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Diversity and regeneration status of tree species at Nainital Catchment, Uttarakhand, India

Kiran Bargali*, Priyanka Bisht, Abida Khan and Y.S. Rawat

Department of Botany, Kumaun University, DSB Campus, Nainital -263002, Uttarakhand, India.

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The existence of a species in a forest community largely depends on its ability to regenerate under varied environmental conditions. In the present study, effect of biotic disturbance was assessed and analysed on diversity and regeneration of pre-dominant tree species of oak forests. For this, two adjacent sites were selected in mixed oak forest zone (2100 m asl), namely, undisturbed open area (inside zoo) and moderately disturbed open area (out side zoo). Phytosociological analysis of tree and shrub layer vegetation was done and density, diversity index, Importance Value Index etc were determined for both the sites. Regeneration status of tree species was analysed by developing population structures. Species richness (tree as well as shrub) was high in disturbed site (11 to 20) as compared to protected site (9 to 11), and in both the sites the species richness was maximum at hill slope. Among the tree species *Quercus floribunda* was dominant with highest value of IVI in protected site. Contrary to this, *Quercus lecotrichophora* was dominant in disturbed site at hill base and hill slope, while *Q. floribunda* was dominant at hill top site. Tree density ranged from 780 to 1000 trees ha^{-1} in protected site and from 260 to 780 trees ha^{-1} in disturbed site. In both the sites, *Q. leucotrichophora* and *Q. floribunda* have higher proportion of individual in younger girth classes (seedlings and saplings), indicating expanding type of population structure. However, conversion into higher girth classes was more prominent at protected site as compared to disturbed site. Thus, it can be concluded that oak species of Kumaun Himalayan region have ability to regenerate when anthropogenic pressures are negligible.

Key words: Basal area, density, diversity, girth class, population structure, regeneration.

INTRODUCTION

Successful regeneration of tree species might be considered to a function of three major components: (i) ability to initiate new seedlings, (ii) ability of seedlings and saplings to survive and (iii) ability of seedlings and saplings to grow (Good and Good, 1972). Measurement of these parameters provides an insight into the regeneration of species in a forest community. Several authors have predicted regeneration status of tree species based on the age and diameter structure of their population (Bhuyan et al., 2003, Khan et al., 1987).

Kumaun region of the Central Himalaya harbors rich biodiversity because of its unique and diverse climate conditions. Composition of the forest is diverse and varies from place to place because of varying topography such as plains, foothills and upper mountains (Singh, 2006). Several studies have described the vegetation of Kumaun (Osmaston, 1927; Dhar et al., 1997; Singh and Singh, 1987; Hussain et al., 2008). Species composition of major forest types of Central Himalaya have already been described by Ralhan et al. (1982), Saxena et al. (1984), Singh and Singh (1987), Tewari and Singh (1981) and Upreti et al. (1985). Various changes in the

*Corresponding author E-mail: kiranbargali@yahoo.co.in.

Himalayan Forests are appearing in their structure, density, composition and regeneration due to biotic pressure on them namely, uncontrolled lopping and felling of trees for fuel wood, fodder and grazing (Bargali et al., 1998; Kumar et al., 2004). These biotic pressures play an important role in forest community dynamics (Pickett and White, 1985) and regulate the regeneration ability of a species. The human influence on biodiversity and ecosystem functioning have largely taken in the form of rapid, large and frequent changes in land and resource use, increased frequency of biotic invasion, reduction in species number, creation of stresses and the potential for changes in climatic systems. Such changes have a direct impact through habitat destruction and over- exploitation of resources such as overgrazing and indirect impact through their impact on the composition of the atmosphere and climate. In the present study, tree and shrub layer vegetation was analysed in a protected and disturbed oak forest area of Nainital town. The aim of this study was: (i) to analyse the composition and diversity of tree and shrub layer in selected study sites within and around Nainital Zoo, and (ii) to determine the current natural regeneration status of the tree species at both the study sites.

MATERIALS AND METHODS

Study site

The present study area Nainital is located between 29° 21' to 29°24' N latitude and 79° 25' to 79°29' E longitude. The study sites are located within and around The Bharat Ratna Pt. Govind Ballabh Pant High Altitude Zoo, Nainital in Uttarakhand state of India (Figure 1). The area is dominated by mixed oak forest situated in the hills of Sher- ka danda. The elevation range between 2100 and 2200 m above sea level. The zoo was established in 1984 and it spread over an area of 4.693 ha. It was opened to visitors on 1st June 1995 and is being managed by The Bharat Ratna Pt. Govind Ballabh Pant High Altitude Zoo Management Society, Nainital since 1st March, 2002. This zoo was established with the objectives to conserve and protect the wildlife and biodiversity. The disturbed forest site is situated outside the boundary of zoo at the same altitudinal gradient and it spread over an area of about 6.50 ha.

