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Rotation grazing as a conservation management tool: Vegetation changes after six years of application in a salt marsh ecosystem

D.D. Georgette Lagendijk[a,b,*], Ruth A. Howison[a], Peter Esselink[a,c], Richard Ubels[a], Christian Smit[a]

[a] Conservation Ecology Group, Groningen Institute for Evolutionary Life Sciences, University of Groningen, P.O. Box 11103, 9700 CC Groningen, The Netherlands
[b] School of Life Sciences, University of KwaZulu-Natal, Westville Campus, Private Bag X54001, Durban 4000, South Africa
[c] Puccimar, Boermarke 35, 9481 HD Vries, The Netherlands

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ABSTRACT

Grazing is commonly used in conservation to promote biodiversity, but the search for a grazing management regime that optimises biodiversity is still ongoing. Rotation grazing, where grazing is followed by a relatively long period of non-grazing, is a relative new tool in conservation management, and empirical studies on its effects on biodiversity are scarce. In this study, we tested for the effects of this rotation grazing on vegetation in comparison with more traditional regimes. We used a grazing experiment on the salt marsh of Noord-Friesland Buitendijks, The Netherlands, where we determined the effect of three rotation cycles (6 years; one year summer grazing with 1 cattle ha^{-1} alternated with an ungrazed year) on species richness, temporal turnover and composition in comparison with more traditional regimes of summer grazing with horses and cattle at two densities (0.5 and 1 animal ha^{-1}). We also determined the change in cover of two species of specific concern, *Aster tripolium* (an important host plant for pollinators) and *Elytrigia atherica* (an invasive dominant species). After six years, species richness increased in all grazing regimes, but less in rotation than in grazing with 1 horse or 1 cattle ha^{-1}. Species turnover was similar across all grazing regimes. Species composition in rotation differed from compositions in 1 cattle and 1 horse ha^{-1}. The increase in cover of *A. tripolium* was lower under rotation than grazing with 0.5 cattle ha^{-1}, but not different to the other regimes. Change in cover of *E. atherica* did not significantly differ across regimes, and showed a trend of increase in the ungrazed regime only. Hence, we found that the effects of rotation grazing on vegetation are relatively similar to the grazing regimes with cattle or horses in low densities. The implementation of this rotation regime over the more traditional regimes remains to be decided by the conservation body, depending on its applicability in terms of available grazing areas and livestock, as well as overall conservation goals.

1. Introduction

Grazing is a common management tool used in nature conservation to promote biodiversity (Knapp et al., 1999; Middleton et al., 2006; van Klink et al., 2016; Wallis De Vries et al., 1998). Grazing is the impact of large herbivores through their foraging activities which includes defoliation and trampling of vegetation and soil compaction (Milchunas et al., 1988; Schrama et al., 2013). This affects amongst others plant diversity with cascading effects into other trophic levels, such as invertebrates and small mammals (Evans et al., 2015). The current challenge is to develop a management strategy which best promotes biodiversity of a wide range of taxa simultaneously. At present, various grazing regimes are used in conservation management, varying in herbivore densities and timing of grazing (e.g. year-round vs. seasonal), but also in species (e.g. sheep, cattle, horses either or not in combination with natural occurring herbivores, such as deer, geese and rabbits) (Austrheim and Eriksson, 2001; Catorci et al., 2012; van Klink et al., 2016; van Wieren and Bakker, 2008). Grazing in moderate densities generally improves plant diversity and vegetation dynamics (incl. recruitment) in productive (non-arid) systems, mainly via selective feeding, trampling and dung deposition (Bakker et al., 2006; Milchunas et al., 1988). However, grazing in high densities may lead to biodiversity loss, through the reduction in vegetation biomass, structure, and disturbance (Evans et al., 2015; Nolte et al., 2014; Teuber et al., 2013). Furthermore, different grazing regimes (i.e. varying in densities and species) have differential impact on the various taxa (van Klink et al., 2016). For example, while high density grazing favours different geese species which are attracted to the short-grazed

* Corresponding author at: Conservation Ecology Group, Groningen Institute for Evolutionary Life Sciences, University of Groningen, P.O. Box 11103, 9700 CC Groningen, The Netherlands.
E-mail address: d.d.g.lagendijk@rug.nl (D.D.G. Lagendijk).

