Indian Forester, 140 (4) : 395-406, 2014
http://www.indianforester.co.in
ISSN No. 0019-4816 (Print)
ISSN No. 2321-094X (Online)

COMMUNITY COMPOSITION, TREE POPULATION STRUCTURE IN A TEMPERATE BROAD-LEAVED EVERGREEN OAK FOREST ALONG A DISTURBANCE GRADIENT IN GARHWAL HIMALAYA, UTTARAKHAND, INDIA

D. S. CHAUHAN; SUNIL PRASAD; VIKASPAL SINGH AND N.P. TODARIA

Department of Forestry and NR, H.N.B. Garhwal University,
Srinagar Garhwal, 246 174, Uttarakhand, India.
e-mail: dschauhan2008@gmail.com/ dsc_oci@rediffmail.com

ABSTRACT

The present study was carried out in broad leaved evergreen oak forests of Garhwal Himalaya, Uttarakhand, India (1500-2100 m amsl.) along disturbance gradient. In this study, some disturbance indicators i.e. canopy cover, stand density, grazing intensity, lopping intensity, number of cut stumps and climber invasion have been evaluated and with the help of these indicators the forest area has been categorized into three categories viz. undisturbed, moderately disturbed and highly disturbed. The study revealed that tree diversity decreased with increasing intensity of disturbance in case of tree and herb species but it was found maximum in moderately disturbed stands for both layers (tree, herb) whereas, in case of shrub species, Shannon diversity increased with increasing disturbance level. Simpson dominance index was found as reverse of the Shannon index in all three layers of vegetation for all disturbance categories. Almost same trend was found in species richness. It was found more vulnerable to disturbance in case of tree and herb layers as it decreased with increasing level of disturbance but its highest values were recorded in the moderately disturbed stands in both vegetation layers. On the other hand shrub species richness favored the disturbance as it increased with increasing intensity of disturbance. As far as the regeneration is concerned, sapling and seedling density was decreased with increasing disturbance level but both the classes were found maximum in the intermediate level of disturbance. Diameter-density curves depicted a successive reduction in the number of trees from lower girth classes to upper. All the above variations in relation to species richness, distribution pattern and regeneration potential are related to anthropogenic interference.

Key words: Disturbance categories, Elevational range, Floristic analysis, Plant diversity, Population structure.

Introduction

The recurrent interventions into the forest communities for large-scale collection of fuel wood and minor forest products and the practices of grazing and trampling may alter the habitat of many species (Visalakshi, 1995). Therefore, many time the structure of plant and animal communities in many natural ecosystems is largely determined by the disturbances, which occur quite frequently (Vogl, 1980; Armesto and Pickett, 1985). Disturbances are viewed as extraordinary events, unnatural deviation from the normal successional development of equilibrium communities but sometime it is considered as a positive force that might increase species diversity in the community by preventing competitive exclusion by dominant species. Disturbances also influence species diversity in many landscapes and a better understanding of interactions between spatial pattern and disturbance is needed (Roberts and Gilliam, 1995).

In Himalayan region chronic form of disturbances are those in which people remove only a small fraction of forest biomass in the form of grazing, lopping, surface burning and litter removal at a given time in a year but the process continues year after year. The problem with the chronic form of forest disturbance is that plants or ecosystems often do not get time to recover adequately because the human onslaught never stops (Singh, 1998).

Quercus is a large genus with many of its five hundred species being canopy dominants. This broad-leaved genus of family Fagaceae has many superior characteristics for its wide acceptance as fuel, timber and nutritious fodder throughout the Himalaya. Among these species, many are dominant tree/shrub species of Garhwal and Kumaun Himalaya (Osmoston, 1927). These broad-leaved forests of *Quercus* are considered to provide the most effective for soil and water conservation (Saxena and Singh, 1982). Owing to multifarious nature of this genus most of the species are over-exploited for various purposes (Singh and Singh, 1984). Among these species, *Q. leucotrichophora* is one of the most affected species (Pandey and Shukla, 1999). Major area under oak forest is surrounding by local inhabitants of hilly areas in Garhwal Himalaya, therefore, nature and frequency of disturbance and the history of

> Tree and herb diversity was decreased with increasing intensity of disturbance whereas, in case of shrub species, Shannon diversity increased with increasing disturbance level.

forests are not available. To quantify the intensity of disturbance, many disturbance indicators e.g. tree density, canopy cover, light interception and number of cut stumps have been used (Mishra *et al.,* 2004; Pandey and Shukla, 1999; Rao *et al.,* 1990).

Keeping in view the aforementioned facts, this paper deals to investigate the variation of community composition, plant species diversity and tree population structure along disturbance gradient in two oak forest stands of Garhwal Himalaya.

Material and Methods

Study area

Present study was carried out in two *Q. leucotrichophora* dominated forest stands in which one was located between 30^0 08' 17.1"N to 30^0 06' 22.8"N latitude and 79^0 14' 30.4"E to 79^0 16' 48.4"E longitude and falls in north-facing aspect at elevations between 1500 m and 2100 m amsl. The Diwalikhal Oak forest stand is situated between 12 to 40 km West of Gairsain town in Garhwal region of Uttarakhand. Diwalikhal, Malsi, Kheti, Sirana and Bedi are the villages in the vicinity of the study area under Dhanpur range which is a part of Kedarnath Wildlife Sanctuary. Anthropogenic activities are strictly banned in the whole area but small fraction of resources is still obtained by the inhabitants to sustain their livelihood. Besides basic needs (fuel, fodder and timber), the valuable lichen species locally called "Makku" and "Jhulla" are extracted from this forest area continuously and it is a valuable economic exercise of inhabitants. Another oak forest stand is Khirsoo situated under the reserve forest of Garhwal Forest Division is situated between 30^0 08' 18.5"N to 30^0 09' 36.8"N latitude and $78^0$50'48.6" E to $78^0$50'16.8" E longitude and located between 1600 to 2100 m amsl in both north and south-facing aspects. This forest stand is 18 Km. away from the district headquarter Pauri and is known as Khirsoo Oak forest. Bhattigaon, Danda, Gwadigad, Fairkhal, Chaubbata and Kathuli are the villages in and around the forest. Most of the villagers in this area are dependent on this forest for their basic needs of fuel, fodder and leaf-litter. Thus a total of seven (five in north-facing and two in south-aspect) elevational ranges in Diwalikhal stand and eight (six in north-facing and two in south-facing) in Khirsoo forest stand have been studied in this study.

Preliminary Survey and Disturbance Classification

Preliminary survey of the study area was conducted to design the transects (two to three vertical transects were designed in each aspect of a stand). Transects were laid down along altitudinal gradient (100 m width) and were spatially distributed so as to minimize the autocorrelation among the vegetational and disturbance elements. After that detailed survey was carried out to determine canopy cover (by the spherical densiometer), tree density (by quadrat sampling), lopped trees % (total number of lopped trees/density X 100), grazing intensity (by counting dung piles), number of cut stumps (by direct counting) and climber affected trees % (total number of climber affected trees/density X 100). All these disturbance indicators have been surveyed with the elevational interval of 100 m in each transect. By using maximum and minimum values of above said parameters, each altitudinal zone has been classified into a separate disturbance category viz. an undisturbed stand consisted of >1200 tree density (h^{-1}), >40% canopy cover, <10% lopping, <80 cut stumps (h^{-1}), <20 climber affected trees (h^{-1}) and <100 dung piles (ha^{-1}) whereas a highly disturbed site has been consisted of = 800 tree density (h^{-1}), <10% canopy cover, >25% lopping, >150 cut stumps (h^{-1}), >40% climber affected trees (h^{-1}) and >200 dung piles (ha^{-1}). The intermediate position of above said values was considered as moderately disturbed stand. While tree density and canopy cover were considered as the negative indicators, lopping, number of cut stumps, climber affected trees and grazing were assumed positive indicators to disturbance.

