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Presence and dynamics of ambrosia beetles and other xylophagous insects in a Mediterranean cork oak forest following fire

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ABSTRACT

Cork oak ecosystems, which are biodiversity hotspots and have great socio-economic importance in the western Mediterranean Basin, have been experiencing serious decline in the last decades attributed to different causes, including wildfires. Besides direct mortality, the surviving burned trees become more vulnerable following fire and may be attacked by wood boring insects (Coleoptera), which may further affect tree vigor and give rise to massive dispersing offspring affecting surrounding areas. In the first spring after a wildfire that occurred in July 2013 in a cork oak stand in central Portugal, we set up different types of insect traps (interception, emergence and aggregation pheromone traps), and monitored them for up to 16 months. Fire occurrence had a great impact on cork oak trees attractiveness to xylophagous insects, which increased significantly with increasing fire severity. Living unburned trees located close to the fire edge were clearly avoided, while burned trees with no regeneration were the most attractive. Four species of ambrosia beetles, represented nearly 90% of all xylophagous insects captured in interception and emergence traps, namely *Platypus cylindrus* (Platypodinae), *Xyleborus monographus, Xyleborinus saxeseni* and *Xyleborus dryographus* (Scolytinae). Therefore, the presence of ambrosia beetles in recently burned forests should be carefully assessed, and their control should focus on preventing colonization and the spread of infestation. Forest management should primarily focus on increasing tree vigor, and on reducing the factors that may increase burn severity if a fire occurs. In the first years after a wildfire, it is advisable to avoid any activities that are likely to increase stress of burned and neighbouring unburned trees, such as cork extraction, branch pruning and soil ploughing. Additionally, post-fire logging and removal of dead trees before the next spring (when first emergences start to occur), and the use of pheromone traps, are other possible measures to reduce the number of beetles in these situations.

1. Introduction

Cork oak forests comprise unique ecosystems dominated by *Quercus suber* L. trees, which were shaped by millenary human activities and currently cover nearly 2.1 million hectares in the western Mediterranean Basin (APCOR, 2015; Euforgeen, 2016). More than one third of the world cork oak woodlands and nearly half of the world cork production are located in Portugal, while the remaining cork production is located in Spain, Morocco, Algeria, Tunisia, Italy and France, by decreasing order of importance (APCOR, 2015). Cork oak ecosystems have a high economic value, mostly due to cork production (cork is a highly valued renewable product), but also because they usually have different uses that may include extensive agriculture and livestock production, among others. Further, these ecosystems which often have a low tree density, give rise to a diverse understory of grassland and shrubs, turning it a biodiversity hotspot of major ecological importance in the Mediterranean Basin (Díaz et al., 1997; Catry et al., 2012).

In spite of their value, these unique ecosystems have become increasingly threatened by a number of biotic and abiotic factors (most of them directly or indirectly related to human activity), which prompted cork oak trees decline (e.g. Silva and Catry, 2006; Schaffhauser et al., 2012; Tiberi et al., 2016). Two of these factors are wildfires and insect pests, and although they are likely interrelated, no previous studies attempted to analyze them together. In the one hand, the frequency and severity of forest fires increased markedly in the western Mediterranean Basin in recent decades, in great part justified by changes in land

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management and climate (Pausas and Fernández-Muñoz, 2012). For example, the average annual area burned in Portugal increased from about 73,000 ha in the 80s to more than 150,000 ha in the 2000s (JRC, 2015). In the other hand, when forests are affected by wildfires, the burned trees often become an attractive breeding material for xylophagous insect species. This is a commonly reported problem in Mediterranean conifer forests (Santolamazza-Carbone et al., 2011; Lieutier et al., 2016). However, to our knowledge, there is no published information concerning post-fire colonization of Mediterranean broadleaves by wood-boring insects. A particular concern is due to ambrosia beetles which are known to attack and kill weakened trees, and especially *Platypus cylindrus* Fab., which is a key pest in cork oak ecosystems in the studied region (Branco et al., 2014). Additionally, under favorable circumstances, ambrosia beetles may change their behavior and start attacking healthy trees (Ploetz et al., 2013), which represents an additional concern to forest managers.

Ambrosia beetles comprise about 3400 insect species, which dig galleries inside the tree trunk colonizing the xylem with a symbiotic interaction with fungi. Adults and larvae feed on mycelia of previously inoculated fungi, and thus differentiate from bark beetles that feed on inner bark. Fungi spores of *Ambrosia*, *Graphium*, *Raffaelea, Ophiostoma* and other genus are transported by adults on specialized organs (mycangia) allowing colonizing new trees (Gebhardt et al., 2004; Inácio et al., 2012; Ploetz et al., 2013). This activity ultimately may result in tree death. There are at least eight lineages of ambrosia beetles which evolved from different bark beetle ancestors (Ploetz et al., 2013), belonging to the subfamilies Platypodinae and Scolytinae (Coleoptera: Curculionidae).

