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ORIGINAL ARTICLE: IMPACT OF FOREST FIRE ON SOIL INSECT DIVERSITY IN SAL FOREST, DOON VALLEY, UTTARAKHAND.

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Abstract— **The Himalayan forests particularly, Garhwal Himalayas being the youngest mountain ranges are the most vulnerable stretches of the world susceptible to forest fires. Soils are alive with biological organisms which respond directly to variations in the environment and modify environment physically and chemically. Biological properties of soil are most sensitive to soil heating, with fatal temperatures for most living organisms occurring below 100 ^{0}C. In recent years extended droughts and the demand for conversion of forest to other land uses has resulted in significant increase in wildfire size, frequency and related environment impacts. In this study the impact of forest fire was assessed on the insect diversity in sal forest of Lachhiwala for burned and unburned (control) site in four different season, viz. monsoon, winter, spring and summer. A total of 805 individuals of arthropods were grouped into 14 orders and 25 families collected during the entire sampling period. Of all sampled data, a total of 239 individuals were observed in burned and 566 individuals in control site representing 10 orders and 17 families in burned against 13 orders and 24 families in control site.**

Keywords- **Forest fires, Insect biodiversity, Sal forest.**

I. Introduction

India is one of the 12 mega biodiversity countries of the world. It is the seventh largest country by area with a wide variety of physical and climatic conditions including varied ecosystems ranging from the tropical rain forests to high alpine cold deserts, grassland, wetlands and coasts. India embraces three major biological realms, viz, Indo-Malayan, Eurasian and Afro-tropical and adorned with 10 biogeographic zones and 26 biotic provinces [1].

Forest is a complex ecological system in which trees are dominant life forms. The most common hazard in forests is forests fire which are frequent along the Himalayan foothills and also in the deciduous forests elsewhere. In India the large area of tropical deciduous forests is under intense pressure due to recurrent fires. Forests fire in sal forest which is largely distributed in tropical and sub tropical climatic condition of the country takes the form of ground fires.

Forest Survey of India carried out vulnerability analysis which was based on the frequency of forest fire occurrences throughout the country and estimated a total of 8,645 forest fire incidence during 2004-2005; 20,567 during 2005-2006; 16,779 during 2006-2007; 17,264 during 2007-2008; 26,180 during 2008-2009; 30,892 during 2009-2010 and 13,898 incidence during 2010-2011 respectively in the country and 143 forest fire incidence during 2004-2005; 165 during 2005-2006; 222 during 2006-2007; 717 during 2007-2008; 631 during 2008-2009; 855 during 2009-2010 and 85 fire incidence during 2010-2011 in Uttarakhand also [2].

Impact of forest fire on soil fauna

Soils are alive with biological organisms with large population of microorganisms, roots, mycorrhizae, invertebrates and burrowing animals inhabit the upper part of the soil profile [3]. They collectively contribute to soil productivity by enhancing decomposition, N cycling, humus formation, soil physical properties, plant promulgation, plant nutrition and stability. Soil organisms range from microbiota to macrobiota. Microbiota are less than about 100 µm in body width, mesobiota are between 100 µm and 2 mm and macrobiota are between 2 and 20 mm [4]. Soil microorganisms are concentrated in the surface L layer and D layer, because these soil layers contain large amounts of organic matter and are active sites for decomposition and other microbial processes. Biological properties of soil are most sensitive to soil heating, with fatal temperatures for most living organisms occurring below 100 ^{0}C [5]. Effects of forest fire on invertebrates, as with other living organisms, depend largely on the severity of the fire, either uncontrolled wildfire or low-intensity prescribed fire [6]. In either case the effect of fire on invertebrates can be transitory or longer lasting [7]. Invertebrates residing more permanently in the upper soil layers are most likely affected when these soil layers are heated to lethal temperatures due to direct impact of fire on organisms or their eggs.

However, no attempt has so far been made in sal forest from Uttarakhand to take up studies to establish the impact of forest fire on soil insects. As in Doon valley most of the forest area is covered by sal forest, therefore keeping in view the role of

soil insects in forest ecosystem, present study was undertaken in sal Forest.