During the disturbance classification, only those disturbance indicators have been taken into consideration which were present in the stand/elevation. On the basis of above mentioned index, each elevation range has been classified into highly disturbed, moderately disturbed and undisturbed elevational range. On the basis of these categorizations, two undisturbed (at 1800 m, 1900 m amsl), three moderately disturbed (at 1600 m, 2000 m, 2100 m amsl.) and two highly disturbed (at 1500 m, 1700 m amsl) elevational ranges were mapped for observation in Diwalikhal forest stand while in Khirsoo forest, a total of three undisturbed (at 2100 m, 2000 m and 1900 m north-facing,) three moderately disturbed (at 1800 m north-facing, 2100 m and 1700 m south-facing) and two highly disturbed (at 1600 m and 1700 m north-facing) elevational ranges were mapped for the study.

Field Sampling

In designated transects, approximately twenty sample plots or quadrats (10 x 10 m = 100 m^2) at 100 m intervals were laid randomly to observe the occurrence of different species. The quadrats were laid as much as possible at similar elevational ranges. In each plot (quadrat), diameter at breast height (DBH) and height of all trees were measured individually and species wise. Two sample plots or quadrats (2x5m) which were nested within 100 m^2 plots were used for shrubs and saplings and five $1m^2$ (1m x 1m) sample plots which were also

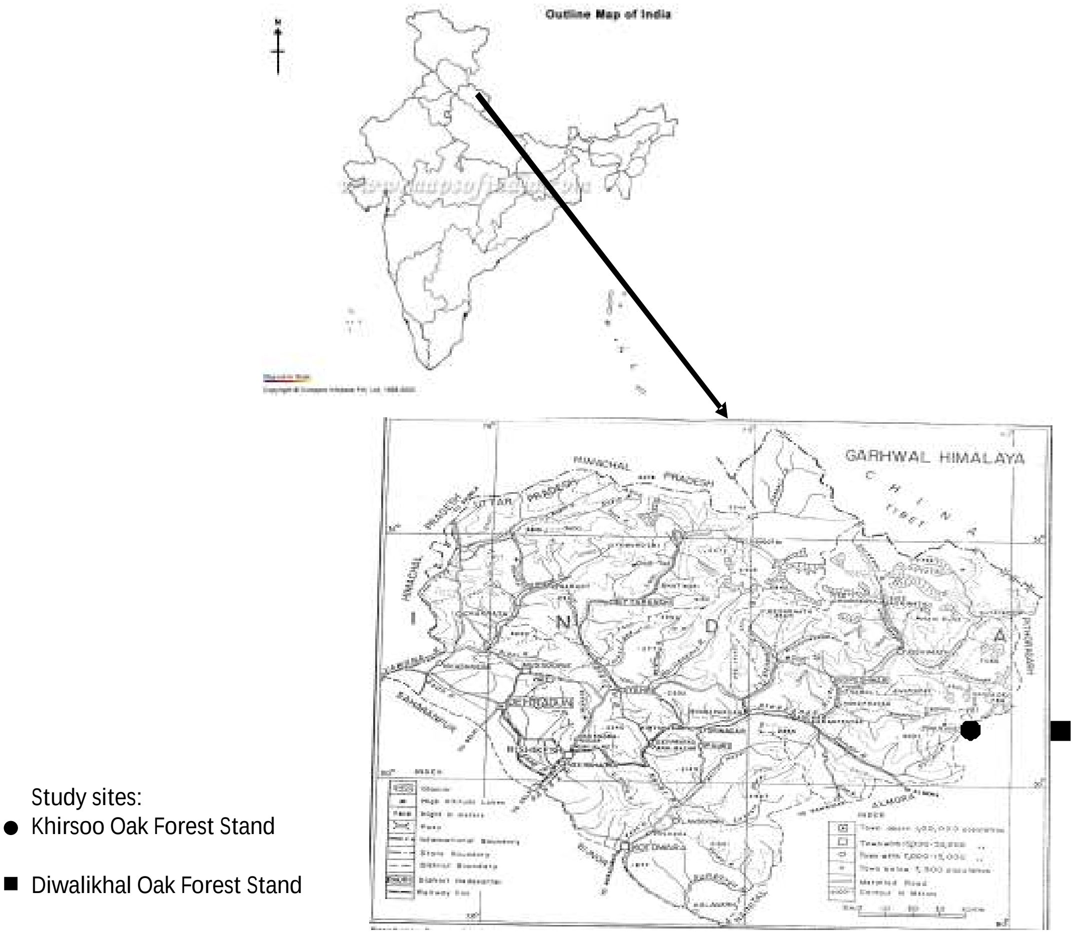


Fig. 1 : Site map showing the location of the study sites in Garhwal Himalaya, Uttarakhand India.

nested within 100 m^2 were used for herbs and seedlings. The species that were characterized by short stature and with spiny structures (thorns or spines), were classified as shrubs. Herbs included shade-loving, annual, biannual or perennial herbaceous species. Trees with = 31.5 cm. cbh were individually measured for cbh. Individuals having < 11 cm. circumference at root collar were determined as seedlings while the intermediate position between trees and seedlings was considered as sapling. Any species which could not be identified in the field, the same was brought back in the department and identified with the help of the herbarium, Department of Botany, H.N.B. Garhwal University, Srinagar (Garhwal).

Data analysis: The tree component was divided into following diameter classes *viz*. 31-50, 51-70, 71-90 and >90 cm. Density, frequency, abundance and basal cover of all the species was determined by standard methods (Mishra, 1968; Muller and Ellenberg, 1974). The Important Value Index (IVI) for different species was calculated as sum of relative frequency, relative density and relative dominance of each species. The concentration of dominance (Cd) for each community was calculated by Simpson's index (Simpson, 1949) and species diversity by Shannon's index (Shannon and Wiener, 1963). The proportional abundance of the most abundant species was calculated by Berger Parker Index (Berger and Parker, 1970). Species richness expressing estimates of the number of species per specified number of individuals or biomass or species density as numerical species richness was calculated by Margalef Index (Margalef, 1958).

Results

Floristic composition: A total of 74 species (17 trees, 31 shrubs and 26 herbs), 68 genus and 36 families were recorded in the both oak forests stand. Among the families Rosaceae (12) was found dominant followed by Asteraceae (10) in the both oak forests stand. Tree layer represent 12 families, shrub layer 17 families, herb layer 7 families and 5 families were found common in tree, shrub and herb layers (Fig. 2). Maximum numbers of tree, shrubs and herbs were present in the site 2 (Khirshoo). On the other hand a total numbers of species (tree, shrubs and herb) were present maximum in the undisturbed stand on both the forest (Diwalikhal was 41

Table 1 : Density (plant/100 m^2) and Importance Value Index (IVI) of important species in two oak forests of Garhwal Himalaya along disturbance gradient.

