Ecological effects of bottom-up game management: does supplemental feeding mitigate herbivory pressure on native vegetation?

María Miranda^{1,2}, Ignacio Cristóbal¹, Leticia Díaz¹, Marisa Sicilia¹, Eduarda Molina-Alcaide³, Jordi Bartolomé⁴, Yolanda Fierro⁵ & Jorge Cassinello¹

¹Instituto de Investigación en Recursos Cinegéticos, IREC (CSIC-UCLM-JCCM), Ronda de Toledo s/n, 13071, Ciudad Real, Spain

²Centre for African Ecology, School of Animal, Plant and Environmental Sciences, University of the Witwatersrand, Private Bag 3, Wits 2050, Johannesburg, South Africa

³Estación Experimental del Zaidín (CSIC), Profesor Albareda 1, 18008 Granada, Spain

⁴Departament de Ciència Animal i del Aliments, Grup de Recerca en Remugants, Universitat Autònoma de Barcelona, Bellaterra, Barcelona, Spain

⁵Yolfi Properties S.L., Abenójar, Ciudad Real, Spain

Corresponding author: María Miranda, e-mail: maria.miranda@wits.ac.za, maria.mirandaroves@gmail.com; phone number: +34687770848

Running head: Effect of ungulate supplemental feeding on plants

Abstract

Context

Supplemental feeding of large herbivores is a common management tool mainly aimed at promoting healthy populations and increased productivity and trophy sizes. Such management measure may indirectly affect herbivore effects on the natural plant community through altered foraging patterns. The quantification of the ecological effects of large herbivore management is important for designing holistic management and conservation programmes.

Aims

Here we aimed at quantifying the ecological effects of supplemental feeding of Iberian red deer *Cervus elaphus hispanicus* on the composition and development of Mediterranean woody plant community.

Methods

An experiment was set up in a hunting rangeland located in central Spain, where female deer were kept in enclosures with either exclusive access to natural forages or with additional *ad libitum* access to a nutritionally rich concentrate. The experiment also included a control area where deer were absent.

Key results

We observed significant differences in browsing impacts between the supplemented, non-supplemented and control areas, and such effect varied for the different plant species. Observed differences in browsing intensity related to the nutritional composition of plants in relation to fodder. Native vegetation development differed across treatments and species, while the presence of deer and the concentrate supplied did not influence relative shrub species abundances.

Conclusions

Provisioning of supplemental feeding to red deer lead to increased herbivory on plants whose nutrient content complemented that of the supplemental feeding provided.

Implications

In order to alleviate herbivory impact on all shrubs, we suggest that composition of supplemental feeding should adjust both to the natural forage availability and quality and to ungulates' requirements across seasons.

Key words

herbivory, native vegetation, red deer, supplemental feeding, wildlife management

Introduction

Large wild herbivores provide a source of income for many rural communities around the world as assets for commercial activity based on their aesthetic and hunting values (Barnes *et al.* 1999; Loibooki *et al.* 2002; Van der Merwe *et al.* 2004; Fischer *et al.* 2013). They therefore often occur under intense management practises directed towards an increased productivity and trophy size, and to promote the maintenance of healthy populations and habitats (Mysterud 2010). Management practices include top-down regulation such as selective harvesting, fencing, breeding programmes, release of farm-reared animals and predator control; and bottom-up regulations such as water provisioning, supplemental feeding, and habitat management (Reynolds and Tapper 1996; Putman and Staines 2004; Allendorf *et al.* 2008; Hayward and Kerley 2009; Macaulay *et al.* 2013).

Large herbivores have a crucial role in the ecosystem as they shape the structure and determine the function and dynamics of both lower and higher trophic levels (Du Toit and Cumming 1999; Gordon and Prins 2008). Thus the implementation of top-down management measures on large herbivores may negatively affect higher trophic levels in the ecosystem by precluding predator mobility due to fencing or by reducing predator populations through control measures (Packer *et al.* 2009; Somers *et al.* 2012), while facilitating other non-harvested prey species (Arroyo and Beja 2002). Such top-down management effects might additionally cascade and alter the plant community due to increased impacts on vegetation caused by fence restriction of herbivore movements and limitation on predator populations (Halofsky and Ripple 2008; Ripple and Beschta 2008; Cassidy *et al.* 2013). Alteration of herbivore effects on the lower trophic level (i.e. the plant community) due to bottom-up practises directed to improve resource availability are also expected, although they have more rarely been evaluated (Cooper *et al.* 2006). The quantification of the ecological effects of the different tools implemented for large herbivore management is of crucial importance for the design of holistic management programmes that consider the different ecosystem components (Weisberg *et al.* 2002) and that allow for simultaneously benefiting economic, social and conservation aims (Gordon *et al.* 2004).

