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Phytosociological analysis of woody vegetation under burnt and unburnt oak dominated forest at Pauri, Garhwal Himalaya, India

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Abstract

The present study was carried out in oak (*Quercus leucotrichophora*) dominated forest of Pauri. Two permanent plots were selected of which one was BPS and other was UBPS. The vegetational data were analysed for both the sites i.e., floristic composition, density, basal cover, A/F, Shannon Wiener index and Simpson's index of dominance (cd). A total of 6-8 trees species and 24-26 shrub species were found on both BPS and UBPS. BPS showed maximum density than UBPS. Contagious pattern of distribution was common. This paper represents a close association among man, fire and forest ecosystem.

Keywords: Burn, Contagious, Density, Distribution, Dominance and Phytosociological

Introduction

The Himalayan forests are wealthy in biodiversity and scattered over a great extent from lower to higher elevation. The tree vegetation is overwhelming segments of these forests. Himalayan forests are vital not only for the people for the existing in the Himalaya but also for many more living in the adjoining plains (Singh *et al.,* 2014). In India forest fire creating serious threats to biodiversity and sometimes also engages villages residing near the forest and since last few years, incidences of forest fire are increasing very rapidly in Uttarakhand. Almost all fires are man-caused (intentional or accidental) in India. Neighborhood inhabitants of the area blaze chir pine forests during summers to boost the growth of herbaceous vegetation for fodder. Yet fire assumes a paramount part in the biotic community of different land forms and its effect depends on the type, duration and extent of fire, topography, weather conditions and phenology phase of the community (Tiwari *et al.,* 1986). Forest biodiversity is the main source of livelihood of the inhabitants of Uttarakhand. Banj oak (*Quercus leucotrichophora*) forests are the imperative broadleaf forests in the Uttarakhand Himalaya. These forests bring been under colossal biotic stress, similarly as they furnished fuel and fodder. Focus of mankind's settlements near the oak forest areas increase the risk of over lopping, felling and furthermore principally fire spreading from pine forest have lessen the region under oak forest (Champion and Seth, 1968). These blazes are placed mostly on pine forests in the slopes of the Sub-Himalayan region, provoked haze of smoke. Oak forest is not ignitable but has experienced a great deal of fire spreading from the pine forest because pine is fire adapted and fire promoting species. The brutal management methods and the biotic anxiety executed by the inhabitants encouraged the vegetation of pine species in the place of oak species in various ways (Saxena and Singh, 1984). Alteration of oak forests to pine is still happening around bigger scale, and this pattern might prompt extreme decrease in oak forest in Uttarakhand. (Joshi *et al.,* 2013). Hence, one of the urgent ecological troubles in this region is forest fire which creates adverse effect on oak forests, and the present research is undertaken to investigate the effect of forest fire on Oak dominated forests.

Material and Methods

Study area: Broadly the area selected for the present study falls under Pauri Garhwal Uttrakhand, India and is located at Pauri (30^{o}09N-30.15^{o}N latitude and 78.78^{o}E-78^{o}47E longitude). Pauri is a spectacular place surrounded by dense forest cover.

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The average altitudinal range of Pauri is 1,814 m asl. The forests region of the area includes the dominance of Oak (*Quercus leucotrichophora*), Deodar (*Cedrus deodara*) and Chir-Pine (*Pinus roxburghii*) in lower altitude to mixed conifer species at the highest altitude. Two permanent plots (1hectare) were selected in Oak *(Quercus leucotrichophora*) dominated forest of Pauri of which one was burnt (Mandakhal Forest) and other was unburnt (Buakhal Forest) (Fig. 1). Both the forests are dominated by Oak (1700 to 2000 m asl). The study was carried out prior to 4 months after prescribed fix treatment applied by forest officials. There was no history of prior burning on the unburnt site although the burnt sites had experienced frequent fires episodes at 2-3 years intervals. The study area experienced sub-tropical to temperate type of climate with very cold in winter, rainy and pleasant in summer. Temperature of the area ranged between -2ºC-20ºC in January and 24ºC- 36ºC in July.

