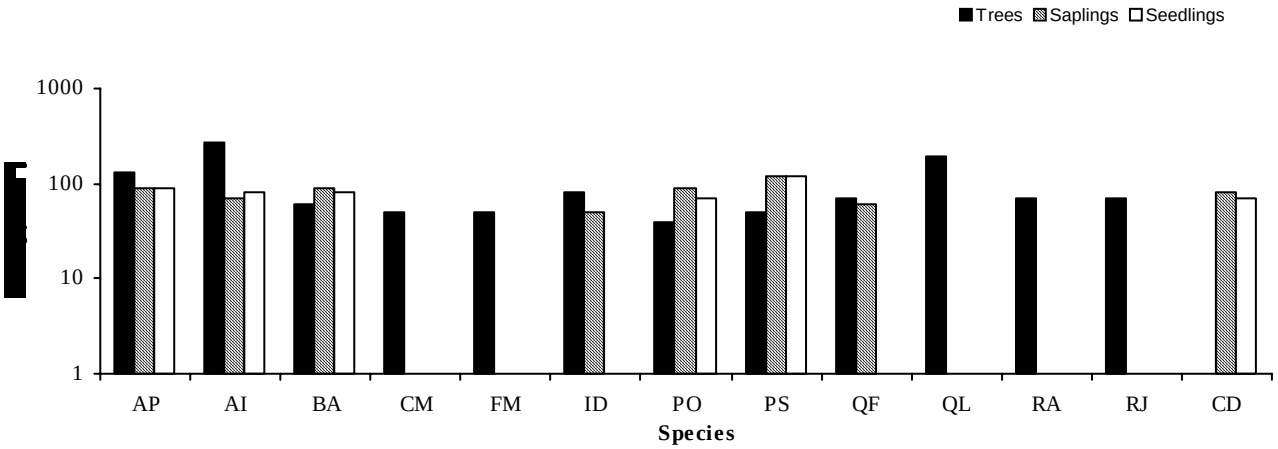
H. *Picea smithiana* community

Fig. 1 (A-H). Population structure of communities having highest regeneration of dominant species.

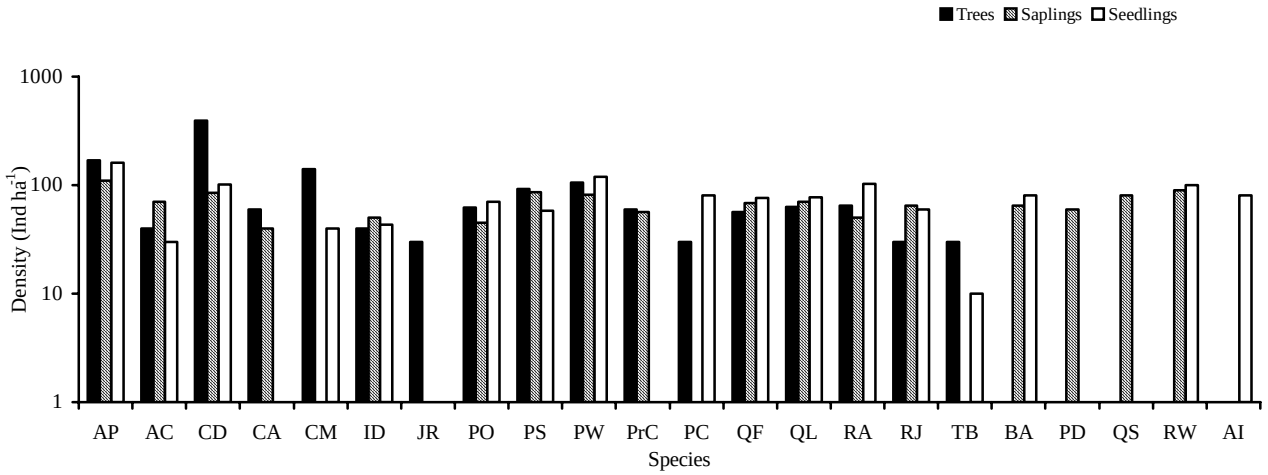
Abbreviations used (A-H) : AC = *Acer cappadocicum*; AI = *Aesculus indica*; AN = *Alnus nitida*; AP = *Abies pindrow*; BA = *Betula alnoides*; CD = *Cedrus deodara*; CM = *Cornus macrophylla*; FM = *Fraxinus micrantha*; ID = *Ilex dipyrena*; JR = *Juglans regia*; PC = *Prunus cornuta*; PCI = *Populus ciliata*; PD = *Persea duthiei*; PO = *Persea odoratissima*; PP = *Pyrus pashia*; PrC = *Prunus cerasoides*; PS = *Picea smithiana*; PW = *Pinus wallichiana*; QF = *Quercus floribunda*; QG = *Quercus glauca*; QL = *Quercus leucotrichophora*; QS = *Quercus semecarpifolia*; RA = *Rhododendron arboreum*; RJ = *Rhus javanica*; RW = *Rhus wallichii*; TB = *Taxus baccata* subsp. *wallichiana*; TS = *Toona serrata*; and UW = *Ulmus wallichiana.*