Among the bottom-up management practises, supplemental feeding of wild herbivores is

commonly implemented in North America and Europe with different motivations (Peek *et al.* 2002; Putman and Staines 2004). The primary aim is usually to enable animals to meet their nutrient requirements under limiting environmental conditions or under ungulate overabundance, ensuring their survival and reproduction while maximizing trophy size and quality (Baker and Hobbs 1985; Ouellet *et al.* 2001; Rodríguez-Hidalgo *et al.* 2010). In some cases there is a secondary target: to mitigate herbivore pressure on commercial forests, agricultural systems and native vegetation under the typical high ungulate densities existing in managed rangelands (Kowalczyk *et al.* 2011; Garrido *et al.* 2014). Providing animals with dietary supplements may alter their feeding patterns on natural forages towards a more selective feeding (Stephen and Krebs 1986; Boutin 1990; Murden and Risenhoover 1993), thus leading to a variation in plant species abundances, diversity, development and structure, which subsequently affects the suitability of the habitat for many other organisms (Gordon *et al.* 2004). However, the impacts of game supplemental feeding on native plant community composition and development are still poorly known, with studies being mainly focused on reducing damages to crops (Geisser and Reyer 2004; Calenge *et al.* 2006) or concentrated on the effect of distance to feeding station on browsing intensity (Gundersen *et al.* 2004; Cooper *et al.* 2006).

In Spain, hunting activity has great social and economic importance with over 60% of the territory devoted to game related activities (FACE 2010), and captures having directly generated over 1000 million euro in 2011 (Garrido 2012). Castile-La Mancha, central Spain, is a particularly active region in hunting terms where six big game species occur, yielding the 28% of big game hunts in Spain (Ministerio de Agricultura, Alimentación y Medio Ambiente 2010). Of these, the Iberian red deer (*Cervus elaphus hispanicus*) is one of the most appreciated game species and occurs at higher densities than other ungulates, sometimes reaching 0.5 individuals/ha (Lazo *et al.* 1994; Vicente *et al.* 2007). Red deer in Spain mainly occurs in privately managed hunting estates that constitute potential important reservoirs of the native Mediterranean flora and fauna, but are subjected to intensive management practises (chiefly fencing, supplementary feeding and predator control) of which ecological outcomes have not always been quantified. Here we specifically focused on the ecological effects of supplemental artificial feeding of red deer populations on the Mediterranean woody plant community. For that purpose we set an experiment in a privately owned hunting estate located in Castile-La Mancha, where deer

were kept in enclosures with either exclusive access to natural forages or with additional year-round *ad libitum* access to a nutritionally rich concentrate. This allowed us to assess the direct effects of supplemental feeding on plant use by Iberian red deer and the derived effects on the development and composition of the native Mediterranean plant community. Supplemental feeding was expected to influence browsing intensity and hence plant height (Vallentine 1990). However, we predicted the effect of supplementation to vary for different plant species due to an increased selectivity of supplemented deer for nutritionally-rich plants caused by a reduction in the time animals need to invest on food searching and handling (Boutin 1990; Murden and Risenhoover 1993). This would lead to effects on the plant community composition. We discuss to which extent a measure implemented with the main aim of alleviating resource limitation for high-density herbivore populations, additionally influenced herbivory effects on the natural plant community.

Materials and methods

Study area

The study was carried out in an experimental fenced area, located within a private hunting rangeland in Ciudad Real province, central Spain (38°54'N 4°16'O). The region has a Mediterranean continental climate characterised by dry hot summers that lead to restrictions in resource availability and quality for herbivores between July and September (mean annual rainfall 356 mm, and in August mean rainfall 7 mm and mean temperature 25°C, period 1971-2000). Rains concentrate in spring (April-June) and autumn (October-December), while winters (January-March) are generally dry and with mild temperatures (mean temperature in January: 5.7°C) (Agencia Estatal de Meteorología 2010).

