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Management of burnt wood after fire affects post-dispersal acorn predation

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ABSTRACT

The management of burnt wood after a fire may affect seed predation by vertebrates due to the change produced in habitat structure. We analyze the effect of burnt wood management on post-dispersal seed predation in the Holm oak. Three plots were established in a burnt forest, with three treatments per plot: (1) non-intervention (NI, all trees left standing), (2) "partial cut plus lopping" (PCL, felling 90% of trees, cutting their main branches, leaving all the biomass *in situ*), and (3) "salvage logging" (SL, felling the logs for their removal and masticating the woody debris). Acorns were buried to mimic dispersal by jays or rodents two and three years after fire, with two trials per year (7200 monitored acorns), and the predation rate was evaluated until the time of seedling emergence. The spatial patterns of acorn predation were assessed by computing a transformed-Ripley's *K* function and Moran's I correlograms. There was a large spatial and temporal variability in acorn predation, with differences among trials, plots, and replicates within treatments and plots. Overall, PCL showed the lowest predation values (83.0% versus 87.4 in NI and 88.0 in SL). Predator species (mice versus wild boar) also differed among treatments, wild boar having a negligible effect in PCL, presumably due to the physical barrier of felled logs and branches. The results support that: (1) salvage logging offers no advantage against predators and (2) that post-fire burnt wood management alters the guild of acorn predators and may reshape the pattern of seedling establishment.

1. Introduction

Seed predation can be a key process for natural population dynamics as well as for applied restoration purposes. Post-dispersal seed predation may reshape the spatial pattern of seedling emergence and thus have strong influence on the regeneration dynamics of natural systems (Rey and Alcántara, 2000; Rey et al., 2002; Forget et al., 2005; Gómez-Aparicio, 2008). In the last decades, many studies have shown that predation may vary among predator agents (García et al., 2005) that differently predate throughout different elements of the landscape (García et al., 2005; García-Castaño et al., 2006; Muñoz and Bonal, 2007; Gómez-Aparicio, 2008). Therefore, in many cases seed predation can determine the final distribution of plants going from the smaller to the larger spatio-temporal scales depending on the case.

Seed predation rate is strongly determined by habitat characteristics. Predator activity can be conditioned by the ability or impediment to forage under different circumstances (Forget et al., 2005), the vicinity of the territories of each species (García-Castaño et al., 2006; Muñoz and Bonal, 2007), or the risk of predation for seed predators while foraging (Muñoz et al., 2009), among other major factors. It is usually assumed that habitats with scant overstory complexity, such as open areas or grasslands, will represent a greater risk for seed predators than habitats with a woody overstory (García-Castaño et al., 2006; Muñoz and Bonal, 2007; Pons and Pausas, 2007). Thus, seed predators are expected to spend less time in open areas than in sites with more refuge, such as dense forest (Muñoz and Bonal, 2007). On the other hand, the amount of stones, debris, and remaining wood in some areas can impede rooting by big predators (Massei et al., 1997; Meriggi and Sacchi, 2000; Gómez and Hódar, 2008). Consequently, less seed predation by ungulates should be expected in dense understory areas. Furthermore, species differ in traits such as body size and home-range, which determine the use of the landscape where they live (Wiens, 2000). Larger predator species such as ungulates are expected to forage at broader spatio-temporal scales than smaller species such as rodents. This species-specific landscape perception within a common area can also lead to differences in seed predation in both spatial and temporal dimensions (García-Castaño et al., 2006; García and Chacoff, 2007; Matías et al., 2009).

Fires provoke a strong alteration of habitat structure and impact resource availability, consequently affecting the abundance of seed predators (Torre and Díaz, 2004; Zwolak, 2009). In addition, burnt wood is usually managed after fires, provoking an additional change in habitat characteristics that can alter the facility of animals to move and forage throughout the burnt area (Zwolak, 2009). A com-

