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Full Length Research Paper

Forest vegetation patterns along an altitudinal gradient in sub-alpine zone of west Himalaya, India

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The present study describes vegetation diversity along an altitudinal gradient in three sites of sub-alpine forests. The altitude of the study sites ranged from 2800 - 3600 m asl and represented a transition from closed canopy temperate forests to open canopy sub-alpine forests. The results revealed that from low to high altitude strata, size and density of trees decline sharply. The density of sapling and seedling do not follow the trend of trees and exhibit site/location specific trends. Shrub and herb also did not exhibit uniform patterns across altitudinal range of the sites. As sub-alpine forests are considered to be potentially prone to the adverse effects of climate change, present study will provide important baseline information for future evaluation of the impact of climate change on sub-alpine forest communities.

Key words: Diversity, timberline, altitude, west Himalaya.

INTRODUCTION

Variation in species diversity along environmental gradient is a major topic of ecological investigation and has been explained by reference to climate, productivity, biotic interaction, habitat heterogeneity and history (Givnish, 1999; Willig et al., 2003; Currie and Francis, 2004; Gonzalez-Espinosa et al., 2004; Qian and Ricklefs, 2004). Mountain ecosystems around the globe usually have distinct biological communities and high level of endemism, due to their topography and history (Gentry, 1993). Hence, the existence of distinct forest types is indicative of diversity in climatic and edaphic factors. The plant community of a region is a function of time; however, altitude, slope, latitude, aspect, rainfall and humidity play a role in the formation of plant communities and their composition (Kharkwal et al., 2005). In addition, vertical canopies also play a vital role in a forest ecosystem (Whittaker, 1975).

The sub-alpine forests (SAFs) of the Himalaya represent a transition (ecotone) between alpine grassland and temperate forest ecosystems. Thus, while sharing elements of high alpine and low temperate zones, these forests have their own specialized elements. These forests are recognized for their unique conservation value and richness of economically important biodiversity. In the west Himalayan region, along the altitudinal transect, distinct changes in vegetation types are apparent. The sub-tropical Sal (*Shorea robusta*) and Chir-pine (*Pinus roxburghii*) forests are replaced by broadleaf (Oak – *Quercus* spp. and mixed broadleaf) and coniferous (*Cedrus deodara*, *Cupressus torulosa*, etc.) forests in temperate zone. In sub-alpine areas, birch (*Betula utilis*) and fir (*Abies pindrow*) forests along with the various combinations of broadleaf species exhibit dominance, which finally give way to the vast areas of alpine meadows. The most prominent of these changes along the altitudinal range is represented by the sub-alpine transition between temperate forests and alpine grassland ecosystems, termed as timberline zone (Dhar, 2000).

Studies specifically focusing on SAF (timberline) of Indian Himalaya are very few. However, some qualitative

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Abbreviations: SAF- Sub-alpine forest; **CBH** - Circumference at breast height; **ANOVA** - Analysis of Variance; **TBA** - Total basal area.

Table 1. Characteristic features of the study sites.

Study sites	Latitude (N)	Longitude (E)	Aspect	Slope
Tungnath	30˚ 14’	79 ˚ 13’	NW	25-30 ˚
Lata	30 ˚ 29’	79 ˚ 44’	SW	30-35 ˚
Pindari	30 ˚ 10’	79 ˚ 52’	NW	25-30 ˚

and quantitative descriptions of vegetation types are available (Osmaston, 1927; Champion and Seth, 1968; Puri et al., 1989; Singh and Singh, 1992). Community structure (Sundriyal and Bisht, 1988; Rawal and Pangtey, 1993, 1994), vegetation and animal abundance (Quan, 1993), phenological rhythm (Rawal et al., 1991) are some other aspects which have been studied. Floristic sensitivity of SAF was analyzed (Rawal and Dhar, 1997) to highlight the conservation significance of this zone, and prioritization of conservation sites have also been attempted (Dhar, 2000). A few other studies on structural and functional characteristics of individual forest ecosystem also pertain to this zone (Bankoti, 1990; Adhikari et al., 1989, 1991; Garkoti, 1992 ; Rawal et al., 1994; Rikhari et al., 1997; Rikhari and Adhikari, 1998; Kala and Uniyal, 1999; Samant, 1999). Other important contributions to our understanding of the patterns of sub-alpine forests include studies by Garkoti and Singh (1995) and Adhikari et al. (1995). Despite these efforts, limited research has been conducted on the spatial patterns of vegetation along altitude in the sub-alpine zone of west Himalaya. We envisage that documentation of changes in the vegetation parameters in SAF zones can provide important insights on the impact of climate change on these ecosystems. As ecotones resulting from environmental gradients are hypothesized to be sensitive indicators of climate change (Lavoie and Payette, 1992), such type of studies can provide important baseline information on vegetation parameters of sub-alpine forests. Therefore, the present study aims to describe trends in forest vegetation along altitude in three sites of sub-alpine forests with a particular focus on diversity and community composition.