II. Material and Method

The study was conducted in burned and unburned sites in Lachhiwala Reserve Forest of Doon valley. Five plots of 1m x 1 m were taken randomly for both selected sites. At each plot, two sites were chosen and soil samples each measuring 25 cm x 25 cm surface area with the depth of 30 cm, divided into three layers of 0-10 cm, 10-20 cm and 20-30 cm were taken from the burned and controlled site. Soil samples were collected seasonally i.e, in monsoon, winter, spring and summer. The litter samples from 1m x 1m plots were taken from both sites during each sampling period.

A. Soil and litter insects:

All soil samples were taken in the field by using iron sampler block of 25 cm x 25 cm dimension with depth of 10 cm. At each sample site soil sample was collected according to the standard method used by the Tropical Soil Biology and Fertility Institute (TSBF) (referred to as the 'TSBF soil monolith method') [8-9].

Surface active insects were collected using pitfall traps, which consisted of 9 cm diameter cups containing 70% ethanol [10]. For the sampling of soil insects, each plot consisted of a transect containing six sampling points at approximately 5-10 m intervals apart from each other. Sweep nets were used to collect insects from grass layer and above ground vegetation. Collected samples were preserved in 70% ethanol. The specimen in the litter was dried in berlese funnel and all extracted specimens collected from soil sampler, pitfall traps, and berlese funnel were identified upto family level and counted.

B. Insect diversity:

The insect diversity is determined by Shannon-Wiener Index [11], as per the given below.

$$\mathbf{H'} = -\sum_{i=1}^{s} \mathbf{pi \ ln \ pi}$$

Where,

H′ = Shannon-Wiener Index of species diversity
pi = the proportion of individuals or the abundance of i^{th} species expressed as a proportion of total cover
s = the number of individuals of all the species
ln = the natural log

C. Data Analysis:

All statistical analysis were done using PAST, biodiversity software. Chi-square test as a statistical tool was performed to analyze the relationship between fire and its impact on insects diversity.

III. Results

A total of 805 individuals were collected during the entire sampling period, representing 25 families and 14 orders. In addition, a total of 239 individuals observed in burned and 566 individuals in unburned site representing 10 orders in burned against 13 orders in control and 17 families in burned site in comparison of 24 families in unburned site. The extracted orders included Coeloptera, Lepidoptera, Orthoptera, Hemiptera, Diptera, Hymenoptera, Isoptera, Blattodea, Dermaptera, Thysanura, Myriapoda, Diplura, and Annelida in unburned site while Coeloptera, Lepidoptera, Orthoptera, Hemiptera, Hymenoptera, Isoptera, Blattodea, Dermaptera, Neuroptera and Annelida in burned site during study period. Diversity of insects in both selected sites was observed and calculated by Shannon-Wiener Index (H') (Table 1 and 2). It revealed through the Shannon-Wiener index that there was a considerable variation of the insects population among the burned and unburned sites. The decline trend of soil insects was exhibited in burned site on comparing with unburned (Figure 1 and 2). In burned site insects population declined sharply among all four seasons, specifically in monsoon and winter. It was further analyzed that higher H' value was observed in unburned site as compare to burned site. The result presented in table 1 and 2, depicted the variation in H' value between burned and unburned site. On comparing the H' value in four selected seasons among two selected sites, it was observed that the value of H' recorded in monsoon season was 2.24 in case of insects collected by soil sampler and 2.62 in case of insects collected by pitfall in burned site against 3.38 and 2.88 respectively in unburned site. During winter, the H' value was 1.56 in case of insects collected by soil sampler and 2.59 in case of insects collected by pitfall in burned site whereas 3.17 and 3.08 respectively in unburned site. Likewise, 1.38 and 2.51 in burned site against 2.16 and 2.32 in control site during spring. Similar result was obtained in summer season, where it was 2.23 in case of insects collected by soil sampler and 2.79 in case of insects collected by pitfall in burned and 2.54 and 2.88 in unburned site.

