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Full Length Research Paper

Influence of post-fire successional gradients in *Pinus brutia* forests on ground beetle community changes

Burçin Yenisey Kaynaş

Department of Biology, Faculty of Arts and Science, Mehmet Akif Ersoy University, İstiklal Campus, Burdur/Turkey.

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Fire is a common disturbance factor in Mediterranean ecosystems. It is a very spectacular ecological force because it destroys ecosystems in a very short time. Insect groups are commonly used as indicators to evaluate habitat changes after disturbances. In this study, the successional changes were evaluated by the composition of ground beetles communities in East Mediterranean pine forests. Ground beetle fauna was investigated using pit-fall traps at 17 sampling sites in *Pinus brutia* forests burned in different times. Plant species richness, vegetation and surface characteristics were measured as microhabitat variables in the study sites and the relationships between ground beetle abundance and microhabitat variables were estimated with Pearson Correlation Analysis. As a result, it was determined that recolonization of ground beetle communities did not occur in early successional stages. In the sites burned 9, 16 and 26 years ago, that represent middle and late successional stages, the abundance and species richness of Carabidae were higher and then decrease again in mature pine forest. The relationships between microhabitat parameters and Carabidae abundance were estimated and changes of ground beetle communities depending on microhabitat structure were not determined.

Key words: Carabidae, disturbance, Mediterranean, succession, fire.

INTRODUCTION

Fire is a common feature of Mediterranean landscapes (Bilgili and Sağlam, 2003). Vegetation composition and structure in Mediterranean type ecosystems are strongly shaped by the fire regime (Díaz-Delgado et al., 2002; Radea and Arianoutsou, 2000; Trabaud, 2000). Post fire regeneration of vegetation in every level of biological organisation hierarchies and life-hisory traits has been studied intensively (Thanos et al., 1989; Ne’eman et al., 1992; Spanos et al., 2000).

Changes of forest habitat structure and vegetation after disturbance make lead changes in the structure and dynamics of faunal communities. The effects of fire on faunal communities and changes of faunal community dynamics after fire concentrated on more affects especially to insects and small mammals (Prodonet al., 1987; Haim and Izhaki, 2000; Kaynaş and Gurkan, 2008). Effects of fire on insects and other arthropods can operate through a variety of mechanisms at different temporal scales (Andersen and Müller, 2000). Direct effects of fires include mortality, forced emigration (Whelan, 1995), or immigration of pyrophilous insects that are favored by fire (Wikars, 2002; Wikars and Schimmel, 2001). Indirect effects of fire mostly depend on vegetational changes. Following fire, changes of plant

E-mail: bykaynas@mehmetakif.edu.tr, Tel: +902482133052.

Table 1. Locations and altitutes of sampling sites.

Successional age	Replication sites	Locations	Altitudes (m)
3	1	36° 59' 24'' N, 28° 20' 05'' E	217
	2	36° 59' 30'' N, 28° 20' 05'' E	175
	3	36° 59' 33'' N, 28° 19' 23'' E	105
6	1	36° 50' 17'' N, 28° 18' 02'' E	55
	2	36° 50' 08'' N, 28° 18' 08'' E	35
	3	36° 49' 53'' N, 28° 18' 30'' E	35
9	1	36° 55' 43'' N, 28° 12' 14'' E	105
	2	36° 55' 42'' N, 28° 12' 12'' E	80
	3	36° 53' 44'' N, 28° 11' 49'' E	35
16	1	36° 58' 50'' N, 28° 18' 53'' E	185
	2	36° 58' 57'' N, 28° 18' 46'' E	140
	3	36° 59' 05'' N, 28° 18' 25'' E	125
26	1	36° 49' 58'' N, 28° 20' 25'' E	180
	2	36° 49' 51'' N, 28° 20' 00'' E	150
	3	36° 49' 20'' N, 28° 19' 05'' E	90
50<	1	36° 50' 54'' N, 28° 17' 42'' E	55
	2	36° 54' 24'' N, 28° 10' 36'' E	35

species composition, plant diversity (Lawton, 1983; Siemann, 1998; Siemann et al., 1999) and plant architecture (Southwood et al., 1979; Lawton, 1983) influence the diversity and richness of insect communities. In Mediterranean ecosystems, the changes of plant architecture and vegetation structure should be more important on insect community change (Kaynaş and Gürkan, 2008), because re-establishment of the pre-fire plant communities is rapid (Trabaud, 1994) and there is no real succession in the sense of replacement of species or communities (Keeley, 1986; Trabaud, 2000).

