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Original article

Does fire severity influence shrub resprouting after spring prescribed burning?

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A B S T R A C T

Prescribed burning is commonly used to reduce the risk of severe wildfire. However, further information about the associated environmental effects is required to help forest managers select the most appropriate treatment. To address this question, we evaluated if fire severity during spring prescribed burning significantly affects the resprouting ability of two common shrub species in shrubland under a Mediterranean climate in NW Spain. Fire behaviour and temperatures were recorded in tagged individuals of *Erica australis* and *Pterospartum tridentatum* during prescribed burning. The number and length of resprouted shoots were measured three times (6, 12 and 18 months) after the prescribed burning. The influence of a series of fire severity indicators on some plant resprouting vigour parameters was tested by canonical correlation analysis. Six months and one year after prescribed burning, soil burn severity (measured by the absolute reduction in depth of the organic soil layer, maximum temperatures in the organic soil layer and the mineral soil surface during burning and the post-fire depth of the organic soil layer) reduced the resprouting vigour of *E. australis* and *P. tridentatum*. In contrast, direct measurements of fire effects on plants (minimum branch diameter, duration of temperatures above 300 °C in the shrub crown and fireline intensity) did not affect the post-fire plant vigour.

Soil burn severity during spring prescribed burning significantly affected the short-term resprouting vigour in a mixed heathland in Galicia. The lack of effects eighteen months after prescribed burning indicates the high resilience of these species and illustrates the need to conciliate fire prevention and conservation goals.

1. Introduction

Shrub communities cover 21% of the land area of Galicia (Ministerio Medio Ambiente, 2011). In the period 2001–2010 there were about 8000 fires per year in Galicia, representing 46% of wildfires in Spain (Ministerio Medio Ambiente, 2010). In the same period, more than 70% of the wildland area burned annually in Galicia was shrubland (Ministerio Medio Ambiente, 2010). Many of these wildfires occurred in summer under unfavourable conditions (high temperatures and low relative humidity) and reached high intensities.

Prescribed fire is commonly used to reduce the risk of severe wildfires occurring (e.g. Pyne et al., 1996; Vega et al., 2000; Baeza et al., 2002; Oliveras and Bell, 2008). The Spanish Environmental Ministry is currently implementing a Forest Fires Prevention Programme that includes prescribed burning in shrubland areas with the aim of reducing fire risk (Vélez, 2010). The present study was carried out within this context. Although prescribed burning is a flexible and relatively inexpensive method, it is also limited by the scant number of days when meteorological conditions are suitable for its application, as well as by the risk of fire spread, the potential effects on vegetation dynamics (e.g. Keeley et al., 2008; Potts and Stephens, 2009), the risk of soil erosion (e.g. Vega et al., 2005) and smoke effects on human health (Haines et al., 2001).

Management of fire severity in order to meet fuel reduction objectives and to minimize undesired effects is an important consideration in the use of prescribed burning. Different indicators have been used to estimate fire severity. For example, Moreno and Oechel (1989) and Pérez and Moreno (1998) proposed post-fire plant minimum stem diameter as good indicator of fire properties; this parameter has also been used to study post-fire shrub resprouting in Californian shrublands (Moreno and Oechel, 1992; Keeley, 1998; Keeley et al., 2005, 2006). Most studies on fire severity and post-fire shrub regeneration have been carried out in areas affected by wildfire or with experimental fires of high intensity. However, few studies have addressed the relationships

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between fire severity indicators (measured as effects on plants or measurements of soil heating or destruction of the organic soil) and shrub resprouting ability following prescribed burning (Mallik and Gimingham, 1985; Nilsen et al., 2005).

Understanding how fire intensity or fire severity will affect ecosystem responses is crucial for post-fire management, particularly as regards vegetative regeneration and soil erosion (Keeley, 2009).This is especially pertinent to the intentional use of fire in prescribed burning, in order to establish how fire can be used in shrub communities, while minimizing any undesired effects on the ecosystem.

The shrub species *Erica australis* L. and *Pterospartum tridentatum* (L.) Willk display a good ability to resprout after fire (Cruz and Moreno, 2001a; 2001b; Cruz et al., 2002; Reyes and Casal, 2008; Reyes et al., 2009). In particular, *E. australis* has a large lignotuber, which can store huge reserves of carbohydrate (Cruz et al., 2003). The effects of fire on vegetation cover, soil seed banks and species diversity have been studied in *E. australis* and *P. tridentatum* shrubland areas elsewhere (e.g. Valbuena et al., 2000; Calvo et al., 2002, 2005, 2012). These studies have shown the importance of resprouting in the post-fire shrub recovery process. However, none of these studies have specifically explored the possible relationship between fire severity components and shrub resprouting vigour. Both shrub species are essential components in Galician shrublands and cover large areas of land. Consequently, understanding resprouting is important for understanding vegetation dynamics and plant management (Clarke et al., 2010; Lawes and Clarke, 2011).

