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Establishing grazing and grazing-excluded patches increases plant and invertebrate diversity in a Mediterranean oak woodland

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ABSTRACT

Grazing is a global, dominant land use affecting biodiversity and ecosystem processes. In Mediterranean ecosystems grazing is a major ecological and evolutionary driver but, surprisingly, there is little information on the use of grazing as a tool to manage biodiversity in these ecosystems. We conducted an experiment to assess if establishing grazing and small scale grazing-excluded areas would increase plant and invertebrate diversity in a Mediterranean evergreen oak woodland. Plant community traits were different between treatments. Biomass of herbs ($176.7 \pm 18.3\ g\ m^{-2}$ *vs* $100.4 \pm 10.6\ g\ m^{-2}$) and litter ($291.0 \pm 38.3\ g\ m^{-2}$ *vs* $186.8 \pm 26.4\ g\ m^{-2}$), as well as the total cover of legumes (0.83 ± 0.05 *vs* 0.91 ± 0.03) were higher, and the proportion of bare ground (0.83 ± 0.05 *vs* 0.91 ± 0.03) was lower, in ungrazed plots. There were no differences in the number of plant species between treatments. Some plant species and invertebrate taxa were recorded exclusively in grazed or ungrazed plots. Invertebrate detritivores and sap sucking insects were more abundant in ungrazed plots. Ant assemblages were functionally different between treatments: Honeydew-gatherer ants were associated with ungrazed and higher plant biomass plots, and seed-eaters as well as aggressive predator ant species were associated with grazed, open habitat, plots. Management practices that maintain grazing and small scale grazing-excluded areas can increase habitat heterogeneity and promote herbaceous plant and invertebrate diversity at the local level.

1. Introduction

Grazing is a global, dominant land use covering more than 25% of the terrestrial surface of the globe and a larger geographic area than any other land use (Asner et al., 2004). Grazing affects plant communities and associated fauna, with implications for biodiversity and ecosystem processes (Huntly, 1991; Rooney and Waller, 2003). It can lead to changes on plant species composition (Putman et al., 1991), community nutrient pools (Binkley et al., 2003; Pastor et al., 1993; Piñeiro et al., 2009), plant productivity (Frank et al., 2002) or the structure of plant communities (Putman et al., 1991). Grazing can also affect plant-associated animal communities, particularly those of invertebrates (Dennis et al., 1998; González-Megías et al., 2004; Lindsay and Cunningham, 2009; Putman et al., 1989) and consequently mediate ecosystem functions where invertebrates have a key role such as decomposition, plant seed dispersal and pollination, or regulation of other invertebrate populations through predation and parasitism (Coleman et al., 2004; Samways, 2005).

The effects of grazing on plant and invertebrate diversity have been investigated in different ecosystems (Suominen and Danell, 2007; Singer and Schoenecker, 2003) and using grazing management to promote biodiversity has been addressed (Durant et al., 2008; Gordon et al., 2004; Pykala, 2003), particularly in temperate ecosystems (Rook and Tallowin, 2003; Suominen and Danell, 2007; van Wieren and Bakker, 2008). Surprisingly, there is a dearth of information for Mediterranean systems (but see Sternberg et al., 2000 and Gordon et al., 1990) where, paradoxically, grazing is a major ecological and evolutionary driving force (Perevolotsky and Seligman, 1998). In the Mediterranean region, many plant species have evolved life history traits adapted to grazing, including high re-sprouting capability of shrub species or summer dormancy of mainly annual herb species (Agra and Ne'eman, 2011; Naveh and Carmel, 2003).

Grazing prevails in different natural or human-shaped ecosystems. *Montados*, for example, are savannah-type ecosystems where grazing is usually a dominant land-use. *Montados* have a dominant tree cover of cork (*Quercus suber*) or holm oak (*Quercus rotundifolia*) and a diverse grassland understorey, interspaced with shrubland patches, which are traditionally grazed by livestock (Bugalho et al., 2009). The system occurs in the Western part of Mediterranean Basin, both in the southern Europe and North Africa, and is a dom-

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inant land use in southern Iberian Peninsula. Beyond providing direct products as cork, livestock, or game species, *montados* harbour high biodiversity (Diaz et al., 1997) being classified as an habitat of conservation interest under the European Union (EU) conservation policies (Bugalho et al., 2011).

Partly due to EU policies of financial incentives (Kleijn and Sutherland, 2003; Moreno and Pulido, 2009), sheep have been progressively replaced by cattle in the Iberian Peninsula *montados*. Until five decades ago grazing of oak woodlands, mainly by sheep or goats, were associated with transhumance which involved moving animals to high mountain pastures in summer, when pastures dried off, and back down to lower pastures in mid-autumn, when pastures of oak woodlands became green again. This practice, almost completely abandoned nowadays, led to lower stocking rates than those presently associated with cattle (Moreno and Pulido, 2009) and which are impacting oak regeneration negatively. More recently, deer were introduced, for hunting purposes and as a complementary source of income in these marginal agricultural lands. Nowadays, cattle and deer frequently co-occur, or cattle were substituted by deer (mainly red deer *Cervus elaphus*), as the dominant grazers of the system.