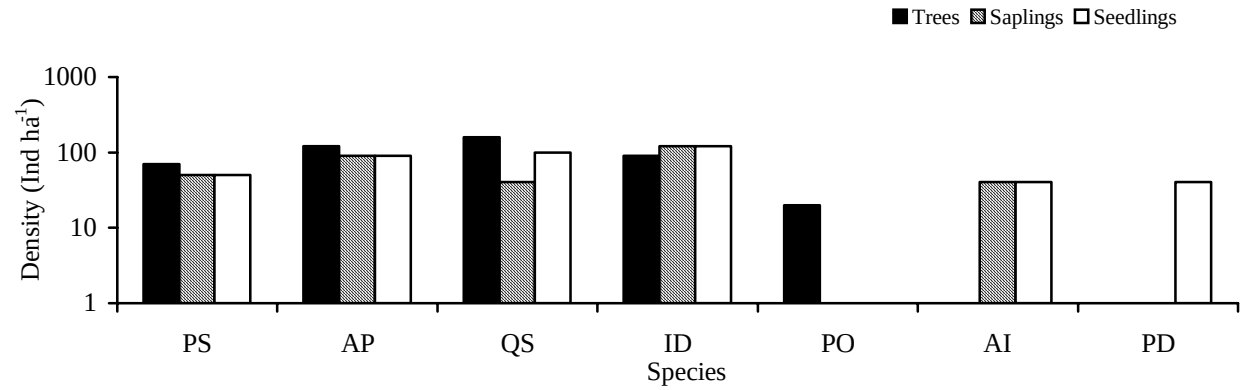
I. *Abies pindrow* community



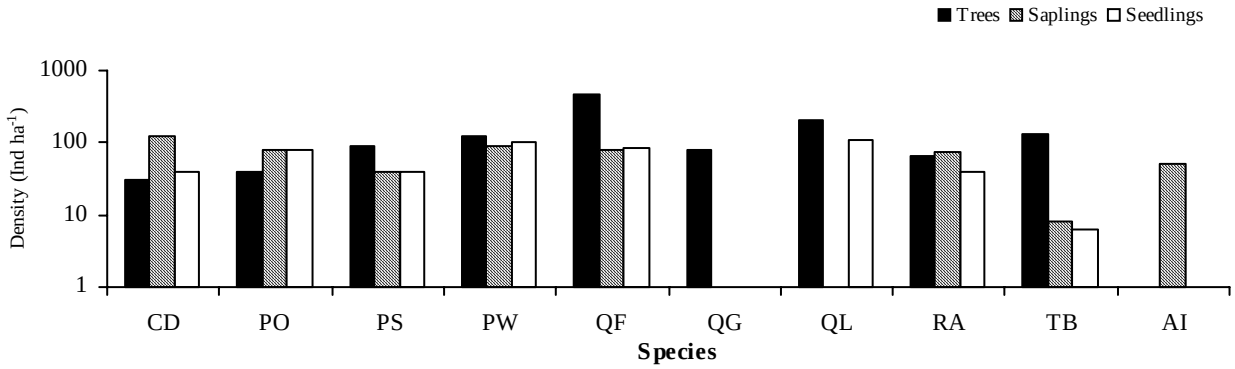
J. *Aesculus indica* community



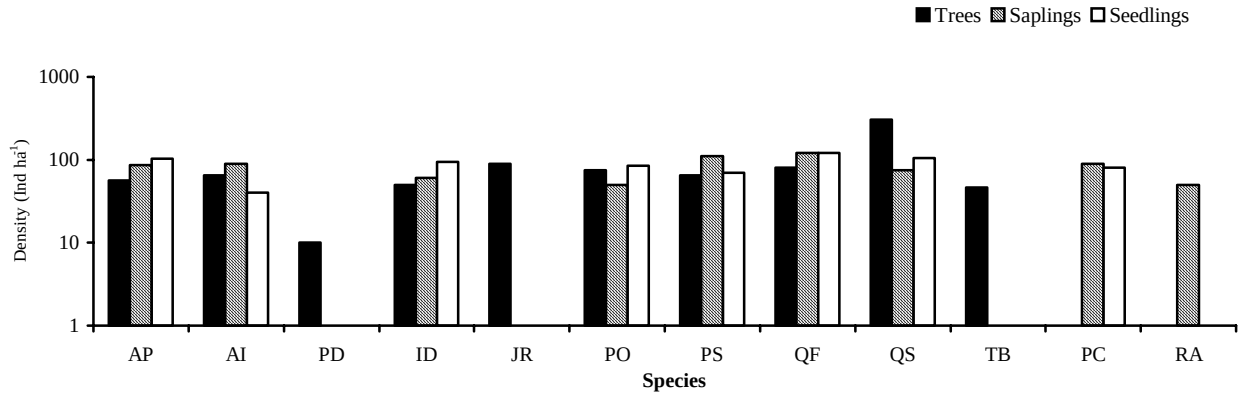
K. *Cedrus deodara* community



L. *Quercus semecarpifolia-Abies pindrow* mixed community