Carabid beetles are among the best studied taxa regarding microhabitat changes. They are used as indicator group for the evaluation of the effects of habitat fragmentation (Magura et al., 2004), different types of disturbance (Latty et al., 2006; Ribera et al., 2001), forestry applications (Heliola et al., 2001), and classification of landscapes (Rykken et al., 1997). They are appropriate subjects for such studies because they are diverse and abundant, taxonomically well-known and sensitive to habitat changes (Niemalä et al., 1993, 1992, 1988).

In this research we aimed to study the changes of Carabid communities during post-fire successions and microhabitat features which influence the Carabid communities in this period.

MATERIALS AND METHODS

The study was conducted in several *Pinus brutia* Ten. 1815 forests with many areas affected by fire in different degree (as a result of being burned in different years). These forests are located at Marmaris district (36°50’ N, 28°17’ E) and its surrounding areas, which is situated on the Mediterranean coast of southwestern Turkey. This area has a typical Mediterranean climate with a hot and dry summer. The total precipitation is 1211.7 mm year^{-1} (between 1975 and 2006), with a dry period that lasts for 5 months, between May and September. Monthly mean temperatures range from 10.6°C in January to 28.3°C in July. The vegetation on the area is mostly represented by *Pinus brutia* forests; other major vegetation types are Maquis, Phrygana and *Liquidambar orientalis* Mill.1768 forests.

For the samplings, the areas were selected in order to cover the major range of successional gradient of forest recuperation after the effects of a fire, by choosing areas burned with natural fires 3, 6, 9, 16 and 26 years ago and areas that has not been affected by fire for a longer period (>50 years). The samplings were made in three replication sites for every successional stage and two for unburned areas. The dominant vegetation types of all sites was *P. brutia* forest and all the samplings stretches from an altitude of 0 to 250 m (Table 1).

Ground beetles were sampled during a three-days period in March, May, June and August of 2005, using pit-fall traps. The traps consisted of plastic jars with a diameter of about 7 cm buried in the soil up to the brink and half filled with 30% ethylene alcohol. Sixteen pitfall traps were placed at each site in a 4x4 grid with 10 m intervals between each trap.

Microhabitat structure of the sites was analyzed with the point quadrats technique (Sutherland, 2006). For each trap locations, nine points were selected, one of these was center and remaining eight were situated in four different directions around the trap (Figure 1). In every point, the plant species were identified, the height of plant at this point was measured and surface characteristics were recorded.

After emptying, each individual was mounting and equipped with cardboard label identifying its trap number, site name and sampling

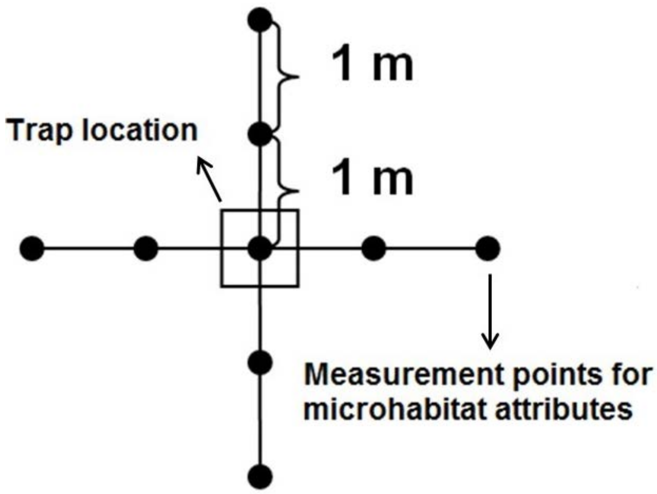

Figure 1. Sampling design for microhabitat attribures in each trap locations

time before preserving in wooden drawers. They were identified to species level in Entomology Laboratory at Hacettepe University.

Species richness and abundance of successional sites were estimated by calculating arithmetic average of number of species and individuals of replication sites respectively.

