The Bioscan 7(2) : 325-330, 2012
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
www.thebioscan.in

ANALYSIS OF HERBACEOUS DIVERSITY IN FIRE AFFECTED AREAS OF BHORAMDEO WILDLIFE SANCTUARY, CHHATTISGARH

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KEY WORDS
Diversity indices
Forest fire
Herbaceous vegetation
Pre-fire
Post-fire

Received on :
09.03.2012

Accepted on :
21.04.2012

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ABSTRACT
The present work aimed to study the impact of forest fire on herbaceous vegetation of Bhoramdeo Wildlife Sanctuary situated in Chhattisgarh. Four sites (High, medium, low and non-fire zone) were selected; in each of these sites pre-fire and post-fire observation were taken for measuring varying degree of disturbances. A total of 19 and 30 herbs species were recorded during pre-fire season and post-fire season, respectively. The total densities of herbs in pre-fire season were ranged from 112000 to 668000 ha^{-1}, whereas during post-fire it varied from 230000 to 510000 ha^{-1}. The herb layer showed higher density after post-fire in high and low fire zones, whereas decreased in medium fire zone due to the change in season (rainy), the density of herb layer also increased (40.03%) after post-fire in non-fire zone. The diversity indices in pre-fire season showed that Shannon index in different fire zones varied from 1.69 to 2.71, concentration of dominance (Cd) 0.20 to 0.36, species richness 0.33 to 0.67, equitability 1.05 to 1.33 and beta diversity 1.9 to 3.8, whereas during the post-fire season Shannon index and species richness values were increasing. The abundance to frequency ratio (A/F) indicated most of the species performed contagious pattern of distribution.

INTRODUCTION

Herbaceous vegetation is a vital component of deciduous forests, typically comprising the largest proportion of forest diversity. Understory composition is often correlated with micro-environmental and site conditions such as topography, light availability and edaphic conditions and provides important indications of site quality, overstory regeneration patterns and ecosystem health (Small, 2001). The global biodiversity crisis has given rise to a growing concern at the prospect of a rapidly accelerating loss of species, population, domesticated varieties, medicinal herbs and natural habitats. Recent estimates suggest that more than half of the habitable surface of the planet has already been significantly altered by the human activity (Hannah and Bowles, 1995) and we are on the verge of mass extinction of the species (Wilson, 1985).

Forest fires are driving factor in shaping forest vegetation and the landscape in many parts of India (Hiremath, 2007). Every year forest fires cause great loss to the forest ecosystem, diversity of flora and fauna and economic wealth. In India, out of 67.5 million ha of forests, about 55% of the forest cover is being subjected to fires each year (Gubbi, 2003). Majority of these forests burning are surface fires, deliberately linked to human activities and has close relationship to their socio-economic conditions. The normal fire season in India is from the month of February to mid June. The human activities can influence natural fire regimes by increasing fires in forests that would seldom burn under natural conditions (Goldammer, 2003). Existing biotic pressures on forests in the form of logging, slash-and-burn cultivation, grazing and collection of non-timber forest products have rendered forests vulnerable to forest fires (Kodandapani, 2001). Fire enhances the productivity of ecosystems by releasing chemicals and nutrients locked up in the old herbage. Ultimately the impact of fire will be detrimental to the growth of vegetation and microclimate of the area (Devagiri *et al.*, 2006) but also the disturbance has become a requirement for vigorous ecosystem functioning (Harper, 1977) and should be considered a normal part of an ecosystem's physical environment. Given the extensive benefits and risks to environmental, social and economic well- being from fire, biodiversity conservation must take fire into account. Tropical forests harbour the greatest wealth of biological and genetic diversity. The herbaceous layer composition is changing continuously in space and time due to multitude of factors such as grazing, fire and rainfall which differs in intensity and duration. Forests are the primary source to rejuvenate productivity of land through recycling of nutrients, which make physicochemical conditions of the soils favourable for plant growth (Bargali *et al.,* 1998). Due to increasing human population, the biotic pressure on native forest is inevitable. The uncontrolled lopping and felling of trees for fuel wood, leaf fodder, burning of ground vegetation, livestock grazing and harvesting of ground vegetation for forage are some of the factors responsible for exploitation of forests (Bargali *et al.,* 1998). Anthropogenic disturbances in forests followed by livestock grazing in pasture lands adversely affected the composition of herbaceous vegetation, it is therefore imperative to conserve the herbaceous vegetation of these sites. The findings of the present study will help to researcher, ecologist and foresters to work in other localities of the same area. Therefore the present study was undertaken to investigate the impact of forest fire on regeneration and diversity of herbaceous layers.