Chi-square test performed for insects sampled in both sites revealed that sites were statistically highly significant ($P < 0.001$). In monsoon, minimum insect sampling count recorded out of all other seasons in burned site which revealed that the decline trend was due to direct impact of fire on soil insects through heating. Furthermore, it was investigated that decline in insect population was highly significant in upper layer of soil in monsoon season as compare to other depths in burned area (Figure 1). On comparing the sites during winter season, similar pattern of decline was recorded in burned site. A significant correlation was found between the sites ($p < 0.05$), whereas in spring the reduced insect population persisted in burned area, but did not established any statistical significance. As there was a decrease in trend of insect population among selected sites throughout study period, no statistical correlation was observed in month of summer too. However, the declined insect population started to recover during spring or summer or after that.

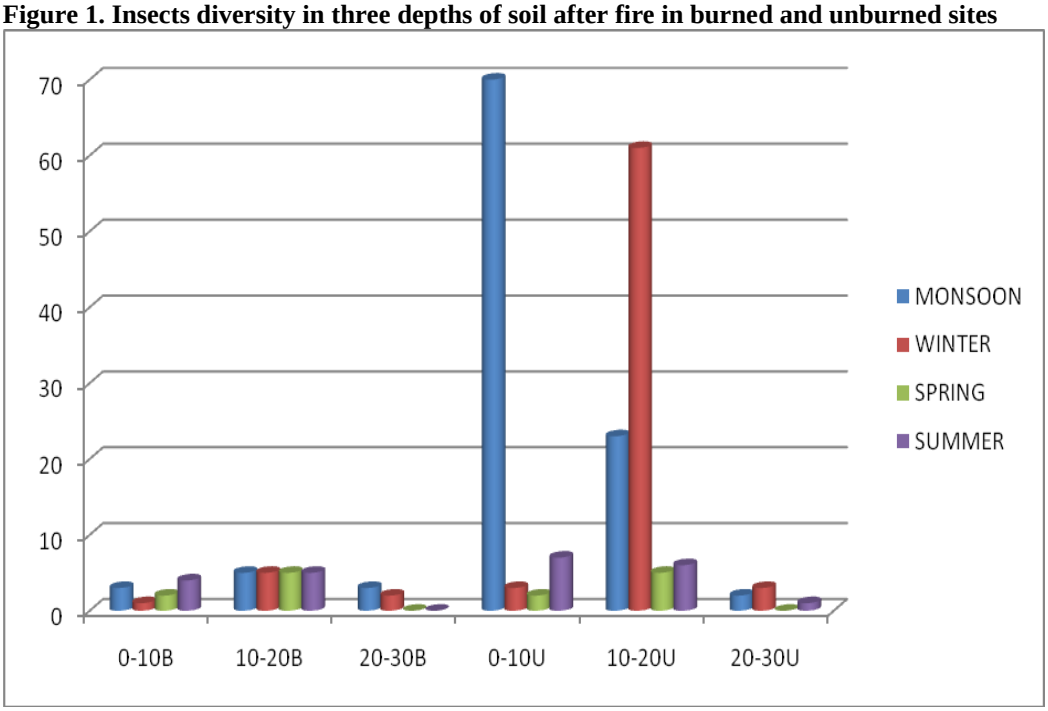
Table 1. Shannon Wiener index values of soil insects in burned and unburned sites in different season

Season	Shannon Wiener (H') value in burned site	Shannon Wiener (H') value in unburned site
Monsoon	2.24	3.38
Winter	1.56	3.17
Spring	1.38	2.16
Summer	2.23	2.54

Table 2. Shannon Wiener index values of soil insects collected by pitfall in burned and unburned sites in different season

