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Biological fire prevention method: Evaluating the effects of goat grazing on the fire-prone mediterranean scrub

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Abstract

The effect of goat grazing on the shrubby understory of a pine forest in Doñana Natural Park was evaluated using non-destructive measures of vegetation volume over a period of twenty-four months. After establishing grazing exclusion fenced plots 350 adult Payoyas goats were introduced. Vegetation was sampled before the introduction of goats and afterwards twice a year, using the point intercept method and thereby obtaining data of height, frequency, cover and biovolume of species. After two years the total biovolume of the vegetation of the ungrazed area had increased significantly by 32.9%, while at grazed area, vegetation biovolume decreased significantly by 23.1%, leading to a significant decrease in mean height of the species. Although the number of species remained unchanged throughout the study, significant changes in their relative abundance were found in grazed area. The different responses of scrub species to grazing can be used as a tool to control species sensitive to grazing in shrubby forested areas. Significant reduction of total biovolume due to a reduction in vegetation height will help to reduce fire risk, thus contributing to the conservation of Mediterranean woodlands and forests while also fulfilling an important role in the economic and social lives of the rural population of Mediterranean countries.

Key words: Silviculture; Doñana Natural Park; resprouting species; seeder species.

Resumen

Un método natural para la prevención de incendio: evaluación del efecto del pastoreo sobre el biocombustible acumulado

Durante veinticuatro meses y con medidas no destructivas, se ha evaluado el efecto del pastoreo de cabras sobre el biovolumen del matorral del sotobosque de un pinar en el Parque Natural de Doñana. Tras establecer nueve cercados de exclusión al pastoreo, se introdujo un rebaño de 350 cabras adultas de raza Payoyas. La vegetación se muestreó utilizando el método punto- intercepción obteniéndose datos de altura, frecuencia, cobertura y biovolumen de las especies. Después de dos años, el biovolumen total de la vegetación del área pastada aumentó significativamente un 32,9%, mientras que en el área pastada la vegetación disminuyó significativamente un 23,1%, con una reducción en la altura media de las especies. Aunque el número de especies se mantuvo sin cambios durante todo el estudio, se encontraron cambios significativos en la abundancia relativa. La diferente respuestas de las especies de matorral al pastoreo puede ser utilizado como una herramienta para controlar y gestionar el biocombustible en las zonas forestales. Esta reducción significativa del biovolumen puede favorecer la reducción del riesgo de incendio, contribuyendo así a la conservación de los ecosistemas mediterráneos, además de contribuir en la vida social y económica de la población rural de la zona.

Palabras clave: Silvicultura; Parque Natural de Doñana; especies rebrotadoras; especies germinadoras.

Introduction

Due in part to the evolution of traditional social systems (rural depopulation, decline of agriculture, low profitability of forest products, etc) and partly to policies adopted in recent decades regarding the exclusion of livestock from the forests, the amount of combustible plant material has risen considerably and there has been a consequent increase in the number of fires and land burnt each year (Pausas, 2004). During the last decade, the number of fires in many European countries has increased, relative to previous decades, to reach an annual average of 20,000 fires in Spain (Röder *et al.*, 2008).

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Several management practices have been used to reduce the presence of inflammable species (cutting with manual or heavy equipment, prescribed fire, tillage, herbicides, etc). As an alternative to aggressive techniques, the use of grazing animals could be an efficient method to control shrub encroachment, reducing the risk of fire (Tsiouvaras *et al.*, 1989; Celaya *et al.*, 2007). Goats are suitable for this purpose because of their browsing ability, and it has been shown that they can reduce woody biomass with adequate stocking rates (Celaya *et al.*, 2007), thus reducing the risk of harmful intense wildfires. Due to its physiological characteristics, the goat is the animal best adapted to the consumption of the scrub found in the Mediterranean forest understory (Green and Newell, 1982). It is able to incorporate a greater variety of scrub species into its diet compared with other domestic ruminants and choose different plants or groups of plants according to the period of the year, therefore consuming everything that grows within the Mediterranean forests. Furthermore, goat grazing improves sward quality (McNaughton, 1993), with a consequent increase in food availability for wild herbivores.

In this study we investigated the effect of goat's grazing on the shrubby understory of a pine forest in Doñana Natural Park (Spain). The objectives were: i) to assess, through non-destructive measures, if the goats decrease plant biomass and can be an effective tool for the prevention wildfires ii) to evaluate the effect of grazing on the different shrub species iii) to evaluate the effect of grazing on diversity and species richness.

