Post-fire tree mortality and regeneration in a mixed forest: evaluating the cumulative impacts of herbivory

Filipe Catry,[1,2] Francisco Rego,[1] Miguel Bugalho,[1] Tito Lopes,[1] Joaquim Silva and Francisco Moreira[1]

[1] Technical University of Lisbon, Institute of Agronomy, Centre of Applied Ecology, Portugal
[2] Contact should be made to F. Catry, email fcatry@mail.telepac.pt

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Aims and Introduction

Forest fires and forest recovery are topics of serious concern in the Mediterranean Basin, especially in Portugal, where burnt area significantly increased in the last two decades, contrarily to other southern European Mediterranean countries (EC, 2005). Since 2000 more than 1.3 million hectares were burned (DGRF, 2006), representing about 15% of the Portuguese mainland. However, there is a lack of information about several trees species mortality and recovery capacity in burned areas, which would be very useful for post-fire forest management. Aiming to contribute to this knowledge, we started a research project after a wildfire that affected about 3,000 hectares. The main goal of this study was to evaluate the survival/mortality of several tree species in relation to variables such as fire severity and tree characteristics, and to evaluate species regeneration strategies, as well as the regeneration growth after fire disturbance. In this research we also monitored the cumulative impacts of wild herbivores on the post-fire regeneration processes. Here we present the results on mortality and sucker growth observed three years after the fire.

Materials and Methods

The study area (885 ha) is located in central west Portugal (38°58′30″ N, 9°15′52″ W), 8 km far from the sea, in a public protected area that was severely affected by a wildfire in September 2003. The altitude ranges between 100 and 350 m and the soils are humic cambisols derived from sandstone. The mean annual precipitation is 798 mm and the mean annual temperature is 14.6 ºC. The vegetation is mainly dominated by forests, composed by broadleaved and coniferous species, and by shrublands. The study area was mapped and divided into a regular grid of 500 m, and 20 points (centers of each grid) were randomly selected in the burned area as the initial point for field transects. In the beginning, we needed to change the initial location of some of these points because they were located in areas without trees. Transects were established at each point to assess fire intensity and the vegetative condition of each tree.
The results presented here concerns 636 trees from 10 different species (minimum of 30 trees for each species), which were monitored during three consecutive years. We selected the most common tree species in the burned area, namely: *Crataegus monogyna* (weissdorn), *Eucalyptus globulus* (eucalyptus), *Fraxinus angustifolia* (narrowleaf ash), *Olea europaea* var. *sylvestris* (wild olive), *Pinus pinaster* (maritime pine), *Pinus pinea* (umbrella pine), *Pistacia lentiscus* (evergreen pistache), *Quercus coccifera* (kermes oak), *Quercus faginea* (Portuguese oak), and *Quercus suber* (cork oak). This study began three months after the wildfire, and for each individual tree we evaluated mortality, regeneration strategies (sprouting from base, roots, trunk, and crown or seed establishment), as well as suckers growth for species which regenerated from the base of the trunk. Because of the presence of a population of wild herbivores in the area (density of 0.4 deer/ha), constituted by *Dama dama* (fallow deer) and *Cervus elaphus* (red deer), several trees (only those which resprouted from the base) were protected from browsing to further evaluate the cumulative impacts of herbivory on post-fire recovery. *E. globulus* was not protected because we already knew that it was not consumed.

Results

Three years after the fire we observed that, independently of herbivores consumption, most broadleaved trees survived, while the majority of coniferous died (Table 1). Cumulative impacts of deer population on tree survival were observed in *Q. coccifera*, *Q. faginea* and *C. monogyna*, but significant differences were only observed in *Q. coccifera* (χ^2=4.957; p<0.05). *Q. coccifera* and *C. monogyna* mortality only occurred during the third year, and in the first species was only observed on trees subjected to browsing, while in the second species, browsed trees had three times more mortality. *Q. faginea* mortality was two times higher in browsed trees. In spite of low mortality observed in broadleaves, most of them did not show crown regeneration and only regenerated from the base of the trunk, roots or stem. Exceptions to this were *Q. suber* which showed crown resprouting. Only two species (*Q. coccifera* and *C. monogyna*) sprouted both from base and roots, and most coniferous trees showed only seed regeneration.

