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Short research contribution

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SPECIES RICHNESS AND ABUNDANCE OF INSECTS DURING POST-FIRE SUCCESSION OF A *PINUS BRUTIA* FOREST IN MEDITERRANEAN REGION

ABSTRACT: In the Marmaris National Park (located on the Mediterranean coast of SW Turkey) mostly covered with *Pinus brutia* forests, four sites were selected to study the post-fire successional trends in vegetation and insect communities. The sites represented: 1, 5, and 21 years after fire as well as control site (more than 45 years after fire). On the study plots (0.5 ha) the insects were collected with the sweep net swung along three transects each of 100 m length, in monthly intervals between August 2000 and September 2001. The number of plant species decreased from 41 to 32 along succession, as well as the number of stage-specific species but the mean height of vegetation increased with successional stage. The abundance and species richness of herbivorous insects decreased along succession as well as two main herbivore groups – xylophagous and sap-feeders. However, no major changes were found between the sites in terms of abundance or species richness of predators. This decrease in herbivorous forms may be a result of changes in the plant architecture and vegetation structure between post-fire successional stages.

KEY WORDS: pine forest, herbivore insects, predator insects, vegetation architecture, Marmaris National Park

Fire is a common feature of Mediterranean landscapes (Bilgili and Saglam

2003) and is considered as an environmental factor shaping the region (Radea and Arianoutsou 2000, Trabaud 2000). The fire regime is related to fire frequency (interval between fires), season of burning, the extent of fire (fire patchiness), and the type of fire (e.g. ground or crown fire) (Whelan 1995). The fire regime has altered in recent decades due to human intervention. It is estimated that 75 255 fires consumed 1561 026 ha in Turkey between 1937 and 2004. Although the number of fires increased after 1972, following this year no substantial changes in the size of the area burned were recorded (Anonymous 2004).

Pine forests constitute one of the three dominant Mediterranean-type ecosystems in the Mediterranean basin, the other two being tall shrublands with evergreen plant species (maquis) and low shrublands with seasonal dimorphic plants (phrygana) (Radea and Arianoutsou 2000). The geographical range of the tree species *Pinus brutia* Ten. (Turkish red pine or East Mediterranean pine) covers the widest area in Turkey, from the Aegean coast to the Mediterranean regions of Anatolia (Öktem 1987). *Pinus brutia* forests are frequently exposed to fire as a result of the flammable characteristics

of these communities and dry and hot summers.

The post-fire recovery process of vegetation has been studied intensively in Mediterranean ecosystems (e.g. Traubad *et al.* 1985, Thanos *et al.* 1989, Ne'eman *et al.* 1992, Martínez-Sánchez *et al.* 1997, Pausas 1999, Spanos *et al.* 2000, Traubad 2000, Tavşanoğlu and Gürkan 2005). However, the changes in insect communities after fire in the Mediterranean ecosystems have received little attention (but see Prodon *et al.* 1987, Broza *et al.* 1993, Kaynaş and Gürkan 2004, 2007). The effects of fire on insects and other arthropods can occur through a variety of mechanisms, at different temporal scales (Andersen and Müller 2000). Fires may exert an effect either directly by causing mortality, forcing emigration (Smith 2000, Warren *et al.* 1987, Whelan 1995), or through immigration of pyrophilous insects, which are favored by fire (Wikars and Schimmel 2001, Wikars 2002). The indirect effects of fire depend mainly on the changes in the vegetation structure. Following fire, the changes in the composition of plant species, plant diversity (Siemann 1998, Lawton 1983, Siemann *et al.* 1999), and plant architecture (Lawton 1983, Southwood *et al.* 1979) influence the diversity and richness of insect communities.

In this context, this study aimed to determine the changes in different trophic groups of the insect community during post-fire successional stages of a pine forest.

The study was conducted in the Marmaris National Park (36°50' N, 28°17' E), which is located on the Mediterranean coast of southwestern Turkey. The National Park covers approximately 34,000 ha; it has a typi-

cal Mediterranean climate with a hot and dry summer, and a mild winter, and it is mostly covered by *Pinus brutia* forests; other major vegetation types are maquis and *Liquibamber orientalis* forests.

The study was conducted at four sites, three sites representing different stages of succession at post-fire sites and one site representing the unburned forest:

- I. burned a year before
- II. burned 5 years before
- III. burned 21 years before
- IV. Control site (not burned at least for 45 years).

These sites overlie the same geological material (ophiolitic rock) and have the same soil type (non-calcic brown forest soil). Altitudes of all sites were below 100 m. At all sites, after burning, branches and cones were spread over the ground, creating suitable conditions for seedling establishment.