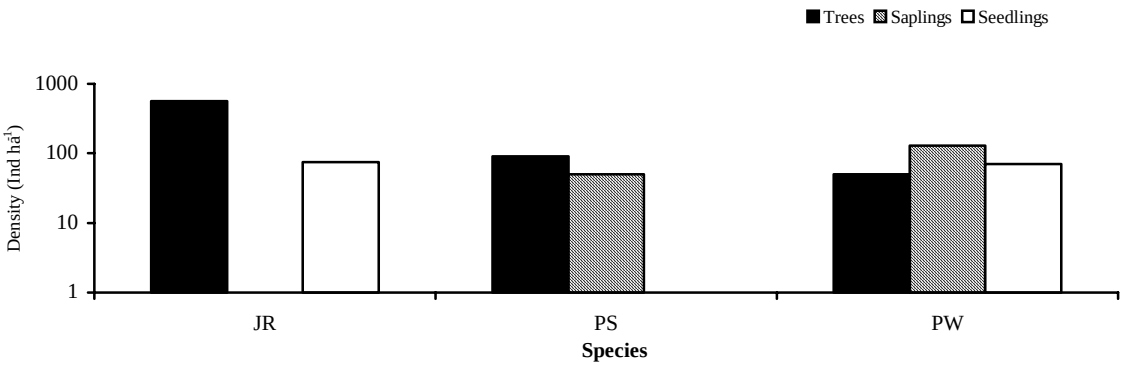
M. Regeneration status of *Quercus floribunda* community in KhWLS



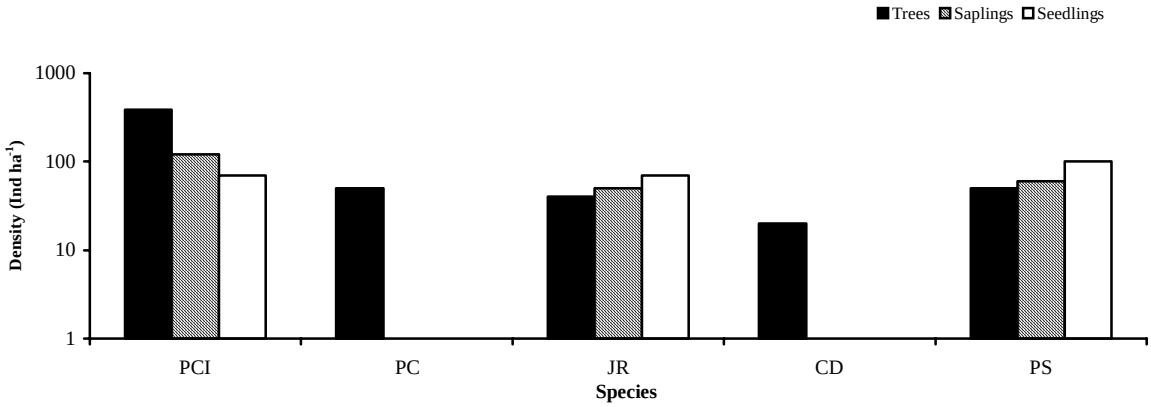
N. *Quercus semecarpifolia* community

Fig. 2 (I-N). Population structure of communities having highest regeneration of co-dominant species.