Prescribed fire treatment was conceded out in January 2015 (Mandakhal). The phytosociological analysis was carried out in both burnt and unburnt sites. To understand the vegetation structure and Phytosociological features of plant community, 10 quadrats of 10m x 10m (trees) and 20 quadrats of 5m x 5m (shrubs) size sample were randomly placed in each burnt and unburnt plot for assessment of composition (Misra, 1968). In each quadrat, all trees (>31.5 cm cbh) and saplings or shrubs (10.5-31.4 cm cbh) were individually measured for cbh (circumference at breast height, i.e. 1.37 m from the ground). The individuals of trees with less than 10.5 cm cbh were recorded as seedlings. The vegetational data were quantitatively analyzed, separately for each species and for each layer, for frequency, density and abundance (Curtis and Mclntosh, 1950) and for importance value index (IVI) following (Phillips, 1959). The abundance to frequency (A/F) was used to interpret the distribution pattern of the species (Curtis and Cottam, 1956). Total basal cover (TBC) of all species was measured (Misra, 1968). In the present study, diversity indices were used and were calculated separately for each stratum (tree, sapling, seedling and shrub) on the basis of density. The diversity ($\overline{H}$) was determined using the Shannon Wiener information index (Shannon and Wiener, 1963) $H= \Sigma(ni/n)^{2log2} (ni/n)$ (where ni is the density of a species, and n is the sum of total density of all species in that forest type). The Simpson's concentration of dominance (Simpson, 1949) was measured as $CD = \Sigma Pi^2$, where $\Sigma Pi = \Sigma ni/n$.

Statistical analysis

The two-tailed Carl-Pearson correlation coefficient was calculated between different studied phytosociological parameters.

Results and Discussion

Community composition and vegetation analysis (Burn protected site-BPS and unburn protected site-UBPS)

The studied forests are composed of broad leaf forest mainly dominated by *Quercus leucotrichophora.* On BP site tree, sapling and seedling strata were dominated by *Quercus leucotrichophora,* in which we recorded 7 tree species belonging to 7 genera and 6 families. In the shrub layer, a total of 26 species belonging to 23 genera and 14 families were present. On UBP site of study area only 6 tree species belonging to 5 genera and 5 families were present, and in the shrub layer, 24 species belonging to 21 genera and 14 families were recorded.

The phytosociological analysis carried out in BP site revealed that *Quercus leucotrichophora* was the most dense among tree layer and exhibits absolute dominance in terms of density (390 ind/ha) and TBC (5.86 m^2/ha) while *Prunus cerosoides* showed minimum density (20 ind/ha) and TBC (0.615 m^2/ha) among trees. The Density and TBC of other associated tree species were *Myrica esculenta* (150 ind/ha) & (2.185 m^2/ha), *Pinus roxburghii* (140 ind/ha) & (2.825 m^2/ha), *Rhododendron arboreum* (90ind/ha) & (1.993 m^2/ha), *Lyonia ovalifolia* (90 ind/ha) & (1.428 m^2/ha) etc. In the sapling and seedling layer highest (600 ind/ha) and (500 ind/ha) value of density was recorded for *Quercus leucotrichophora* and lowest for *Ficus racemosa* (40 ind/ha) and *Prunus cerosoides* (20 ind/ha), respectively. Among the shrubs, *Eupatorium adenophorum* is dominant in terms of density (1000 ind/ha) followed by *Himalrandria tetrasperma* (780 individiuals/ha) *and Myrsini africana* (560 ind/ha) etc. On the basis of TBC *Himalrandria*

Table 1 Phytosociological parameters of Trees, Sapling and Seedlings at BPS and UPS