S. No.	Tree species	Undisturbed stand				Moderately disturbed stand				Highly disturbed stand			
		Density		IVI		Density		IVI		Density		IVI	
		S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
1	*Acacia dealbata*	-	-	-	-	0.60	-	20.4(5)	-	-	-	-	-
2	*Benthamidia capitata*	0.26	0.02	8.8(6)	0.88(9)	-	0.10	-	3.7(6)	-	-	-	-
3	*Cupressus torulosa*	-	0.07	-	1.94(8)	-	-	-	-	-	-	-	-
4	*Engelhardtia spicata*	-	0.12	-	3.28(7)	-	-	-	-	-	-	-	-
5	*Lindera pulcherrima*	0.06	0.05	2.3(7)	1.8(10)	0.60	0.10	20.8(4)	3.40(7)	0.10	-	6.2(6)	-
6	*Lyonia ovalifolia*	1.53	0.70	36.9(3)	23.924)	1.30	0.70	33.0(2)	24.5(4)	0.50	0.60	24.3(4)	27.3(4)
7	*Myrica esculenta*	1.06	1.52	26.0(4)	43.0(2)	0.60	1.80	18.3(5)	57.6(2)	0.50	1.20	27.5(3)	41.5(2)
8	*Neolitsea pallens*	0.06	-	2.3(7)	-	0.30	-	7.8(7)	-	-	-	-	-
9	*Pinus roxburghii*	-	0.2	-	9.45(5)	-	-	-	-	-	-	-	-
10	*Prunus cornuta*	-	0.02	-	0.98(11)	-	-	-	-	-	-	-	-
11	*Pyrus pashia*	0.33	0.15	11.3(5)	4.16(6)	-	-	-	-	0.30	0.10	16.9(5)	18.4(5)
12	*Quercus leucotrichophora*	9.80	8.42	167.1(1)	161.1(1)	7.50	6.2	175.2(1)	160.3(1)	5.80	5.20	186.2(1)	153(1)
13	*Quercus floribunda*	-	-	-	-	0.20	-	7.2(8)	-	-	-	-	-
14	*Rhododendron arboreum*	1.60	1.07	45.3(2)	34.0(3)	0.70	0.90	21.9(3)	26.5(3)	0.60	0.60	32.8(2)	41.0(3)
15	*Sapium insigne*	-	0.05	-	1.80(10)	-	-	-	-	-	-	-	-
16	*Sorbus aucuparia*	-	-	-	-	0.60	-	15.8(6)	-	-	-	-	-
17	*Symplocos paniculata*	-	0.45	-	14.2(4)	-	0.10	-	3.4(7)	-	0.30	-	18.4(5)
	Shrub species												
1	*Artemisia roxburghiana*	-	-	-	-	-	-	-	-	0.16	-	4.1(12)	-
2	*Asparagus adscendens*	0.16	-	3.5(10)	-	-	-	-	-	-	-	-	-
3	*Asparagus racemosus*	0.11	0.18	2.8(11)	3.77(16)	-	0.25	-	4.4(15)	-	0.16	-	4.26(8)
4	*Berberis aristata*	1.44	1.39	35.5(2)	15.3(4)	0.66	0.92	26.2(3)	12.9(4)	1.25	0.66	29.9(1)	11.0(4)
5	*Berberis lysium*	-	0.18	-	3.30(19)	-	0.83	-	7.44(7)	-	0.16	-	4.26(8)
6	*Boenninghausenia albiflora*	-	-	-	-	0.16	-	5.2(9)	-	0.33	-	10.3(8)	-
7	*Boerhavia diffusa*	-	0.72	-	5.98(10)	-	0.25	-	2.28(17)	-	-	-	-
8	*Caryopteris foetida*	1.94	1.7	41.3(1)	16.6(3)	0.25	0.42	9.1(6)	6.5(10)	1	0.66	18.5(6)	11(4)
9	*Colebrookia oppositifolia*	-	0.87	-	9.18(7)	-	0.67	-	7.03(8)	0.91	0.33	23.7(3)	8.53(6)
10	*Cotoneaster bacillaris*	-	0.56	-	5.19(12)	-	2.92	-	24.3(2)	-	1.33	-	19.0(3)
11	*Daphne papyracea*	0.05	0.81	2.2(12)	12.5(5)	-	2.33	-	20.4(3)	-	1.83	-	25.7(2)
12	*Desmodium elegans*	-	0.25	-	3.61(18)	-	-	-	-	-	0.16	-	4.26(8)
13	*Eupatorium adenophorum*	0.33	7.41	8.5(7)	46.2(1)	2.33	7.17	44.4(2)	44.4(1)	1.33	5.5	24.7(2)	58.9(1)
14	*Excoecaria acerifolia*	-	0.18	-	2.39(21)	-	-	-	-	-	-	-	-
15	*Hypericum uralum*	-	0.58	-	5.59(11)	-	0.25	-	2.28(17)	-	-	-	-
16	*Indigofera atropurpurea*	0.05	0.83	2.2(12)	9.56(6)	0.33	0.58	10.3(5)	6.4(11)	0.08	0.5	3.1(13)	6.73(7)
17	*Inula cuspidata*	0.27	-	6.3(8)	-	-	-	-	-	-	-	-	-
18	*Leptodermis lanceolata*	0.88	-	16.6(4)	-	0.33	-	10.3(5)	-	0.16	-	6.2(10)	-
19	*Myricina Africana*	0.83	2.43	20.6(3)	20.2(2)	1.58	1.08	47.6(1)	10.5(5)	0.91	-	21.6(4)	-
20	*Perilla frutescens*	-	0.18	-	2.77(20)	-	-	-	-	-	-	-	-
21	*Prinsepia utilis*	-	0.54	-	4.22(15)	-	0.75	-	6.85(9)	-	-	-	-

22	*Pyracantha crenulata*	0.44	0.31	11.4(6)	0.48(23)	0.33	-	10.3(5)	-	-	-	-	-
23	*Rhamnus purpureus*	-	0.47	-	4.55(14)	-	-	-	-	-	0.16	-	4.26(8)
24	*Rhus parviflora*	0.05	0.37	2.2(12)	3.73(17)	-	0.42	-	5.61(14)	0.16	0.66	6.2(10)	11.0(4)
25	*Rosa macrophylla*	-	0.31	-	5.12(13)	0.25	0.42	11.9(4)	6.38(12)	0.41	0.5	13.4(7)	9.76(5)
26	*Rubus ellipticus*	0.44	0.64	11.4(6)	9.15(8)	0.25	0.83	6.3(8)	9.4(6)	0.16	0.33	6.2(10)	8.5(6)
27	*Rubus foliolosus*	0.27	0.66	6.3(8)	8.51(9)	0.33	0.33	10.3(5)	6.07(13)	0.25	0.16	7.2(9)	4.26(8)
28	*Sinarundinaria falcata*	0.33	-	8.5(7)	-	-	-	-	-	0.25	-	5.1(11)	-
29	*Spiraea canescens*	-	0.08	-	1.81(22)	-	0.17	-	3.89(16)	-	0.16	-	4.26(8)
30	*Viburnum erubescens*	0.16	-	5.0(9)	-	-	-	-	-	-	-	-	-
31	*Wikstroemia canescens*	0.66	-	15.5	-	0.16	-	7.9(7)	-	0.75	-	19.6(5)	-
	Herb species												
1	*Achyranthes aspera*	75.6	-	7.0(8)	-	53.3	-	5.7(11)	-	63.3	-	6.5(10)	-
2	*Ainsliaea latifolia*	88.9	-	8.0(7)	-	70	-	8.6(10)	-	33.3	-	4.0(14)	-
3	*Anaphalis adnata*	104.4	114	10.1(6)	18.1(3)	106.7	93	13.5(6)	15.4(3)	123.3	93.3	19.5(4)	12.7(5)
4	*Andropogon munroi*	388.9	410	37.6(3)	43.0(1)	336.7	523	26.8(3)	47.1(1)	200	460	24.2(3)	43.3(1)
5	*Apluda mutica*	-	0.07	-	1.18(18)	-	-	-	-	-	-	-	-
6	*Aster peduncularis*	-	-	-	-	46.7	-	5.0(13)	4.0(15)	-	-	-	-
7	*Bergenia ciliata*	-	52	-	10.1(8)	-	87	-	13.4(5)	-	46.7	-	7.5(10)
8	*Bidens pilosa*	75.6	-	6.6(9)	-	103.3	-	14.4(5)	-	90	-	8.7(8)	-
9	*Carex caricina*	17.8	13	2.1(15)	4.12(13)	50	53	5.2(12)	-	46.7	-	6.1(11)	-
10	*Chrysopogon gryllus*	-	113	-	14.7(4)	133.3	130	9.9(9)	15.2(4)	-	-	-	-
11	*Crotalaria albida*	15.6	-	1.6(16)	-	-	-	-	-	-	-	-	-
12	*Cyeprus niveus*	24.4	33	2.4(14)	5.61(12)	46.7	27	3.7(14)	5.13(12)	36.7	-	4.2(13)	-
13	*Cynodon dactylon*	448.9	304	40.4(1)	31.8(2)	340	293	26.9(2)	31.1(2)	586.7	413.3	42.9(1)	41.6
14	*Fragaria nubicola*	120	45	13.4(4)	8.47(9)	123.3	57	15.0(4)	10.0(9)	86.7	73.3	9.5(7)	13.8
15	*Galium asperifolium*	82.2	25	6.5(10)	3.12(14)	66.7	-	10.2(8)	-	76.7	-	7.6(9)	-
16	*Herteropogon contortus*	426.7	113	39.0(2)	11.4(5)	416.7	140	29.9(1)	13.0(6)	433.3	206.7	35.5(2)	24.3
17	*Micromeria biflora*	-	68	-	10.9(6)	-	33	-	4.9(13)	123.3	86.7	12.7(6)	13.4
18	*Potentilla gerardiana*	111.1	49	12.5(5)	8.3(10)	66.7	30	11.2(7)	5.3(11)	-	-	-	-
19	*Ranunaculus arvensis*	-	0.06	-	1.24(19)	-	17	-	4.32(14)	-	-	-	-
20	*Reinwardtia indica*	51.1	-	5.0(11)	-	-	-	-	-	113.3	-	13.2(5)	-
21	*Rumex hastatus*	-	0.07	-	1.32(17)	-	-	-	-	-	-	-	-
22	*Senecio graciliflorus*	-	44	-	8.25(11)	-	57	-	10.4(8)	-	-	-	-
23	*Senecio nudicaulis*	57.8	-	4.9(12)	-	33.3	-	2.7(15)	-	50	-	5.3(12)	-
24	*Valeriana jatamansii*	26.7	61	3.0(13)	10.9(7)	-	50	-	10.4(7)	-	86.7	-	15.8
25	*Viola canescens*	-	16	-	2.57(16)	-	-	-	-	-	46.7	-	8.6