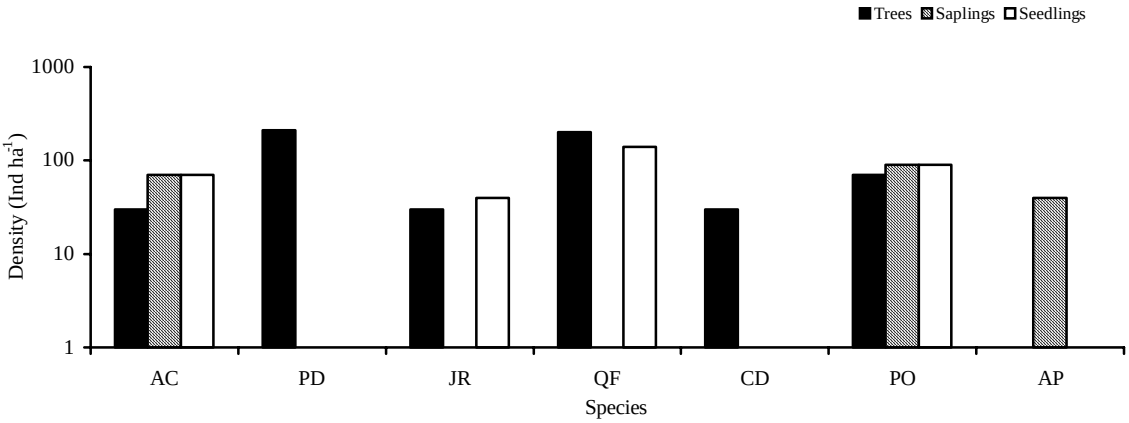
Abbreviations used (I-N) : AC = *Acer cappadocicum*; AI = *Aesculus indica*; AP = *Abies pindrow*; BA = *Betula alnoides*; CD = *Cedrus deodara*; CM = *Cornus macrophylla*; FM = *Fraxinus micrantha*; ID = *Ilex dipyrena*; JR = *Juglans regia*; PC = *Prunus cornuta*; PCI = *Populus ciliata*; PD = *Persea duthiei*; PO = *Persea odoratissima*; PrC = *Prunus cerasoides*; PS = *Picea smithiana*; PW = *Pinus wallichiana*; QF = *Quercus floribunda*; QG = *Quercus glauca*; QL = *Quercus leucotrichophora*; QS = *Quercus semecarpifolia*; RA = *Rhododendron arboreum*; RJ = *Rhus javanica*; RW = *Rhus wallichii*; and TB = *Taxus baccata* subsp. w*allichiana.*



O. *Juglans regia* community



P. *Populus ciliata* community



Q. *Persea duthiei-Quercus floribunda* mixed community

Fig. 3 (O-Q). Population structure of communities having poor or no regeneration of dominant species.

Abbreviations used (O-Q) : JR = *Juglans regia*; PC = *Prunus cornuta*; PD = *Persea duthiei*; PO = *Persea odoratissima*; PS = *Picea smithiana*; PW = *Pinus wallichiana*; and QF = *Quercus floribunda.*

Density of trees, saplings and seedlings, and total basal area for the KhWLS communities are comparable to the values reported earlier from low and high altitude forests (Adhikari *et al.* 1991; Joshi 2002; Kalakoti *et al.* 1986; Rawat 2001; Ralhan *et al.* 1982; Rawal *et al.* 1994; Samant *et al.* 2002; and Saxena & Singh 1982). The values for Shannon-Wiener diversity of the present communities are comparable to the previous records from various regions of west Himalaya (Adhikari *et al.* 1991; Bankoti *et al.* 1992; Joshi 2002; Joshi & Samant 2004; and Pant & Samant 2007).