MATERIALS AND METHODS

The present study was conducted at Bhoramdeo Wildlife Sanctuary of Kawardha Forest Division in Chhattisgarh, Central India. Bhoramdeo Wildlife Sanctuary occupies a special position in the state of Chhattisgarh from biodiversity and tourism point of view. The study area is located between 21°23′-22°00′ NL and 80°58′-82°34′ EL. The entire area of Bhoramdeo Wildlife Sanctuary is located in the Maikla Range of the Satpura hills. The whole part is hilly and area is situated at a height of 600-900m from the sea level. The soil of study area grouped in two classes viz. Entisols and Ultisols. Entisols characterized by extreme depth and gray or grayish brown color. The Ultisols poor in lime and magnesia, occasionally higher humus, mixture of hydrated oxide of Al and Fe. Different types of forest vegetation occur in the study area. Northern and Eastern directions are covered with luxuriant forests, whereas Teak plantations occupy a major area in Southern direction. In Western direction, a large area is covered by degraded and mixed forest and also with bamboo brakes occasionally found as patches in this direction.

To study the community composition and other phytosociological characteristics of the herbaceous vegetation at four sites viz., high, medium, low and non-fire zones, after the repeated reconnaissance survey of Bhoramdeo Wildlife Sanctuary in each of these sites pre-fire and post-fire observation were taken for measuring varying degree of disturbances. The disturbance gradients were categorized by historical data taken from forest department. Phytosociological attributes of herb species were studied by randomly laying quadrats of 1 x 1m^2 size at each site for measuring herbs during pre-fire and post-fire season.

The vegetation data were collected and analysed for its structure in different fire zones (*i.e.,* high, medium, low and non-fire zone). Vegetational data were quantitatively analysed for frequency, density, abundance following Curtis and McIntosh (1950). The relative values of these indices were calculated following Philips (1959). These values were summed up to get importance value index (IVI) of individual species (Curtis, 1959). A/F ratio (abundance to frequency) for different species was determined by eliciting the distribution pattern. This ratio has indicated regular (< 0.025), random (0.025 – 0.05) and contagious (> 0.05) distribution (Whiteford, 1949; Curtis and Cotton, 1956). Species diversity parameters for herb layers were determined using the Shannon-Weiner information function (1963) for species diversity. Concentration of dominance was measured following Simpson's index method (1949). Vegetations were also measured for species richness (Marglef, 1958), equitability (Pielou, 1966) and Beta diversity (Whittaker, 1972). The analysis of variance (ANOVA) were performed by complete randomize design (CRD) using the WASP 1.

RESULTS AND DISCUSSION

The data of herb layer in high fire zone during pre-fire season showed that the *Apluda mutica* recorded the highest density (51%) followed by *Clebrookia oppositifolia and Conyza japonica* (22.02% each) whereas the lowest value of density recorded by *Paspalidium flavidum* (1.47%) in this fire zone. The result on herb layer of high fire zone during post-fire season revealed that *Cassia tora* recorded higher density (58.82%) and frequency value among the all species found in herb layer of high fire zone. The lowest density was found in *Coriandrum setium* (0.78%) followed by *Imperata cylindrical* and *Ocimum basilicum,* whereas *Coriandrum setium* and *Euphorbia hirta* have lowest frequency value (20% for each). The high fire zone supported minimum number of species during pre-fire (5) and post-fire season (11) as compare to other fire zones (Table 1). The IVI value of this zone was ranged from 22.94 to 122.94 during pre-fire and 6.95 to 116.76 during post-fire season (Table 2).