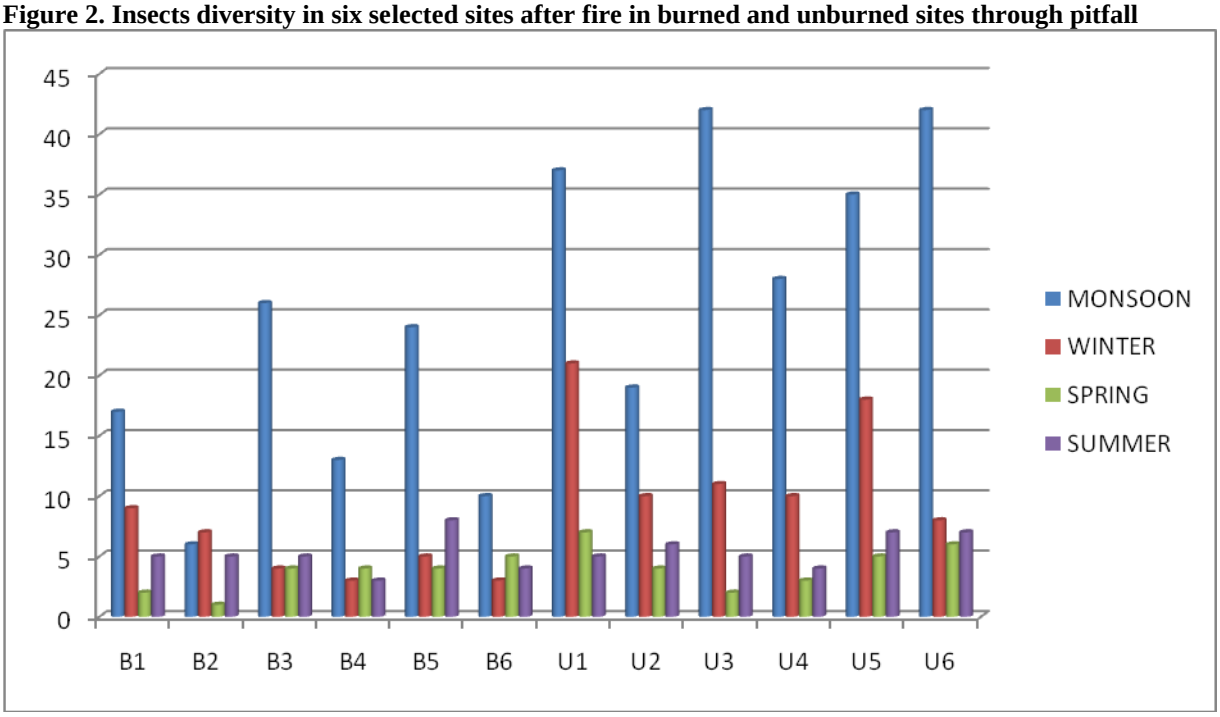
Season	Shannon Wiener (H') value in burned site	Shannon Wiener (H') value in unburned site
Monsoon	2.62	2.88
Winter	2.59	3.08
Spring	2.51	2.32
Summer	2.79	2.88

Figure 1. Insects diversity in three depths of soil after fire in burned and unburned sites



B = burned
U = unburned

Figure 2. Insects diversity in six selected sites after fire in burned and unburned sites through pitfall