The habitat structure of the study sites was evaluated from vegetation and surface characteristics. The parameters about vegetation were: Plant species richness, mean height of vegetation, stratification and cover of vegetation, and were calculated for every replication sites.

The overlap ration of plants at one sampling point can be used expression of vertical stratification in a habitat. In a point of forest habitat, a subshrub, a shrub and a tree can be found together in the same point vertically and stratification increase with increasing number of plants in a sampling point. Vegetation stratification was calculated by total number of counted plants to sampling points (9) for each trap location. Vegetation cover is expression of cover area of plants on surface and it was estimated by dividing numbers of points which were occupied any plants (not empty points) to total sampling points.

Surface characteristics were analyzed at the same trap locations. Surface structure was evaluated in terms of soil, stone, rock, leaf, branch and needle. Surface complexity was estimated by calculating the mean of component numbers at a measure point.

The number of variables to be analyzed was reduced by applying a principal component analysis (PCA) on all the variables that resulted highly correlated. After all of these variables were reduced with Principal Component Analysis, calculating scores and abundance of Carabidae of all sites was done with Pearson Correlation Analysis (SPSS Statistics 17.0).

RESULTS

A total of 29 individuals belonging to 10 species of ground beetles were captured in 4080 trap/nights. With respect to changes of Carabid communities depending on successional gradient, we see that abundance and species richness of ground beetle communities was very low in early successional stages and they progressively increase towards middle and late successional stages. In unburned forest these values decrease again. The sites burned 3 and 6 years ago were represented by a very small number of species and individuals. The sites burned 9, 16 and 26 years ago have relatively higher species richness and abundance compared the other sites (Figure 2). The species with the highest rate of capture was *Leistus rufomarginatus* (Duftschmid, 1812). *Carabus graecus morio* (Mannerheim, 1830) and *Ditomus calydonius* (Rossi, 1790) were also common. While *C. graecus morio* did not display any change depending on successional gradient, *D. calydonius* was captured only in middle and late successional stages. The other species were captured in very small numbers and generally appears in only one of the sampled successional stages (Table 2).

Principal component analysis displayed that the cumulative percentage of variance for the three axes was 80.3%. The first axes was highly correlated with characters peculiar to late successional stages such as total plant species richness, habitat stratification, cover and height of vegetation and needle cover. Second axes were relevant with two variables cover leaf and branch, third one was rock cover. Because correlation coefficients between total Carabid abundance and obtained three axes were very low (Pearson correlation coefficients; 1. Axes: 0,121; 2. Axes: -0,110; 3. Axes: 0,018), no significant relationship was found between microhabitat variables and Carabid abundance.

DISCUSSION

In Mediterranean region, plant communities which have been shaped with fire for thousands of years are resilient, with different regeneration strategies (Keeley, 1986). Although ground beetles were stated as resilient for prairie habitats (Cook and Holt, 2006), an early regeneration of ground beetle communities seems not to be the case in this study for *P. brutia* forests. In early stages of succession, ground beetle communities were represented by very few individuals and species. This result may be due to species still have to colonize in significant numbers. The retardation in colonization may occur for ground beetles communities at recently opened areas (Niemelä et al., 1993; Saint-Germain et al., 2005). In stressed climatic conditions like Mediterranean ecosystems, open habitats can limit colonization and activation of ground beetles. Greater temperature fluctuations and reduced humidity levels may disturb the invertebrate community (Pearce and Venier, 2006). Vegetation cover may have an important role in protecting Carabidae from direct insulation and desiccation and a decrease in vegetation and litter cover have a negative impact on surface moisture (Barone and Frank, 2003). A suitable humidity condition, provided by vegetation cover, is important for ground beetles in habitat preference (Thiele, 1977). The reduction in the