For the detailed study of tree and shrub layer composition and other vegetational parameters, the area was divided into three sub-sites, that is, hill base, hill slope and hill top along the altitudinal gradient. These three sites are located at different altitudinal range and dominated by *Q. leucotrichophora* and *Q. floribunda* trees. The soil is residual to fairly deep being derived from dolomite limestone, sand stones with Quartzite and silt.

Climate

The climate of the study area is influenced by the monsoon pattern of rainfall. The annual rainfall was 2214mm of which three fourth occurred in rainy season (mid-June to mid-September). The mean monthly maximum temperature ranged between 17.1°C (January) to 26.1°C (June), and mean minimum temperature ranged between 7.1°C (January) to 26.1°C (June). Winters are very severe at the higher elevations and snowfall takes place above 1,524 m and occasionally lowers down but melts and even above this snow seldom stays long on sunny slopes.

Approach

The number and size of the quadrats were determined by the running mean method (Kershaw 1973) and species area curve (Misra, 1968). Ten plots of 10×10 m at each site (disturbed and protected) were randomly established at hill base (4 plots), slope (3 plots) and top (3 plots), within and outside the zoo area for determination of species richness and other vegetational parameters (total 20 plots). Trees and saplings were analysed in 10×10 m, shrubs in 5×5 m and seedlings in 10, 1×1 m area within each plot (Curtis and McIntosh, 1950; Phillips, 1959).Circumference at breast height (cbh at 1.37 m from the ground) of all the trees (≥ 31.5) was measured in each plot. Tree mean basal area of a species ($C^2/4\pi$ where, C = sum of cbh value of all individuals of a tree species within each plot and π = 3.14) was multiplied by its density value to calculate total basal area of a tree species. Importance Value Index (IVI) was calculated following Phillips, 1959) as:

IVI = Relative frequency + relative density +relative dominance.

Equitability (EC) or species evenness was determined following Whittaker (1975) as:

$$EC = \frac{s}{\text{Log 10 ni} - \text{log 10 ns}}$$

Where s is the number of species in the site and ni and ns are the IVI value of most and least important species, respectively.

Species diversity (H) for each vegetation layer in each site was determined by using Shannon –Weiner (Shannon and Weiner, 1963) information index as:

$$H = -\sum_{I=1}^{s} (Ni/N) \log_2 (Ni/N)$$

Where; Ni= Total number of individuals of a species, N= Total number of individuals of all species

The log 2 is converted into log 10 as:

$$H = -\Sigma (Ni/N) \times 3.322 \times \log_{10}(Ni/N)$$

Concentration of Dominance (CD) was measured by Simpson's index (Simpson 1949) as:

$$C = \sum_{i=1}^{s} (Ni/N)^2$$

Where, Ni is the total number of individuals of species and N is the total number of individuals of all species.

Population structure was used to express the regeneration status of individual tree species. Individuals > 30 cm circumference were categorized as trees, 10 to 30 cm as saplings, and < 10 cm as seedlings to determine the regeneration status of tree species in each forest site (Saxena et al., 1984).

Index of similarity between protected and disturbed site was calculated following Sorenson (1948) using species richness as:

$$\text{Index of similarity (IS)} = \frac{2C}{A + B} \times 100$$

Where C is the common species in comparison forest, A is the total number of species at site A and B is the total number of species at site B.