Regeneration status of tree species of any forest is determined by recruitment of saplings and seedlings (Dhar *et al.* 1997; Samant *et al.* 2002; Singh & Singh 1992). In KhWLS, the number of species in seedling and sapling stages varied from community to community. Among the identified communities, *P. odoratissima, P. wallichiana, Q. glauca, Q. leucotrichophora, R. arboreum, P. smithiana - C. deodara - Q. leucotrichophora* mixed, *A. pindrow - C. deodara* mixed and *P. smithiana* showed highest regeneration of the dominant species, particularly in the sapling layer, indicating that these communities will persist for posterity; *A. pindrow, A. indica, C. deodara*, *Q. semecarpifolia-A. pindrow* mixed, *Q. floribunda* and *Q. semecarpifolia* communities showed sufficient regeneration of the dominant species but the highest regeneration was found for the co-dominant species, particularly in the sapling layer, indicating the possibility of at least partial replacement of the present dominants by the co-dominant species in the future; *J. regia, P. ciliata* and *P. duthiei - Q. floribunda* mixed communities showed poor or no regeneration of the dominant species indicating their total replacement by other associate tree species in the coming years.

Most of the species present in these communities are used for fuel, fodder, making agricultural tools, house building and miscellaneous purposes. During the surveys, it has been observed that use-pressure on species along with heavy grazing is responsible for habitat degradation, poor regeneration and population depletion of the tree species.

Based on the present results, it can be concluded that the Sanctuary supports a high diversity of forest trees and communities. The changing environmental conditions coupled with high anthropogenic pressures may, however, lead to depletion of population of the tree species and replacement by spiny species with no or very little economic value (Samant *et al.* 2000, 2006) in near future. Therefore, regular long-term monitoring of all the identified communities is suggested to understand the dynamics of vegetation. In addition, database developed through regular monitoring of these communities would help in developing adequate management plan for their conservation.

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Appendix Table 1. Physical characteristics of sites in Khokhan Wildlife Sanctuary.

Altitude (m)	Habitat	Slope (°)	Aspect	Major Associate Species
1640	R	40	E	*Rhododendron arboreum*, *Pinus wallichiana*, *Quercus glauca*, *Persea odoratissima*
1660	SM	34	W	*Alnus nitida*, *Acer cappadocicum*, *Persea odoratissima*
1700	SM	35	W	*Aesculus indica*, *Quercus glauca*, *Persea odoratissima*
1740	E	65	E	*Cedrus deodara*, *Pinus wallichiana*
1840	E	65	E	*Pinus wallichiana*, *Cedrus deodara*, *Quercus leucotrichophora*, *Quercus floribunda*
1840	SM	35	E	*Abies pindrow*, *Persea odoratissima*, *Juglans regia*
1860	SM	25	NW	*Abies pindrow*, *Picea smithiana*, *Quercus floribunda*
1940	SM	25	NE	*Cedrus deodara, Picea smithiana, Rhododendron arboreum, Quercus leucotrichophora, Quercus floribunda*
2040	SM	40	NW	*Abies pindrow, Picea smithiana*
2100	SM	25	NW	*Abies pindrow, Picea smithiana, Cedrus deodara*
2140	SM	15	NW	*Abies pindrow, Picea smithiana, Cedrus deodara, Taxus baccata* subsp. *wallichiana*
2180	SM	35	NW	*Cedrus deodara, Abies pindrow*
2200	SM	45	NW	*Cedrus deodara, Picea smithiana, Taxus baccata* subsp. *wallichiana*
2220	SM	35	NW	*Abies pindrow, Cedrus deodara, Quercus floribunda*
2380	SM	35	NW	*Abies pindrow, Taxus baccata* subsp. *wallichiana*
2320	SM	45	NW	*Quercus semecarpifolia, Quercus floribunda, Picea smithiana*
2320	SM	45	NE	*Picea smithiana, Abies pindrow, Quercus semecarpifolia*
2260	SM	40	NW	*Quercus semecarpifolia, Picea smithiana, Quercus floribunda, Juglans regia, Persea odoratissima*
2240	SM	15	W	*Quercus floribunda, Abies pindrow, Aesculus indica*
2250	SM	20	NW	*Picea smithiana, Quercus floribunda, Pinus wallichiana*
2220	SM	35	W	*Cedrus deodara, Persea odoratissima, Quercus floribunda, Persea duthiei*
2200	SM	5	NW	*Cedrus deodara, Pinus wallichiana, Picea smithiana, Quercus floribunda*
2140	SM	15	NE	*Picea smithiana, Cedrus deodara, Persea odoratissima*
2200	SM	45	NE	*Cedrus deodara, Quercus floribunda*
2200	SM	60	NW	*Cedrus deodara, Picea smithiana, Quercus floribunda*
2140	SM	20	NW	*Cedrus deodara, Quercus floribunda*
2100	SM	45	SW	*Cedrus deodara, Pinus wallichiana, Quercus leucotrichophora*
2380	SM	20	SW	*Cedrus deodara, Pinus wallichiana*
2400	SM	45	SW	*Cedrus deodara, Pinus wallichiana*
2340	SM	20	NW	*Abies pindrow, Quercus floribunda, Quercus leucotrichophora, Picea smithiana*
2320	E	20	W	*Cedrus deodara, Picea smithiana*
2320	SM	20	W	*Picea smithiana, Juglans regia*
2340	SM	35	NW	*Abies pindrow, Aesculus indica*
2380	D	65	W	*Pinus wallichiana, Cedrus deodara*
2380	SM	35	SW	*Cedrus deodara*