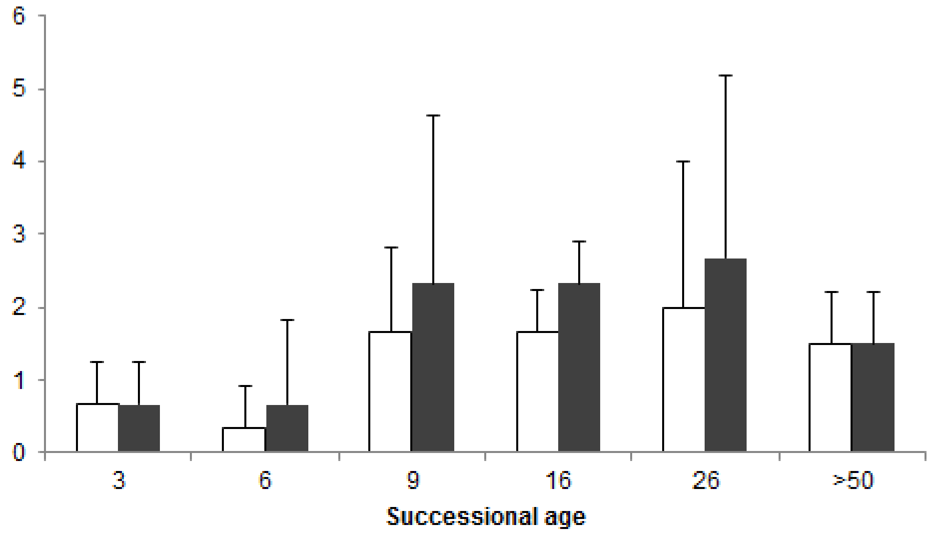

Figure 2. Mean species richness (open bar) and abundance (solid bar) of ground beetless in successional stages after fire.

Table 2. Total number of individuals of Carabid beetles at successional stages after fire.

Species	Years after fire					
	3	**6**	**9**	**16**	**26**	**>50**
Bembidion tetracolum			1			
Calathus melanocephalus						1
Calosoma reticulatum				2		
Carabus graecus morio		2	3		1	1
Cymindis lineata			1			
Ditomus calydonius				2	2	
Leistus ferrugineus					1	
Leistus rufomarginatus	2			2	4	1
Ocydromus sp.			1			
Pterostichus sp.			1	1		

amount of tree leaf litter may have contributed to the reduced abundance of taxa that requires shelter, moisture, and food provided by tree leaf litter (Blanche et al., 2001).

Mediterranean ecosystems is known resilient to fire and re-establishment of the pre-fire communities is very rapid (Trabaud, 1994). Even if there is no change in species composition of plant community with time after fire, vegetation characteristics such as height, cover display to change with successional gradient in post-fire areas (Tavşanoğlu and Gürkan, 2014). In this study, no relationship was determined between habitat variables and Carabid abundance. Similarly Chapman (2014) stated that level of heterogeneity in habitat structure did not have a great influence in Carabid communities. To make a certain interpretation like this is impossible because remarkable low number of individuals belong to Carabid communities for this study. Although a clear association was not detected in here, the importance of habitat structure in Carabid community structure was revealed in many studies.

The increase in habitat heterogeneity with successional age depends on vegetation height (Kruess and Tscharntke, 2002) and heterogeneity of vegetation was a better predictor of Carabidae species richness than plant species diversity (Brose, 2003). The importance of habitat heterogeneity was displayed in some studies (Sroka and Finch, 2006). Complex habitats, respect of floristic and physical features, create a preferable microclimate for ground beetles (Larsen et al., 2003; Lassau et al., 2005). In addition Shelef and Groner (2011) stated that beetle behavior is affected by shrub structure and beetles use shrub shading for their thermoregulation. In this respect the middle aged sites in successional gradient had a higher shrub cover and could be more suitable habitats for ground beetles. However, mature forest unburned for very long time had complex habitat attributes and display low abundance and species richness value in comparison to middle and late successional stages. In studies carried out in the same ecosystems, Kaynaş and Gürkan (2007) stated the negative impact of closed canopy structure of vegetation on some insect groups. Middle and late successional stages had heterogenous environments depend on increase vegetation height and lack of closed canopy closure constitutes favorable habitats for ground beetles.

In conclusion, despite such a tendency with successional gradient in communites of Carabidae, low number of species and the lack of correlation between Carabid correlation and habitat variables obstructed to make certain evaluations. In Mediterranean ecosystems, there is limited knowledge about subjects of interactions between fire and insects, and adaptations of insect communities to fire-induced habitat alterations. Long-term studies are needed for comprehensive and accurate evaluations.

Conflict of Interest

The authors have not declared any conflict of interest.

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