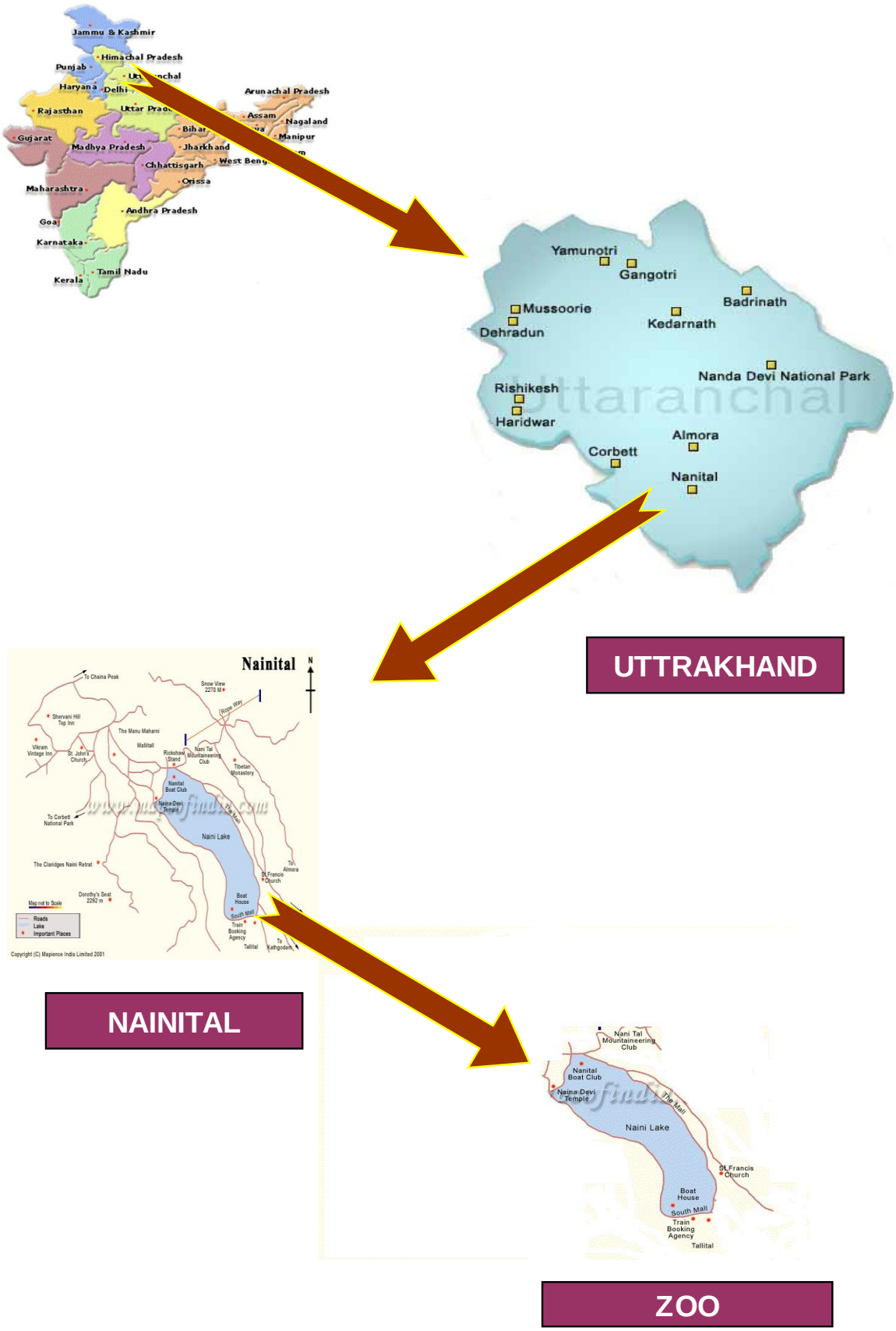

Figure 1. Map of the study area.

Table 1. Species richness and equitability in protected and disturbed forest site at hill base, hill slope and hill top.

Site	Forest feature	Forest	
		Protected site	Disturbed site
Hill base	Tree	03	03
	Shrub	07	09
	Total	10	12
	Equitability	10.11	4.39
Hill slope	Tree	02	04
	Shrub	09	16
	Total	11	20
	Equitability	4.09	7.62
Hill Top	Tree	02	04
	Shrub	07	15
	Total	09	19
	Equitability	5.33	5.19

Photo Plate 1. Protected forest site.

RESULTS

Species richness and diversity index

Total species richness (tree and shrub) was higher in disturbed forest site as compared to protected forest site (Table 1 and Photo Plate 1) and was maximum at hill slope in both the site. Most of the tree and shrub species were common at both the sites thus, resulting in 75% similarity in tree layer and 70% similarity in shrub layer. Diversity index was also higher in disturbed forest site (1.85 to 2.09) than protected site (1.00 to1.48; Table 2). Concentration of dominance also followed the same trend (Table 2).

Density of trees and shrubs

In the protected forest area, density of trees (number of tree ha^{-1}) was higher at hill slope (970 trees ha^{-1}) and it

Table 2. Diversity Index (H') and concentration of dominance (CD) for tree, sapling, seedling and shrub in protected and disturbed forest area.

Site	Parameter	Forest feature	Forest	
			Protected	Disturbed
		Tree	0.44	0.52
		Sapling	0.30	0.53
	H'	Seedling	0.45	0.51
		Shrub	0.29	0.53
		Total	1.48	2.09
Hill base				
		Tree	0.15	0.29
		Sapling	0.13	0.38
	CD	Seedling	0.28	0.50
		Shrub	0.05	0.03
		Total	0.61	1.20
		Tree	0.09	0.53
		Sapling	0.17	0.38
	H'	Seedling	0.48	0.50
		Shrub	0.26	0.44
		Total	1.00	1.85
Hill slope				
		Tree	0.46	0.21
		Sapling	0.44	0.29
	CD	Seedling	0.25	0.55
		Shrub	0.02	0.03
		Total	1.17	1.08
		Tree	0.31	0.53
		Sapling	0.41	0.38
	H'	Seedling	0.46	0.50
		Shrub	0.34	0.47
		Total	1.52	1.88
Hill Top				
		Tree	0.35	0.15
		Sapling	0.31	0.58
	CD	Seedling	0.46	0.24
		Shrub	0.03	0.04
		Total	1.15	1.01