The herb layer of medium fire zone during pre-fire season revealed that the highest density (36.22%) recorded by *Ischaemum pilosum* while the lowest density noticed in *Achyranthus aspera* (1.19%) among the all species found in

Table 1: Comparisons of community characters of different forest fire zones of Bhoramdeo wildlife sanctuary during pre-fire and post-fire season

Pre-fire season					
Vegetation Layer	Characters	High Fire Zone	Medium Fire Zone	Low Fire Zone	Non-Fire Zone
Herb Layer	Species	5	10	7	6
	Density (individuals ha^{-1})	136000	668000	138000	112000
	Shannon Index ($\overline{H}$)	1.69	2.71	2.50	2.39
	Simpson's Index (Cd)	0.36	0.20	0.21	0.20
	Species richness (d)	0.33	0.67	0.50	0.43
	Equitability (e)	1.05	1.17	1.28	1.33
	Beta diversity (βd)	3.8	1.9	2.71	3.16
Post-fire season					
Vegetation Layer	Characters	High Fire Zone	Medium Fire Zone	Low Fire Zone	Non-Fire Zone
Herb Layer	Species	11	20	14	13
	Density (individuals ha^{-1})	510000	360000	376000	230000
	Shannon Index ($\overline{H}$)	2.22	3.39	3.15	3.37
	Simpson's Index (Cd)	0.37	0.13	0.16	0.11
	Species richness (d)	0.76	1.48	1.01	0.97
	Equitability (e)	0.92	1.13	1.19	1.31
	Beta diversity (βd)	2.72	1.50	2.14	2.30

Table 2: IVI values of herbaceous species across the fire zones during pre-fire and post-fire season in Bhoramdeo Wildlife Sanctuary

Species	IVI Values During Pre-fire Season				IVI Values During Post-fire Season			
	High fire zone	Medium fire zone	Low fire zone	Non-fire zone	High fire zone	Medium fire zone	Low fire zone	Non-fire zone
Achyranthus aspera	—	10.44	—	—	—	11.63	—	—
Ageratum conyzoides	—	—	—	—	—	4.67	—	—
Apluda mutica	122.94	—	—	—	—	—	—	—
Biophytum reinnardtii	—	25.24	—	—	—	—	—	—
Cassia tora	—	28.28	—	—	116.76	52.99	69.61	49.76
Clebrookia oppositifolia	64.11	20.31	33.44	—	—	—	—	—
Convolvulus arvensis	—	—	—	34.52	—	—	—	—
Conyza japonica	64.11	—	—	—	—	—	—	—
Corchorus aequitans	25.88	13.87	83.14	41.67	—	6.48	—	16.80
Coriandrum setium	—	33.08	29.06	27.38	6.95	4.67	—	—
Crotolaria calycina	—	—	—	66.68	—	10.09	—	—
Curculigo orchoides	—	—	—	—	15.46	28.81	—	24.74
Curcuma aromatica	—	—	—	—	—	4.67	—	—
Cynodon dactylon	—	—	—	—	19.74	6.48	20.93	28.24
Cyprus esculentus	—	—	—	—	17.60	36.80	33.55	31.33
Desmodium pulchellum	—	—	—	70.24	—	—	15.14	8.86
Dodonoea viscose	—	—	—	—	29.76	—	—	—
Eragrotis tenella	—	48.18	—	—	—	6.48	12.01	—
Euphorbia hirta	—	—	—	—	15.69	—	18.28	—
Evolvulus nummularius	—	—	—	—	—	20.25	26.54	19.45
Fimbritylis dichotoma	—	—	—	—	—	—	—	17.69
Floscope scandens	—	—	—	—	—	—	24.55	14.16
Imperata cylindrica	—	—	—	—	11.18	6.48	20.93	21.21
Ischaemum pilosum	—	75.02	—	—	33.16	8.28	7.30	14.17
Malvastrum coromandelica	—	—	—	—	—	26.09	15.14	35.57
Ocimum basilicum	—	—	—	—	13.32	—	—	—
Paspalidium flavidum	22.94	—	52.98	—	—	—	—	—
Peristnphe paniculate	—	33.08	—	—	—	4.67	—	—
Perotis hordeiformis	—	—	29.06	—	—	—	—	—
Setaria glauca	—	—	—	—	—	17.54	8.87	—
Sida cardata	—	—	25.95	—	—	10.09	—	—
Themeda arundinaceae	—	12.50	46.36	59.52	—	—	—	—
Trifolium spp	—	—	—	—	—	26.38	—	—
Rumex dentatus	—	—	—	—	20.37	6.48	8.87	18.02
Xanthium strumarium	—	—	—	—	—	—	18.28	—

this layer. The highest frequency values were recorded by *Ischaemum pilosum, Biophytum reinnardtii* and *Clebrookia oppositifolia* (40% for each species). The maximum numbers of species (10) as well as density (63.37%) were encountered by this zone among the all fire zone studied during the pre-fire season. The IVI values ranged from 10.44 (*Achyranthus aspera)* to 75.02 (*Ischaemum pilosum*). In medium fire affected zone during post-fire the highest density (26.66%) and frequency (100%) values were recorded by *Cassia tora,* whereas lowest density (0.55%) was found in *Ageratum conyzoides, Curcuma aromatica, Coriandrum setium* and *Peristnphe paniculate*, respectively. The maximum numbers of species (20) were encountered by this zone among the all fire zone studied during the post-fire season. The IVI values ranged from 4.67 to 52.99.