The main objective of the present study was to determine if fire severity during prescribed burning, estimated by a set of proxy variables, significantly affects resprouting ability of two common shrub species in shrubland communities under a Mediterranean climate in northern Spain. The specific aims of the study were: (1) to explore possible relationships between a series of variables (post-fire plant basal area, plant height relative reduction and minimum diameter of branches) and soil thermal regime parameters during burning, and (2) to examine linear relationships between vigour of sprouts and two sets of fire severity indicators.

2. Material and methods

2.1. Study site

The study was carried out in the Edreiras Mountains (42°8′02″N–7°26′17″W; 1330 m a.s.l) in the province of Orense. The mean slope in the study area is 10%. The shrub community is a typical mixed heathland dominated by *Erica australis* L. ssp. *aragonensis* (Willk) and *Pterospartum tridentatum* (L.) Willk., initially covering respectively 55% and 40% of the study area. The other main woody species present was *Halimium lasianthum* ssp. *alyssoides* (cover 5%). The species richness is very low in the area and the only other species present are *Pseudoarrhenaterum longifolium* (Thore) Rouy, *Agrostis curtissii* Kerguélen and *Polygala vulgaris* L., all of which occur at a low frequency. The climate in the area is Mediterranean (Rivas-Martínez, 1987). The average rainfall is about 1100 mm year^{-1} with a pronounced dry period of three months in the summer. The mean annual temperature is 10 °C, with a pronounced degree of diurnal thermal contrast. The soils are Alumiumbric Regosols (FAO, 1998) developed on schist, and the texture of the soils is sandy-loam. The main physicochemical properties of the soil are as follows: pH 4.6 (determined in a suspension of soil in deionised water-1:2.5 w/v), organic carbon content 13.0% and total N 0.8% (both analysed by dry combustion with a LECO Elemental Analyzer). In the past the site was repeatedly burned with low frequency (every 5–10 years) by controlled burning and more recently (after implementation of a fire exclusion policy) it has been burned by summer wildfires. Cattle grazing and roe deer are frequent in the area. At the beginning of the experiment, the time since the last wildfire was seven years.

2.2. Experimental design

Four experimental units (each 50 × 50 m) were installed. The units had one side parallel to the maximum slope and were separated by firebreaks. The area was surrounded by electric fencing to prevent grazing by animals. 20 individual specimens of *E. australis* and 20 specimens of *P. tridentatum* were selected at random in each plot. All individuals were tagged with metallic tags.

Prescribed burnings were carried out in April 2010 and conducted under a fairly broad range of conditions to favour the occurrence of different levels of fire severity. Immediately before each burn samples of different fuel fractions, organic soil layer (litter + duff) and mineral soil surface (0–5 cm) were collected at ten randomly selected points within each plot. The samples were oven-dried for 24 h at 105 °C for determination of the moisture content.

Meteorological data (air temperature, relative humidity and wind direction and velocity) were also recorded during each burning event by an automatic meteorological station situated close to the plot but outside the area affected by burning.

Plots were burned by a strip head fire of strip width 10 m. The fire behaviour during burning was recorded on videotape, and the flame length was estimated by comparison with pre-positioned stakes of known length. The fire rate of spread was determined on the basis of the time needed by fire to run a predefined distance between the pre-positioned stakes. Fire linear intensity (Byram, 1959) was calculated from the flame length in each plot, by use of a relationship between these two variables obtained in prescribed fires in Galician shrublands (Vega et al., 2001). Mean meteorological and fire behaviour characteristics during burning are shown in Table 1.

Immediately before burning, chromel-alumel type thermocouples (1 mm external sheath diameter) were placed in one randomly chosen stem of each tagged individual and also immediately beside each plant, at the surface of the organic soil layer, mineral soil surface and 2 cm below the mineral soil surface. The thermocouples were connected to data-loggers in order to monitor the temperature during burning Temperatures were recorded at 1 s intervals. The mean variables of the thermal regime during burning are included in Table 2.

Changes in litter depth resulting from the burning were measured by use of metal pins placed flush with the litter surface at the base of each tagged plant. Immediately after fire, the emergent portion of the pins and the residual litter depth were measured to determine the difference (absolute and relative) in the litter thickness.

Table 1
Mean values of environmental and fire behaviour parameters during prescribed burnings (range of variation in brackets).

Variables	Mean
Air temperature (°C)	14.9 (11.5–18.1)
Relative air humidity (%)	53.2 (48.0–58.0)
Wind velocity (m s^{-1})	3.5 (2.4–4.5)
Elevated fine (0–6 mm) dead fuel moisture content (%)	16.8 (13.6–22.0)
Elevated fine (0–6 mm) live fuel moisture content (%)	90.0 (86.6–96.2)
Moisture content of organic soil layer (%)	60.8 (30.0–103.1)
Soil moisture content, dry weight basis (%)	41.4 (33.6–47.8)
Fire rate of spread (m min^{-1}), head fire front	11.8 (5.8–19.4)
Flame length (m)	4.0 (3.7–4.7)
Fireline intensity (kW m^{-1})	5347 (4610–7314)