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lawns (Bos et al., 2005), it reduces insect diversity in comparison with low density grazing (Kruess and Tscharntke, 2002). Similarly, grazer species may cause differential effects on the same target species. For example, grazing with horses was found to be more detrimental to voles (*Microtus* spp.) than grazing with cattle (van Klink et al., 2016). From these examples, it is clear that the more traditional grazing regimes using a fixed grazing pressure and the same herbivore species each year fail to maximise biodiversity over all taxa.

A new development in conservation is the use of rotation grazing, with relatively long periods of rest (≥1 year), to promote biodiversity. This deviates from the more commonly used rotation regimes in agriculture, where intensive grazing periods of a few days are followed by a resting period with several rotations per season, to recover vegetation and soil after overgrazing and increase vegetation productivity and agricultural output (Briske et al., 2011; Dale et al., 2008; Jacobo et al., 2006; Jerrentrup et al., 2015). The use of rotation grazing in conservation is novel, in the sense that it mimics (temporal) natural absence or low densities of herbivores due to disease outbreaks or migrations, possibly allowing for recovery or establishment of plant communities and associated animals after grazing disturbance. Rotation grazing has therefore been suggested as a potential tool to enhance and maintain biodiversity in conservation areas (Smit et al., 2010; see review in Smit et al., 2015), but empirical studies are thus far rare.

We had the opportunity to investigate rotation grazing as a conservation management tool in a salt marsh ecosystem in The Netherlands. Salt marshes are shaped by tidal salt water inundations resulting in a typical vegetation zonation between the low marsh (e.g. *Aster tripolium*, *Plantago maritima*, *Puccinellia maritima*, *Triglochin maritima*) and the high marsh (e.g. *Agrostis stolonifera*, *Elytrigia atherica*, *Festuca rubra*, *Potentilla anserina*; Bakker et al., 1985). Salt marshes are protected under the EU Habitat Directive, as they are important habitats for characteristic plant species (e.g. *Salicornia* spp.) and associated endemic fauna (e.g. *Praestigia duffeyi – Araneae*), serve as fish nurseries, and are important staging and breeding grounds for waders (e.g. Eurasian spoonbills), meadow birds and waterfowl (Doody, 2008; Laffaille et al., 2005; van Klink and van Schrojenstein Lantman, 2015). Traditionally, European salt marshes were used for livestock grazing (i.e. cattle, sheep or horses), but this diminished in many areas due to socio-economic developments during the last quarter of the 20th century (e.g. Esselink et al., 2009). In absence of grazing or other disturbances, most salt marshes develop into late successional, species-poor vegetation communities (e.g. dominated by *Elytrigia atherica* (hereafter *Elytrigia*); Bakker et al., 2003; Veeneklaas et al., 2013). Due to large-scale embankment, not only existing salt marshes, but also the development of new salt marshes in Europe, and thus the typical diversity associated with early successional phases, have declined. Restoring grazing suppresses the dominance of late successional salt marsh species (e.g. *Elytrigia*) and so provides the opportunity for earlier successional species to return, and mid-successional species to appear, thereby increasing biodiversity (Olff et al., 1997; van Wieren and Bakker, 2008). However, which grazing regime is optimal for biodiversity conservation in salt marshes is thus far unclear (van Klink et al., 2016).