MATERIALS AND METHODS

The study area

The study was conducted in three sites namely, Tungnath and Lata in Garhwal region, and Pindari in Kumaun region of west Himalaya covering an altitude of 2800 to 3600 m asl. The description of each site is given in Table 1. The altitudinal range covered in the present study represents a transition from closed canopy temperate forests to open canopy sub-alpine forests. In general, a gradual decrease in tree height from tall erect forests of *Abies* and *Quercus* to low statured krummholz of *B. utilis* and *Rhododendron campanulatum* is evident at the timberline zone of west Himalaya (Rawal and Pangtey, 1993). Anthropogenic disturbance in these sites mainly occurs in the form of grazing (including migratory grazing).

However, logging of trees for fuel wood and fodder, removal of litter and tourist activities during summer season are other factors.

Vegetation sampling and data analysis

For vegetation sampling in each site, two vertical belt transects were laid across the selected area along an altitudinal gradient, capturing the observed vegetation variation. Each transect was stratified into three elevational zones/ strata (viz. <2800 m; 3000 - 3200 m; >3200 m). After general reconnaissance of the study area, three plots measuring 50 x 50 m were laid systematically in each stratum. In each site, 18 plots were laid and estimated for their species composition and diversity. In total 54 plots were laid in three sites. In each 50 x 50 m plot, five (10 x10 m) quadrats were laid randomly for investigation of species richness and other vegetation parameters. Trees and shrubs were recorded in 10 x 10 m. However, each 10 x 10 m quadrat was subdivided into 2 x 2 m sub-quadrat for seedlings and saplings and 1 x 1 m for herbs. For trees, CBH (circumference at breast height, 1.37 m from the ground) was measured and individuals were classified as trees : > 30 cm ; sapling: 11 – 30 cm ; seedlings: <11 cm. Quadrat data was pooled by plots to estimate density, frequency, total basal area and relative values of density, frequency, total basal area (Misra, 1968; Muller-Dombois and Ellenberg, 1974). Density and basal area per hectare were calculated for all tree species. Densities of shrubs, saplings, seedlings and herbs were also calculated on a per hectare basis. Importance value index (IVI) was calculated by summing up the relative values of density (RD), frequency (RF), and total basal area (RTBA) (Curtis, 1959). The species diversity index was computed using the Shannon – Wiener information function (Shannon and Wiener, 1963). Species richness was determined as the number of species per unit area (Whittaker, 1975). Differences in mean values of the studied parameters along an altitude were determined by analysis of variance (ANOVA) using SYSTAT statistical programme (Wilkinson, 1987).

RESULTS

In all the study sites, a characteristic decline in total tree density and total basal area was apparent with increasing altitude. Tree density was lowest in Tungnath as compare to Lata and Pindari sites. The variation in tree density along altitude was significant in Tungnath (F = 3.61, P<0.05) and Lata (F=8.71, P<0.001) sites only. However, total basal area significantly decreased in all the sites (Tungnath: F = 19.02, P<0.01; Lata: F = 16.81, P<0.001; Pindari: F = 7.29, P<0.01). Overall seedling density was highest in Pindari site as compared to Lata and Tungnath. The highest seedling density (10135 indi.ha^{-1}) was recorded at <3000 m altitude in Pindari and lowest (1867 indi.ha^{-1}) at >3200 m in Lata. Variation in seedling density along altitude was significant for Tungnath (F = 12.19, P<0.001) and Pindari (F = 4.25, P<0.01) sites only. Sapling density was highest (8333 indi.ha^{-1}) at 3000 – 3200 m altitude in Lata and lowest (2200 indi.ha^{-1}) at >3200 m altitude in Tungnath. Significant variation in sapling density along altitude was recorded only in Lata site. Shrub density ranged between 813 indi.ha^{-1} at <3200 m altitude in Tungnath to 4357 indi.ha^{-1} at 3000 –

Table 2. Summary of forest structure across sites and along altitude.