decreased towards hill base (460 trees ha^{-1}) and hill top (780 trees ha^{-1}). Contrary to this, the tree density increased from hill base (260 trees ha^{-1}) to hill top in moderately disturbed forest area (780 trees ha^{-1}) (Table 3 and Photo Plate 2). Shrub species also followed the same trend in both the sites (Table 4). Among trees, *Q. floribunda* was the most dominant species (IVI 139.2-227.5) at all the three sites of protected forest area (Table 3). In the disturbed forest site, *Q. leucotrichophora* was dominant at hill base (IVI 188.6) and hill slope (IVI 164.3), while *Cedrus deodara* was dominant at hill top (IVI 128.7; Table 3). Among shrubs, *Salvia officinalis* was dominant at hill base and hill sope and *Indigofera heterantha* showed dominance at hill top of protected forest site (Table 4). In disturbed forest site, *S. officinalis* was dominant shrub at hiil base, *Hypericum oblongofolium* at hill slope and *I. heterantha* at hill top (Table 4).

Total basal area (TBA)

In protected forest area, total basal area was higher for *Q. floribunda* (9.65 to 44.28 m^2ha^{-1}) possibly due to higher density of trees (Table 5). In disturbed forest area, total basal area was higher for *Q. leucotrichophora* (3.51 to 10.96 m^2ha^{-1}) at hill base and hill slope and for *Q. floribunda* (11.4 m^2ha^{-1}) at hill top (Table 5).

Population structure

In the disturbed site, both the oak species (*Q. leucotrichophora* and *Q. floribunda*) exhibits an expanding type of population structure (Figures 2 to 4). It represents the stage with high density of trees in younger girth classes and decrease in density in higher girth classes. However, in protected site the population structure of these two oaks showed higher density in the younger girth classes and absence of trees in higher girth classes despite the fact that it has been under protection for the last 25 years. This may be due to deforestation of existing old trees of oak before protection of zoo area. Similar observation for undisturbed forest has been reported by Rao et al. (1990) and Gupta and Yadav (2005). The population structure of tree species were following three types according to the criteria given by Saxena and Singh (1984):

1. Q. floribunda and *Q. leucotrichophora* with higher proportion of individuals in younger girth classes as compared to higher girth classes. This type of population structure represents frequent reproduction (Knight, 1975).
2. Cupressus torulosa and *C. deodara* with high density in the intermediate girth classes and decreasing density towards lower and higher girth classes. According to Knight (1975) this type of population structure represents infrequent reproduction.
3. Seedlings and saplings were absent in case of *Rhododendron arboreum* and *Gravillea robusta* indicating that these species were not regenerating and may be replaced by some other tree species in future.

DISCUSSION

Our understanding of the various aspects of tree regeneration in the Himalaya is far from adequate. Unregulated man-made disturbances have greatly limited

Table 3. Density (number of trees ha^{-1}) and Importance Value Index (IVI) of tree species at different sites in protected and open forest area at hill base, hill slope and hill top.

Site	Species	Forest			
		Protected		Disturbed	
		Density	IVI	Density	IVI
Hill base	*Quercus leucotrichophora*	60	70.36	140	188.66
	Quercus floribunda	280	139.20	80	72.17
	Cupressus torulosa	120	90.40	-	-
	Rhododendron arboreum	-	-	40	39.17
	Total	460		260	
Hill slope	*Quercus leucotrichophora*	-	-	191	164.31
	Quercus floribunda	940	227.57	100	67.45
	Cupressus torulosa	-	-	100	49.01
	Cedrus deodara	-	-	25	19.17
	Gravillea robusta	30	73.91	-	-
	Total	970		325	
Hill top	*Quercus leucotrichophora*	140	88.90	50	21.81
	Quercus floribunda	640	211.08	250	82.1
	Cupressus torulosa	-	-	180	67.31
	Cedrus deodara	-	-	300	128.79
	Total	780		780	

Photo Plate 2. Open forest site.

the possibility of designing studies for assessing the response of species to a particular scale and kind of disturbances. The broadleaf trees (particularly *Q. leucotrichophora* and *Q. floribunda*) are repeatedly lopped for leaves and firewood, leading to their gradual disappearance. As a result of these activities, the forest sites have been either reduced or dramatically modified and have led to the expansion of xerophytic conditions (Singh and Singh, 1987). This protected zoo site would help to formulate planning for long- term studies as far as

Table 4. Density (number /100 m^2) of shrub species in protected and disturbed forest site at hill base, hill slope and hill top.

