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

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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

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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).

2.3. Vegetation sampling

In total, 88 permanent quadrats (hereafter PQs) of 4 m × 4 m were sampled, with eight PQs per paddock (i.e. four at both the low and the high marsh; see also van Klink et al., 2016). Plant species composition (i.e. species and cover) was recorded estimating percentage cover using the decimal Londo scale (Londo, 1976). Nomenclature of plant species follows van der Meijden (2005). In August 2009, a baseline study was conducted, which we use here to determine the changes in vegetation, after three completed grazing rotation cycles, with data collected in August 2015.

2.4. Statistical analyses

2.4.1. Species richness and turnover

Species richness was determined as the number of plant species present within each PQ within each sampling year. To determine the actual change in plant species richness per PQ after three rotations we used two different measures: (1) the absolute change in number of species per PQ from 2009 compared with 2015, and (2) the temporal species turnover per PQ from 2009 to 2015. Temporal species turnover was calculated using Cody's measure of β-diversity following Lagendijk et al. (2012). Cody's measure focusses on the compositional changes between assemblages, particularly taking into account species gains and losses, and thus not merely species richness (Koleff et al., 2003). Cody's measure of β-diversity is described as:

$$\beta_{co} = 1 - \frac{a(2a + b + c)}{2(a + b)(a + c)}$$

where a is the number of species present in both sampling years, b the gain of species in 2015 and c the number of species lost since 2009. β_{co} ranges from 0 to 1 (low to high species turnover).

We used mixed linear effects models (lmerTest package; Kuznetsov et al., 2016) with a Gaussian distribution, to analyse differences in effects specifically of the rotation grazing regime compared with the other four grazing regimes, and separating between marsh zones (i.e. low *vs.* high marsh) on species richness in 2015, change in species richness and turnover after three rotation cycles. Marsh zone was nested within regime, which was included as a fixed factor, and site as random factor (accounting for any differences arising from site), as we were interested in the effect of grazing regime. Marsh zone was removed from the model when not significant. In the mixed linear effects models (LMER) we set the rotation regime as the intercept. This means that where $P < 0.05$ regimes were significantly different to rotation. Tukey posthoc testing (lsmeans package; Lenth, 2016) was conducted for pairwise comparisons among the remaining grazing regimes. The models were run separately for species richness in 2015, change in species richness and turnover.

In addition, we tested if the observed changes in species richness were significantly different from zero, and can thus be considered genuine changes, using 1 sample *t*-tests. A Wilcoxon signed-rank test was used when data did not show a normal distribution. Results are indicated as positive (significant increase), negative (significant decrease) and neutral (no significant change from zero).

2.4.2. Species composition

We used the vegan-package (Oksanen, 2011) to analyse species composition. Species compositions in 2015 (i.e. after 6 years of application of the grazing regimes) were compared among regimes, and between marsh zones, using a PERMANOVA on square root transformed data, based on 9999 permutations using the Bray-Curtis distance method. We ran a similarity percentage analysis (SIMPER) on square root transformed data to identify which species contributed most to differences in species composition between grazing regimes. In addition, we ran a SIMPER analyses per grazing regime to identify the compositional changes per grazing regime after six years.

2.4.3. Change in cover of Elytrigia and Aster

The data of the absolute change in cover of *Elytrigia* were not normally distributed and we used a Kruskal–Wallis test to determine if change in *Elytrigia* cover after 6 years differed among regimes, and a Mann–Whitney *U*-test to determine if there was an effect of marsh zone. The absolute change in cover of *Aster* after 6 years across regimes and marsh zone were analysed using mixed linear effects models (LMER, Gaussian distribution), with marsh zone nested within regime as a fixed factor, and site as a random factor. Marsh zone was removed from the model when not significant. Again, we also determined if the observed changes (i.e. in cover of *Elytrigia* and *Aster*) were significantly different from zero, and were thus genuine changes, using 1 sample *t*-tests (or Wilcoxon signed-rank tests; see Section 2.4.1).

All statistical analyses were performed using R version 3.2.4 (R Core Team, 2016). Significance levels were set at $P < 0.05$. Normality was assessed by a Shapiro–Wilk normality test over the residuals of the best fit model. We used Tukey posthoc testing (lsmeans package; Lenth, 2016) for pairwise comparisons among grazing regimes, and only significant pairwise comparisons are reported. The ungrazed regime has been omitted from statistical analyses determining differences across regimes and between marsh zones due to lack of replication, but has been presented graphically for visual comparison.