In low fire zone during pre-fire season herb layer revealed that the highest density (36.23%) and frequency (80%) were recorded by *Corchorus aequitans* and the lowest density noticed in *Sida cardata* (5.79%), while the lowest frequency was recorded by *Clebrookia oppositifolia* (20%), *Coriandrum setium* (20%) and *Perotis hordeiformis* (20%). The herb layer of low fire zone during post-fire season revealed that the highest density (35.10%), frequency (100%) was recorded by *Cassia tora*. The lowest density noticed in *Ischaemum pilosum* (1.06%) among the all species found in this layer. *Cassia tora* recognized as dominant species among the all species found in this layer. After the medium fire zone, the low fire zone showed maximum numbers of species occurrence (7) during pre-fire and (14) during post-fire season among the all zones. IVI value in this zone varied from 25.95 to 83.14 during pre-fire and 7.30 to 69.61 during post-fire season.

Result of non-fire zone on herb layer showed that the highest density (26%) was recorded by the *Desmodium pulchellum* followed by *Crotolaria calycina* (25%) and *Xanthium strumarium* (21.42%), respectively. The IVI values ranged from 27.38 (*Coriandrum setium)* to 70.24 (*Desmodium pulchellum*). It is recorded from the study that the non-fire zone had minimum density (10.62%) across the all fire zones. The data presented of herb layer during post-fire in this zone showed that the *Casia tora* recorded the highest density (23.47%), whereas the lowest density (1.73%) was found in *Desmodium pulchellum* among the all recorded species. In the non-fire zone the numbers of species occurrence were 6 during pre-fire and 13 during post-fire season. IVI values in this zone varied from 27.38 to 70.24 during pre-fire and 8.86 to 49.76 during post-fire season.

The number of species in a community is ecologically important. Species diversity parameters in all the four forest fire zones are summarized in the Table 1. The diversity parameters in the herb layer in pre-fire season showed that Shannon index in different fire zones varied from 1.69 to 2.71, equitability 1.05 to 1.33, species richness 0.33 to 0.67, concentration of dominance 0.20 to 0.36 and beta diversity 1.90 to 3.80 under the herb layer.

The diversity parameters in the herb layer in post-fire season showed that Shannon index in different fire zones varied from 2.22 to 3.39, equitability 0.92 to 1.31, species richness 0.76 to 1.48, concentration of dominance 0.11 to 0.37 and beta diversity 1.50 to 2.72 under the herb layer. The perusal of data revealed diversity index (H′) and species richness obtained maximum value at medium fire zone whereas Simpson's index and Beta diversity obtained maximum value at high fire zone and the non-fire zone had maximum value of equitability index during both the season of observation (pre-fire and post-fire).

In the high fire zone the abundance to frequency ratio (A/F) indicated most of the species showed contagious (98.52%) and few species showed random (1.47%) distribution pattern during pre-fire season and most of the species distributed contagiously (85.49%) and randomly (14.50%) during post-fire season. Abundance to frequency ratio in medium fire zone revealed that all the recorded species showed contagious distribution pattern during pre-fire season and 80% species distributed contagiously during post-fire season. In low fire zone abundance to frequency ratio showed that most of the species showed contagious and random distribution pattern during both the seasons. In case of non-fire zone A/F ratio indicated that most of the species showed contagious and few species were distributed randomly during pre-fire season and most of the species contagious and few species showed both random and regular distribution pattern during post-fire season.

Analysis of variance indicated that the variation in density between site to site during the pre-fire and post-fire season were found significant at $p < 0.05$ level. The number of species was found non-significant during pre-fire season whereas, in post-fire season it was found significant at $p < 0.05$ level.