Tavşanoğlu (2002) described the dominant plant species for all sites according to percentages of cover. *Quercus infectoria* Olivier, 1801 and *Phillyrea latifolia* Linnaeus, 1753 are the dominant species at all sites. Apart from these two species, in site I (a year after fire) – *Cistus salviifolius* Linnaeus, 1753 and *Cistus creticus* Linnaeus, 1762, in site II (five years after fire) – *Pinus brutia*, *Cistus salviifolius*, and *Smilax aspera* Linnaeus, 1753 and in site III (21 years after fire) – *Pinus brutia*, *Cistus salviifolius*, and *Cistus creticus* were the dominant plants. At the control site (site IV) *Pinus brutia* and *Smilax aspera* dominated.

Because of opportunistic species that appeared after fire, the number of specific plant species was higher at the site burned a year before (Table 1). Although the higher number of specific plant species increased the

Table 1. Total species richness (number of species) of plants (TSRP), number of specific plant species (the species which occur only at one site) (SPS) and mean height of vegetation (MHV±SE cm) for each study sites (each of 0.5 ha) between August 2000-September 2001. Different superscript letters point out significant differences between study sites.

| | Years after fire | | | |
|-------------------|-------------------------|--------------------------|--------------------------|---------|
| | 1 | 5 | 21 | >45 |
| TSRP ¹ | 41 | 36 | 32 | 34 |
| SPS ¹ | 13 | 1 | 3 | 0 |
| MHV ² | 96.0 ± 6.2 ^a | 128.5 ± 3.6 ^b | 184.4 ± 4.4 ^c | no data |

¹ Data were taken from Tavşanoğlu *et al.* (2002).

² Data were taken from Kaynaş and Gürkan (2004).

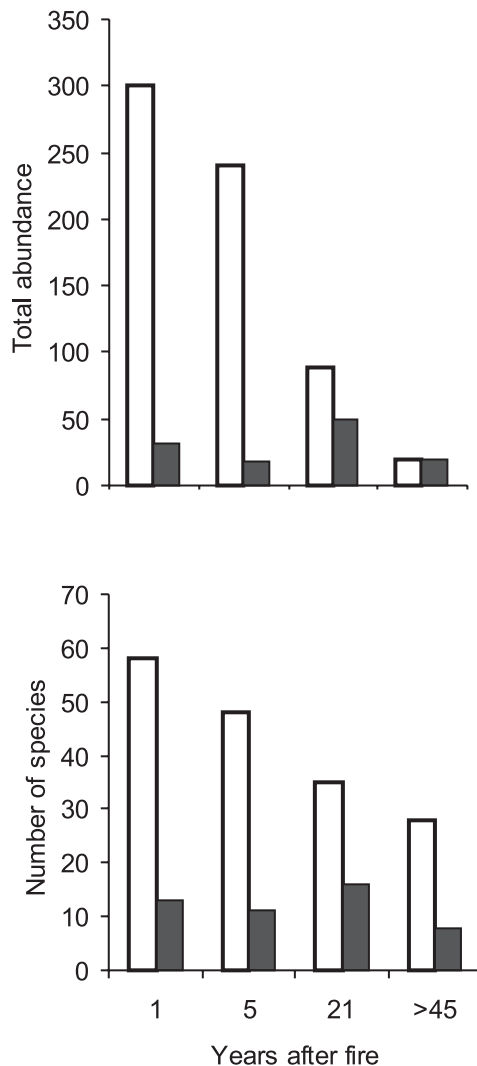


Fig. 1. Total abundance (number of individuals) and total number of species of herbivore (open bar) and predatory (solid bar) insects in post-fire successional stages along study period. Data for all sweep net samples taken from three transects each of 100 m length in monthly intervals between August 2000 to September 2001.

species richness of plants at this site, species richness varied little between the sites.

Vegetation complexity was related to mean vegetation height, as it may indicate enhanced biomass and architectural complexity of plants (Kruess and Tscharncke 2002). Mean height of vegetation was lowest at the site burned in 1999 (site I) and increased with successional age. At the control site, vegetation height was not measured.

Since the heights of trees were approximately above 10 m, mean vegetation height was taken as 10 m for statistical estimations (Kaynaş and Gürkan 2004) (Table 1).

Sweep net sampling was conducted in the morning. Each sample contained insects captured with a 32-cm diameter net that was swung 200 times by a researcher walking along a 100-m transect. Sampling was performed along three transects in an area of 100 × 50 m (0.5 ha). During the sweep net sampling the species observed were recorded. Sampling was conducted at the same time of day and by the same person.

Specimens were sorted and most of them identified into species. Several species that were not identified were described as morphospecies within known genera. Abundance, number of species, and Shannon-Weaver diversity index (H') were estimated.

The study was carried out from August 2000 to September 2001. During this period, sampling was done monthly except during winter (December, January, February).