S1-Diwalikhal, S2-Khirsoo

and Khirsoo was 54 species). All species were distributed in three distinct stories, viz. trees, shrubs and herbs. The top canopy layer (trees) was mainly comprised of *Quercus leucotrichophora, Rhododendron arboreum, Lyonia ovalifolia* and *Myrica esculenta* in both the stands. Among them *Q. leucotrichophora* was found first in species ranking in all the three disturbance categories in both the forest stands. It was interesting to see that dominant top canopy species lost their density values with increasing intensity of disturbance. Maximum tree density (9.80 tree/100 m^2) was recorded for *Quercus leucotrichophora* in Diwalikhal forest at the undisturbed stand while minimum tree density (0.02 tree/100 m^2) was found in undisturbed stand of Khirsoo forest for *Benthamidia capitata* and *Prnus cornuta*. *Quercus leucotrichophora* showed maximum (186.2) IVI in highly disturbed stand might be due to occurrence of higher diameter class (old age) trees. While minimum IVI (0.88) was found in the Khirsoo forest for *Benthamidia capitata* in the undisturbed stand (Table 1). Due to presence of new age group (pole crop) trees resulted in lowest basal area.

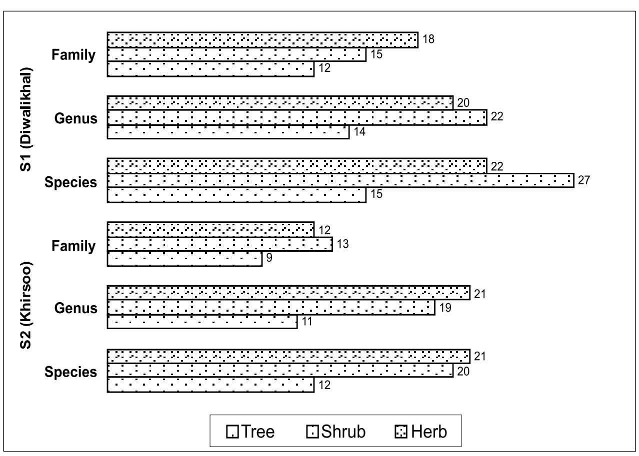


Fig. 2 : Species, genus and family distribution of two Oak forest stand (S1 and S2) in Garhwal Himalaya.

The sub-canopy (shrub) was dominated by *Caryopteris foetida, Berberis aristata* and *Myricina africana* in the undisturbed stand, whereas the dominant species in moderately disturbed stand were *Myricina africana* and *Berberis aristata. Caryopteris foetida* was found dominant in the highly disturbed stand in Diwalikhal forest. On the other hand *Eupatorium adenophorum*, *Myricina africana* and *Caryopteris foetida* were dominant in undisturbed stand, *Eupatorium adenophorum*, *Cotoneaster bacillaris* and *Daphne papyracea* in moderately and highly disturbed stands in Khirsoo forest stand. The number of herbaceous species did not differ among the stands and dominant herb species were *Andropogon munroi*, *Cynodon dactylon*, *Anaphalis adnata*, *Fragaria nubicola* and *Chrysopogon gryllus* in all three classes. As far as the seedling and sapling density were concerned, *Q. leucotrichophora* was the dominant species in both seedling and sapling stages for all categories in both forest stands. *Rhododendron arboreum, Lyonia ovalifolia* in seedling stage and *Rhododendron arboreum* and *Myrica esculenta* in sapling stage were found in good numbers in undisturbed stand along with *Q. leucotrichophora* in Diwalikhal forest. The seedlings of *Lyonia ovalifolia* and *Rhus punjabensis* and saplings of *Myrica esculenta* and *Sorbus aucuparia* were abundant on the forest floor in moderately disturbed stand of the same forest while seedlings of *R. arboreum* and *Lyonia ovalifolia* and saplings of *R. arboreum* were found accountable on highly disturbed stand's floor of this forest. Khirsoo forest was co-dominated with *Myrica esculenta*, *Rhododendron arboreum* and *Lyonia ovalifolia* at sapling as well as seedling stages in undisturbed to moderately disturbed stands but in highly disturbed stands, seedling of *Lyonia ovalifolia* and *Engelhardtia spicata* were co-dominant along with *Q. leucotrichophora*. The overall density of sapling decreased with increasing disturbance but was recorded highest in moderately disturbed stand but seedling density was found decreasing with increasing disturbance in Diwalikhal forest. But in Khirsoo forest, both seedlings and saplings was recorded highest in the moderately disturbed stand and decreased towards highly disturbed stand (Table 2).

Diversity-indices: Diversity (Shannon diversity index) decreased with increasing magnitude of disturbance for tree species but its maximum values were recorded at the intermediate (moderately disturbed) stands. It was recorded to be as 1.092, 1.287, 0.832 in Diwalikhal forest and 1.123, 1.204, 1.052 in Khirsoo forest for undisturbed, moderately disturbed and highly disturbed stands, respectively. For shrub species, Shannon diversity index was recorded highest in highly disturbed stand and lowest in moderately disturbed stands for both forests. But in case of herb species it is decreased with increasing disturbance level in both studied forests, but moderately disturbance site received highest values. On the other hand Simpson dominance index was recorded as reverse of the Shannon index in all three layers of vegetation for all disturbance categories in both sites. Margalef index of species richness for tree species was recorded highest at moderately disturbed stands for both forests but these values were lowest in highly disturbed stand and undisturbed stand for Diwalikhal and Khirsoo forests, respectively. But in case of shrub species, Margalef index increased with increasing magnitude of disturbance in both forests, whereas its highest values were recorded in moderately disturbed stands for herb species in both

Table 2 : Density of tree seedlings and saplings (Plant/ha) in two oak forests exposed to different degree of disturbance.