Materials and methods

The study was conducted in a 100 ha fenced pine forest situated in Doñana Natural Park (37º14'N, 6º20'W, SW Spain). The pine forest is dominated by *Pinus pinea,* with an average density of 217 trees/ha and an average diameter at breast height (dbh) of 26.92 cm. A few cork (*Quercus suber*) and holm (*Quercus ilex* subsp. *ballota*) oaks appear intermingled with the pines. The understory is covered with shrubs, being *Cistus salvifolius*, *Halimium halimifolium*, *H. calycinum*, *Myrtus communis*, *Pistacia lentiscus* and *Rosmarinus officinalis* the more common species. The climate is Mediterranean, with a mild and rainy winter (monthly average temperature is 10 °C in December and January), and a long dry summer, (mean temperature of 25 °C in July and August). Mean annual rainfall is around 540 mm, with 80% of precipitation occurring from October to March.

The study area is used for timber production, hunting (rabbit, partridge) and grazing. The area was gradually protected from grazing from 1970 to 2002. Wild herbivores (deer) were eliminated in 1970, and domestic goats excluded in 2002. The experiment began in 2007, after five years of the complete exclusion of browsers from the area. In the spring of 2007 a herd of 350 adult female *Payoya* goats (average weight of 40 kg) was introduced into the area at the care of a shepherd that moved it uniformly over the whole area during three consecutive days. The fourth day the herd grazed in the nearby dehesas. Thus the goats spent 280 days/year grazing the study area at a stocking rate of 2.7 goats / ha / yr; which has been characterized as moderate grazing (Green and Newell, 1982).

Nine fixed grazing exclusion plots (0.25 ha each) were installed in the pine forest prior to the introduction of goats. Five permanent linear transects 25 m long were established in each exclusion plot and its surrounding area: one inside the plot and four outside, in the grazed area, at the N, S, E and W of the exclusion plot. Vegetation was sampled using the point-intercept method, annotating the shrub species in contact with a stick placed every 10 cm along the transect. The height of each species in each point was also measured. Vegetation was sampled five times along two years: before the goats entered in the pine forest (April 2007), and every six months over a 24 month period of grazing (October 2007, April and October 2008 and April 2009).

Cover of each species in each plot and date was calculated as the percentage of points occupied by the species. Total shrub cover was calculated as percentage of points with shrub. Biovolume (m^3 / ha) of each species and of the shrub was calculated as the percentage of cover by mean height.

Species diversity in each plot and date was calculated with the Shannon–Wiener index H' (Magurran, 1988): $H' = -\sum p_i \ln p_i$, where $p_i = n_i/N$: n_i = number of points with species i and $N = \sum n_i$.

An ANOVA model for repeated measures was fitted for each dependent variable (total biovolume, biovolume of each species and species diversity). The model included two within-unit factors: treatment (grazed and non-grazed), and time (five sampling dates). The results are presented according to the Huynh-Feldt corrections. SPSS 18.0 for Windows (SPSS Inc., Chicago, IL, USA) was used in all statistical analyses.

Results

Continuous grazing significantly decreased the total biovolume of the scrub. In the grazed area the biovolume decreased 7.0% at 6 months and 23.1% at 24 months, relative to the initial measurements. By contrast, in the exclusion plots the biovolume significantly increased: 13.9 % at 6 months and 32.9 % at 24 months (Figure 1 and Table 1).

Species responded to grazing in different ways. The trend of change was significantly different in grazed and ungrazed plots in nine species (*Cistus ladanifer, C. libanotis, Erica scoparia, Halimium calycinum, Myrtus communis, Pistacia lentiscus, Phillyrea angustifolia, Quercus coccifera* and *Stauracanthus genistoides* + *Genista* spp., Table 1), which decreased in grazed plots and increased in ungrazed ones (Figure 1). The other eight species did not showed significant differences between grazed and ungrazed plots (Table 1). *Thymus mastichina, Rosmarinus officinalis, Lavandula stoechas, Helichrysum italicum, Daphne gnidium and Cistus crispus* increased in both areas, while *Halimium halimifolium* and *Cistus salvifolius* decreased (Figure 1).

Diversity index decreased significantly in the grazed area from 1.51 ± 0.12 before grazing to 1.30 ± 0.13 after grazing (HF eps = 0.241, $p < 0.001$), due to changes in species abundance, because no species were lost. In the ungrazed area diversity did not changed significantly along the study period (1.48 ± 0.15, after 24 month).

Biovolume loss in the grazed area was related with loss of cover and height. Table 2 shows the initial and final height, cover and biovolume of the species grouped by their regenerative strategies, seeders (spp) and resprouters (spp) (The list of resprouters and seeders is present in the legend of Table 2). Resprouter species were taller than seeders, and mainly lost height (Table 2). All these species lost biovolume in the grazed area (Table 1 and Figure 1). Seeders did not showed differences in height between grazed and ungrazed areas (Table 2), but differences in cover, losing cover in the grazed area. The majority of the seeders were not affected by grazing (Table and Figure 1).

