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Original article

Shrub control by browsing: Targeting adult plants

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A B S T R A C T

Reconciling the well known benefits of shrubs for forage with environmental goals, whilst preventing their dominance, is a major challenge in rangeland management. Browsing may be an economical solution for shrubby rangelands as herbivore browsing has been shown to control juvenile shrub growth. Less convincing results have been obtained for adult plants, and long-term experiments are required to investigate the cumulative effects on adult plants. We therefore assessed the impact of different levels of browsing intensity on key demographic parameters for a major dominant shrub species (broom, *Cytisus scoparius*), focusing on adult plants. We assigned individual broom plants to one of three age classes: 3–5 years (young adults); 5–7 years (adults); and 7–9 years (mature adults). These plants were then left untouched or had 50% or 90% of their total edible stem biomass removed in simulated low-intensity and high-intensity browsing treatments, respectively. Morphological, survival and fecundity data were collected over a period of four years. Browsing affected the morphology of individual plants, promoting changes in subsequent regrowth, and decreasing seed production. The heavily browsed plants were 17% shorter, 32% narrower, and their twigs were 28% shorter. Light browsing seemed to control the growth of young adult plants more effectively than that of older plants. Reproductive output was considerably lower than for control plants after light browsing, and almost 100% lower after heavy browsing. High-intensity browsing had a major effect on survival causing high levels of plant mortality. We conclude that suitable browsing practices could be used to modify adult shrub demography in the management of shrub dominance and forage value.

1. Introduction

In many countries shrub species are an important food resource for small ruminants on rangelands, throughout the year (Papachristou et al., 2005; Rogosic et al., 2008). Nitrogen-fixing leguminous shrubs are considered to be key species, because they provide protein-rich fodder (e.g. more than 18% protein in flowering *Cytisus scoparius*, Holst et al., 2004), supplementing more fibrous herbaceous biomass. Consequently, for ruminants feeding in mixed vegetation the presence of shrubs helps to maximize food intake (Meuret, 1997; Agreil et al., 2005). However, some shrub species often achieve competitive dominance, decreasing the biodiversity of the shrub community as a whole (Prévosto et al., 2004; Potter et al., 2009). In rangeland management, the key challenge is to promote the well known benefits of shrubs (e.g. for forage) with environmental goals while preventing their dominance (Magda et al., 2009; Eldridge et al., 2013).

Browsing has been proposed as a useful method of controlling shrub encroachment (Valderrábano and Torrano, 2000; Bellingham and Coomes, 2003; Frost and Launchbaugh, 2003), as this approach can provide key ecosystem services, such as the maintenance of biodiversity (Eldridge et al., 2013; Pekin et al., 2014). This is particularly important in the context of the abandonment of pastoral farming practices, which may promote the expansion of shrub populations (Bartolomé et al., 2005; Kesting et al., 2009; Potter et al., 2009). However, little evidence is available concerning the ways in which browsing be used to meet these goals (Agreil et al., 2010). We need to improve our understanding of the response of plant populations to browsing of dominant shrubs (e.g. *Phillyrea latifolia*, Sirkou et al., 2002; *Cytisus scoparius*, Prévosto et al., 2006)

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to propose relevant management strategies that reduce shrub encroachment.

Recent studies using modeling approaches (e.g. Cippriotti and Aguiar, 2012; Pontes et al., 2012; Komac et al., 2013) have increased our understanding of how browsing can be used to restrict shrub expansion so as to maintain favorable conditions for grass-shrub coexistence (Agreil et al., 2010). Progress has also been made toward understanding the effects of browsing on shrubs at different stages of growth, making it possible to draw inferences about long-term population dynamics (Magda et al., 2009). Further exploration of the impact of browsing intensity on specific organs or growth stages are urgently required, to provide insight into population dynamics in response to browsing and the best ways of managing shrub encroachment (Sankaran et al., 2005). Several studies (Fenner et al., 1999; Pontes et al., 2012; Holst et al., 2004; Irl et al., 2012) have shown that plants in early stages of growth (seedlings and juveniles, i.e. plants at emergence or before reproductive maturity) have several characteristics (e.g. accessibility, palatability) rendering them particularly attractive for browsing. The survival rates of these plants are also a demographic parameter for population dynamics (Magda et al., 2009; Pontes et al., 2012). Young shrubs thus constitute an important target for control by browsing.