S.N	Plant species	Density (ind/ha)	TBC (m^2/ha)	IVI	A/F	H	CD	Ev
I.	**TREES**							
1	***Ficus racemosa***	30	0.450	12.891	0.033	0.162	0.001	0.083
2	***Lyonia ovalifolia***	90	1.428	34.743	0.018	0.330	0.010	0.169
3	***Myrica esculenta***	150 (140)	2.185 (2.080)	48.487 (61.245)	0.023 (0.017)	0.429 (0.467)	0.027 (0.041)	0.220 (0.261)
4	***Pinus roxburghii***	140 (50)	2.825 (0.855)	51.559 (27.796)	0.022 (0.020)	0.415 (0.274)	0.024 (0.005)	0.213 (0.153)
5	***Pinus walliachiana***	(20)	(0.210)	(10.151)	(0.050)	(0.148)	(0.001)	(0.083)
6	***Prunus cerosoides***	20 (10)	0.615 (0.339)	10.644 (6.790)	0.05 (0.100)	0.121 (0.089)	0.001 (0.001)	0.062 (0.049)
7	***Quercus leucotrichophora***	390 (350)	5.863 (6.650)	103.26 (128.013)	0.039 (0.035)	0.524 (0.497)	0.183 (0.257)	0.269 (0.277)
8	***Rhododendron arboreum***	90 (120)	1.993 (3.516)	38.422 (66.006)	0.018 (0.019)	0.330 (0.439)	0.010 (0.030)	0.1696 (0.245)
	Total	**910 (690)**	**15.357 (13.650)**	**300 (300)**		**2.311 (1.913)**	**0.255 (0.335)**	**1.1876 (1.068)**
II.	**SAPLING**							
1	***Ficus racemosa***	40	0.076	7.43	0.100	0.123	0.005	0.056
2	***Lyonia ovalifolia***	160	0.352	27.83	0.044	0.312	0.008	0.142
3	***Myrica esculenta***	260 (300)	0.702 (0.616)	47.48 (61.214)	0.032 (0.025)	0.405 (0.464)	0.021 (0.040)	0.184 (0.223)
4	***Pinus roxburghii***	280 (120)	0.616 (0.289)	49.50 (25.111)	0.023 (0.075)	0.420 (0.291)	0.025 (0.006)	0.191 (0.140)
5	***Pinus walliachiana***	(60)	(0.102)	(13.100)	(0.067)	(0.186)	(0.002)	(0.089)
6	***Prunus cerosoides***	60 (40)	0.132 (0.074)	10.04 (8.940)	0.15 (0.10)	0.165 (0.139)	0.001 (0.001)	0.075 (0.067)
7	***Quercus leucotrichophora***	600 (560)	1.32 (1.364)	94.06 (110.622)	0.023 (0.025)	0.529 (0.531)	0.113 (0.139)	0.241 (0.255)
8	***Rhododendron arboreum***	240 (240)	0.456 (0.529)	41.43 (50.539)	0.024 (0.019)	0.390 (0.478)	0.018 (0.047)	0.177 (0.245)
9	***Celtis australis***	60 (100)	0.066 (0.050)	9.88 (16.002)	0.067 (0.033)	0.165 (0.294)	0.001 (0.007)	0.075 (0.151)
10	***Pyrus pashia***	80 (80)	0.056 (0.044)	12.33 (14.472)	0.05 (0.063)	0.201 (0.263)	0.002 (0.005)	0.091 (0.135)
	TOTAL	**1780 (1700)**	**3.776 (3.069)**	**300 (300)**		**2.709 (2.507)**	**0.191 (0.307)**	**1.233 (1.288)**
III.	**SEEDLING**							
1	***Ficus racemosa***	80	0.007	12.276	0.089	0.209	0.002	0.095
2	***Lyonia ovalifolia***	140	0.043	29.333	0.056	0.299	0.006	0.135
3	***Myrica esculenta***	200 (340)	0.032 (0.010)	29.843 (44.233)	0.080 (0.017)	0.365 (0.487)	0.014 (0.053)	0.166 (0.250)
4	***Pinus roxburghii***	300 (140)	0.081 (0.003)	60.497 (18.415)	0.025 (0.039)	0.444 (0.322)	0.032 (0.009)	0.201 (0.165)
5	***Pinus walliachiana***	(40)	0.002	6.011	0.100	0.141	0.001	0.072
6	***Prunus cerosoides***	20	0.013	6.498	0.2	0.076	0.001	0.034
7	***Quercus leucotrichophora***	500 (640)	0.148 (0.161)	100.032 (97.393)	0.020 (0.020)	0.520 (0.523)	0.088 (0.187)	0.236 (0.269)
8	***Rhododendron arboreum***	220 (320)	0.038 (0.048)	38.308 (48.818)	0.034 (0.019)	0.384 (0.478)	0.017 (0.047)	0.174 (0.245)
9	***Celtis australis***	100 (120)	0.001 (0.004)	10.072 (17.262)	0.25 (0.033)	0.242 (0.294)	0.003 (0.007)	0.110 (0.151)
10	***Pyrus pashia***	120 (100)	0.002 (0.287)	13.141 (67.869)	0.133 (0.063)	0.272 (0.263)	0.005 (0.005)	0.124 (0.135)
	TOTAL	**1680 (1700)**	**0.3647 (0.516)**	**300 (300)**		**2.811 (2.507)**	**0.16978 (0.307)**	**1.045 (1.288)**