Table 1. Epsilon values and P-values for the interaction between treatment (grazed, ungrazed) and time (five sampling dates), using Huynh-Feldt corrections. (*significant differences $p <= 0.05$)

Variable	Epsilon-values	P- values
Total biovolume	12.224	0.001*
Cistus crispus	1.236	0.301
Cistus salvifolius	1.440	0.255
Cistus ladanifer	6.083	0.013*
Cistus libanotis	3.921	0.042*
Daphne gnidium	1.875	0.190
Erica scoparia	4.971	0.030*
Halimium calycinum	4.320	0.048*
Halimium halimifolium	1.638	0.217
Helichrysum italicum	1.470	0.248
Lavandula stoechas	1.000	0.340
Myrtus communis	5.870	0.025*
Pistacia lentiscus	3.636	0.050*
Phillyrea angustifolia	5.870	0.028*
Quercus coccifera	14.297	0.004*
Rosmarinus officinalis	0.496	0.558
Thymus mastichina	0.404	0.606
Stauracanthus genistoides + *Genista* spp.	9.603	0.002*

Table 2. Height, cover and biovolume of species grouped according to their regeneration strategy: seeders (*Cistus crispus, C. ladanifer, C. libanotis, C. salvifolius, Halimium calycinum, H. halimifolium, Helichrysum italicum, Lavandula stoechas, Rosmarinus officinalis* and *Thymus mastichina*) and resprouters (*Daphne gnidium, Erica scoparia, Myrtus communis, Phillyrea angustifolia, Pistacia lentiscus, Quercus coccifera*, and *Genista* + *Stauracanthus genistoides* + Genista *spp.*) before and after 24 months of grazing in a Mediterranean pine forest in Doñana, SW Spain (Mean values ± SE)

	Height (cm)		Cover (%)		Biovolume (m^3/ha)	
	No Grazed area	Grazed Area	No Grazed area	Grazed Area	No Grazed area	Grazed Area
Initial						
Seeders	54.27 ± 6.72		32.25 ± 9.26		2299.98 ± 314.06	
Resprouters	90.14 ± 18.26		10.66 ± 3.72		970.58 ± 163.17	
After 24 months						
Seeders	63.69 ± 15.26	57.08 ± 6.19	41.78 ± 5.05	30.22 ± 3.48	2618.02 ± 471.92	2248.97 ±304.09
Resprouters	115.21 ± 8.47	59.11 ± 11.36	13.42 ± 3.52	7.75 ± 2.76	1387.96 ± 206.34	612.54 ± 145.22