Species were classified according to their feeding habits. The feeding habits of representatives from orders, families and species of different trophic categories were mainly determined from published sources (Borror *et al.* 1989, Booth *et al.* 1990).

Because the data were not consistent with a normal distribution even after log-transformation, non-parametric two-way ANOVA (Friedman's test) without replication (sampling period × study sites) was used to compare successional sites in terms of abundance and species richness.

Eight orders (Coleoptera, Hemiptera, Homoptera, Hymenoptera, Lepidoptera, Neuroptera, Odonata and Orthoptera) of insects belonging to herbivores and predators were encountered during the study (Tables 2 and 3). Herbivore abundance and species richness decreased with post-fire successional age (Fig. 1). Although herbivore abundance varied significantly between successional stages (Friedman's test, $P < 0.05$), there was no significant difference between successional stages in species richness of herbivore insects. There was no clear tendency and significant difference for changes in abundance or species richness of preda-

tor insects along the successional gradient. For predatory insects these parameters were higher at the site III burned 21 years before. The Shannon-Weaver diversity indices estimated for herbivorous and predatory insects were similar to each other at post-fire successional sites (Fig. 2).

Herbivores can be separated into more specific trophic categories, as sap-feeders and xylophagous. The results show that species richness and abundances of sap-feeders decreased along the successional gradient in spite of higher values at the control site. The species richness and abundance of xylophagous were higher at early successional sites (Fig. 3).

Mediterranean vegetation is resilient to fire and the re-establishment of the pre-fire communities is rapid (Trabaud 1994).

After fire, there is no real succession in the sense of substitution of species or communities, but only a progressive return towards a stage similar to that existing before the fire. The pre-fire species are present immediately after the fire (Trabaud 2000).

The pattern of arthropod succession may have been influenced by the pattern of plant succession. Because a diversity of plants may represent a diversity of resources for herbivores, increasing plant diversity may increase the diversity of herbivores (Siemann *et al.* 1999). In Mediterranean ecosystems no substantial difference exists between successional stages related to plant species composition. The main difference between successional stages of plant communities results from plant architecture and vegetation structure after

Table 2. Species richness (number of species) and total abundance (number of individuals) of herbivorous insects by orders found in the each post-fire successional stage along study period. Total data for all sweep net samples taken from three transects (each of 100 m length) in monthly intervals from August 2000 to September 2001. 1, 5, 21, 45 - years after fire.

| Herbivores | Species richness | | | | Abundance | | | |
|--------------------------|------------------|----|----|-----|-----------|----|----|-----|
| | 1 | 5 | 21 | >45 | 1 | 5 | 21 | >45 |
| Coleoptera | 12 | 13 | 8 | 4 | 31 | 81 | 19 | 12 |
| Hemiptera | 21 | 11 | 3 | 11 | 75 | 34 | 4 | 27 |
| Homoptera | 4 | 4 | 3 | 2 | 15 | 5 | 4 | 5 |
| Hymenoptera | 5 | 1 | 2 | 0 | 13 | 1 | 8 | 0 |
| Lepidoptera ¹ | 8 | 11 | 11 | 7 | 38 | 36 | 26 | 14 |
| Orthoptera | 8 | 8 | 8 | 4 | 117 | 79 | 27 | 9 |

¹Data were taken from Kaynaş and Gürkan (2007).

Table 3. Species richness (number of species) and total abundance (number of individuals) of predator insects by orders found in the each post-fire successional stage along study period. Total data for all sweep net samples taken from three transects (each of 100 m length) in monthly intervals from August 2000 to September 2001. 1, 5, 21, 45 - years after fire.

| Predators | Species richness | | | | Abundance | | | |
|-------------|------------------|---|----|-----|-----------|----|----|-----|
| | 1 | 5 | 21 | >45 | 1 | 5 | 21 | >45 |
| Coleoptera | 4 | 1 | 0 | 0 | 5 | 1 | 0 | 0 |
| Hemiptera | 2 | 1 | 1 | 0 | 11 | 1 | 2 | 0 |
| Hymenoptera | 1 | 0 | 1 | 0 | 2 | 0 | 4 | 0 |
| Neuroptera | 1 | 0 | 2 | 2 | 3 | 0 | 5 | 2 |
| Odonata | 4 | 8 | 11 | 6 | 10 | 15 | 38 | 17 |
| Orthoptera | 1 | 1 | 1 | 0 | 1 | 1 | 2 | 0 |

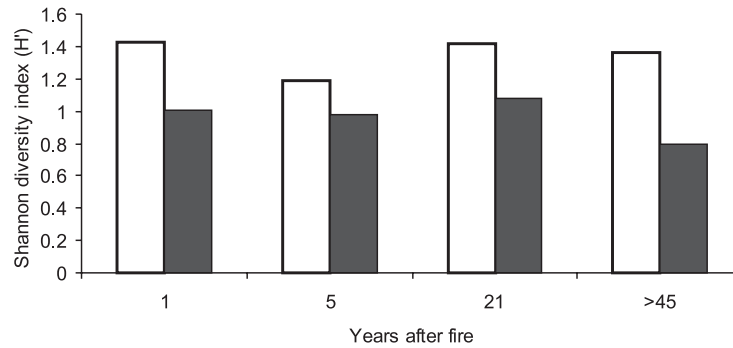


Fig. 2. Shannon-Weaver diversity indices (H') of herbivore (open bar) and predatory (solid bar) insects in post-fire successional stages along study period. Based on the all data from between August 2000–September 2001 (see Fig. 1).