Contd…

Appendix Table 1. Continued.

Altitude (m)	Habitat	Slope (º)	Aspect	*Major Associate Species*
2300	SM	35	NW	*Cedrus deodara, Pinus wallichiana, Picea smithiana, Abies pindrow*
2280	SM	15	N	*Abies pindrow, Picea smithiana*
2250	SM	15	NW	*Cedrus deodara, Pinus wallichiana, Picea smithiana, Rhododendron arboreum*
2207	SM	20	W	*Pinus wallichiana, Picea smithiana*
2140	SM	35	NW	*Pinus wallichiana, Picea smithiana, Rhododendron arboreum, Cedrus deodara*
2020	SM	25	W	*Quercus floribunda, Quercus leucotrichophora*
1900	E	25	NW	*Pinus wallichiana, Quercus floribunda*
1870	D	25	W	*Quercus floribunda, Quercus leucotrichophora, Pinus wallichiana*
1870	SM	25	NW	*Quercus floribunda, Quercus leucotrichophora, Pinus wallichiana*
1850	SM	30	NW	*Quercus floribunda, Quercus leucotrichophora, Pinus wallichiana*
1850	SM	40	NW	*Quercus floribunda, Quercus leucotrichophora*
2300	SM	25	NE	*Quercus floribunda, Quercus leucotrichophora, Abies pindrow*
2250	SM	30	NE	*Aesculus indica*
2200	SM	15	NE	*Quercus floribunda*
2180	SM	10	NE	*Ilex dipyrena*
2180	SM	60	NE	*Quercus semecarpifolia*
2100	SM	40	SW	*Abies pindrow*
2040	SM	5	SW	*Prunus cornuta*
2100	SM	25	NE	*Taxus baccata* subsp. *wallichiana*
2040	R	15	SW	*Cedrus deodara, Pinus wallichiana, Picea smithiana*
2240	SM	35	SW	*Cedrus deodara, Picea smithiana*
2200	SM	35	SW	*Betula alnoides, Rhododendron arboreum, Aesculus indica*
2100	SM	25	SW	*Cedrus deodara, Rhododendron arboreum, Quercus floribunda*
2080	SM	15	SW	*Cedrus deodara, Quercus leucotrichophora, Quercus floribunda*
1900	SM	40	SW	*Quercus leucotrichophora, Quercus floribunda*
1860	SM	25	SW	*Quercus leucotrichophora, Quercus floribunda*
1820	R	15	SW	*Aesculus indica, Betula alnoides, Persea odoratissima*
1800	SM	45	SW	*Cedrus deodara, Pinus wallichiana, Quercus leucotrichophora, Rhododendron arboreum*
1810	SM	45	SW	*Cedrus deodara, Pinus wallichiana, Quercus leucotrichophora*
1790	SM	25	SW	*Quercus glauca, Q. floribunda, Rhododendron arboreum*

Abbreviations used : SM=Shady Moist; R=Riverine; E=Exposed; D=Degraded; SW=South West; NE=North East; W=West; NW=North West; and E=East.