Abbreviations: TBC=Total Basal Cover, A/F=Abundance frequency ratio, CD=Concentration of Dominance, H=Shannon-wiener Diversity Index, Ev=Evenness, value in () for UBPS, BPS=Burn protected site, UBPS= Unburn protected site.

tetrasperma exhibits maximum TBC (0.23 m^2/ha) followed by *Pyracantha crenulata* (0.13m^2/ha) and *Berberis asiatica* (0.10m^2/ha) etc. The data revealed that *Pinus roxburghii* and *Myrica esculenta* as the competing species in the sapling stratum and these two species were also competing with *Rhododendron arboreum* in the seedling stratum, and among the shrubs, *Himalrandria tetrasperma*, *Rhus parviflora* and *Desmodium multiflorum* were competing with *Urena lobata*, *Asparagus adscendens* and *Rubus ellipticus* (table 1 and 2).On UBP site of study area *Quercus leucotrichophora* showed maximum density (350 ind/ha) & TBC (6.65 m^2/ha) followed by *Rhododendron arboreum* (120 ind/ha) & (3.516m^2/ha), *Myrica esculenta* (140 ind/ha) & (2.080 m^2/ha) and *Pinus roxburghii* (50 ind/ha) & (0.85m^2/ha) etc. However, *Prunus cerosoides* recorded as minimum density (10 ind/ha), and *Pinus walliachiana* exhibit minimum TBC (0.21 m^2/ha) in UBP site among tree layer. In sapling and seedling layer highest (560 ind/ha) & (640 ind/ha) value of density was recorded for *Quercus leucotrichophora* and lowest for *Prunus cerosoides* (40 ind/ha) and *Pinus walliachiana* (40 ind/ha), respectively. Based on detailed analysis of shrubs layer *Eupatorium adenophorum* dominant in terms of density (700 ind/ha) followed by *Myrsini africana* (460 ind/ha) and *Berberis aristata* (400 ind/ha) etc. while *Himalrandria tetrasperma* showed maximum TBC value (0.20 m^2/ha) followed by *Berberis aristata* (0.10 m^2/ha) and *Pyracantha crenulata* (0.08 m^2/ha) etc. The results revealed that *Myrica esculenta* and *Rhododendron arboreum* as the competing species in the sapling stratum and seedling stratum, and among the shrubs *Myrsini Africana, Berberis aristata, Indigofera heterantha and Himalrandria tetrasperma* were competing with *Asparagus adscendens*, *Daphne papyraceae* and *Reinwartia indica* etc. Total Frequency % and abundance at BPS and UBPS as shown in Fig 2.

Pattern of plant diversity within and among ecological communities often show variable responses to fire. This variability could appear due to assortment about components including variation in flames severity, ecosystem efficiency and how nature behave to fire episodes (Suding and Gross, 2006). Phytososociological aspects vary with different environment type and along with tree species. The present study shows the species richness ranged between 6-7 for both sites BPS and UBPS whereas Ram *et al.,* (2004) have reported the tree richness (11 species). There are different research has been carried out on the temperate oak and oak mixed forest indicate that the tree richness lies between 3 and 43 species (Tewari and Singh, (1981); Baduni and Sharma, (1997); Rekhari *et al.,* (1997); Ghildiyal *et al.,* (1998) and Kharakwal, (2005). The total tree density calculated in our study ranging between the given values (30-910 ind/ha BP & 20-690 ind/ha) for both sites were slightly lower than work done by Singh *et al.,* (1994), Jina (2006) and Kharkwal (2009) for different oak forests of Central Himalayas. In sapling and seedling total density ranged between (40-600 ind/ha and 20-500 ind/ha) and maximum density was showed by *Quercus leucotrichophora, Pinus roxburghii* and *Myrica esculenta* at BPS as shown in table 1.