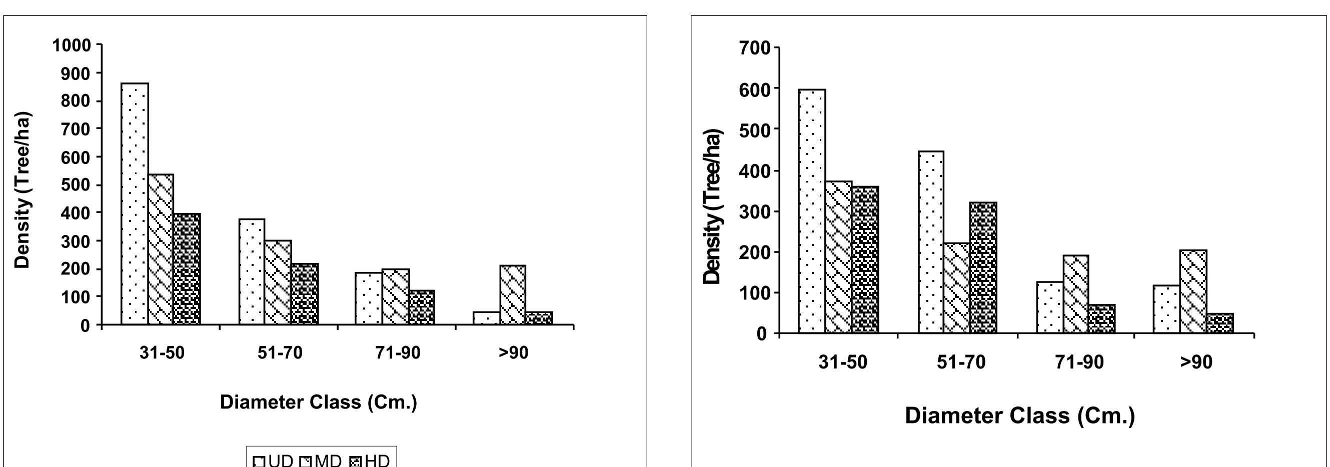
	Undisturbed stand				Moderately disturbed stand				Highly disturbed stand			
	Sapling		Seedling		Sapling		Seedling		Sapling		Seedling	
Species	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
Quercus leucotrichophora	1066.6	2300	4667	15563	1300	3000	7000	21000	1000	1100	4000	8000
Rhododendron arboreum	466.7	350	333.3	3500	200	400	1000	3000	600	560	4000	-
Lyonia ovalifolia	266.7	350	2667	500	200	300	2000	4000	400	730	1000	2000
Myrica esculenta	533.3	500	2667	3250	500	600	1000	4000	300	400	2000	-
Sorbus aucuparia	133.3	-	2000	-	400	-	-	-	-	-	1000	-
Lindera pulcherrima	-	-	667	-	200	-	1000	-	-	-	1000	-
Benthamidia capitata	-	50	2667	250	300	100	2000	-	-	-	1000	-
Pyrus pasia	466.7	75	133.3	250	200	-	1000	-	200	-	1000	-
Rhus punjabensis	-	-	-	-	-	-	2000	-	-	-	-	-
Symplocos paniculata	-	275	-	1250	200	-	-	-	-	400	-	-
Engelhardtia spicata	-	75	-	-	-	-	-	-	-	-	-	2000
Celtis australis	-	-	-	2000	-	-	-	-	-	-	-	-
Madhuca longifolia	-	-	-	500	-	-	-	-	-	-	-	-
Total	2933.3	3975	15801.6	27063	3500	4400	17000	32000	2500	3190	15000	12000

S1-Diwalikhal, S2-Khirsoo

forest and found to be decreasing towards disturbance level. Berger Parker index increased with increasing disturbance level for tree species in both forests, but in case of shrub and herb species its values did not exhibit any trend for all categories of disturbance in both forests (Table 3).

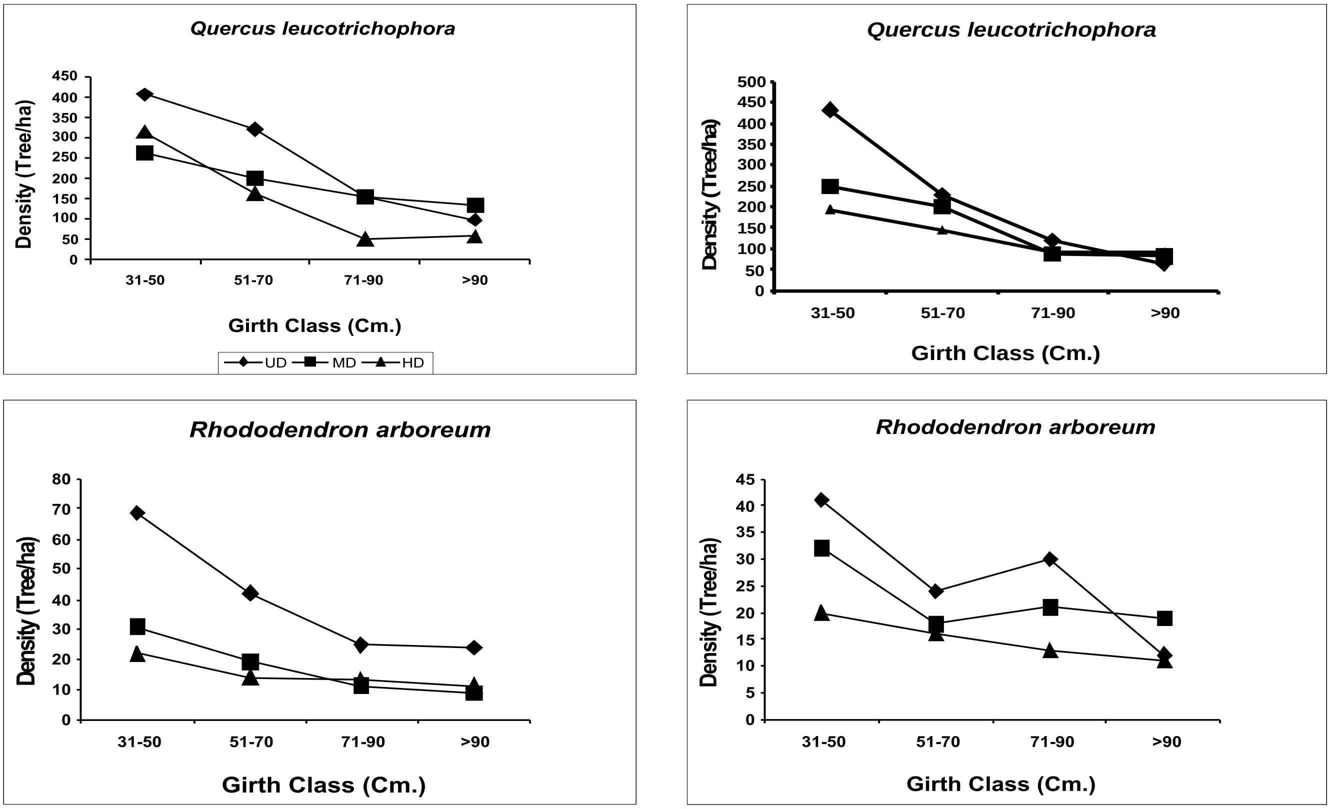
Density-diameter distribution: The density-diameter distribution of tree species is directly correlated with the age-structure of the stand. Density of higher diameter classes was found low in all the three categories of disturbance in both forests. Only in moderately disturbed categories slightly higher density was found in >90 cm dbh class than predecessor dbh class (71 to 90 cm). The density of first diameter class (31 to 50 cm) deceased with increasing intensity of disturbance in both forests and slight downfall in density was found in the second diameter class (51 to 70 cm) from undisturbed to moderately disturbed but it was found more or less similar in moderately and highly disturbed stand for Diwalikhal forest but this age class was found lowest at moderately disturbed category in Khirsoo forest. Third diameter class (71 to 90 cm) exhibited its highest density in moderately disturbed category but lowest in highly disturbed category for both the forests. Same trend was found with the fourth diameter class (>90 cm) in both forests (Fig. 3).

Population structure of dominant tree species: In Diwalikhal forest stand, *Quercus leucotrichophora* exhibited decreasing density with increasing diameter upto III[rd] class (71-90 cm d.b.h.) in both stands. But after that it showed slight increase in density in moderately disturbed stand while undisturbed stand showed a straight line curve after this diameter class. Highly disturbed stand showed regular downfall in density with increasing diameter class. It was noticeable that undisturbed and highly disturbed stands had more or less