B = burned
U = unburned

IV. Discussion

During the study period the decline in insect population was exhibited in burned site against unburned site in all four seasons. The reduction of soil insects was attributed to direct mortality of insects or their eggs due to fire and indirect post fire alteration in soil such as, increase in soil temperature, low moisture content, increase in pH, loss of organic matter, habitat destruction due to change in vegetation, significant decrease in litter cover and humus. Earlier the same findings were also reported by many investigators [12-14] who reported that soil porosity may be reduced because fire destroys soil dwelling insects and other macro organisms which helps in channelization of the soil. During a study period a significant loss of litter layer and organic matter was observed in burned site while in normal site accumulation of a thick layer of undisturbed litter layer leads to aggregation and accumulation of large number of individuals in the top most layer of soil was noticed throughout the study period. Removal of insulated litter layer from forest floor has significant influence on the population of soil insects. Earlier York [15] also reported that unburned sites were characterized by high grass and litter cover with litter depth. It is due to correlation between variables these sites were also characterized by high soil moisture and ambient humidity level, a greater number of grass species, which supports our findings. Springett [16] observed the similar finding of reduction in litter quantity which decreased both the number and density of invertebrate species in soil and litter due to fire in Australia. Furthermore, it was observed that the insect count observed immediately after fire was significantly reduced comparing to control site. In general maximum insect count was noted during monsoon season followed by winter, summer and spring. The difference in H' value among the sites revealed less number of insects in burned site against unburned. It was further observed that layer-wise analysis of soil samples revealed more insects in lower layer than uppermost layer, which is contrary to normal site. Likewise, similar decline in insect population has been observed in case of insect sorted through pitfall method, berlese funnel and net sweeping method in burned site against control site. Beetles (Scarabaeidae and Carabaeidae), ants, termites and earthworms were among the more abundant organisms in burned site throughout the season. Out of which beetles, ants and termites found to be more adaptable organisms in burned site. However, the survival of earthworm in burned site was supported by downward movement of these organisms from disturbed uppermost layer of the soil to undisturbed lower layers. Several other studies have also reported these groups to be amongst the dominant soil macrofauna taxa [17-23]. French and Keirle [24] also observed that ants were among the first to colonize the burned area due to their preference for a more xeric habitat. It was also observed that ants were more abundantly and significantly found specifically in dry season i.e in spring and summer season throughout the study. Several other studies also indicates the fact that increased ant abundance in the dry season [20,25-27]. In the present study, while insects collected by net sweeping, it was observed that grasshopper and green lace wing were the two taxa that noticed among the burned site in monsoon season, after one month of the fire. It was analyzed that the reason of this was attributed to immigration of grasshopper from unburned area as vegetation and grass cover recovered in burned site and higher temperature after fire supports their recolonization. Earlier almost similar results were observed by Hurst [28] and Rice [29]. Furthermore, Phillips [30] has

also reported almost similar result of reduction in the number and type of litter and soil invertebrates such as Coeloptera, Lepidoptera and Diptera after fire.

V. Conclusion

During the investigation, post fire decrease in insect population was analyzed for four seasons, i.e, in monsoon, winter, spring and summer. In case of burned site, a marked decline in insect count was observed during monsoon season (one month after fire) with respect to unburned site and the decline in insect population was highly significant in upper layer of the soil. The results also indicate that beetles, ants and termites were among the more abundant and first to colonize the burned site.

References

[1] Rodgers, W.A. and Panwar, H.S., 1990. Planning a Protected Area Network in India., Vol. 1 & 2. Wildlife Institute of India, Dehra Dun.

[2] Forest Survey of India (FSI)., 2012. Vulnerability of India's Forests to Fires. Forest Survey of India Report. Ministry of Environment and Forests. Dehra Dun.

[3] Singer, M.J. and Munns, D.N., 1996. Soils: An Introduction. Prentice Hall, Upper Saddle River, New Jersey.

[4] Verhoef, H.A., and Brussaard, L., 1990. Decomposition and nitrogen mineralization in natural and agroecosystems: the contribution of soil animals. Biogeochemistry. 11:175-211.

[5] DeBano, L., Neary, D. and Ffolliott, P., 1998. Fire Effects on Ecosystems. John Wiley and Sons, USA.

[6] Campbell, A.J., Tanton, M.T., 1981. Effects of fire on the invertebrate fauna of soil and litter of a eucalyptus forest. In: Gill, A.M., B. H. groves, and I.R. Noble, editors. Fire and the Australian Biota. Australian Academy of Science Canberra, Australia, pp. 215- 241.

[7] Lyon, J.L., Crawford, H.S., Czuhai, E., Fredricksen, R.I., Harlow, R.F., Metz, L.J. and Pearson, H.A., 1978. Effects of fire on fauna: a state-of-knowledge review. USDA For. Serv., Gen. Tech. Rep. WO-6.

[8] Anderson, J., Ingram, J., 1993. Tropical Soil Biology and Fertility: A Handbook of Methods. CAB International, Wallingford, U.K.

[9] Moreira, F.M.S., Huising, E.J. and Bignell, D., 2008. A Handbook of Tropical Soil Biology; Sampling and Characterization of Below-ground Diversity. Earthscan, London.

[10] Gist, C.S. and Crossley, D.A., 1973. A method of quantifying pitfall trapping. Environmental Entomology, 2, 951- 951.

[11] Shannon, C.E. and Wiener, W., 1963. The Mathematical Theory of Communication. University of Illinois Press, Urbana.117pp.