Two different vegetation types are present in the area; a savanna-like vegetation type made up of pastures and scattered holm oaks (*Quercus ilex*), and a Mediterranean scrubland comprising perennial shrubs dominated by *Cistus ladanifer*, *Phillyrea angustifolia*, *Rosmarinus officinalis*, holm oaks, *Genista hirsuta*, and various *Erica* spp. Grasses dominate the herbaceous layer, with a smaller proportion of forbs (mainly *Compositae*, *Leguminosae*, *Cistaceae* and *Brassicaceae*). The experimental area had a surface of 29.5 ha, a total perimeter of 2500 m, and was divided into three contiguous enclosures where deer were kept in high densities in relation to the regional context

(Vicente *et al.* 2007; Acevedo *et al.* 2008) and different treatments were applied in each enclosure:

- Supplemented area: 10.3 ha of pastures and 3.2 ha of Mediterranean scrubland in which 15 Iberian red deer hinds were kept with year-round *ad libitum* and protein-rich dietary supplement (pellets) provided in a trough.
- Non-supplemented area: 10.3 ha of pastures and 3.2 ha of Mediterranean scrubland in which 14 Iberian red deer hinds were kept with no dietary supplement.
- Control area: 0.22 ha of pasture and 2.3 ha of Mediterranean scrubland in which red deer were excluded.

Topography and aspect as well as initial vegetation composition were similar for the different enclosures (Fernández de Mera 2007). All deer were free ranging non-supplemented individuals captured as calves at weaning in Cabañeros National Park (50 km away from the study area) and released and kept in the study enclosures between September 2003 and November 2007 when all animals were culled (Santos *et al.* 2013). Water supply, sanitary treatments applied, and health status prior to release were similar for animals on supplemented and non-supplemented areas (Fernández de Mera 2007; Santos *et al.* 2013). No other ungulates were present in the experimental area, while European wild rabbit (*Oryctolagus cuniculus*) could access all the experimental enclosures. The supplemental concentrate provided comprised cereals and legumes in different proportions depending on the season, with composition differing between October-March and March-October. The experiment was set up in 2003 and before that the study area had been fenced excluding ungulate herbivory for 10 years (Fernández de Mera 2007). We followed the European and Spanish guidelines and laws for the use of animals in research.

Plant sampling

In July 2007, after almost four years of differing feeding treatment, availability of shrub species was recorded following the line-intercept method (Eberhardt 1978; Hanley 1978) along two 100 m-transects randomly distributed within each of the enclosures. Shrubs were regarded as available if they had green foliage within red deer reach (≤ 2 m high).

10 individuals of each of the shrub species present were randomly selected in each of the three areas (when available). Height was measured as a proxy to plant development, and the number of browsed branches over the total of branches was counted (hereafter accumulated browsing intensity). Accumulated browsing intensity was independently collected for upper and lower vegetation strata (individuals >1 m and ≤ 1 m, respectively). European wild rabbit, which foraging activity mainly occurs in the lower 50 cm of shrubs (Bergman *et al.* 2005), had access to all three enclosures. Browsing signs by rabbit could not be distinguished from those of deer browsing. In order to account for rabbit effects, browsing signs were sampled above 50 cm height for plant individuals in the upper stratum and below 50 cm for individuals in the lower stratum and assumed rabbit effect to be equal for all treatments. This approach allows for independent comparisons between plant parts accessible to both rabbit and deer on the one hand, and between plant parts accessible only to deer on the other hand, thus accounting for the rabbit browsing effect.