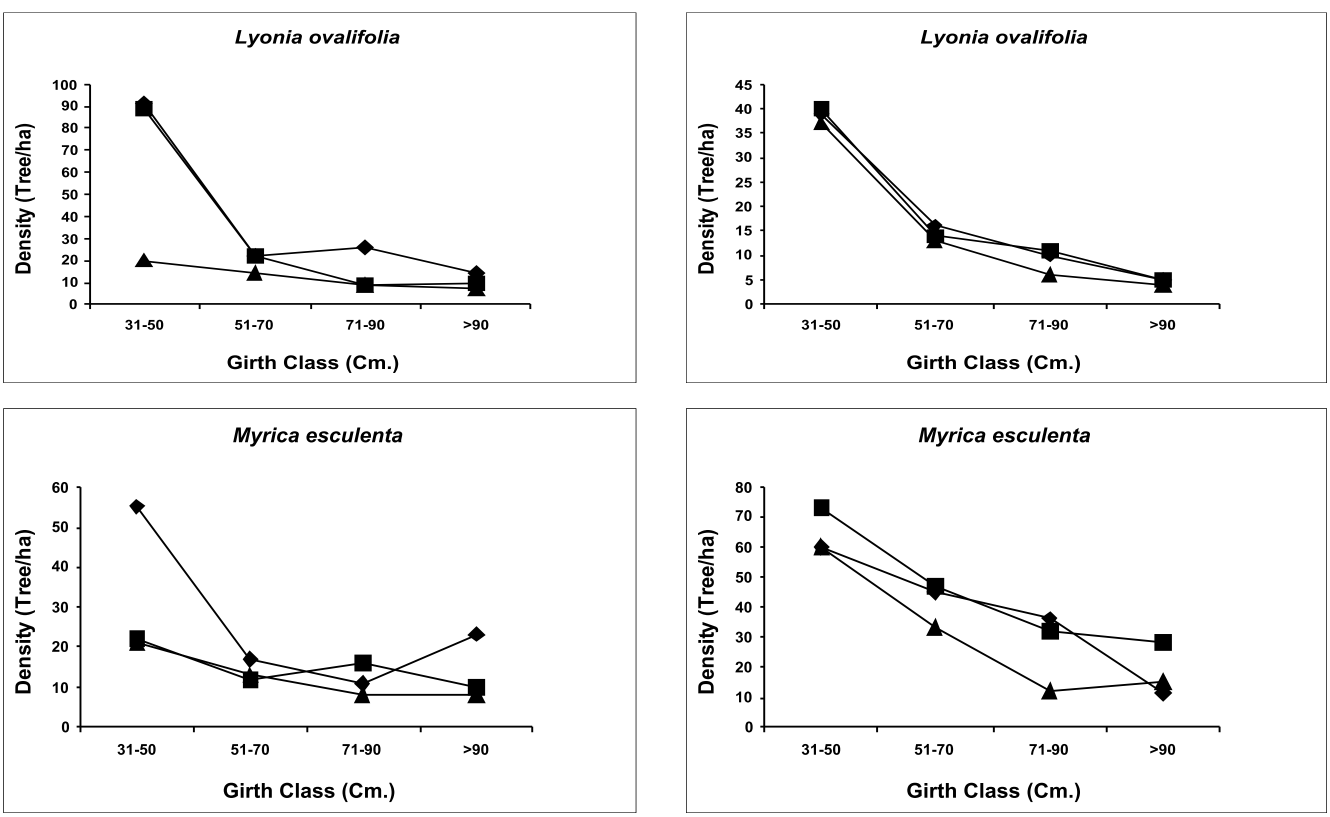


(S1) (S2)

Fig. 3 : Density-diameter distribution of different tree species along disturbance gradient for both forests (S1-Diwalikhal, S2-Khirsoo)
UD = Undisturbed MD = Moderately disturbed H D = Highly disturbed



(S1) (S2)



(S1) (S2)

Fig. 4 : Density – diameter distribution curves for some dominant species along disturbance gradient for both forests (S1- Diwalikhal, S2- Khirsoo).
UD = Undisturbed, MD = Moderately disturbed, HD = Highly disturbed

similar density at lower diameter classes. Density of *Rhododendron arboreum* decreased upto the third diameter class for undisturbed stands but occupied the straight line right from the second diameter class in case of highly disturbed stand. In moderately disturbed stand, density decreased upto the third diameter class and after that slight increase in density was shown towards higher diameter class. *Lyonia ovalifolia* was found decreasing in density upto the second diameter class in highly disturbed forest and upto third class in case of moderately disturbed forest. This species was present in all diameter classes only in the undisturbed category. *Myrica esculenta* was present upto second class in moderately and highly disturbed categories of disturbance and density found in decreasing manner with increasing diameter for both the above mentioned classes, while in undisturbed category, density decreased upto the third (90 cm dbh) class and good increment was found in the density of fourth class for this stand. In Khirsoo forest stand, *Q. leucotrichophora* exhibited a steep downfall in density towards higher girth class upto third (71-90 cm dbh) class but after that it showed a gentle downfall towards next diameter class. In this stand, *Rhododendron arboreum* showed decreasing density from Ist diameter class to IInd diameter class in all type of disturbance classes but IInd and IIIrd diameter class did not show any trend, but fourth class (>90 cm) was recorded lowest in all the three categories. In this forest stand, *Lyonia ovalifolia* rapidly decreased in density from first (31-50 cm d.b.h.) to second (51-70 cm d.b.h.) class but after that a slight reduction in density was observed towards higher girth classes in two categories and highly disturbed stand recorded slight increment in density towards higher diameter classes . A straight line downfall in density from lower girth classes to higher girth classes was observed in *Myrica esculenta* in two categories (undisturbed and moderately disturbed) but slight downfall in density was observed in highly disturbed category with increasing diameter classes in this species (Fig. 4).

Discussion

The observations clearly showed that more disturbed sites were situated at lower elevational ranges and it might be the result of higher anthropogenic pressures at lower elevations as most of the habitations in both the study sites are located near to lower elevational ranges and these ranges are more approachable to collect the daily needs. *Quercus leucotrichophora* is broadleaf evergreen species lopped for fodder, leaf litter, fuelwood and for making agricultural implements by the local inhabitants. Thus, two important factors are responsible for the high anthropogenic impact on these forests: (I) easy approach, and (II) high plant biodiversity in mixed broadleaf forests. The day-to-day needs of the people are animal fodder, leaf litter, grazing and fuelwood, and the periodical needs are timber, industrial raw materials and non timber forest products. Fire is used for the growth and establishment of grass, which is used for grazing as well as for off season animal-feeding (Kumar and Ram, 2005). A study carried out by Whittaker (1972) and Connell (1978) revealed that mild disturbance not only provides greater opportunity for species turnover, but also favours colonization and persistence of high species richness. Our observations are in conformity with this result. As far as the shrub species richness is concerned, our results agreed with the study of Bhuyan *et al.* (2001) who have reported shrub species richness was maximum in moderately disturbed forest. Annuals and /or short lived perennials were favored by disturbance, which is in agreement with the findings of Raizada *et al.* (1998). The Importance value index (IVI) of most dominant species including *Quercus leucotrichophora*, varied from undisturbed to highly disturbed forest and it increased from undisturbed to highly disturbed forest. This study also agrees with the findings of Mishra *et al.* (2004); Kadavul and Parthsarathy (1999) and Visalakshi (1995). Maximum (186.2) IVI for *Quercus leucotrichophora* was recorded in highly disturbed stand might be due to occurrence of higher diameter class (old age) trees. While minimum (0.88) IVI was found in the khirsoo forest for *Benthamidia capitata* in the undisturbed stand (Table 1). Tree density decreased from highly disturbed to undisturbed forest stands. Bhuyan *et al.* (2001) also found that tree density and basal cover of tropical wet-evergreen forest of north-east, India decreased with increasing disturbance and it agrees with our findings. This could be due to the cutting of trees for fuel, fodder and timber. Due to presence of new age group (pole crop) trees resulted in lowest basal area. The top canopy layer (trees) was mainly composed by *Quercus leucotrichophora, Rhododendron arboreum, Lyonia ovalifolia* and *Myrica esculenta* in both the forests stand. The sub-canopy (shrub) was composed by *Caryopteris foetida, Berberis aristata, Myricine africana Caryopteris foetida, Eupatorium adenophorum*, *Cotoneaster bacillaris* and *Daphne papyracea* in both the forests stand. The herbaceous composition did not differ among the stands and main herb species were *Andropogon munroi*, *Cynodon dactylon*, *Anaphalis adnata*, *Fragaria nubicola* and *Chrysopogon gryllus* in both the forests stand. Among them *Q. leucotrichophora* was found first in tree species ranking in all the three disturbance categories in both the forest stands. It was interesting to see that dominant top canopy species lost their density values with increasing intensity of disturbance. Highly disturbed stand might be due to occurrence of higher diameter class (old age) trees. Rosaceae was the dominant family in all disturbance classes in both the forests. The co-dominant family was Asteraceae each being represented by 10 species.