Site / Strata	Tree density (Indi.ha^{-1})	TBA (m^2 ha^{-1})	Seedling density (Indi.ha^{-1})	Sapling density (Indi.ha^{-1})	Herb density (Indi.ha^{-1})	Shrub density (Indi.ha^{-1})
Tungnath						
<3000 m	634	69.84	2267	4067	157267	813
3000-3200 m	384	35.83	2867	3667	156200	1504
>3200 m	243	8.94	9333	2200	98667	1469
LSD (0.05)	**249.10**	**21.15**	**3416.13**	**4951.60**	**23700**	**1284.47**
***F* ratio**	**3.61***	**19.02****	**12.19*****	**0.358**	**18.06*****	**0.834**
Lata						
<3000 m	843	35.33	4467	7017	213533	2801
3000-3200m	636	30.16	4533	8333	122333	4357
>3200 m	453	15.29	1867	2267	55067	2034
LSD (0.05)	**199.32**	**7.76**	**3697.28**	**2294.03**	**29700**	**3050.54**
***F* ratio**	**8.711*****	**16.81*****	**1.538**	**17.76*****	**64.74*****	**1.369**
Pindari						
<3000 m	646	37.16	10135	4934	133333	2093
3000-3200 m	580	31.09	7666	5267	149000	871
>3200 m	557	16.75	9866	6667	93733	1822
LSD (0.05)	**244.50**	**13.75**	**1977.98**	**3619.98**	**32200**	**1005.87**
***F* ratio**	**0.279**	**7.29****	**4.25****	**0.587**	**7.08****	**3.711***

Significant at *p<0.05; **p<0.01; ***p<0.001 respectively.

Table 3. Species richness (r) and Shannon diversity index (H') values for different life forms across sites and along altitude.

Sites/life forms	<3000 m		3000-3200 m		>3200 m	
	r	H'	r	H'	r	H'
Pindari						
Trees	13	1.05	12	1.55	2	0.44
Shrubs	8	1.11	8	1.45	12	1.99
Herbs	32	3.17	41	3.33	23	2.78
Lata						
Trees	5	0.64	6	1.09	3	0.56
Shrubs	15	2.26	18	2.57	7	1.63
Herbs	32	2.64	33	3.06	15	2.40
Tungnath						
Trees	6	0.79	9	0.87	7	0.63
Shrubs	6	1.05	11	2.02	9	1.29
Herbs	40	3.30	35	3.35	21	2.65

3200 m altitude in Lata site. Variation in shrub density along altitude was significant for Pindari site only. Herb density decreased with increasing altitude in Lata and Tungnath sites only. However, along altitude, herb density varied significantly in all the sites (Table 2). Considering importance value index as an indicator of dominance, the major contributors of tree layer at different altitudinal strata varied across sites. For instance, at <3000 m altitude, *Acer caesium* (IVI-85.88) and *Rhododendron arboreum* (IVI-69.26) dominate in Pindari; *Pinus wallichiana* (IVI-210.08) and *Abies pindrow* (IVI-40.73) in Lata; and *Quercus semecarpifolia* (IVI-166.91) and *Rhododendron barbatum* (IVI-95.27) in Tungnath. At 3000 – 3200 m altitude, *A. pindrow* (IVI-49.32), *B. utilis* (IVI-48.32) and *A. caesium* (IVI-45.54) showed dominance in Pindari; *P. wallichiana* (IVI-123.18) and *B. utilis* (IVI-88.80) dominate in Lata; while *A. pindrow* (IVI-96.49) and *A. caesium* (IVI-91.05) dominate in Tungnath. However at >3200m altitude, *B. utilis* (IVI-222.5) and *R. campanulatum* (IVI-77.4) were found to be the most important constituents of tree layer in Pindari; *B. utilis* (IVI-222.5) and *R. campanulatum* (IVI-41.36) in Lata; and *A. pindrow* (IVI-90.08) and *Q. semecarpifolia* (IVI-70.80) in Tungnath. In all the sites, the mid altitude stratum (3000 – 3200 m) showed high species diversity for all the life forms. With a few exceptions, pattern of species richness more or less followed the similar trends (Table 3). The dominance - diversity curve (d-d curve) for the tree layers (based on IVI) approached a geometric series at >3200m in Pindari and Lata, and <3000 m in Lata and Tungnath, whereas, log normal series was revealed in the remaining cases (Figure 1). Theforests with relatively high IVI of dominant species exhibited steeply oblique geometric series. The d-d curve for the shrubs, constructed on the basis of density, showed the log normal series at all three altitude strata of Lata site. However, in Pindari and Tungnath at <3000 m, geometric