Nutrient composition of plants

Samples of the most ubiquitous shrub genera within the experimental area (*Cistus*, *Cytisus*, *Erica*, *Genista*, *Phillyrea*, *Quercus* and *Rosmarinus*) were seasonally collected in order to determine their nutritive value, as well as samples of the concentrate supplied in the supplemented area both between March and October and between October and March. All samples were dried in an oven at 60°C until constant weight and then stabilised at ambient temperature for 48h. They were then ground (1 mm). Dry matter (DM) content was determined by drying in a fan-forced air oven at 103 ± 1°C for 24h, and organic matter (OM) was determined by incineration in a muffle furnace at 550°C for 3h. Total N content was determined by using the Kjeldhal method. Those analyses were carried out following the methodology of AOAC (2005). Neutral detergent fibre (NDF), acid detergent (ADF) fibre, and acid detergent lignin (ADL) were determined by the sequential procedure of Van Soest *et al.* (1991) using an Ankom 200 Fiber Analyser (ANKOM Technology Corporation, Macedon, NY, USA). Both NDF and ADF were expressed without residual ash. Hemicellulose (HC) was estimated as the difference between NDF and ADF, and cellulose (C) as the difference between ADF and ADL. All analyses were done on duplicate samples and results are reported as g per 100 g DM.

Data analysis

The effect of deer presence and of supplemental feeding on browsing intensity and plant height was evaluated by three linear models. Accumulated browsing intensity on the upper and lower stratum and height were the response variables, and treatment and plant species were the predictors in the linear models. For each of those analysis we only used the plant species for which we had collected data for at least three individuals per category, thus, six species were analysed for supplementation effects on the upper stratum browsing intensity (n=135), four for the lower stratum browsing intensity (n=97), and 10 species for the effects on plant height (n=232). To account for heterocedasticity, height data were log-transformed, browsing intensity on the upper stratum was arcsin-transformed (Zar 1984), while we used a variance exponential weight function in data for browsing intensity in the lower stratum (Pinheiro and Bates 2000; Pinheiro *et al.* 2014).

We quantified the effect of treatment on plant community composition by means of a permutational MANOVA using dissimilarity matrices. This is a non-parametric method applicable e.g. to test responses of species relative abundances across different treatments, when assumptions of normality are violated (Anderson 2001), as is the case with our data. We used the Euclidean distance to calculate the dissimilarity matrix and we used 999 random permutations.

A Principal Component Analysis (PCA) was carried out to reduce the set of nutritional variables analysed and in order to describe the seasonal nutritional differences among the different shrub species and the fodders. The correlation matrix between original variables was used. Principal components were not rotated, as this did not improve the variance explained by the principal components. Nutritional variables were considered to be explanatory of nutritional differences between plants when their correlation with the principal components was higher than 0.6.

We conducted all statistical analyses in R version 3.1.0 (R Core Team 2014) using the nlme package for linear models (Pinheiro *et al.* 2014), vegan for permutational MANOVA (Oksanen *et al.* 2013) and FactoMineR for the PCA (Husson *et al.* 2014).

Results

Effect of supplemental feeding on browsing intensity

Individuals in the upper stratum belonged to *Arbutus unedo*, *Cistus ladanifer*, *Erica cinerea*, *Erica scoparia*, *Phillyrea angustifolia*, and *Quercus ilex* species. In the lower height stratum, the species present were *Genista hirsuta*, *Globularia alypum*, *Lavandula stoechas*, and *Rosmarinus officinalis*. For plant individuals belonging to the upper stratum, we measured browsing signs over 50cm, representing the plant parts only accessible to deer browsing. The degree of accumulated browsing intensity for this stratum significantly varied between treatments depending on the plant species measured (treatment*species: $F_{10,117} = 8.5803$, $P < 0.0001$). Browsing intensity in this stratum was, for all plant species, lower for individuals in the control area where ungulates had been absent for 10 years (Figure 1a). In the area where deer were present and supplemented with fodder, herbivory damages were reduced for *C. ladanifer* and *Q. ilex* while the browsing impact increased for both *Erica* species as compared to the non-supplemented area.

For plant individuals which height was less than 1m (i.e. lower stratum), we measured browsing signs under 50 cm, representing the plant parts accessible for both deer and rabbit browsing. There was an interactive effect between treatment and plant species on the degree of browsing intensity below 50cm (treatment*species: $F_{6,85} = 5.01947$, $P < 0.001$). As shown in Figure 1b, browsing was reduced for *G. alypum* in the control area as compared to areas where deer was present. *L. stoechas* and *R. officinalis* were less browsed when supplementary feeding was provided.