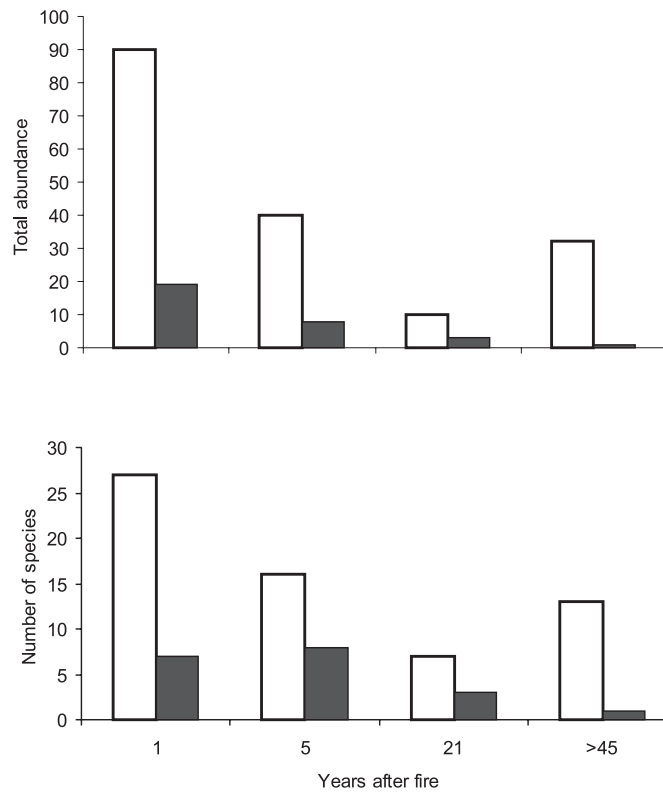


Fig. 3. Total abundance (number of individuals) and number of species of sap-feeders (open bar) and xylophagous insects (solid bar) in post-fire successional stages along study period. For data explanations see Fig. 1.

fire. The decrease in abundance and species richness of herbivorous insects measured during the post-fire succession may be caused by structural components of the vegetation. Habitat conditions appearing after post-fire removal of the crown layer

enhance the colonization of many insect species that usually are not found in mature *P. brutia* forests. In the first year after fire, increasing plant species richness with colonization of opportunistic plant species is another important factor causing higher

insect abundance and species richness in the early stages of succession.

Plant species have adaptive traits that allow them to regenerate after fire. The species that survive fire and regenerate vegetatively from adventive buds are classified as 'post-fire resprouters'. The species whose mature plants are not resistant to fire but whose seedling recruitment is timed for post-fire conditions are classified as 'post-fire seeders' (Keeley 1991). Except for *Pinus brutia*, all obligate seeders are entomophyllous and thus depend on the services of insects (Petanidou and Ellis 1993). After fire *C. salviifolius* and *C. creticus*, which colonize rapidly and densely, are pollinated by a large array of various insects (Bosch 1992). In the early stages of succession, higher abundances and species richness of herbivorous insects may be an adaptive attribute to fire for post-fire seeders and insects.

Many xylophagous beetles take advantage of areas opened up by fire and the numerous trees weakened by fire. These species are principally typical of semi-open forests or forest edges that require clearings or structured forest edges for depositing their eggs and for obtaining food (Moretti *et al.* 2002). After fire, trees and branches at the sites constitute the food resources for many wood-eating beetles.

Sap-feeders are one of the most frequently studied guilds in successional studies (Murdoch *et al.* 1972, Brown and Southwood 1983, Brown 1985, Anderson *et al.* 1989). Brown and Southwood (1983) stated that sap-feeders are characteristic for the later successional stages because of having a narrow niche breadth. In the present study, it was observed that the abundance and species richness of sap-feeders decreased along the successional gradient parallel to herbivores. With regard to the constancy of plant species richness along the successional gradient, it is suggested that changes in sap-feeders are favored by habitat conditions in the early successional stages.

The changes in predator abundance and predator species richness should be positively correlated with herbivore diversity. However, in our study no trend similar to that of herbivorous insects was found.

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