3. Results

Regimes were similar at the start of the experiment as there were no significant differences in species richness (LMER: $P = 0.46$), species composition (PERMANOVA: $P = 0.45$), cover of *Elytrigia* (Kruskal–Wallis test: $P = 0.77$) and cover of *Aster* (Kruskal–Wallis test: $P = 0.74$).

3.1. Species richness

Species richness generally increased from 2009 to 2015 (Fig. 1a). Species richness in 2015 significantly differed among regimes (LMER: $F_{4,69} = 6.469$, $P < 0.001$) and between marsh zones (LMER: $F_{5,69} = 15.945$, $P < 0.0001$; Fig. 1b). The rotation regime had a lower species richness ($\bar{x} = 7.8$) than the regimes with 1 cattle ha^{-1} ($\bar{x} = 10.2$) and 1 horse ha^{-1} ($\bar{x} = 10.2$; LMER: $P \leq 0.0001$; Fig. 1b, Appendix A). Species richness in 2015 was lower in both 0.5 cattle ha^{-1} and 0.5 horse ha^{-1} compared with 1 cattle ha^{-1} and 1 horse ha^{-1} (Tukey: $P \leq 0.043$). The ungrazed regime harboured the lowest number of species ($\bar{x} = 4.0$). The high marsh harboured more species than the low marsh in all regimes (LMER: $P \leq 0.014$; Fig. 1b), except in the regime with 0.5 cattle ha^{-1}.

3.2. Changes in richness and species turnover after 6 years

The absolute change in number of species differed significantly among regimes (LMER: $F_{4,70} = 3.2105$, $P = 0.018$) and between marsh zones (LMER: $F_{5,70} = 8.0109$, $P < 0.0001$; Fig. 2a, Appendix A). The rotation regime shows a lower increase in species richness than the regimes with 1 cattle ha^{-1} and 1 horse ha^{-1} (LMER: $P \leq 0.01$). The increase in species richness on the high marsh within rotation was almost significantly different from zero (1 sample *t*-test: $P = 0.058$) and neutral on the low marsh (Wilcoxon signed-rank test: $P = 0.270$). Absolute changes in species richness were positive (1 sample *t*-test: $P \leq 0.017$; *t*-values in Appendix B) with higher increases on the high marsh than the low marsh in the 1 cattle ha^{-1} (LMER: $P < 0.001$), 0.5 horse ha^{-1} (LMER: $P = 0.032$) and 1 horse ha^{-1} regimes (LMER: $P < 0.001$; Fig. 2a). Changes in species richness were also positive at the low marsh with 0.5 cattle ha^{-1}, 1 cattle ha^{-1} and 1 horse ha^{-1} (1 sample *t*-test: $P \leq 0.038$; *t*-values in Appendix B), but changes were neutral for the low marsh with 0.5 horse ha^{-1} (1 sample *t*-test: $P = 0.11$). Conversely, the ungrazed regime showed a trend of decreasing species richness (1 sample *t*-test: $P = 0.058$) and were neutral on