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Considering only the trees which resprouted from the base of the trunk and that were not subjected to deer browsing, we verified that the species with larger suckers growth were *E*. *globulus*, with an average maximum height of 9.7 m, followed by *F*. *angustifolia*, with about 2.8 m, while the species with lower growth was *P*. *lentiscus* with about 1.4 m. In terms of suckers diameter we observed a similar pattern, with *E. globulus* showing the larger growth (11.6 cm), and with *Q*. *coccifera* showing the lowest (1.2 cm). Deer population significantly and negatively affected sucker height growth of most broadleaves, excepting *E. globulus* (not consumed), and *P*. *lentiscus* (only consumed during the first growing months) (Figure 1). Average maximum height growth for the other broadleaved species ranged between 0.2 and 0.4 m.

Discussion

Despite the very low mortality in broadleaved trees, most of them did not regenerate from the crown, which means that the post-fire recovering processes will be much slower, requiring several years until the trees can reach the original size. However, the recovery of a burned area by means of natural regeneration (by suckers, roots or stem) will always be probably much faster than other usually used techniques like plantation or seeding, as the plants root system is already well developed. Contrarily to the broadleaved, the majority of the coniferous (2 species) died after the fire and in these cases the regeneration process occurred mainly from seeds. Within native species, *Q*. *suber* was by far the most resilient to fire, as 98% of trees resprouted vigorously from the crown. The insulating properties of the bark (cork) apparently provided adequate protection to the dormant buds occurring along the tree canopy, as mentioned by some authors (eg. Silva and Catry, 2006).

Herbivores populations can have a strong significant and negative impact on burned areas, hindering the development of several trees natural regeneration. The knowledge of the different tree species responses after fire, and of their interactions with herbivores, still poorly or not studied for many Mediterranean species, constitutes a fundamental aspect in the recovery of burned sites, and should be considered in the management of forested areas.

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Table 1 - Accumulated mortality (%) for each species in the first three years after the fire, and total number of sampled trees

Species		Accumulated Mortality (%)			Sampled Trees
Scientific Name	Common Name	1st Year	2nd Year	3rd Year	
Crataegus monogyna	Weissdorn	0,0	0,0	8,2	73
Eucalyptus globulus	Eucalyptus	0,0	0,0	0,0	31
Fraxinus angustifolia	Narrowleaf Ash	0,0	0,0	0,0	62
Olea europaea var. *sylvestris*	Wild Olive	0,0	0,0	0,0	78
Pinus pinaster	Maritime Pine	92,2	92,2	94,1	51
Pinus pinea	Umbrella Pine	83,1	86,2	87,7	65
Pistacia lentiscus	Evergreen Pistache	0,0	0,0	0,0	64
Quercus coccifera	Kermes Oak	0,0	0,0	10,4	67
Quercus faginea	Portuguese Oak	2,4	3,7	4,9	82
Quercus suber	Cork Oak	1,6	1,6	1,6	63

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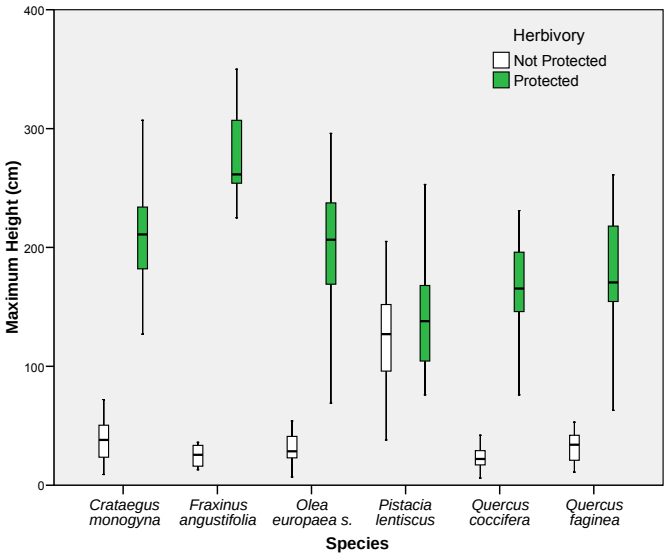

Figure 1 - Median (line inside box), upper and lower quartile (box) and extreme values excluding outliers (whisker) of sucker's average maximum height observed in the third year after the fire: comparison between protected and unprotected trees for the species which regenerated from the base of the trunk

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