Effect of supplemental feeding on vegetation height

The treatment applied significantly interacted with species on its effect on vegetation height ($F_{18,259} = 1.99$, $P = 0.01$), with no consistent effect of concentrate supply across plant species. Thus, *A. unedo* showed a decreased height in the non-supplemented area as compared to the other two treatments, while *P. angustifolia* and *Q. ilex* were higher in non-supplemented areas as compared to those in which deer were supplied with fodder (Figure 2). *C. ladanifer* was higher in the control area.

Effect of supplemental feeding on plant community composition

We did not find significant differences in the plant community composition across

treatments ($F_{2,5} = 0.95$, $P = 0.29$).

Nutrient composition of plants and supplemental feeding

Seasonal nutrient composition of plants and supplemental feeding is shown in Table 1. The two first principal components (PC) summarising the nutrient composition of plants, accounted for the 58.31 and 27.20 % of the variability, respectively. The first component (PC1) distinguished species with a high OM, DM, HC and C from those with high content in total N (Table 2, Figure 3a). The second component (PC2) characterised plants according to their C and total N content (Table 2, Figure 3a). Broadly, the first axis allowed a distinction based on a higher total N but lower OM, DM, HC and C contents in fodders as compared to natural forages (Figure 3 a and b). Conversely, the second axis characterised the genera *Cytisus* and *Genista* as richer in total N and C as compared to the *Erica* genus.

Discussion

Supplemental feeding of large herbivores is a widespread management tool aimed at reducing game nutritional stress under seasonal resource restrictions or under herbivore overabundance. A parallel study in the experimental set up used here found greater levels of fat reserves and better nutritional conditions on supplemented study hinds as compared to non-supplemented ones (Santos *et al.* 2013). Our results show that such supplementation additionally affected deer effects on the natural plant community through altered foraging patterns. We observed significant differences in browsing impacts and native vegetation development between the supplemented, non-supplemented and control areas, and that effect varied for the different plant species. Instead, the presence of deer and the provisioning of dietary supplements in the form of a concentrate did not modify plant community composition.

Red deer have traditionally been classified as mixed-feeders (Hofmann 1989) with an important woody component in their diets (Gebert and Verheyden-Tixier 2001). Microhistological analyses of plant remains in faeces of red deer occurring in our study area had previously confirmed such feeding strategy, being the woody component in their diets larger than that of herbaceous plants throughout the year (Miranda *et al.* 2012).

The provisioning of nutritionally-rich readily-accessible supplements is expected to reduce

herbivores' dependence on less nutritious native shrubs (Stephens and Krebs 1986), alleviating herbivory pressure on the plant community particularly in periods of resource limitation (Vallentine 1990; Moser *et al.* 2006). We specifically predicted the effect of supplementation to vary for different plant species due to an expected increased selectivity of supplemented deer for nutrient-rich plants (Boutin 1990; Murden and Risenhoover 1993). Accordingly, our study outcomes yielded a plant species-specific effect of supplemental feeding on red deer impacts. Thus, most plants suffered an increased browsing impact in the non-supplemented area (e.g. *C. ladanifer*, *Q. ilex* in the higher stratum, and *L. stoechas* and *R. officinalis* in the lower stratum), while other plants received instead a higher herbivory impact in the supplemented area (*E. cinerea* and *E. scoparia*). We suggest that the reason for this inconsistent browsing pattern on different plant species across treatments lies on the high heterogeneity in plant nutrient composition. Fodders were richer in proteins but depleted in digestible fibres (HC and C) as compared to native plants. This could have led deer to alter their foraging strategy when receiving supplemental food, which allows them to increase their selectivity and devote a greater effort to searching and feeding on forages especially rich in HC and C and poor in N (e.g. *Erica spp.*) in order to complement the nutrients acquired by supplement consumption. Plant cell wall fibres (HC and C) in coarse-textured form (i.e. non-ground or non-pelleted fibres) have a crucial physiological function as they promote the rate of passage through the digestive tract in herbivores and they contribute to maintaining the rumen pH in a range that benefits the fibre-digesting microbes (Cammel *et al.* 1972; Sudweeks *et al.* 1981; Van Soest 1982; Mertens 1997). On the other hand, although herbivores generally respond positively to N content in plants (White 1993), diets with high protein content may lead to high ammonia concentrations in rumen that have toxic effects in ruminants (Chalupa *et al.* 1970; Fernández *et al.* 1990; Parker *et al.* 1995). In this respect, adequate crude protein contents for maintenance have been set in deer between 4 and 9% (Dryden 2011), while the crude protein content (6.25 times the total N content) in the fodder supplied to our study hinds was of 19 and 20% in the March-October and October-March periods, respectively. Study animals seem to search for plants that allow for adjusting the imbalances in the nutrient content of the supplemental feeding provided (Provenza 1995). Indeed bark stripping by deer has often been observed as a way to meet their dietary requirements when receiving low-fibre supplemental pellets (Ueckermann 1984; Purman and Staines 2014). In addition, components not analysed