In a replicated large-scale field experiment, we compared rotation grazing with cattle (summer grazing with 1 animal ha^{-1} followed by one fallow year) with four more traditional grazing regimes with yearly summer grazing by cattle or horses with 0.5 or 1 animal ha^{-1}. In this study, we specifically report on the effects after 6 years of rotation grazing (i.e. three rotation cycles) on salt marsh vegetation in terms of species richness, turnover and composition, as well as on the change of cover of two particular plant species of concern: *Elytrigia* and *Aster tripolium* (hereafter *Aster*). *Elytrigia* is a native invasive species that becomes dominant when disturbance (e.g. grazing) is absent, resulting in low plant diversity (Pétillon et al., 2005; Veeneklaas, 2013). In addition, it spreads from the high marsh towards the low marsh, and thus posing a threat to the entire ecosystem (Pétillon et al., 2005; Veeneklaas, 2013). Traditional grazing in high densities (1–2 cattle ha^{-1}; Bakker et al., 1993) can halt the spread of *Elytrigia* in favour of other species (van Klink et al., 2016). *Aster*, on the other hand, is a key species within salt marshes, being an important food source for insects, which are vital prey for birds (Nolte et al., 2013; van Klink and van Schrojenstein Lantman, 2015; van Klink et al., 2016). However, *Aster* is affected by grazing as it is both eaten and trampled by cattle and horses (Nolte et al., 2013). In comparison with the other four regimes, we thus expected to find that the rotation regime would show: (a) a similar increase in species richness and species turnover as low density cattle and horse grazing, and (b) a different species composition with an increase in the cover of *Elytrigia* and *Aster*, due to the biannual release from grazing, creating opportunities for expansion.

2. Methods

2.1. Study area

This study was conducted in Noord-Friesland Buitendijks (hereafter NFB: 53°20′ N, 05°43′ E), a Nature 2000 conservation area of 41.8 km^2 in the northern part of The Netherlands. NFB consists of a relatively large mainland salt marsh area (> 20 km^2) along the Wadden Sea, which is a UNESCO world heritage site. The tidal range at the study area is 1.85 m with an annual mean high tide (MHT) of 1.0 m above NAP (Dutch Ordnance Level). The climate is temperate maritime with an average yearly temperature of 11 °C (monthly range from 3.8 °C in winter to 18.1 °C in summer) and an average yearly rainfall of 785 mm (monthly range from 67 mm in winter to 91 mm in summer: 2005–2015; FetchClimate, Microsoft Research, http://fetchclimate2.cloudappnet, Royal Netherlands Meteorological Institute).

The salt marsh of NFB largely developed from coastal engineering works, using sedimentation fields which marine clay deposits typically consist up to 80% clay and silt (van Klink et al., 2016). These engineering works started in the first half of the 20th century, after which part of the salt marsh was used for livestock grazing (de Vlas et al., 2013). In the study area a clear zonation of the salt marsh is present from the lower salt marsh (0.3–0.5 m +MHT) to the higher salt marsh (0.6–0.8 m +MHT; de Vlas et al., 2013). Native wild mammalian herbivores utilising the salt marsh are hares (*Lepus europaeus*) and roe deer (*Capreolus capreolus*), but these occur here in such low numbers that they are not competing for resources with livestock during the summer grazing season.

2.2. Experimental design

A large-scale grazing experiment was initiated in 2010 and consisted of five grazing regimes with experimental plots of 11 ha each: a rotation regime (1 cattle ha^{-1} for 1 year, followed by 1 fallow year), yearly grazing with horses in two densities (0.5 and 1 horse ha^{-1}), and yearly grazing with cattle in two densities (0.5 and 1 cattle ha^{-1}; see also van Klink et al., 2016). The experiment was performed at two sites approximately 2.5 km apart (i.e. West and East), each site with 5 regimes. Only the western site included an ungrazed paddock of 11 ha in size. Each paddock consists of low and high marsh. Considering the size of the experiment more replicates of sites and the ungrazed paddock were not feasible.

Grazing took place during the summer season from June to early October and grazing within the rotation regime occurred in 2011, 2013 and 2015. Thus, since the initiation of the experiment, three full rotations of summer grazing alternating with fallow years were carried out in the rotation regime. To create similar starting conditions, the two sites were intensively grazed with cattle or horses (1.5–3 animals ha^{-1}) one year prior to the start of the experiment (i.e. 2009).