Species	Hill base		Hill slope		Hill top	
	Protected	Disturbed	Protected	Disturbed	Protected	Disturbed
Achyranthes aspera Linn	-	-	2.4	2.7	-	5.2
Berberis asiatica Roxb.ex. D.Don	1.8	1.8	2.4	2.3	4.0	4.2
Coriaria nepalensis Wall	-	-	-	0.9	-	3.8
Cotoneaster microphylla Wall	-	-	-	5.3	-	4.0
Desmodium elegans DC	-	0.4	-	1.1	0.7	3.1
Goldfussia dalhousiana Nees in DC	1.6	1.6	7.0	3.7	-	1.6
Hypericum oblongifolium Choicsy	1.2	9.2	-	7.0	-	4.5
Indigofera hetrantha Wall. Ex. Brandis	1.4	12.0	4.7	5.5	3.4	9.3
Myrsine africana Wall	-	0.2	-	1.0	-	3.4
Pyracantha crenulata (Don) Roem	-	-	-	2.4	-	2.6
Rosa brunonii Lindl	-	-	2.2	0.2	0.4	0.2
Rubus ellipticus Wall	-	0.6	-	-	-	1.9
Rubus niveus wall	-	-	1.1	0.9	3.1	0.5
Salvia officinalis Linn.	13.4	10.6	8.4	3.2	1.6	
Sarcococca saligna Wall	3.4	0.8	1.0	2.4	1.6	0.7
Urtica parviflora Roxb.	2.0	-	0.9	1.0	-	-
Wickstroemia canescens Meissn	-	-	-	0.7	-	1.1

Table 5. Total basal area (m^2ha^{-1}) in protected and disturbed forest site at hill base, hill slope and hill top.

Site	Species	Forest	
		Protected	Disturbed
Hill base	*Quercus leucotrichophora*	35.87	10.96
	Quercus floribunda	44.28	7.90
	Cupressuss torulosa	44.60	-
	Rhododendron arboreum	-	0.61
	Total	124.75	19.47
Hill slope	*Quercus floribunda*	16.66	8.86
	Gravillea robusta	4.55	-
	Quercus leucotrichophora	-	9.13
	Cupressuss torulosa	-	5.15
	Cedrus deodara	-	1.02
	Total	21.21	24.16
Hill Top	*Quercus floribunda*	9.65	11.47
	Quercus leucotrichophora	4.85	3.51
	Cupressus torulosa	-	5.71
	Cedrus deodara	-	4.78
	Total	14.5	25.47

regeneration parameters and recovery of degraded broadleaf species of Himalayan region are concerned.

The distribution of plant species along the altitudinal transect (Hill base to Hill top) indicate that the distribution of each species is determined by its own ability to survive, grow and reproduce successfully in different environmental conditions. In protected site, a total of 17 species of plants were recorded, out of which 4 were trees and 13 were shrubs. In disturbed forest site, a total of 23 species were recorded with 5 tree and 18 shrub