[12] Haimi, J., Fritze, H. and Moilanen, P., 2000. Response of soil decomposer animals to wood-ash fertilization and burning in a coniferous forest stand. Forest Ecology and Management (129): 53-61.

[13] Phillips, J., 1931. Forest succession and ecology in the Knysna region. Memoirs of the Botanical Survey of South Africa. 14, 1-327.

[14] Wells, C.G., Campbell, R.E., DeBano, L.F., Lewis, C.E., Fredricksen, R.L., Franklin, E.C., Froelich, R.C. and Dunn, P.H., 1979. Effects of fire on soil: a state-of-the-knowledge review. USDA For. Serv. Gen. Tech. Rep. WO-7, Washington, D.C.

[15] York, A., 1999. Long-term effects of repeated prescribed burning on forest invertebrates: management implications for the conservation of biodiversity. Australia's Biodiversity Responses to Fire. Biodiversity Technical Series (1): 181-266.

[16] Springett, J.A., 1976. The effect of prescribed burning on the soil fauna and on litter decomposition in western Australian forests. Australian journal of Ecology. 1:77-82.

[17] Lavelle, P. and Pashanasi, B., 1989. Soil macrofauna and land management in Peruvian Amazonia (Yurimaguas, Loreto). Pedobiologia. 33, 283-291.

[18] Ericksen, P. and McSweeney, K., 1999. Fine-scale analysis of soil quality for various land uses and landforms in central Honduras. Am. Altern. Agric. 17, 146-157.

[19] Feijoo, M.A., Knapp, E.B., Lavelle, P. and Moreno, A.G., 1999. Quantifying soil macrofunna in a Colombian watershed. Pedobiologia. 43, 5137-5517.

[20] Brown, G.G., Moreno, A.G., Barois, I., Fragoso, C., Rojas, P., Hernandez, B. and Patron, J.C., 2004. Soil macrofauna in SE Mexican pastures and the effect of conversion from native to introduced pastures. Agric. Ecosyst. Environ. 103, 313-327.

[21] Deecaens, T., Jimenez, J., Barros, E., Chauvel, A., Blanchart, E., Fragoso, C. and Lavelle, P., 2004. Soil macrofaunal communities in permanent pastures derived from tropical forest or savanna. Agric. Ecosyst. Environ. 103, 301-312.

[22] Mathieu, J., Rossi, J.P., Grimaldi, M., Mora, P., Lavelle, P. and Rouland, C., 2004. A multiscale study of soil macrofauna biodiversity in Amazonian pastures. Eiol. Fert. Soil. 40, 300-305.

[23] Rossi, J.P., Mahieu, J., Cooper, M. and Grimaldi, M., 2006. Soil macrofuna biodiversity in Amazonian pastures: matching sampling with patterns. Soil Biol. Biochem. 38, 2178-2187.

[25] Hofer, H., Hanagarth, W., Garcia, M., Martius, C., Franklin, E., Roembke, J. and Beck, L., 2001. Structure and function of soil fauna communities in Amazonian anthropogenic and natural ecosystems. Eur. J. Soil Biol. 37. 229-235.

[26] Rossi. J.P. and Blanchart, E., 2005. Seasonal and land-use induced variations of soil macrofauna composition in the western Ghats, Southern India. Soil. Biol. Blochem. 37, 1093-1104.

[27] Sileshi, G. and Mafongoya, P., 2006. Variation in macrofauna communities under contrasting land use systems in eastern Zambia. Appl. Soil Ecol. 33, 49-60.

[28] Hurst, G. A., 1971. The effects of controlled burning on arthropod density and biomass in relation to bobwhite quail brood habitat on a right-of-way. Tall timbers conf. Ecol. Anim. Contr. Habitat Manage. Proc. 2:173-183.

[29] Rice, L., 1932. The effect of fire on prairie animal communities. Ecology 13, 392-401.

[30] Phillips, J., 1965. Fire- as master and servant. Its influence on the bioclimatic regions of Trans-Saharan Africa. Tall Timbers Fire Ecol. Conf. Proc. 4:7-109.