The fire frequencies in these zones are mainly surface fire and very rarely canopy fires. After post-fire herb layer showed different patterns of the vegetational composition. The herb layer showed higher density after post-fire in high and low fire zones, whereas decreased in medium fire zone due to the change in season (rainy) the density of herb layer also increased after post-fire in non-fire zone. These results are similar with findings of Naidu and Srivasuki (1994); Kafle (2004). Diversity is considered to be an outcome of evaluation of species in a bio-geographic region. It is considered to be synthetic measure of the structure, complexity and stability of a community (Hubble and Foster, 1983). It is a combination of two factors; the number of species present, referred to as species richness and the distribution of individuals among species, referred to as species evenness or equability. Species diversity therefore, refers to the variation that exists among the different life forms. In the present study general structure of herbaceous species in all sites depicted an increasing trend in species number during the post-fire season. The reason for their maximum occurrence could be due to the availability of moisture present in the form of rains and other environmental factors. Alhassan *et al.* (2006) during their study period reported similar factors responsible for the variation in species number and diversity. According to Joshi and Bharti (2005), plants may facilitate other plants directly, by ameliorating harsh environmental conditions, altering substrate characteristics, or increasing the availability of a resource. During winter, with the decline in temperature, there was a marked accumulation of belowground biomass, perhaps due to translocation of food reserves to the belowground parts with the advent of unfavourable conditions for shoot growth.

The diversity parameters in the herb layer showed that the value of Shannon index in different sites varied from 1.69 to 3.39, equitability 0.92 to 1.33, species richness 0.33 to 1.48, concentration of dominance 0.11 to 0.37 and beta diversity 1.50 to 3.80 under the herb layer during pre-fire and post-fire season. Shameem *et al.* (2010) also reported the species diversity ranged from 1.80 to 3.03 which are found to be similar with present study. The minimum diversity in few sites may also be due to lower rate of evolution and diversification of communities (Fischer, 1960; Simpson, 1964) and severity in environment (Connel and Oris, 1964). Concerning the species richness, a high number of species results with in higher community stability or rather resilience (Guo, 2001). This wide diversity takes the advantage of heterogeneity and increases their diversity. The level of heterogeneity created, obliviously would depend on the height and architecture of the woody species (Sagar *et al.,* 2008).

The disturbed areas or site supports more herbaceous vegetation as compared to undisturbed area because of reduction in competition for space and resources. Moretti *et al.* (2002) and Keith *et al.* (2010) have reported the similar results and stated that the herb species increase in number immediately after fire because of a general reduction in the tree cover that brings more light to the soil and for growing understorey. Connell (1978) and Decocq *et al.* (2004) also stated that species diversity highest in intermediate disturbance ecosystem than in undisturbed systems. The quantity of humus deposition was optimum under medium fire zone this helps for herbs to easily uptake of nutrients from the soil. Danielle *et al.* (2005) reported that the humus characteristics significantly explained the distribution of under story species. The medium fire zone supported higher values of density of herb species while it has drastically reduced in high and non-fire zone. Pandey and Singh (1985) in their study on disturbed ecosystem are in same agreement that species diversity increased in disturbed ecosystem due to moderate disturbances. In the non-fire zone, the herb density was also reduced due to competition for moisture, nutrients, light and for space. Azizi *et al.* (2006) stated that the fire mainly affect the undergrowth and young trees. Kumar and Thakur (2008) have also reported the lesser density and basal area of fire affected sites as compared to non-fire areas. The nature of plant community at a place is determined by the species that grow and develop in such environment (Bliss, 1962). Difference in such composition from one fire zone to another fire zone or site is mostly due to micro-environmental changes (Mishra *et al.,* 1997). The pattern of distribution depends both on the physico-chemical natures of the environment as well as on the biological peculiarities of the organisms themselves. Abundance to frequency ratio was used to assess the distribution pattern of species. It reveals that most of the species were distributed contagiously and randomly whereas regular distribution was found almost negligible during both the pre-fire and post-fire season. Similar finding were also made by the Shadangi and Nath (2005) which reported maximum species in contagious distribution. Odum (1971) described that in natural condition contagious distribution was most common type of distribution and were performed due to small but significant variation in environmental conditions while random distribution was found only in very uniform environment.

ACKNOWLEDGEMENT

Thankful to Chhattisgarh forest department for granting permission and necessary forest staff for conducting research work in the area.

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