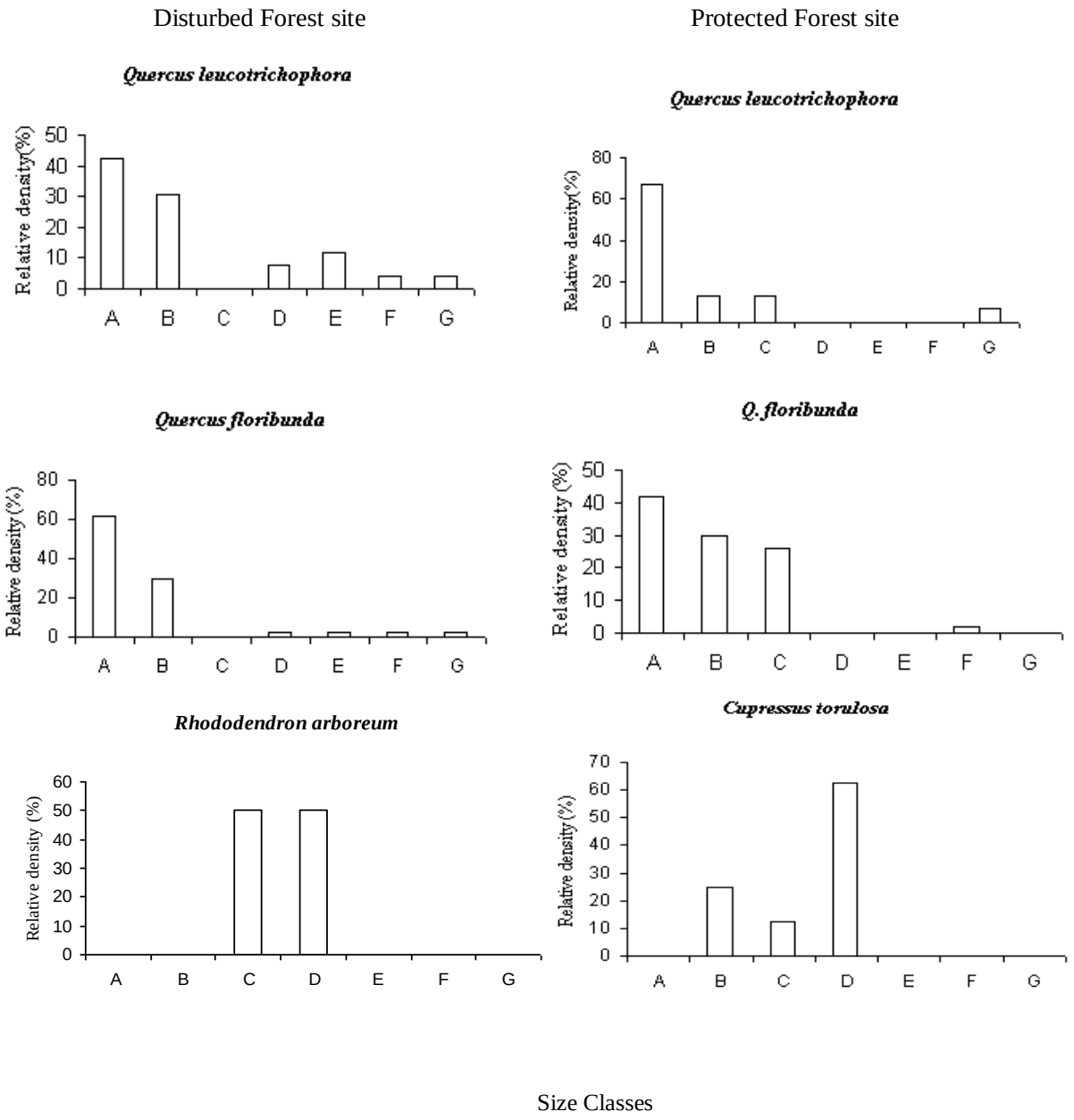

Figure 2. Population structure at Hill base of disturbed and protected forest site. A= seedlings, B= sampling, trees: C= 31-60 cm, D=61-90 cm, E=91-120 cm, F= 121-150 cm and G=>150 cm CBH.

species. These results indicate that moderate disturbance increase species richness (Singh and Singh, 1992). The distribution and species pattern in this region largely depend on the altitude and climatic variable like rainfall and temperature (Kharkwal et al., 2005). The mean basal area was greater for *Q. leucotricophora*, however, total basal area was greater for *Q. floribunda* due to high tree density particularly in protected site. *C. torulosa* and *C. deodara* were present at hill slope and hill top of disturbed forest site as they are high altitude species. The range of diversity was 0.09 to 0.55 for trees, 0.17 to 0.53 for saplings and 0.45 to 0.51 for seedlings. Age distribution is an important population characteristic which is the consequence of both natality and mortality. The ratio of various age groups in a population determines the reproductive status of the population and indicates the future course (Odum, 1971). The data on the population structure of *Q. leucotrichophora* and *Q. floribunda* at both the site suggest that the impact of human disturbance on density of seedlings and saplings was least and was significantly high as far as density of trees of higher girth classes is concerned (Figures 2 to 4). The protected site has highest number of seedlings followed by sapling and young trees. Absence of trees