Tree and shrub species diversity was higher in the moderately and highly disturbed forests compared to undisturbed forests. It was low in single species dominant forests. Thus, single species dominated communities may be important for ecosystem health, but disturbance triggers plant biodiversity and influences the resource availability in the forest. Whittaker (1972) stated that the dominance of one stratum might affect the diversity of another stratum. Herbaceous diversity was comparatively greater in moderately disturbed open canopied forests as compared to the undisturbed closed canopied forests. Thus, this may provide opportunity for the invasion of more shrubs and herbs in highly disturbed open canopied forests. Moral (1972), Whittaker and Niering (1975) and Zobel *et al.* (1976) have also observed a greater diversity in the herb stratum in the absence of closed forest canopy. The highly disturbed forest had sparse canopy, because the trees were lopped for fodder and fuelwood, whereas dense (spreading) canopy was found in moderately disturbed. *Quercus* forests were characteristically moister (Saxena and Singh, 1980), fire free (Champion and Seth, 1968) and closed canopied (Saxena, 1979). A forest having multi-layered canopy with substantial canopy index and depth and well-developed forest floor, has a greater protective value as compared to a forest with fewer layers and a lower canopy index (Lull, 1964).

Species diversity exhibited influence with intensity of disturbance and human-oriented disturbances and livestock grazing also cause changes in species number, tree density and basal area (Rao *et al.*, 1990). Actually unrestricted and open accessibility may cause enhanced utilization of the forest resource and this may eventually lead to a species poor state (Murali *et al.*, 1996; Vetaas, 1993). Some earlier workers like (Grime, 1973; Connell, 1978; Huston, 1979; Armesto and Pickett, 1985; Wilkinson, 1999; Bongers *et al.*, 2009) the intermediate disturbance hypothesis (IDH) predicts that the local species diversity is maximized at an intermediate level of disturbance our study conform to their views. The density of higher d.b.h. classes was found low in the two forest stands which reflect uneven aged character of these forest stands (Schmelz and Lindsey, 1965). It also indicates the selective felling of individuals of higher diameter classes.

Density of saplings and seedlings were found decreasing with increasing disturbance. This may be the result of more biotic pressure in terms of grazing, trampling, fodder collection on the disturbed sites, however, the number of saplings and seedlings were found maximum in the intermediate position (moderately disturbed). Many earlier workers like Harris and Farr (1974) and Boring *et al.* (1981) have emphasized the positive role of moderate disturbance favouring (increasing) the tree regeneration. Barik *et al.* (1990) have also reported better regeneration in mildly disturbed forest in northeast India. Except the undisturbed stand, both the stands were under increasing anthropogenic/biotic pressure due to firewood, fodder and timber collection, and regeneration suffered because in most tree species seeds production coincides with the peak period of collection from forest, particularly in *Quercus* species. Moreover the seed of *Quercus* is a good source of food for Himalayan black bear and the outbreak of a seed borer might be the major causes for poor regeneration

Table 3 : Diversity indices of the species in two oak forests of Garhwal Himalaya along disturbance gradient.

Diversity indices	Undisturbed stand		Moderately disturbed stand		Highly disturbed stand	
Tree	S1	S2	S1	S2	S1	S2
Margalef index	1.085	1.145	1.602	1.263	1.005	1.197
Shannon	1.092	1.123	1.287	1.204	0.832	1.052
Simpson	0.477	0.453	0.43	0.426	0.619	0.404
Berger parker	0.665	0.652	0.635	0.622	0.759	0.665
Shrub						
Margalef index	2.62	3.033	2.76	3.115	3.33	3.64
Shannon	2.05	2.129	2.02	2.027	2.31	2.217
Simpson	0.14	0.194	0.18	0.165	0.12	0.206
Berger parker	0.248	0.347	0.316	0.306	0.21	0.407
Herb						
Margalef index	2.08	1.896	2.09	2.019	1.83	1.817
Shannon	2.23	2.117	2.28	2.285	2.12	2.024
Simpson	0.139	0.156	0.13	0.172	0.158	0.174
Berger parker	0.226	0.269	0.238	0.318	0.285	0.282

S1-Diwalikhal, S2-Khirsoo

(personal observation). All these activities reduce the seed bank on the forest floor.

Oak (*Q. leucotrichophora*) species is generally used to make agricultural implements and 90 cm and above diameter is best suited wood material for this work. On the other hand these classes also showed epidemic problems in the forest as over-aged tree exhibit less resistant against diseases. This may also result into lower density in higher girth classes.

Conclusion

This study indicated that disturbance have influence on tree and shrub species richness and diversity while herb species richness may be less sensitive to disturbance in oak forests. The present study suggested that highly disturbance caused to the oak forests vegetation is due to extraction of animal fodder, leaf litter, grazing and fuel wood, and the periodical needs are timber for industrial raw materials and non timber forest products. However, the increased degree of disturbance caused loss in plant diversity and changes in community characteristics. It is also clear that moderately disturbance is also good for the tree regeneration and the implication is that people can be permitted to collect small fraction of forest biomass in different form to fulfill their daily needs. The result of the study strongly neglects the concept of virgin forest, as such type of forest not only rampers the regeneration potential of the species but also not able to maintained and boost up the species diversity. Moreover, the study also recommends the changes in the lopping season according to the seed maturity of the particular species as lopping should not be carried out in *Q. leucotrichophora* during flowering and maturity of seeds and/or seed years.

Acknowledgement

DS Chauhan thanks to RE Division, Ministry of Environment and Forests, Government of India, New Delhi for financial assistance.

उत्तराखंड ¼भारत½ के गढ़वाल हिमालय में बाधक घटकों के साथ शीतोष्ण चौड़ी पत्ती वाले सदाहरित बांज वनों में सामुदायिक संघटन तथा वृक्ष आबादी संरचना

डी.एस. चौहान, सुनील प्रसाद, विकास पाल सिंह तथा एन.पी. टोडरिया

सारांश

वर्तमान अध्ययन, गढ़वाल हिमालय, उत्तराखंड ¼भारत½ ¼15-2100 एम ए एम एस एल½ में चौड़ी पत्तियों वाले सदाहरित बांज वनों के बाधक घटकों के अनुपात पर किया गया। इस अध्ययन में बाधक सूचकों अर्थात छत्रवरण, खड़-घनत्व, चराई गहनता, काट-छांट की गहनता, काटे गये ठूंठों की संख्या और आरोहियों के अतिक्रमण का मूल्यांकन किया गया है और इन सूचकों की सहायता से वन क्षेत्र को तीन श्रेणियों में बांटा गया है। यथा: बिना गड़बड़ी वाले, कम गड़बड़ी वाले, तथा अत्यधिक गड़बड़ी वाले। अध्ययन से पता चला कि वृक्षों और जड़ियों के मामले में अव्यवस्था बढ़ने पर वृक्ष वैविध्य कम हो जाता है लेकिन कम अस्त-व्यस्त खड़ों की दोनों परतों ¼वृक्ष, जड़ी½ पर पाया जाता है। जबकि झाड़ी प्रजातियों में गड़बड़ी का स्तर बढ़ने पर शैन्नान वैविध्य बढ़ जाता है। सभी गड़बड़ी वाली श्रेणियों में सिम्पसन प्रभुत्व वाली सूची, वनस्पति की तीनों परतों में, शैन्नान सूची की विपरीत पाई गई। प्रजाति बाहुल्य में भी लगभग यहीं प्रवृत्ति पाई गई। वृक्षों और जड़ियों के मामले में अस्त-व्यस्तता के प्रति इसे अधिक संवेदन”ील पाया गया क्योंकि गड़बडी अधिक होने पर इसमें कमी आ जाती है लेकिन दोनों वानस्पतिक परतों में कम गड़बड़ी वाले खड़ों में इसकी उच्चतम गहनता रिकार्ड की गई। दूसरी ओर गड़बड़ी का घनत्व बढ़ने से झाड़ी प्रजातियों का प्रभुत्व बढ़ जाता है। जहां तक पुनरूत्पति का प्रश्न है,गड़बड़ी का स्तर बढ़ने से बाल-वृक्षों और पौधों का घनत्व कम हो जाता है लेकिन मध्यम स्तर की गड़बड़ी होने पर दोनों श्रेणियों में अधिकतम वृद्धि होती है। व्यास घनत्व वक्र में वृक्षों की संख्या को कम घेरा श्रेणी से उच्च घेरा श्रेणी में चित्रित किया गया है। प्रजाति बाहुल्य, वितरण पद्धति और पुनर्जनन, क्षमता के उपरोक्त सभी वैविध्य, मानवीय हस्तक्षेप में संबंधित हैं।

References

Armesto, J.J. and Pickett, S.T.A. (1985). Experiments on Disturbance in Old-field Plant Communities: Impact of Species Richness and Abundance. *Ecology,* 66: 230-240.