Much less is known about the suitability of adult plants for browsing and the consequences of such browsing for population dynamics. This lack of information reflects the greater difficulties involved in monitoring and quantifying the effects of browsing on adult plants. For instance, seed production varies considerably between individual plants and between years (Wheeler et al., 1979; Williams, 1981; Magda et al., 2009) making it difficult to estimate the effects of browsing on reproductive output. It is also difficult to estimate survival of adult plants due to the longevity of shrub species, some of which may live for 30 years (e.g. *Atriplex vesicaria*, Crisp, 1978; cited by Hunt, 2001). This parameter has therefore generally been estimated in demographic models (e.g. Magda et al., 2009) assuming low rates of adult mortality (e.g. <20%, Parker, 2000) due to browsing. However, browsing has been observed to cause high rates of adult mortality in shrubs in the field (D. Magda, pers. obs.) demonstrating the need for more accurate quantification. Furthermore, the rapid vertical growth of seedlings allows shrubs to compete successfully with grass species, with most seedlings surviving until maturity. This results in a high population density (Rousseau and Loiseau, 1982), and high levels of seed production over the life time of the plant (Paynter et al., 1998; Downey and Smith, 2000). It may be easier to influence shrub dynamics by decreasing the number of reproductive plants, thereby also decreasing seed production. The quantification of survival rates of adult plants at different browsing intensities may therefore open up new perspectives for evaluating the possible contribution of browsing to the regulation of shrub population growth.

Shrub biomass must also be taken into account in shrub control strategies, particularly for more mature shrub stands. Density may decrease while biomass per plant continues to increase (Parker, 2000) resulting in the production of several kilograms of plant material per square meter of a less palatable and less accessible nature making it unavailable for browsing. Furthermore, a higher density/biomass ratio is associated with a greater ability of each shrub to deplete local resources (soil nutrients, light, water, Parker, 2000) and a greater risk of fire, due to the accumulation of fuel (Kramer et al., 2003). Thus, important objectives for future studies on control strategies for shrub encroachment include decreasing shrub biomass over time, in addition to reducing adult survival rate, fecundity and/or numerical density, and assessing the impact of adult shrubs on the associated community, and on the feeding behavior of ruminants.

The aim of this project was to study the possible use of browsing, targeting adult plants, to avoid shrub encroachment, and to restore or maintain the forage resource quality of a major dominant European shrub, *Cytisus scoparius* (L.) Link (Fabaceae) (Scotch broom). We addressed the following questions: i) What are the long-term effects of browsing on the morphological characteristics (e.g. biomass) of adult broom plants? ii) How does browsing affect flowering? iii) How many years of repeated browsing are required before an effect on survival of adult plants can be detected? We also investigated the indirect impact of these changes over time, through repeated browsing, at three browsing intensities. We focused on the effects on functional features of this dominant shrub species, such as forage accessibility and quality. Finally, we considered the feasibility of using ruminant browsing to target more mature stages of the life cycle of a dominant species, as a means of limiting shrub encroachment.

2. Materials and methods

2.1. Study species

Cytisus scoparius, a long-lived shrub native to most of Europe, is a key shrub species due to its ability to dominate rangelands and its importance as a pastoral resource (Agreil et al., 2005). It spreads rapidly, and the abandonment of traditional pastoral farming practices in Europe, particularly over the last few decades, has led to an increase in its dominance, with undesirable effects on the environment (e.g. local decreases in species richness and forage resources, Agreil et al., 2010). Furthermore, this species has become a serious weed of pasture, native bush and forests in several countries around the world (Harrington, 2009; Potter et al., 2009; Shaben and Myers, 2010). Several traits are thought to contribute to the successful spread of broom: its long-lived seeds, which may remain viable for years, possibly even decades, in the seed bank, its ability to fix nitrogen, its production of alkaloid compounds and the formation of dense stands (Bossard and Rejmanek, 1994; Gresser et al., 1996; Paynter et al., 1998; Peterson and Prasad, 1998; Holst et al., 2004). According to Magda et al. (2009), many factors, including the survival rates of seeds, seedlings and juveniles, and the fecundity of young adults, contribute to the high growth rates of broom populations.

2.2. Study site and the broom population studied

The experiment was conducted over four years (2010–2013), on private property in the southwest Ariège-Pyrénées region (France), at a mean elevation of 900 m. The study area consisted of a natural broom shrubland, which had not been subjected to browsing for many years (>20 years). A 20 × 40 m plot within this large broom population was defined and fenced off, to keep out stray cattle and other wild herbivores. In 2010, we selected a total of 182 adult individuals (i.e. plants aged 3–9 years) at random from the total population. The ages of the selected plants were estimated with an equation defining the relationship between diameter (Y) and age (x) ($n = 44$; $r^2 = 0.95$, $Y = 1.22x^{1.64}$). We split the plants into three age classes: 3–5 years (young adult plants with a stem diameter of 7.4–17 mm); 5–7 years (adult plants with a diameter of 17.1–29.7 mm); and 7–9 years (mature or older adults with a diameter of 29.8–44.8 mm). Adult plants varied considerably in size (Parker, 2000) and fecundity (Magda et al., 2009). We chose to assign them to three age classes, as this number of classes made it possible to obtain a balance between sample size and fecundity for a particular age range, and for accuracy in the representation of the mean size and fecundity of individuals. These age classes for reproductive adults (young to mature adults) have already been