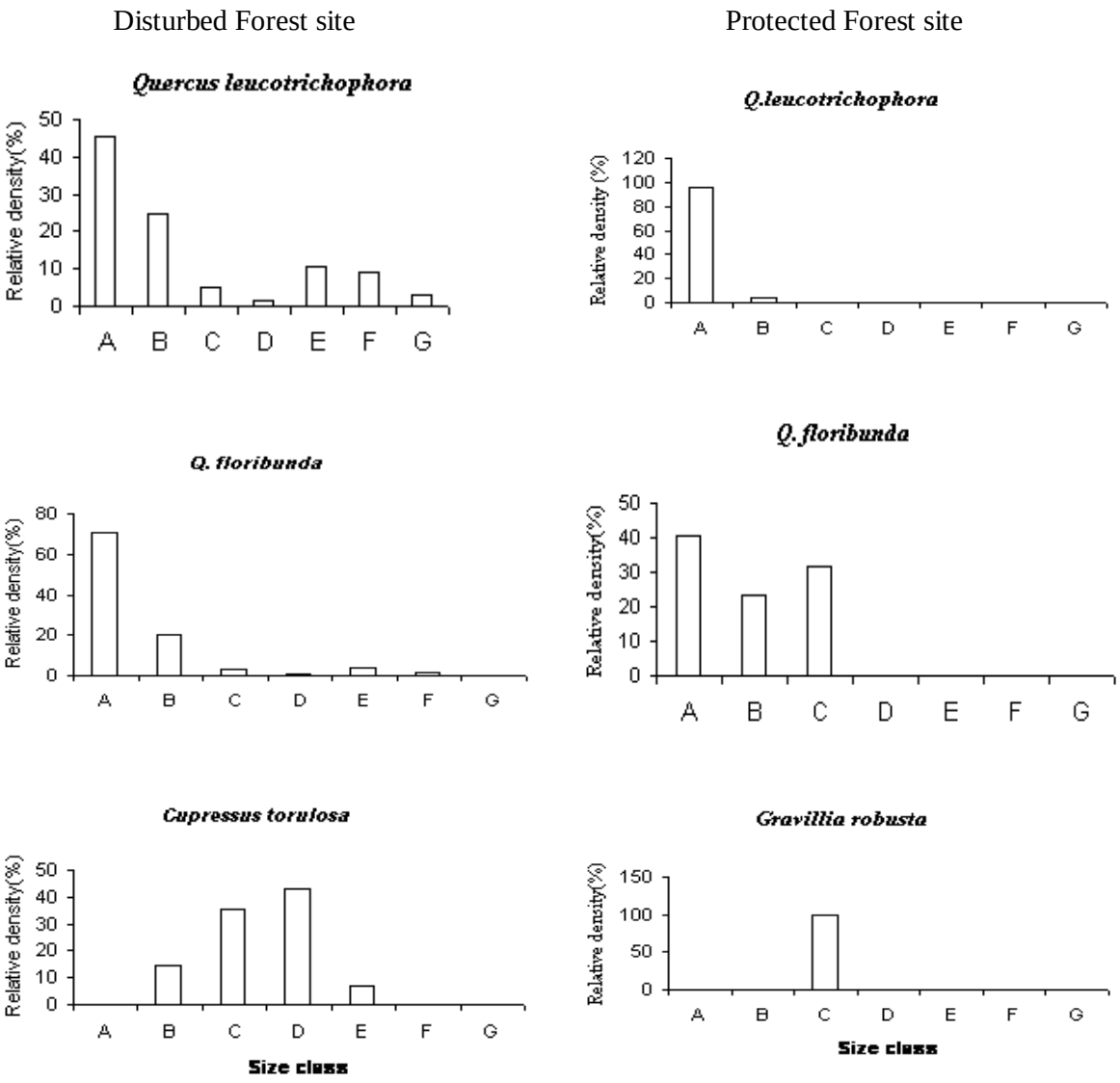

Figure 3. Population structure at Hill slope of disturbed and protected forest site. A= Seedlings, B= sampling, trees: C= 31-60 cm, D=61-90 cm, E=91-120 cm, F= 121-150 cm and G=>150 cm CBH.

in higher girth class indicates that this site represents young forest type. It may be due to deforestation of old trees in the past. A greater proportion of individual in lower size classes compared to large size classes of *Q. floribunda* indicates frequent reproduction (Singh and Singh, 1992). This site was protected by the Forest Department in the year 1984, and biotic disturbances were checked completely, resulting in greater survival of seedlings and saplings. According to Singh and Singh (1992) more individual in intermediate size classes and decreasing numbers towards the higher and lower size classes in *Q. leucotrichophora* indicates that the population is on the way of extinction. In a number of forest stands *Q. leucotrichophora* was regenerating well until recently but not now. *Q. floribunda* has been regenerating well in its own forest. Absence of trees in lower girth classes and slightly higher density in the higher girth classes in disturbed forest may be due to the presence of some old trees exhibiting the adverse effect of human disturbance. It may be suggested that partial disturbance favours the regeneration of oak species through increased micro-sites for seedling establishment and protection of seedlings from overgrazing and trampling by cattle (Gupta and Yadav, 2005). Mature trees were lopped for fuel wood and fodder by the local inhabitants, which not only reduce the vigour but also seed production and ultimately led to poor regeneration of species. The presence of some trees of *Rhododendron arboreum*, *C. torulosa* and *C. deodara* in middle girth classes indicate that these species are not regenerating well.