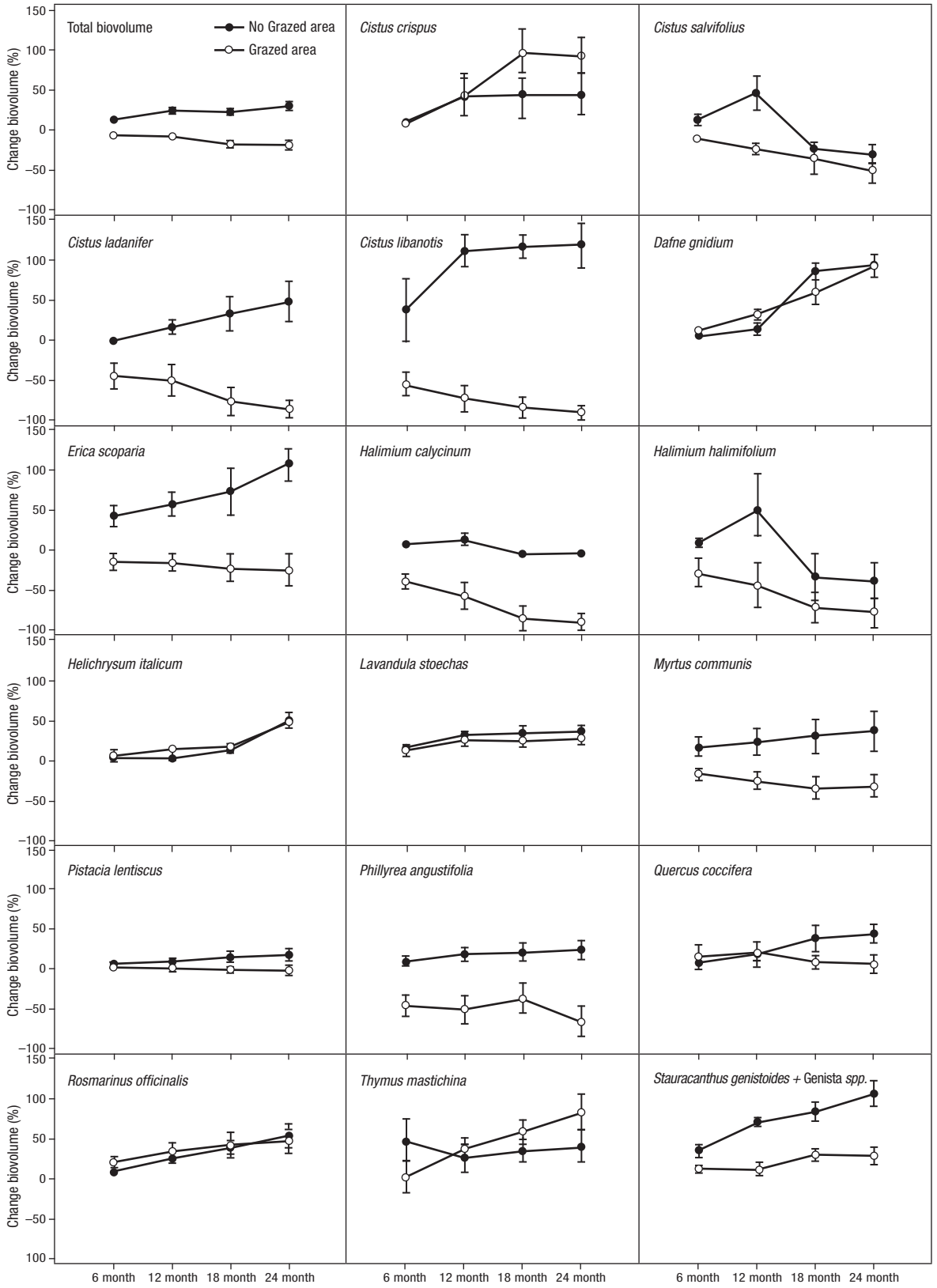

Figure 1. Changes in total and species biovolume along 24 months under goat grazing and in protected areas. (Mean values ± SE, n = 9).

Discussion

After two years of grazing with a stocking rate of 2.7 goats/ha/year the biovolume of the shrub decreased significantly. Resprouters, the taller species, decreased in height. Also, many of the species that decreased significantly (*Cistus ladanifer, Erica scoparia, Stauracanthus genistoides* + *Genista* spp., *Myrtus communis*, *Phillyrea angustifolia* and *Quercus coccifera*) have been described as highly inflammable, not only in summer, but throughout the year (Valette, 1997). The inflammability of a forest is determined by height, cover and mainly by the pyrophytism, or characteristic inflammability, of the shrub species of the understory (Valette, 1997), consequently, goat grazing reduced the risk of fire in the pine forest. Other studies have also showed that livestock can effectively control shrub biomass (Jauregui *et al.*, 2007; Celaya *et al.*, 2007).

Within the exclusion plots the biovolume of all the species increased, with the exception of two species, *Cistus salvifolius* and *Halimium halimifolium* that decreased after 18 months of exclusion due to the death of several individuals (senescence). Demographic characteristics of Cistus spp., such as a recruitment limited to 5 years after a fire, light inhibition of germination and short longevity could lead to a population decline at around 15 years after a fire event (Roy and Sonié, 1992). The low rainfall that has prevailed in Southern Spain in 2003-05, with annual rainfall well below average (200 mm and 382 mm, respectively, Data from the Natural Processes Monitoring Team of Doñana Biological Station) might have accelerated the process.

Species responded to grazing in different ways. Eight of them followed the same trend of change in the grazed and ungrazed plots, showing that they were not affected by grazing, possibly due to low consumption by goats (Martín *et al.*, 2011). Aromatic species as *Helichrysum italicum, Lavandula stoechas, Rosmarinus officinalis and Thymus mastichina,* with high oil content which reduces their palatability (Guillen and Cabo, 1996) were included in this group. Nine species followed opposite trends of change in the grazed and ungrazed plots, decreasing in the former and increasing in the latter. Species that are usually consumed by the goats, as *Erica* spp*., Halimium calycinum, Myrtus comminus, Phillyrea angustifolia* and *Quercus coccifera* (Mancilla-Leytón *et al.,* 2009) or intensively consumed when leafing, flowering or fruiting, as *Pistacia lentiscus* and *Stauracanthus genistoides* + Genista *spp.* (Martín *et al.,* 2011) are among these species.

