Agriculture, Ecosystems and Environment 244 (2017) 22–31

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Impacts of contrasting conservation grazing management on plants and carabid beetles in upland calcareous grasslands

Ashley Lyons*, Paul A. Ashton, Ian Powell, Anne Oxbrough

Department of Biology, Biosciences Building, Edge Hill University, St Helens Road, Ormskirk, Lancashire, L39 4QP, United Kingdom

ARTICLE INFO

Keywords:
Community
Carabid beetle
Livestock
Ungrazed
Upland
Vegetation

ABSTRACT

Calcareous grassland is among the most species rich and diverse habitat in Europe, but has faced decline due to agricultural intensification and abandonment. In recent years, conservation organisations have changed grazing practices in this habitat in an attempt to maintain characteristic vegetation. However, there has been little consideration of the effects of changes in grazing practices on invertebrate communities or their relationship with plant communities. This study determines the impacts of commonly used grazing practices in internationally rare upland calcareous grasslands on vegetation and on carabid beetles, a diverse group that is known to respond to environmental change. Typical conservation management regimes (light cattle grazing, light sheep grazing and ungrazed), established for over ten years, were examined in three regions of Britain. Carabid beetles were sampled using pitfall traps from late April – early September 2013 and per cent cover of plant species was recorded in 2 m × 2 m quadrats paired with pitfall traps sequentially throughout the sample period. Plant and beetle species composition differed significantly between regimes, as did plant species richness where ungrazed sites had significantly fewer species than sheep or cattle grazed sites. In contrast, beetle species richness did not differ by grazing type. Three beetle species were significantly associated with grazing management regimes: *Carabus arvensis* with light cattle grazing, and *Carabus violaceaus* and *Synchus vivalis* with light sheep grazing, the former two having undergone major population declines in the UK. Grazing regime affects both plant and carabid beetle communities and is important in supporting distinct species compositions as well as rare and declining species. Carabid beetles did not always respond in the same way as plants to grazing regime, suggesting that conservation managers should exercise caution when using plant species composition or broad measures of plant diversity to indicate biodiversity value, identify priority habitats or select grazing regimes to support a particular habitat condition.

1. Introduction

Calcareous grassland is one of the most species rich and diverse habitats in Europe (Wallis de Vries et al., 2002). Their exceptional diversity of plants and invertebrates renders them of great conservation interest (Boschi and Baur, 2007; Krauss et al., 2003; van Swaay, 2002; Wallis de Vries et al., 2002). In Europe, large areas have been lost since the 1950s due to changes in management practices, such as increased use of fertilisers, greater stocking densities and occasionally abandonment (Fischer and Stöcklin, 1997; Poschlod et al., 2005; Roesch et al., 2013; Wallis de Vries et al., 2002). This has resulted in a dramatic decline in plant species richness (Poschlod and Wallis de Vries, 2002). Consequently, calcareous grassland is now protected in national and international legislation (e.g. EU Habitats Directive).

Semi-natural grasslands are sub-climax communities that require intervention to prevent succession to scrub or woodland (Rook et al., 2004) and to maintain plant diversity (Roesch et al., 2013; Wallis de Vries et al., 2002). Grazing is commonly used as a conservation tool for maintaining diversity within these plant communities. Through grazing the removal of plant biomass alters competitive relationships amongst plants which drives both heterogeneity within a landscape and preserves diversity (Bullock and Marriott, 2000; Rook et al., 2004; Scimone et al., 2007). Dietary choice of livestock, determined by adaptations such as dental anatomy (Ferreira et al., 2013), is the principle factor influencing habitat heterogeneity, diversity and composition (Rook et al., 2004). For instance, sheep exhibit more selectivity in their diet than cattle, resulting in increased cover of less desirable grasses (Grant et al., 1985). Additionally, the intensity of grazing also impacts upon vegetation, as suggested by the intermediate grazing optimisation model (Grime, 1973), with high stocking densities or abandonment resulting in a decline in plant species richness and structural complexity, whilst moderate stocking densities lead to

* Corresponding author.
E-mail addresses: lyonsa@edgehill.ac.uk (A. Lyons), ashtonp@edgehill.ac.uk (P.A. Ashton), powelli@edgehill.ac.uk (I. Powell), oxbrouga@edgehill.ac.uk (A. Oxbrough).

http://dx.doi.org/10.1016/j.agee.2017.04.020
Received 30 November 2016; Received in revised form 21 April 2017; Accepted 24 April 2017

increased plant species richness (Deng et al., 2013; Grime, 1973; Vickery et al., 2001). Further, at low densities, the above ground biomass of grass increases whilst that of forbs decreases (Deng et al., 2013); the resulting encroachment of dominant grasses reduces species richness and the increased litter deposition results in eutrophication (Calaciura and Spinelli, 2008; Jacquemyn et al., 2011; Wallis de Vries et al., 2002; Woodcock et al., 2005).

Selection of grazing regime has implications for invertebrate communities directly through disturbance or provision of resources, such as dung or carrion, and indirectly through its effects on plant species composition, plant architecture and heterogeneity (Dennis et al., 2001; Morris, 2000; Vickery et al., 2001; Woodcock et al., 2005). The *habitat heterogeneity hypothesis* predicts that the greater the heterogeneity of a habitat the more species can coexist in that habitat (Pianka, 1966). Thus, it follows that under grazing conditions that produce a more heterogeneous sward, such as low intensity grazing with cattle or sheep compared to no grazing, invertebrate species richness will be enhanced as there is greater niche availability.