Forests are the important source of subsistence,

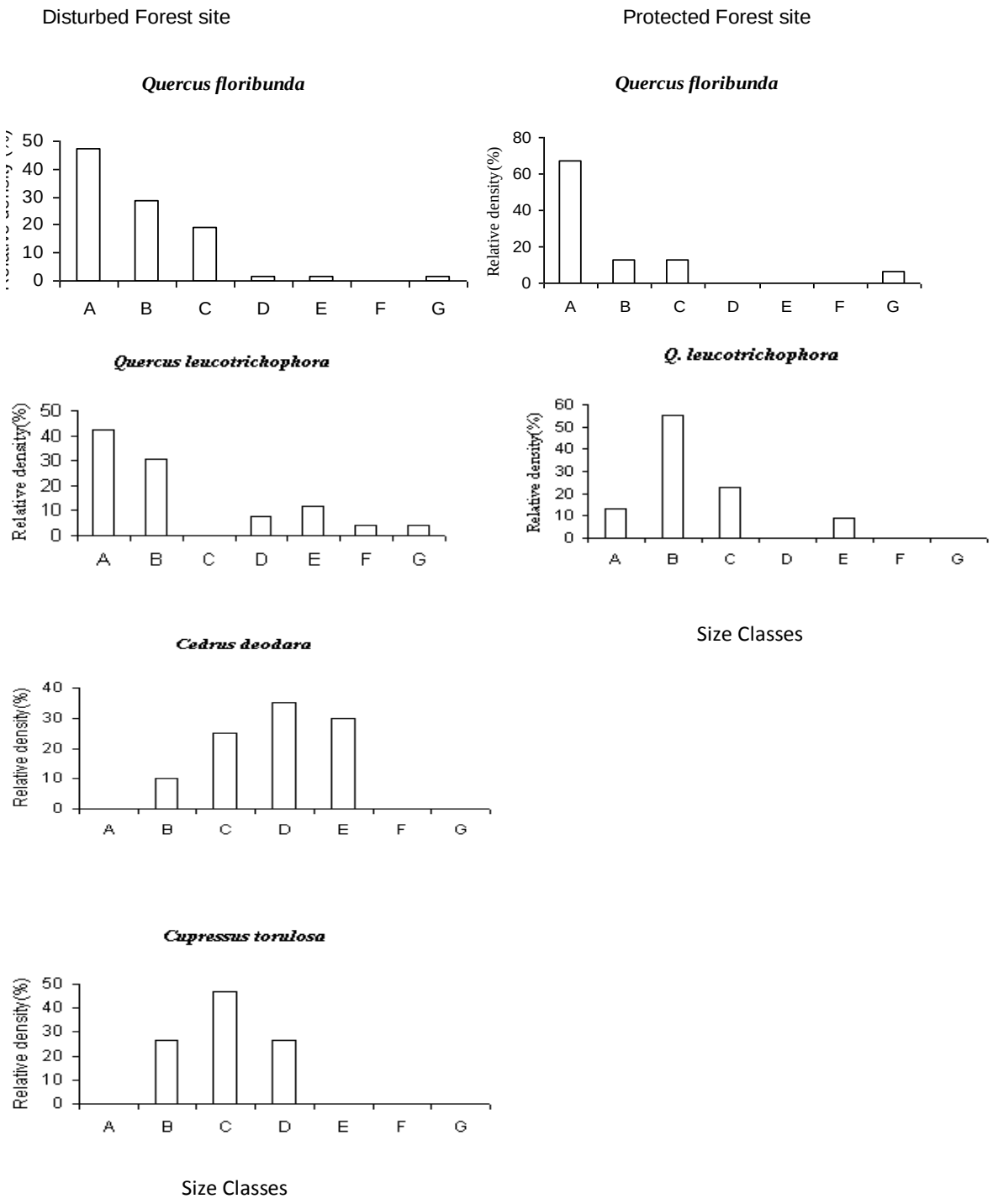

Figure 4. Population structure at Hill top of disturbed and protected forest site. A= Seedlings, B= sampling, trees: C= 31-60 cm, D=61-90 cm, E=91-120 cm, F= 121-150 cm and G=>150 cm CBH.

employment, revenue earning and raw material to various industrial uses. Above all they are most important component of life support system on the earth and provide various ecological services. The present study was conducted to analyse the impact of biotic disturbances on regeneration status of tree species as disturbances are critical elements in controlling the composition and functioning of forest ecosystems. Regeneration is a critical phase of forest management, because it maintains the desired species composition after disturbance. Excessive lopping, concomitant reduction in seed production and enhanced weevils'

infestation of acorns seems to adversely affect regeneration of *Q. leucotrichophora* (Singh and Singh, 1992). Much of brown oak (*Quercus semecarpifolia*) and adjacent alpine meadows have been historically under influence of grazing of migratory livestock such as sheep and goats. The failure of brown oak to regenerate is a case of environmental semi surprise (Singh et al., 1997). The findings of the present study indicate that if anthropogenic pressure continues to operate future perpetuation of oaks (*Q. floribunda* and *Q. leucotrichophora*) in the forest may be threatened. Thus, proper conservation measures have to be formulated to protect these valuable tree species. Awareness programmes regarding the importance of forests and sustainable harvesting may help to minimize the pressure on the forests.

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