Barik, S.K., Pandey, H.N., Tripathi, R.S. and Rao, P. (1990). Community Composition and Tree Population Structure in a Sub-Tropical Broad-leaved Forest along a Disturbance gradient. *Plant Ecology,* 88: 151-162.

Berger, W.H. and Parker, F.L. (1970). Diversity of Planktonic Foraminifera in deep-sea sediments. *Science,* 168: 1345-7.

Bhuyan, P., Khan, M.L. and Tripathi, R.S. (2001). Tree Diversity and Population Structure in Undisturbed and Human impacted Tropical Wet Evergreen Forest of Arunachal Pradesh, North-east, India. In: *Tropical Ecosystems: Structure, diversity and human Welfare* (Ganeshaiah, K.N., Uma Shaanker, R. and Bawa, K.S. eds). pp. 114-115, Proceedings of International Conference on Tropical Ecosystems. Oxford-IBH. New Delhi, India.

Bongers, F., Poorter, L., William, D.H. and Douglas, S. (2009). The intermediate disturbance hypothesis applies to tropical forests, but disturbance contributes little to tree diversity. *Ecology Letters,* 12: 1-8.

Boring, L.R., Monk, C.D. and Swank, W.T. (1981). Early Regeneration of a Clear cut Southern Appalachian Forest. *Ecology,* 62: 1244 – 1253.

Champion, H.G. and Seth, S.K. (1968). *A revised survey of forest type of India*. New Delhi: Manager of Publications, Govt. of India, 404 pp.

Connell, J.H. (1978). Diversity in Tropical rain forests and coral reefs. *Science,* 119:1302-1309.

Grime, J.P. (1973). Competitive exclusion in herbaceous vegetation. *Nature,* 242: 344-347.

Harris, A.S. and Farr, W.A. (1974). The Forest Ecosystem of Southeast Alaska. Forest ecology and timber management. Gen. Tech. Rep. PNW-GTR-025. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Alaska, pp. 116.

Huston, M.A. (1979). A general Hypothesis of Species Diversity. *American Naturalist,* 113: 81-101.

Kadavul, K. and Parthasarathy, N. (1999). Structure and Composition of Woody Species in Tropical Semi-evergreen Forest of Kalrayan hills, Eastern Ghats, India. *Tropical Ecology,* 40: 247-260

Kumar, A. and Ram, J. (2005). Anthropogenic disturbances and plant biodiversity in forests of Uttaranchal, Central Himalaya. *Biodiversity and Conservation,* 14: 309-331.

Lull, H.W. (1964). Ecological and structural aspects. In: *Handbook of Applied Hydrology* (Chow, V.T. ed). Mcgrow-Hill Book Company Inc., New York, pp. 6-30.

Margalef, R. (1958). Information Theory in Ecology. *General Systems,* 3: 36-71.

Mishra, B.P., Tripathi, R.S., Tripathi, O.P. and Pandey, H.N. (2004). Effects of Anthropogenic Disturbance on Plant Diversity and Community Structure of a Sacred Groove in Meghalaya, Northeast India. *Biodiversity and Conservation,* 13: 421-436.

Mishra, R. (1968). *Ecology Work Book.* Oxford and IBH Publication, New Delhi

Moral, R.D. (1972). Diversity pattern in forest vegetation of the Wanatchee Mountains, Washington. *Bulletin Forrey Botanical club,* 99: 57-64.

Muller- Dombois, D. and Ellenberg, H. (1974). *Aims and Methods of Vegetation Ecology.* John Wiley and Sons, New York, 547 pp.

Murali, K.S., Uma Shankar, R., Ganeshaian, K.N. and Bawa, K.S. (1996). Impact of NTFP extraction on regeneration, population structure, and species composition. *Economic Botany,* 50: 252-269.

Osmoston, A.E. (1927). *A Forest Flora of Kumaun*. Allahabad Govt. Press United Province, 605 pp.

Pandey, S.K. and Shukla, R.P. (1999). Plant Diversity and Community Patterns along the Disturbance gradient in Plantation Forest of Sal (*Shorea robusta* Gaerth). *Current Science,* 77: 814-818.

Raizada, A., Joshi, S.P. and Srivastava, M.N. (1998). Composition and Vegetational Diversity in Alpine Grassland in the Garhwal Himalayas. *Tropical Ecology,* 39:133-141.

Rao, P., Barik, S.K., Pandey, H.N. and Tripathi, R.S. (1990). Community Composition and Tree Population Structure in a Subtropical Broad-leaved Forest along a Disturbance gradient. *Vegetatio,* 88: 151-162.

Roberts, M.R. and Gilliam, F.S. (1995). Patterns and Mechanisms of Plant Diversity in Forest Ecosystem: Implication for Forest Management. *Ecological Application,* 51: 317-327.

Saxena, A.K. (1979). *Ecology of vegetation complex of north-western catchment of river Gola*. Ph.D. Thesis submitted in Kumaun University, Nainital, India.

Saxena, A.K. and Singh, J.S. (1980). Analysis of forest grassland vegetation in apart of Kumaun Himalaya. *Ind. J. Range management,* 1: 13-32.

Saxena, A.K. and Singh, J.S. (1982). A Phytosociological Analysis of Woody Species in Forest Communities of a part of Kumaon Himalaya. *Vegetatio,* 50: 3-22.

Schmelz, D.V. and Lindsey, A.A. (1965). Size-class Structure of Old growth Forests in India. *Forest Science,* 11: 258-264.

Shannon, C.E. and Wiener, W. (1963). *The Mathematical Theory of Communication*. University of Illinois Press, Urbana U.S.A.

Simpson, E.H. (1949). Measurement of diversity. *Nature,* 163: 688.

Singh, J.S. and Singh, S.P. (1984). *An Integrated Ecological Study of Eastern Kumaun Himalaya with emphasis on Natural resources*. Kumaun University, Nainital, India. Final Report submitted to the Department of Science and Technology, New Delhi, 155 pp.

Singh, S.P. (1998). Chronic Disturbance, a Principal cause of Environmental Degradation in Developing countries. *Environmental Conservation,* 25: 1-2.

Vetaas, O.R. (1993). Spatial and temporal vegetation changes along a moisture gradient in north-eastern Sudan. *Biotropica,* 25:164-175.

Visalakshi, N. (1995). Vegetation Analysis of Two Tropical Dry Evergreen Forests in Southern India. *Tropical Ecology,* 36 (1): 117-127.

Vogl, R.J. (1980). The Ecological Factors that produce Perturbation–dependent Ecosystems. In : *The Recovery Process in Damaged Ecosystems* (Cairns, J.R. eds.), pp 63-94. Ann Arbor Science Publ., Michigan Ann Arbor Science Publishers Inc.

Whittaker, R.H. (1972). Evolution and measurement of species diversity. *Taxon,* 21: 213-251.

Whittaker, R.H. and Niering, W.A. (1975). Vegetation of the Santa Catalina Mountains, Arizona. V. Biomass production and diversity along the elevation gradient. *Ecology,* 56: 771-790.

Wilkinson, D.M. (1999). The disturbing history of intermediate disturbance. *Oikos,* 84: 145-147.

Zobel, D.B., McKee, A., Hawk, G.M, Dyrness, C.T. (1976). Relationship of environment to composition, structure and diversity of forest communities of the cascade of Oregon. *Ecological Monograph,* 46: 135-156.