Whereas at UBPS total density for sapling and seedling ranged between 10-140 ind/ha and 40-640 ind/ha and maximum density was showed *Quercus leucotrichophora, Myrica esculenta* and *Rhododendron arboreum* as shown in table 1. Between both the sites sapling and seedling of *Pinus roxburghii* is more in BPS after *Quercus leucotrichophora* because Pinus is fire adapted and fire promoting species and replacement of the oak forest by pine forest has become ever-increasing and striking event in Uttarakhand Himalayas (Saxena *et al.,* 1984; Singh *et al.,* 2016). The total shrub density in both sites (BPS and UBPS) lies between the range (140 -1000 ind/ha) are in compliance with earlier studies of Himalayan region (Raturi, 2012; Sharma, 2014). *Eupatorium adenophorum* was dominant species on BPS because fire is one of the major factors for the introduction of invasive species (IFFN, 2002). In the present study the value of total basal cover for both sites (BPS and UBPS) were almost similar to the values reported by Singh *et al.,* (1994). The values of total basal cover of seedling and sapling and shrubs are slightly lower than the values reported by Singh *et al.,* (2014). The lower total basal area of the present study indicates that the forests are in young stage.

Table 2 Phytosociological parameters of Shrubs at BPS and UBPS

S N	Name of the species	Density (ind/ha)	TBC (m^2/ha)	IVI	A/F	H	CD	Ev
1	***Asparagus adscendens***	380 (320)	0.004 (0.004)	8.380 (9.928)	0.026 (0.022)	0.189 (0.203)	0.002 (0.002)	0.058 (0.064)
2	***Berberis aristata***	240 (400)	0.094 (0.098)	17.777 (28.248)	0.030 (0.018)	0.137 (0.236)	0.001 (0.003)	0.042 (0.074)
3	***Berberis asiatica***	300 (300)	0.100 (0.059)	19.809 (18.967)	0.025 (0.021)	0.160 (0.195)	0.001 (0.002)	0.049 (0.061)
4	***Campylotropis speciosa***	280	0.001	6.825	0.019	0.153	0.001	0.047
5	***Carissa opaca***	200 (300)	0.021 (0.003)	7.138 (9.510)	0.041 (0.021)	0.119 (0.195)	0.000 (0.002)	0.037 (0.061)
6	***Cotoneaster rotundifolia***	300 (240)	0.069 (0.048)	15.390 (15.461)	0.030 (0.024)	0.160 (0.167)	0.001 (0.001)	0.049 (0.052)
7	***Daphne papyraceae***	360 (320)	0.012 (0.013)	9.235 (11.832)	0.025 (0.019)	0.182 (0.203)	0.002	0.056 (0.064)
8	***Desmodium multiflorum***	520 (200)	0.005 (0.001)	12.270 (6.019)	0.014 (0.031)	0.233 (0.147)	0.003 (0.001)	0.072 (0.046)
9	***Eupatorium adenophorum***	1000 (700)	0.005 (0.003)	17.369 (16.401)	0.028 (0.031)	0.347 (0.332)	0.012 (0.010)	0.106 (0.104)
10	***Flemingia fruticulosa***	180	0.001	4.551	0.028	0.110	0.001	0.034
11	***Himalrandia tetrasperma***	780 (360)	0.229 (0.202)	44.138 (44.420)	0.024 (0.021)	0.301 (0.220)	0.007 (0.003)	0.092 (0.069)
12	***Hypericum ovlongifolium***	320 (260)	0.001 (0.001)	8.212 (6.946)	0.014 (0.041)	0.168 (0.176)	0.001 (0.001)	0.051 (0.056)
13	***Indigofera heterantha***	340 (400)	0.002 (0.002)	8.580 (11.537)	0.015 (0.020)	0.175 (0.236)	0.001 (0.003)	0.054 (0.074)
14	***Inula cappa***	220 (260)	0.001 (0.001)	5.318 (8.174)	0.027 (0.021)	0.128 (0.176)	0.001 (0.001)	0.039 (0.056)
15	***Leptodermis lanceolata***	360 (200)	0.009 (0.001)	10.441 (6.146)	0.012 (0.031)	0.182 (0.147)	0.002 (0.001)	0.056 (0.046)
16	***Myrsini africana***	560 (460)	0.004 (0.002)	11.868 (12.877)	0.019 (0.020)	0.245 (0.258)	0.004 (0.004)	0.075 (0.081)
17	***Pyracantha crenulata***	260 (260)	0.129 (0.076)	22.571 (20.169)	0.032 (0.032)	0.145 (0.176)	0.001 (0.001)	0.044 (0.056)
18	***Reinwartia indica***	260 (320)	0.001 (0.001)	6.278 (9.803)	0.021 (0.019)	0.145 (0.203)	0.001 (0.002)	0.044 (0.064)
19	***Rhus parviflora***	360 (240)	0.007 (0.003)	9.817 (7.883)	0.014 (0.024)	0.182 (0.167)	0.002 (0.001)	0.056 (0.052)
20	***Rhynchosia rothii***	320 (240)	0.001 (0.001)	7.891 (6.990)	0.016 (0.030)	0.168 (0.167)	0.001 (0.001)	0.051 (0.052)
21	***Rosa brunonii***	200 (140)	0.003 (0.001)	5.012 (4.509)	0.031 (0.039)	0.119 (0.113)	0.001 (0.001)	0.037 (0.036)
22	***Rubus ellipticus***	380 (300)	0.006 (0.003)	8.650 (8.729)	0.026 (0.030)	0.189 (0.195)	0.002 (0.002)	0.058 (0.061)
23	***Rubus niveus***	260 (180)	0.012 (0.010)	6.900 (7.357)	0.041 (0.028)	0.145 (0.136)	0.001 (0.001)	0.044 (0.043)
24	***Rubus paniculatus***	220 (140)	0.007 (0.004)	5.441 (5.032)	0.045 (0.039)	0.128 (0.113)	0.001 (0.001)	0.039 (0.036)
25	***Urena lobata***	400	0.024	12.109	0.018	0.196	0.002	0.060
26	***Vibernum mullahee***	260 (280)	0.016 (0.015)	8.031 (10.105)	0.026 (0.035)	0.145 (0.186)	0.001 (0.002)	0.044 (0.058)
27	***Zanthoxylum americanum***	(180)		12.955	(0.028)	(0.136)	(0.001)	(0.043)
	TOTAL	**9260 (7000)**	**0.762 (0.591)**	**300 (300)**		**4.550 (4.482)**	**0.048 (0.048)**	**1.396 (1.410)**