Grazing significantly reduced species diversity, which did not decreased in the ungrazed areas. It was related with the decrease in biovolume of many species, because none of the species were lost. The stocking rate and length of grazing period reduced the biovolume and diversity of the shrubland, but was unable to remove species from it. Mediterranean shrublands have a long history of grazing by domestic animals (Emanuelsson, 2009), and are able to survive different disturbances (cutting, fire, grazing,...) due to the regeneration of lost organs (resprouting species) or the germination from the soil seed bank (germinating species).

Livestock grazing has historically been perceived as negative to environment due to overgrazing, desertification, methane emissions and decline in species diversity (Alados *et al.*, 2003). However, is not necessarily negative and in practice grazing can maintain natural or cultural landscape processes (Concepcion *et al.*, 2008). The proper use of livestock grazing can play a role in fire prevention while preserving species diversity, often replicating the ecological effects of the wild relatives of livestock, or those of other species now absent or extinct.

At present, silvopastoral systems attempt to reconcile the use of products and services of natural environment with a guarantee of permanence, or similarly attempt to pursue ecological, economic and social stability through the diversification of structures and products with an efficient land use. In this sense, the most important function of domestic herbivores is not only the production of meat and milk (economic activity in rural areas), but also the grazing of forests and shrublands for controlling the understory vegetation, reducing the fire risk at lower economic and environmental costs than mechanical cutting and herbicide application.

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References

Alados C, Pueyo Y, Giner M, Navarro T, Escos J, Barroso F, Cabezudo B, Emlen J, et al. 2003. Quantitative characterization of the regressive ecological succession by fractal analysis of plant spatial patterns. Ecol Model 163, 1-17.

Celaya R, Martínez A, Osoro K, et al. 2007. Vegetation dynamics in Cantabrian heathlands associated with improved pasture areas under single or mixed grazing by sheep and goats. Small Ruminant Res 72, 165-177.

Concepción ED, Díaz M, Baquero RA, et al. 2008. Effects of landscape complexity on the ecological effectiveness of agri-environment schemes. Landscape Ecol 23, 135-148.

Emanuelsson, U. 2009. The rural landscapes of Europe: how man has shaped European nature. Swedish Research Council Formas. 383 pp.

Green L R, Newell LA. 1982. Using goats to control brush regrowth on fuelbreaks. Pac. Southwest For. and Range Exp. Sta. Gen. Tech. Rep. PSW-59. 13 pp.

Guillén M D, Cabo N. 1996. Characterization of the essential oils of some cultivated aromatic plants of industrial interest. J Sci Food and Agri, 70, 359-363.

Jáuregui B, Celaya R, Garcia U, Osoro K, et al. 2007. Vegetation dynamics in burnt heather-gorse shrublands under different grazing management with sheep and goats. Agroforestry Syst 70, 103-111.

Mancilla-Leytón JM, Martin Vicente A. 2009. Análisis de la Apetencia del Ganado Caprino Por las Especies de Matorral en el Espacio Natural de Doñana. In La Multifuncionalidad de los Pastos: Producción Ganadera Sostenible y Gestión de los Ecosistema (Reine R, Barrantes O, Broca A, Ferrer C, eds). Huesca. Sociedad Española para el Estudio de los Pastos. pp. 643-648.

Martín A, Mancilla-Leytón JM, Parejo C, Fernández-Alés R, Leiva MJ, et al. 2011. The function of goat grazing in Doñana Natural Park. Options Méditerranéennes 100, 173-178.

McNaughton S. 1983. Compensatory plant growth as a response to herbivory. Oikos 40, 329-336.

Pausas JG. 2004. Changes in fire and climate in the eastern Iberian Peninsula (Mediterranean basin). Climatic Change 63, 337-350.

Röder A, Hill J, Duguy B, Alloza JA, Vallejo R, et al. 2008. Using long time series of Landsat data to monitor fire events and post-fire dynamics and identify driving factors. A case study in the Ayora region (eastern Spain). Remote Sens of Environ 112, 259-273.

Roy J, Sonié L. 1992. Germination and population dynamics of Cistus species in relation to fire in Journal. App Ecol 29, 647-655.

Tsiouvaras CN, Havlik NA, Bartolome JW, et al.. 1989. Effects of Goats on Understory Vegetation and Fire Hazard Reduction in a Coastal Forest in California. Forest Sci 35, 1125-1131.

Valette, J.C. 1997. Inflammabilities of Mediterranean species. In Forest fire risk and management Porto Carras (Balabanis P, Eftichidis G, Fantechi R. eds.). Chalkidiki, Greece. pp. 51-64.