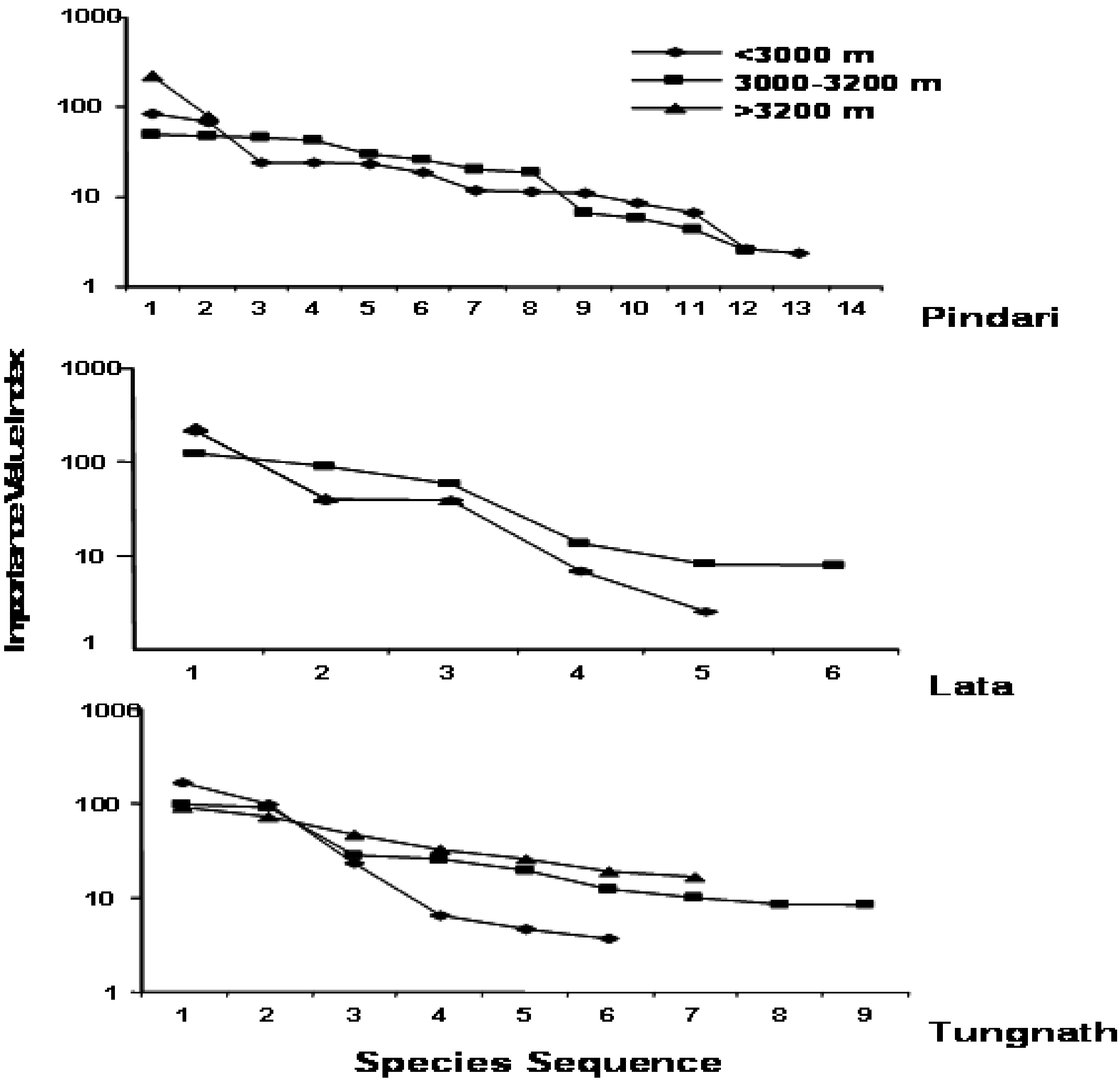

Figure 1. Dominance-diversity curves for tree species along an altitudinal gradient.

series was observed for shrub species (Figure 2).