here such as secondary plant compounds, minerals or metabolisable energy are very probably influencing deer use of available vegetation (Verheyden- Tixier *et al.* 2008; Timmons *et al.* 2010; Ceacero *et al.*, in press)

The effect of treatment on plant height also varied depending on the plant species considered. Some studies have reported a slower plant development reflected in a lower plant height in patches under high herbivory pressure (Schoenecker *et al.* 2004; Kupferschmid and Bugmann 2008). Observed differences in plant height between treatments, however, were probably not exclusively influenced by deer browsing but were likely additionally affected by varying association patterns and competition relationships between plant species mediated by herbivory in the different treatments (Saunders and Puettmann, 1999; Miranda *et al.* 2011), and by the species-specific degree of tolerance and overcompensation after herbivory events (Owen and Wiegert 1976; Augustine and McNaughton 1998; Del-Val and Crawley 2005). Such range of factors affecting plant development, in terms of height, could explain the lack of a consistent plant response to deer presence and feeding treatments.

In spite of the strong interactive effect between treatment and plant species on browsing impacts and plant development, we could not find any response of plant community composition to the different treatments. This lack of effect on community composition could be explained by the relatively short duration of the experiment. Alterations in plant relative availabilities in response to changes in foraging patterns might instead be sensed in the long term (Edenius *et al.* 2002; Perea *et al.*, 2014).

In sum, we found a short-term (four years) effect of supplemental feeding on deer browsing impact and plant height that differed according to the plant species considered. However, no response was detected in relative shrub species abundances. We found that herbivory impacts increased on forages rich in those nutrients that were lacking in the supplied fodder. So, in order to equally reduce excessive herbivory pressure on all native plants during limiting periods, managers should not only focus in supplying concentrates rich in nutrients such as proteins or soluble sugars, but should additionally consider incorporating other functionally and physiologically relevant nutrients (e.g. digestible cell wall fibres, Van Soest 1978; Putman and Staines 2004), according to ungulate seasonal

requirements. This seems particularly important for animals such as grazers and mixed feeders which are adapted to the consumption of diets with high cellulose contents (Hanley *et al.* 1982; Hofmann 1989). The supplementation with fibre-rich supplement in the form of sown pastures would allow for herbivore selection between forages, while such selectivity is impaired when providing finely-ground pelleted forage (Van Soest 1996; Putman and Staines 2004). Wildlife managers should, nevertheless, keep in mind the various unintended effects of feeding supplements to wild ungulates. Most of those effects are related to increased animal densities and aggregation and include alterations in population dynamics, selection pressures, behaviour, parasitism and disease risks (Milner *et al.* 2014). Managers are hence confronted with multiple trade-offs when trying to keep a healthy and productive deer population while promoting habitat conservation, and a good management practise might require the monitoring of unintended effects of management measures.

The outcomes yielded by this study show that provisioning of supplemental feeding leads to increased herbivory on plants whose nutritional content complements that of the provided supplement. This suggests that variations in natural forage availability and quality across plant phenological states as well as variability in ungulates' physiological requirements should be considered to adjust supplement composition, in order to equally decrease herbivory impact on all types of shrubs. Regarding the extrapolation of our results to other populations of red deer, we should bear in mind that no males were present in our enclosures, with the result of hinds not undergoing periods of gestation and lactation. These highly nutritionally demanding states would be expected to affect hinds' use of resources (Landete-Castillejos 2003; Parker *et al.* 2009). Our findings thus, need to be further tested in natural deer populations where the herbivory effects on native vegetation represent that of naturally co-occurring sex-age classes and phenological states. In addition, impacts by deer on vegetation are density-dependent (Gill 1992), where herbivore density and herbivory impact are non-linearly related (Hester *et al.* 2000). Studies including enclosures or areas naturally differing in animal densities would thus be desirable to fully understand the effect of the game supplementation practice on plant community.