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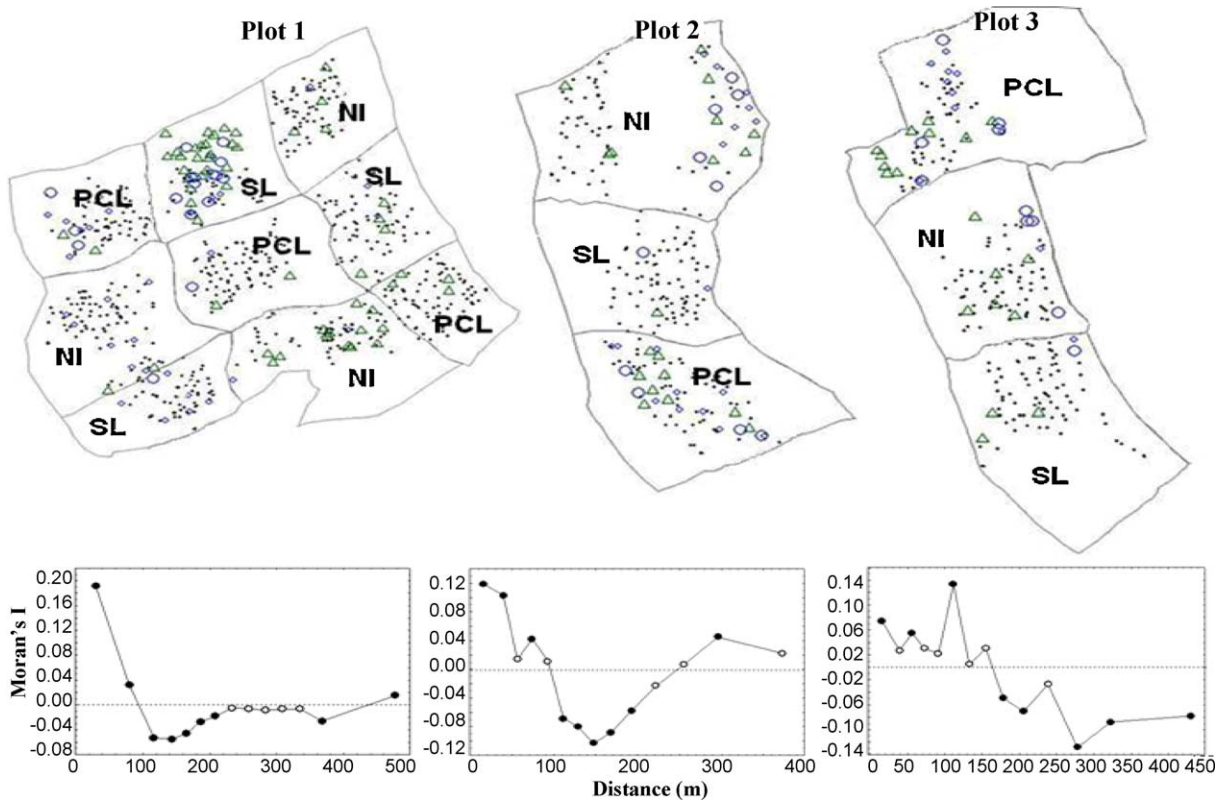

Fig. 1. Spatial patterns of post-dispersal acorn predation. The figure shows the number of predated acorns at each supply point (0–3). Solid black dots correspond to supply points where the three acorns were predated; blue circles to those where one acorn (big circles) or two acorns (small circles) were predated; triangles correspond to supply points where no acorn was predated. At the bottom, the figure shows the auto-correlogram screening the Moran's I in each plot. Solid-black circles correspond to significant distance classes.

mon practice after fires in forested areas worldwide involves the felling and removal of burnt trunks, often eliminating the remaining woody debris (branches, logs, and snags) by chopping, mastication, etc. (Beschta et al., 2004; Lindenmayer and Noss, 2006; Castro et al., 2010a), a practice that is usually termed salvage logging (McIver and Starr, 2000). As a result, the post-fire landscape undergoes a strong transformation driven by a simplification of the habitat characteristics in relation to the situation previous to salvage logging. Despite the common implementation of salvage logging after fires, there is increasing evidence that this practice may have a negative impact on the ecosystem, affecting a wide array of aspects such as the regeneration of plant and animal communities, diversity, water flow dynamics, or nutrient cycling (Beschta et al., 2004; Karr et al., 2004; Donato et al., 2006; Lindenmayer and Noss, 2006; Castro et al., 2010a,b). However, we are not aware of any study on the effect of burnt wood management on the rate of post-dispersal seed predation of tree species with the potential to colonize the burnt area. This is a key question to determine desirable post-fire forest restoration plans that would prompt forest recovery either by natural regeneration or by human intervention via seed sowing.

In this study, we analyze the effect of different post-fire burnt wood management on post-dispersal seed predation of the Holm oak (*Quercus ilex* L. subsp. *ballota* (Desf.) Samp.), a widely distributed tree species in the Mediterranean basin. In September 2005, the "Lanjarón" fire burned ca. 3500 ha in the Sierra Nevada National and Natural Park (southern Spain), including around 1300 ha of pine stands planted in the 1960s, mostly in the distribution area of the Holm oak. We established three experimental treatments that differed in the degree of burnt wood management, ranging from the conventional salvage logging to non-intervention. We hypothesize that this will influence the post-dispersal rates of seed predation, as the treatments contrast sharply in habitat characteristics, ranging from a landscape without tree overstory in salvaged areas to a habitat that still has an overstory of branches and logs in the other treatments, with the potential to affect both seed predators as well as their own predators' activity. The experiments were set up in two consecutive years and at two different times of year (beginning and end of the dispersal period), and a spatial analysis was performed for one of the years. Three questions were formulated: (1) Are there any differences among post-fire burnt wood management in the rates of seed encounter and predation? (2) Are there any differences among predator agents in seed predation in relation to the treatments? and (3) Are there spatio-temporal differences in post-dispersal seed predation?

2. Methods

2.1. Study area and experimental design

The study site is located in Sierra Nevada Natural and National Park (SE Spain), where in September 2005 the Lanjarón fire burned ca. 1300 ha of pine reforestations with Trees 35–45 years old, depending on the stand. Three plots of ~25 ha each were established after the fire across an elevational gradient (Fig. 1). All plots were similar in terms of orientation (SW) and slope (30.1 ± 1.0%; mean ± SE). Plot 1 was located at 1477 m a.s.l. (UTM positions *x*, *y*: 456070; 4089811), Plot 2 at 1698 m (UTM: 455449; 4091728), and Plot 3 at 2053 m (UTM: 457244; 4091551; elevation and position measured at the center of the plot). The pine species present in each plot differed according to their ecological requirements along this elevation/moisture gradient. The cluster pine (*Pinus pinaster*) and the black pine (*P. nigra*) dominated in Plot 1, black pine in Plot 2, and Scots pine (*P. sylvestris*) in Plot 3. All these species are native in the region, although they were extensively planted in the area