Table 3 Correlation between different Phytosociological parameters

	site	LF	SR	F	A	D	MBC	TBC	A/F	CD	H	Ev
Site	1											
LF	0.000	1										
SR	0.099	.811*	1									
F	0.112	.710*	.973**	1								
A	0.171	.777*	.992**	.978**	1							
D	0.114	.821*	.989**	.977**	.980**	1						
MBC	0.070	-.775*	-0.417	-0.238	-0.340	-0.398	1					
TBC	0.100	-.821*	-0.444	-0.272	-0.375	-0.422	.984**	1				
A/F	-0.117	0.537	.772*	.737*	0.703	.734*	-0.445	-0.399	1			
CD	-0.308	-.791*	-.911**	-.816*	-.907**	-.859**	0.538	0.556	-0.675	1		
H	0.130	.877**	.985**	.929**	.970**	.964**	-0.526	-0.556	.750*	-.945**	1	
Ev	-0.115	0.687	.788*	.780*	.727*	.784*	-0.436	-0.452	.871**	-0.651	.802*	1

***. Correlation is significant at the 0.05 level (2-tailed).**

****. Correlation is significant at the 0.01 level (2-tailed).**

Abbreviations: - LF=Life form, SR=Species richness, F=Frequency, D=Density, A=Abundance, MBC=Mean Basal Cover, TBC=Total Basal Cover, A/F=Abundance frequency ratio, CD=Concentration of Dominance, H=Shannon-wiener Diversity Index, Ev=Evenness

Distribution Pattern

The distribution pattern of trees layer on burnt site was regular (57.14%) and random (42.85%). However, sapling (33.33%) and seedling (66.66%) layer were mostly contagiously distributed. The associated shrub layer was equally regularly (50%) and randomly (50%) distributed on burnt site. On unburnt site distribution pattern of trees, layer was mostly regularly distributed (50%) followed by contagiously (33.33%) and randomly distributed (16.66%) whereas sapling layer was mostly contagiously distributed and seedling layer was mostly regularly distributed (42.85%). The associated ground woody flora (shrub layer) was equally, regularly (50%) and randomly (50%) distributed on Unburnt site. Contagious distribution has been reported by several workers (Kershaw, (1986); Singh and Yadav, 1974). Kumar and Bhatt (2006) also recorded (clumped) contagious distribution pattern in foot-hills forests of Garhwal Himalaya. Odum (1971) has accentuated that contagious distribution in forest is the commonest distribution pattern in the nature, random distribution is found in uniform environment, and regular distribution happens where extreme rivalry exists between the individuals (Panchal and Pandey, 2004).