The subfamily Platypodinae comprises more than one thousand species of ambrosia beetles, but most are tropical, and the genus *Platypus* is the only Palearctic distributed. *Platypus* spp. attack mostly broadleaves (Ploetz et al., 2013). Some *Platypus* species have been recently associated with oak forest decline, namely *P. quercivorus* which was associated with Japanese oak wilt caused by *Raffaelea quercivora* (Kinuura and Kobayashi, 2006) and *P. koryoensis* with Korean oak wilt disease caused by *Raffaelea quercus-mongolicae* (Kim et al., 2009). In the western Mediterranean, the oak pinhole borer *P. cylindrus* is the only representative of Platypodinae, and it was not traditionally considered as a pest, but this situation changed in the last decades. Although *P. cylindrus* is known to attack mainly weakened trees, now in southwestern Europe and North Africa it can also attack apparently healthy trees of variable ages which could be ascertained to physiological and other predisposition factors (Sousa and Inácio, 2005) and possibly related with climate changes. First associations of *P. cylindrus* with intense attacks of cork oak tree in Portugal dates from the late 80s (Ferreira and Ferreira, 1989), and today it is considered the major insect pest attacking and killing adult cork oak trees (DGRF, 2007; Sousa and Inácio, 2005).

Among Scolytinae, the existing taxa associated to *Q. suber* (*Xyleborus* spp. and *Xyleborinus* spp.), have not been usually considered as forest pests (Neves, 1947; DGMCPF, 1960; Nogueira, 1978; Bachiller et al., 1981), or in maximum they were considered secondary forest species, not attacking healthy trees (Natividade, 1950; Ferreira and Ferreira, 1989). However, Natividade (1950) also mentioned that some species may sporadically and in restricted areas cause appreciable damages, and more recently one species (*Xyleborus dispar*) has been considered to attack and kill adult cork oak trees (DGRF, 2007).

Cork oak is a particular case among Mediterranean tree species because of its insulating bark (cork) that often enables crown resprouting after wildfires (Catry et al., 2009, 2012). However, even if burned trees are able to survive, they are usually weakened, and the subsequent attack by xylophagous beetles may render the recover more difficult. For this reason, insect attacks are a concern not only for the surrounding unburned trees, but also for the surviving burned cork oaks, which are intended to continue producing cork in the future. Although attacks of *P. cylindrus* and other xylophagous insects are likely to occur following fire events, so far we did not find any information about post-fire activity of ambrosia beetles and other xylophagous insects in cork oak forests.

The work presented in this paper started in the sequence of a wildfire occurred in July 2013 in central Portugal, in the scope of a study to assess the effects of fire and post-fire management on cork oak forest recovery. As a result of a first assessment, in which we observed abundant signs of recent activity of xylophagous beetles (Catry et al., 2014), we decided to install and monitor several traps with the objective of: (i) identifying the main insect species present in the area and the existence of potential pests, (ii) investigate the insect colonization pattern in a post-fire situation, and (iii) analyze the main emergence and flight periods. Our main goal was to improve the knowledge about ambrosia beetles and other xylophagous species behavior following wildfire, in order to help developing tools and recommendations to a more informed and adequate post-fire management of Mediterranean oak forests.

2. Material and methods

2.1. Study area

The study area is located in “Herdade dos Concelhos”, a public land owned by the municipality of Coruche (central Portugal, western Iberian Peninsula). Climate is Mediterranean, with a mean annual precipitation of 600–700 mm, a mean annual temperature of 15–16 °C, and 2 summer months with maximum temperature above 30 °C (APA, 2014).

Before the fire, the vegetation was dominated by forest, where the main tree species were *Q. suber*, *Pinus pinaster* Ait. (maritime pine), and *Pinus pinea* L. (stone pine), which often appeared in mixed stands. The shrub layer was also common and dominated by Mediterranean species such as *Cistus salvifolius* L. (sage-leaved rock-rose), *Calluna vulgaris* L. (heather), *Rosmarinus officinalis* L. (rosemary), *Arbutus unedo* L. (strawberry tree), and *Quercus lusitanica* Lam. (Lusitanian oak), among others.

In the summer of 2013 (4th July), a wildfire affected about 166 ha of land, including about 80 ha of the study area. This event motivated the start of a collaborative research to assess the effects of wildfire and of post-fire management on cork oak forest recovery. In November 2013 we selected the study sites and started monitoring nearly 500 burned and nearby unburned cork oaks for which several characteristics were recorded, including dendrometric measurements and indicators of the presence of potential pests (Catry et al., 2014, 2015). As a result of a first assessment, in which we observed abundant signs of xylophagous beetles’ activity suggesting that a potential outbreak could be in course, we decided to install several traps and to perform the current study.

2.2. Interception and emergence traps

In the first spring following fire (April 22th 2014) we installed 18 insect traps (including 12 interception traps and 6 emergence traps) within a maximum distance of 100 m from each other, in a one-hectare area in the edge of the burned forest (Fig. 1). This area is quite homogeneous, excepting that about half was burned during the wildfire, while the remaining was not. All traps were installed on 15 cork oak trees being exploited for cork production. These 15 trees represented nearly 20% of all trees within the one-hectare area.

2.2.1. Tree and stand assessments

Several tree and stand characteristics were assessed and registered inside this one-hectare study site. The collected characteristics included variables such as tree diameter at breast height (DBH), tree height, bark thickness, debarked surface (in the case of trees exploited for cork), tree cover (by species), shrub cover and height, and measures of fire severity