Grazing management is crucial for the conservation of *montados*. For example, establishing grazing exclusion areas has been suggested as a way to promote natural regeneration of oaks in these systems (Ramírez and Díaz, 2008). Also, under incentives for sustainable management of *montados* such as the Forest Stewardship Council (FSC) certification scheme (Auld et al., 2008; Bugalho et al., 2011), landowners are increasingly requesting information on best grazing management practices for promoting biodiversity.

Our aim was to assess the effects of grazing on the diversity of plant and invertebrates, particularly ant assemblages, in a *montado* system. This has important implications for the management of ecosystems where grazing is a dominant land use, particularly when biodiversity is also a management objective. We focused on ant assemblages as ants are in general good bio-indicators of habitat conservation status and usually respond readily to ecological changes promoted by grazing (Read and Andersen, 2000; Kruess and Tscharntke, 2002; Suominen et al., 2008). Although assessing the effects of grazing gradients on biodiversity is of research interest (Hester et al., 2000) we focused on comparing coexisting grazed and small grazing-excluded areas, with a typical deer density of cork oak woodlands. This is relevant to management, as grazing exclusion would be a relatively simple and low-cost practice to implement for promoting biodiversity at the local level.

We aimed to respond to the following questions:

(1) Can co-occurrence of grazing and small grazing-excluded areas promote plant and invertebrate diversity at the local level? If, yes how does diversity vary between grazing treatments?
(2) Which plant and invertebrate taxonomic groups are promoted by grazing treatments?

More specifically and concerning the ant group:

(3) How do differences in plant community traits (biomass, species composition, litter) induced by grazing relate to ant assemblages?

We hypothesised that co-occurrence of grazed and grazing excluded (ungrazed) patches may promote local biodiversity of plant and invertebrate communities and that grazing exclusion may be used as a tool to promote biodiversity in evergreen oak woodlands.

2. Methods

2.1. Study area

The study area consisted of an estate of approximately 800 ha located in Vila Viçosa, in south-east Portugal (38 47′N, 78 25′W). This region has a Mediterranean-type climate with mean summer temperatures of 25 °C and daytime maxima often exceeding 35 °C. Annual precipitation varies seasonally between 275 mm and 900 mm with at least 65% of rain falling during the winter months. A density of approximately 0.35 red deer (*C. elaphus*) per ha and of 0.1 fallow deer (*Dama dama*) per ha were present in the area during the period of study (Bugalho, unpublished data). These deer densities, generally higher than in northern Europe, are common in the Iberian Peninsula (Carranza, 1993). Deer densities were maintained by a limited culling policy in the area. The study site is a *montado* system with a dominant tree cover of holm oak and cork oak and a diverse grassland understory dominated by grasses, with a lower abundance of legumes species. Density of trees varies, on average, between 50 and 60 individuals per ha. Shrub cover was dominated by gum cistus (*Cistus ladanifer*) with blackberry (*Rubus* spp.) and ash (*Fraxinus angustifolia*) occurring along streamlines.

2.2. Experimental design

Five blocks of paired fenced (grazing-excluded) and unfenced (grazed) plots (25 m × 25 m) were established in homogeneous areas of grassland in the study area, in July 2001, using fences of 2.20 m height.

Cover of vascular plant species and bare ground was measured using the pin-point quadrat method (Bonham, 1989). Four subplots (2 m × 4 m) were randomly located within each of grazed and ungrazed plots and the pin-point quadrat (9 needles per frame quadrat) randomly positioned 8 times in each of these subplots. Cover of plant species and bare ground was recorded as the frequency of the number of touches of the quadrat needles in each species or bare ground, in relation to the total number of touches.

For estimating plant biomass, vegetation was clipped to ground level, using a 50 cm × 25 cm quadrat, in each of the same subplots used for estimating plant cover. All litter within the quadrat area, composed mainly of dead oak leaves and other dead plant material, was also collected. Samples were kept in labelled plastic bags at 5 °C until they were taken to the laboratory, oven-dried at 60 °C to a constant weight and weighed.

For sampling soil invertebrates, one pit-fall trap (10 cm diameter and 22 cm deep) was placed in each of the subplots (total of 4 pit-fall traps per treatment plot) used to estimate plant species composition. Pit-fall traps were filled with car liquid refrigerant, to preserve trapped animal specimens and left in the ground for 15 days. In order to sample both ground and vegetation invertebrates, sweep-net (30 cm diameter) sampling was also conducted, during the same period, once in each of 2 parallel transects (25 m length each), in ungrazed and grazed plots. The collected animal material was sealed in plastic vials filled with ethanol until it was identified in the laboratory.

All invertebrate samples were identified to the order level and the two most abundant orders, Hemiptera and Hymenoptera, to the family level. Formicidae (ant family) was identified to the species level.

Both plant and invertebrate sampling were conducted in late May 2003, with plants being sampled only after invertebrate sampling was completed, as late spring is usually the period of highest invertebrate activity and plant growth in this Mediterranean-type climate region.