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Figure captions

Figure 1. Mean $\pm$ SE of browsing percentage on shrub species corresponding to the upper (A) and lower (B) strata in the study site across treatments; control (black squares), non-supplemented (white circles), and supplemented areas (black circles). Browsing intensity was measured over 50 cm height for the upper stratum and under 50 cm height for the lower stratum.

Figure 2. Mean $\pm$ SE of shrub species heights across treatments; control (black squares), non-supplemented (white circles), and supplemented areas (black circles).

Figure 3. Plot of a) nutritional variables (total N, C-cellulose, HC-hemicellulose, DM-dry matter, OM-organic matter) and b) most abundant plant genera and fodder, on the space generated by the first two nutritional principal components (PC1 and PC2).

Table 1. Nutrient composition of the most ubiquitous woody genera in the study area and the concentrate supplied.

Data are reported as g/100 g dry matter.

Sample	Season	Dry matter (g/100g fresh matter)				
			Organic matter	Hemicellulose	Cellulose	Total N
<i>Cistus</i>	spring	93.9	94.5	17.1	12.6	1.4
<i>Cistus</i>	summer	92.6	96.8	14.2	14.4	1.2
<i>Cistus</i>	autumn	93.2	95.9	12.6	12.7	1.4
<i>Cistus</i>	winter	94.6	95.9	13.3	10.4	1.5
Concentrate	March-October	91.6	89.4	11.7	13.6	3.0
Concentrate	October-March	88.9	86.1	9.7	7.0	3.3
<i>Cytisus</i>	spring	93.6	96.6	24.4	24.3	2.4
<i>Cytisus</i>	summer	94.6	98.2	17.6	39.7	1.5
<i>Cytisus</i>	autumn	95.4	98.7	20.2	30.9	1.8
<i>Cytisus</i>	winter	94.8	98.2	18.5	30.6	2.1
<i>Erica</i>	spring	94.2	97.4	13.7	11.4	1.2
<i>Erica</i>	summer	94.0	97.5	11.2	12.2	1.0
<i>Erica</i>	autumn	94.4	97.8	14.5	11.9	1.0
<i>Erica</i>	winter	94.8	97.9	12.1	11.1	1.1
<i>Genista</i>	spring	93.6	96.6	23.4	32.8	1.5
<i>Genista</i>	summer	95.9	97.4	19.5	31.0	1.1
<i>Genista</i>	autumn	97.0	97.9	20.9	34.4	1.4
<i>Genista</i>	winter	96.0	97.2	19.3	28.2	1.7
<i>Phillyrea</i>	spring	95.3	96.4	18.8	9.0	1.5
<i>Phillyrea</i>	summer	94.0	96.2	13.9	10.8	1.2
<i>Phillyrea</i>	autumn	95.8	97.5	15.1	13.4	1.2
<i>Phillyrea</i>	winter	95.9	97.0	14.8	15.3	1.2
<i>Quercus</i>	spring	93.6	97.1	22.8	21.0	1.3
<i>Quercus</i>	summer	95.2	96.4	20.1	21.5	1.2
<i>Quercus</i>	autumn	95.2	97.4	20.2	21.6	1.3
<i>Quercus</i>	winter	93.6	97.0	18.9	21.8	1.2
<i>Rosmarinus</i>	spring	93.0	94.1	16.3	12.1	1.3
<i>Rosmarinus</i>	summer	92.4	93.9	13.9	12.4	1.4
<i>Rosmarinus</i>	autumn	95.9	94.6	14.1	12.7	1.5
<i>Rosmarinus</i>	winter	93.5	94.8	10.6	12.3	1.6

Table 2. Factor loadings obtained in the principal component analysis performed on the nutritional variables.

Factor loadings indicate the degree of correlation between each nutritional variable and the two principal components (PC1 and PC2).

Nutritional variables	PC1	PC2
Dry matter	0.86	-0.21
Organic matter	0.92	-0.24
Hemicellulose	0.70	0.57
Cellulose	0.67	0.65
Total N	-0.62	0.71

b)

Figure 1.

Figure 2.

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866 **Figure 3.**