Diversity and Concentration of dominance

The value of Shannon-Wiener diversity index ($\overline{H}$) and concentration of dominance of trees layer was recorded 2.31 & 0.25, for sapling layer 2.70 & .190 and for seedling 2.81 and 0.16 on BPS. However, the diversity indices for the shrub layer were 4.54 and 0.048 on burnt site. The diversity index for the tree stratum were lower on the UBPS ($\overline{H}$) 1.91 and concentration of dominance 0.33, sapling stratum 2.52 & 0.22, for seedling stratum 2.51 & 0.31. The diversity index for the shrubs stratum was recorded 4.48 & 0.048 which was almost same on both the sites. The values of $\overline{H}$ for trees, sapling, seedling and shrubs in Central Himalayan forest of Uttarakhand (0.33 - 2.95) are comparable with the research done by Saxena and Singh (1982); Tripathi *et al.,* (1987); Rikhari *et al.,* (1989) and Kharkwal *et al.*, (2005). In the present study, the trend of diversity of community forest is slightly elevated than that reported in the broad leaved forests (Ralhan *et al.,* 1982) because both the sites were protected sites. The range for CD reported by Rikhari and Palni (1999) is between 0.06- 0.37 for western Himalaya is comparable to the values of CD in the present study. The results of CD for shrub layer were almost similar to the values calculated by Iqbal *et al.,* (2012). In the present study, the values of CD for trees, saplings, seedlings and shrubs are more or less similar to values calculated by many researchers i.e. Saxena and Singh (1982) values between 0.131 and 1.00, Ralhan *et al.,* (1982) reported to 1.00, and Tiwari

(1983) values of 0.106 to 0.933 for the forests of Uttarakhand Himalaya.

Evenness

Evenness is the important component of diversity which means the uniformity of abundance between species in a community. High evenness occurs when species are equal in their distribution and abundance. On BPS it was high for shrubs (1.39) followed by sapling (1.23), trees (1.18) and seedling (1.04). On UBPS evenness was also high for shrubs (1.41) followed seedling (1.28), sapling (1.21) and trees (1.06). High evenness occurs when species are equal in their distribution and abundance, and the values of evenness of the present study is more or less similar to the values (0.73-085) reported by Iqbal *et al.,* (2012) (1.11-0.95).

Carl-Pearson correlation coefficient

The two-tailed Carl-Pearson correlation coefficient was calculated between different studied phytosociological parameters as shown in table 3. A/F ratio is significantly and positively correlated with species richness, frequency, and density. Concentration of dominance is negatively correlated with species richness, frequency, abundance, density. Shannon-Wiener diversity index ($\overline{H}$) was significantly and positively correlated with species richness, frequency, abundance and density however negatively correlated with Concentration of dominance. Evenness is significantly and positively correlated with species richness, frequency, abundance, density and $\overline{H}$ (table 3).

Conclusion

There are numerous studies about the significance of fire in shaping the composition and function of forest ecosystems. But our results revealed both positive and negative effects of fire, for instance, increase in density and invasion of exotic species respectively. The present study represents the effect of forest fire on various attributes especially density responded well on BPS than UBPS in both tree and shrub layer. Contagious (clumped) distribution was mostly found in the forest. Introduction of fire increases the density of forest on other hand it also boost the invasion of exotic species i.e. *Pinus roxburghii* and *Eupatorium adenophorum* in forest. The present findings indicate that Pine exhibit maximum density after oak in BPS. Because burnt sites had experienced frequent fires episodes and Pine is fire adapted and fire promoting species and replacement of the oak forest by pine forest has become escalating and prominent event in Uttarakhand Himalayas. Hence this paper represents a close association among man, fire and forest ecosystem.

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