DISCUSSION

Structure, composition and function are the three important attributes of forest ecosystems. These attributes change in response to climate, topography, soil and disturbances. The above mentioned factors along with forest succession are also responsible for both local (within stand) and landscape level variations in forest attributes, thereby producing spatial heterogeneity (Timilsina et al., 2007). In the present study, a characteristic decline in dominant types was observed across the altitudinal strata and among sites, indicating that the sub-alpine forest transition in west Himalaya exhibits diversity in compositional patterns. The differ-rences in terms of species composition suggest a high degree of variation in physical settings of the landscape and disturbance regimes. It is also reported that the regional patterns of species richness are consequences of many interacting factors, such as plant productivity,

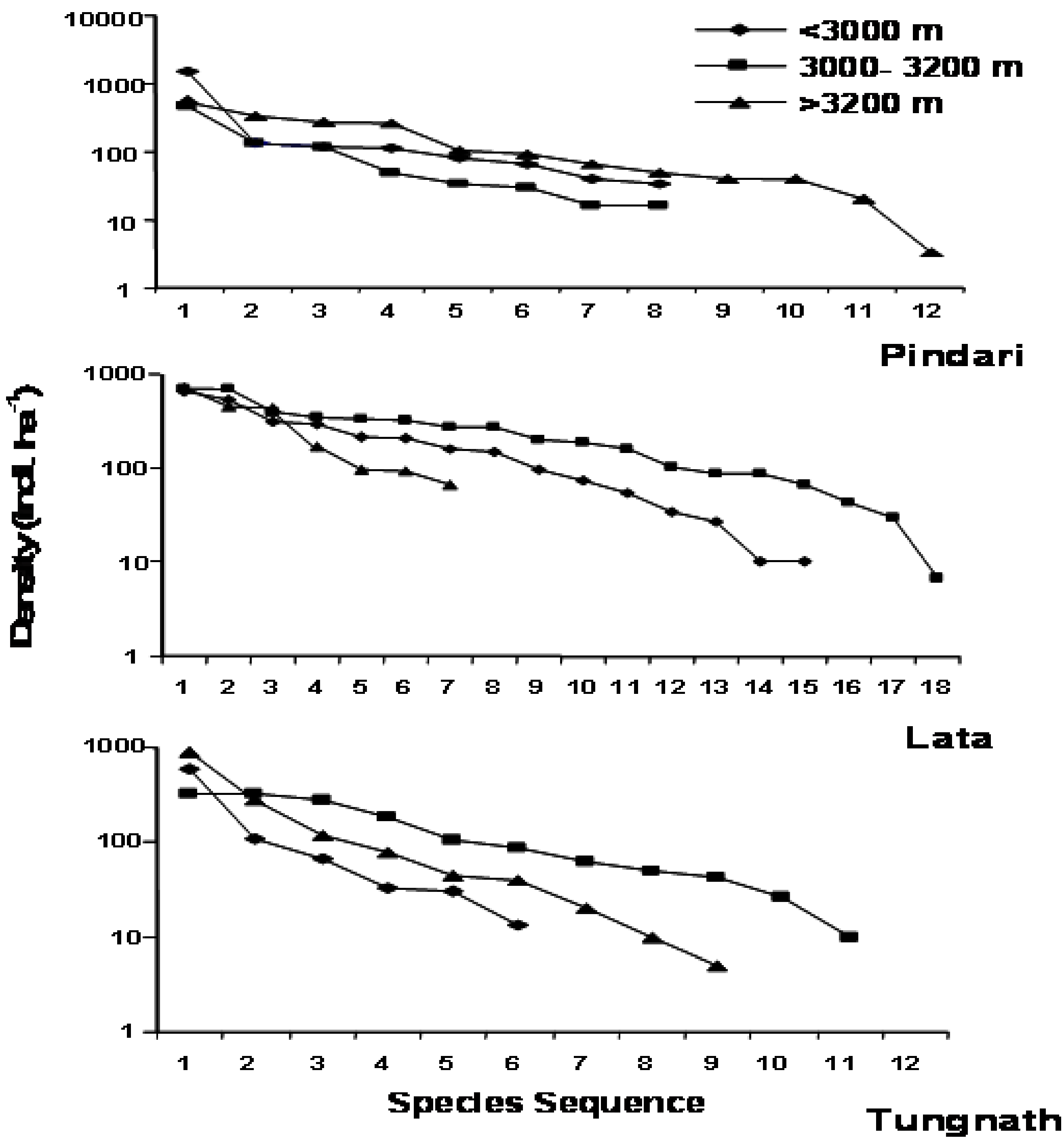

Figure 2. Dominance-diversity curves for shrubs along an altitudinal gradient.

competition, geographical area, historical or evolutionary development, regional species dynamics, regional species pool, environmental variables and human activity (Woodward, 1988; Palmer, 1991; Eriksson, 1996; Zobel, 1997; Criddle et al., 2003). The values of vegetation parameters obtained for most of the stands in the present study fall within a comparable range of values reported for high altitude forest vegetation in Kumaun Himalaya (Rawal et al., 1994), moist temperate forests of Kumaun Himalaya (Ralhan et al., 1982; Saxena and Singh, 1982) and western Himalaya (Kala and Uniyal, 1999). Decline of density and TBA corresponds well with the characteristics of most of the other timberline settings in the region where the density decreases from closed stands to isolated individuals of krummholz (Kalakoti et al., 1986; Rawal and Pangtey, 1994; Dhar et al., 1997;

Noble, 1993).

The range of diversity index values recorded in the present study falls within the lower limit of the values recorded for temperate forests of Himalaya and other parts of the world (Monk, 1967; Risser and Rice, 1971; Saxena and Singh, 1982; Ralhan et al., 1982; Upreti et al.,1985). However, a direct comparison with other studies that used different sample sizes should be made with caution. Considering diversity in different life forms, with an exception of shrubs in Pindari site, the value of diversity index peaked at mid altitude (3000 - 3200 m) strata, suggesting a characteristic transition of elements from low and high altitude strata