There are currently an estimated 5,95,973 ha of calcareous grassland within Europe, of which around 33,419 ha is in the United Kingdom (Calaciura and Spinelli, 2008) and an estimated 60–75 per cent of this occurs in the British uplands (Maddock, 2008). As elsewhere in Europe, upland areas within Britain experienced decline in this habitat due to intensive grazing, typically with sheep (Dennis et al., 2008; Fuller and Gough, 1999). Indeed, between 1990 and 1998 there was an 18% decline in calcareous grassland in the UK (Haines-Young et al., 2000). To conserve the characteristic vegetation of this habitat there has been a reduction in stocking levels within the last decade. This typically involves a shift from grazing with high numbers of sheep to a lower stocking density of cattle, though occasionally lower stocking densities of sheep or no grazing occurs. These so-called 'conservation grazing regimes' are based on suggested appropriate annual stocking rates of 0.25 LU ha^{-1} yr^{-1} for maintaining biodiversity (Backshall et al., 2001). However, there have been few studies which address the impact of these established low stocking conservation grazing regimes and compare ungrazed regimes, on plants and fewer still on invertebrates in these internationally important habitats (Wallis de Vries et al., 2002, 2016). Previous studies of grazing impacts on calcareous grassland have examined small experimental plots (e.g. Barbaro et al., 2001; Woodcock et al., 2005; Jacquemyn et al., 2011). The present study is the first to present an evidence base for the impacts of established (> 10 years) conservation grazing management on biodiversity in upland calcareous grasslands, using plants and carabid beetles as models. This study aims to determine the impact of low intensity sheep grazing, low intensity cattle grazing and ungrazed regimes on plant and carabid beetle communities and tests the following hypotheses:

1. In low intensity conservation grazing regimes with either cattle or sheep, there will be greater plant species richness compared to ungrazed regimes.
2. This follows the intermediate grazing optimisation model where plant species richness reaches a maximum at intermediate biomass as a product of optimum grazing levels (Grime, 1973). According to this model, species richness will increase or decrease depending on grazing intensity, since this directly alters the amount of biomass and hence alters competition. It is expected that even below recommended optimum stocking levels, low intensity cattle or sheep grazing will lead to greater plant species richness compared to ungrazed regimes as a consequence of reduced biomass.
3. Supplementary to hypothesis one, it is expected that owing to equal stocking densities, plant species richness will not differ between low intensity cattle and sheep grazing regimes.
4. It is further expected that in line with plant species richness, and following the *habitat heterogeneity* hypothesis, there will be greater carabid beetle species richness in low intensity conservation grazing regimes with either cattle or sheep than ungrazed regimes.
5. Supplementary to hypothesis two, it is expected that due to the disturbance action of grazing livestock, greater habitat heterogeneity in grazed compared to ungrazed regimes will result in a greater range of food resources available through seeds or prey, thus providing a greater range of niches for more carabid beetle species to occur. Again, it is expected that due to comparable stocking densities, no difference in carabid beetle species richness will be observed between sheep and cattle regimes.
6. There will a distinct species composition among the three grazing types for both plants and carabid beetles due to the different grazing actions of cattle and sheep, as discussed above, even at low intensities.

Plants are directly impacted by grazing and are the target of conservation efforts. Conversely, invertebrates are very rarely considered when grazing management decisions are made for upland calcareous grassland, despite their importance for the functioning of ecosystems. Carabid beetles, for instance, play an important role in grasslands through their roles such as predators, as granivores and as a food source for other animals (Lövei and Sunderland, 1996) yet are overlooked in management decisions. Management is typically focused on maintaining particular plant communities and condition of sites is always assessed based on vegetation characteristics. Results from this study, weighed against other evidence, will inform management recommendations for enhancing biodiversity through grazing regimes in rare calcareous grasslands and determine whether plant species composition can be used to indicate carabid beetle species composition, a useful tool in the context of conservation management in these habitats.

2. Methods

2.1. Study sites

Three grazing types were selected for study within the most extensive upland limestone areas within the UK: ungrazed, cattle grazed and sheep grazed regimes (with a negligible number of cattle (< 0.02 Livestock Units per Hectare per Year (LU ha^{-1} yr^{-1})) and herein referred to as sheep grazed). The current grazing regime had been in place for at least ten years prior to investigation across all locations. Grazed regimes were deemed as being lightly grazed for upland calcareous grassland as they had a grazing intensity of less than 0.24 LU ha^{-1} yr^{-1} (Backshall et al., 2001) calculated as: Annual Equivalent Stocking Density = ((N*GLU/H)*(M/12))

Where: N = Number of individuals, GLU = Grazing Livestock Unit (taken from Nix, 2004), H = Hectares and M = Number of months grazed. Detail of stocking densities and duration of grazing is provided in Table 1.

Each grazing regime was replicated across three geographically distinct regions separated by 20–37 km in Northern England (54°29′18.55″N, 002°32′33.00″W) (54°11′43.30″N, 002°21′00.13″W) (54°06′29.41″N, 002°03′55.04″W) (Fig. 1). In each region three extensive areas of limestone grassland (size 15 ha–525.68 ha, median 82.75) were selected within which three sampling locations were

Table 1
Annual stocking intensities and duration of grazing for each grazing regime within each region.

Site	Livestock Type	Grazing Intensity (LU/ha^{-1}/yr^{-1})	Duration of Grazing (months)
Region 1	Cattle	0.18	6
Region 2	Cattle	0.13	5
Region 3	Cattle	0.19	10
Region 1	Sheep	0.10	12
Region 2	Sheep	0.12	12
Region 3	Sheep	0.15	5