of this zone. In view of this, the mid altitude strata (3000 - 3200 m) may be considered as most representative for long term monitoring of forest ecosystem elements in SAF. Investigations on change dynamics of these elements at this stratum would help in depicting and/ or predicting changes both towards upper and lower altitude strata. The decrease in diversity and species richness at high elevation strata could be due to ecophysiological constraints, such as reduced growing season, low temperature and low productivity (Korner, 1998). Other factors such as soil fertility and topography may also affect the patterns of species richness along altitudinal gradient. The study revealed that the recruitment patterns at SAF are location specific. These patterns are apparent because elevation gradients create varied climates along with resultant soil differentiation which promote the diversification of plant species (Brown, 2001; Lomolino, 2001). As such, the range of seedlings and saplings was high as compared to previous reports (Rawal and Pangtey, 1994) for SAF zone of Himalaya. These patterns indicate that factors other than altitude may have an influence on the species regeneration patterns. Among the study sites, maximum seedling density throughout the altitudinal strata in Pindari suggests that the slope and aspect favours regeneration of tree species. However, low temperature, wind direction and snow depth has also been considered the main factors which determine the seed germination and rate of seedling survival (Qingshan et al., 2007).

In the present study, the log normal series in most cases of tree and shrubs is indicative of the highly mixed nature of vegetation (Whittaker, 1975; Tiwari, 1982; Saxena and Singh, 1982; Upreti et al., 1985; Rawal, 1991). However, the geometric series observed in some cases confirm the niche-preemption hypothesis (Motonura, 1934). The geometric form is often shown by vascular plants having lower density (Whittaker, 1975). Among others, the diversity of vegetation types in present study sites can be attributed to the prevailing monsoon effects in the region, which remains one of the major factors for high vegetation diversity in the main Himalayan region (Singh and Singh, 1987). The findings of the present study will contribute to biodiversity conservation and sustainable management of the sub-alpine forests of this region. However, studies addressing the disturbances and climate change impacts on vegetation patterns are needed for long term management of these forests.

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