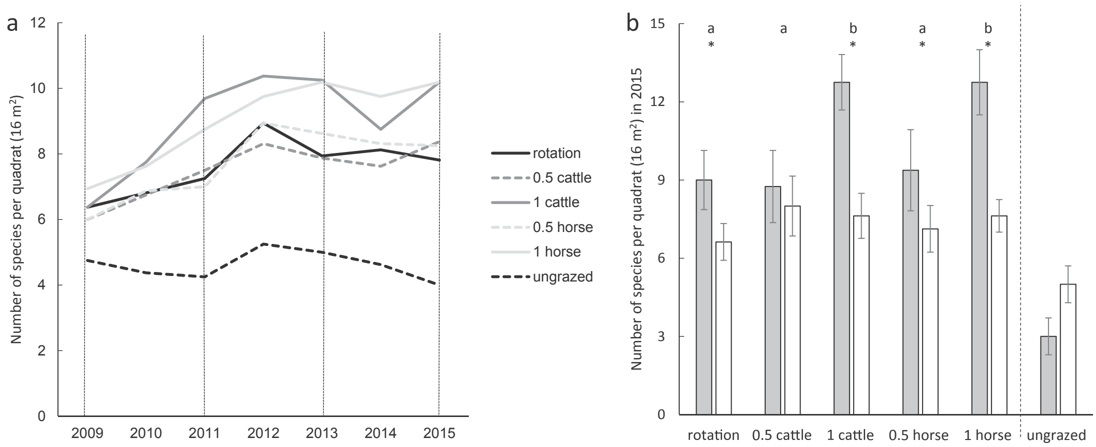

Fig. 1. Plant species richness under different grazing regimes (a) between 2009 and 2015, and (b) in 2015 at the high (grey bars) and low salt marsh (open bars) in Noord-Friesland Buitendijks, The Netherlands. Dotted vertical lines in 1a indicate grazed years. Error bars in 1b represent mean ± 1SE; significant differences among grazing regimes are indicated with letters, and between marsh zones with '*'. $N = 16$ for each grazing regime, except ungrazed ($N = 8$). The ungrazed regime has been omitted from statistical analyses due to lack of replication, however included graphically as a visual reference.

the low marsh (1 sample *t*-test: $P = 0.32$).

Species turnover was similar across regimes (LMER: $F_{4,69} = 1.1116$, $P = 0.36$), but was affected by marsh zone (LMER: $F_{5,69} = 5.1416$, $P < 0.001$; Fig. 2b, Appendix A), with higher turnover on the high marsh than the low marsh only statistically significant in the rotation regime and 1 cattle ha^{-1} ($P \leq 0.007$).

3.3. Changes in species composition after 6 years

Species compositions were significantly different among grazing regimes (PERMANOVA: $F_{4,70} = 2.4722$, $P = 0.0022$) and between the low and high marsh (PERMANOVA: $F_{5,70} = 4.3133$, $P = 0.0001$; Appendix A). The species composition differed significantly between the rotation regime in 2015 and 1 cattle and 1 horse ha^{-1}. Between rotation and 1 cattle ha^{-1}, *S. maritima*, *A. stolonifera*, *Puccinellia maritima*, *Atriplex prostrata*, *Potentilla anserina* and *Elytrigia*, and between rotation and 1 horse ha^{-1}, *Puccinellia maritima*, *S. maritima*, *A. stolonifera*, *A. prostrata* and *Elytrigia* contributed most (> 50%; and all were less abundant in rotation except for *A. prostrata* and *Elytrigia*) to the observed differences in species composition after three rotation cycles (Appendix C). Within the rotation regime *A. stolonifera*, *Elytrigia*, *Puccinellia maritima*, *A. prostrata* and *Aster* contributed most (> 50%; increase in *Elytrigia*, *A. prostrata*, *Aster*) to changes in species composition after 6 years of application of the regimes (Appendix D). See Appendix C for all species contributions to the significant pairwise comparisons between grazing regimes in 2015 and Appendix D for all species contributions (and disappearances) within each grazing regime between 2009 and 2015.

3.4. Changes in cover of *Elytrigia* and *Aster* after 6 years

The change in cover of *Elytrigia* did not differ among regimes (Kruskal–Wallis test: $\chi^2_4 = 3.6514$, $P = 0.455$; Fig. 3a, Appendix A), and was neutral in all grazing regimes (Wilcoxon signed-rank test: $P \geq 0.18$; *V*-values in Appendix B), except in the ungrazed regime which showed a trend of increasing cover (1 sample *t*-test: $P = 0.052$). Marsh zone was not significant for change in cover (Mann–Whitney *U*-test: $P = 0.17$; Appendix A).

The change in *Aster* cover differed among regimes (LMER: $F_{4,74} = 7.4999$, $P < 0.0001$; Fig. 3b; Appendix A). The change in cover was smaller in the rotation regime compared with 0.5 cattle ha^{-1} (LMER: $P < 0.001$), and greater in 0.5 cattle ha^{-1} and 0.5 horse ha^{-1} compared with 1 cattle ha^{-1} (Tukey: $P \leq 0.033$). The changes in cover were positive in rotation, 0.5 cattle ha^{-1}, 0.5 horse ha^{-1} (1 sample *t*-test: $P \leq 0.039$; *t*-values in Appendix B) and 1 horse ha^{-1} (Wilcoxon signed-rank test: $P = 0.003$), but were neutral in 1 cattle ha^{-1} (Wilcoxon signed-rank test: $P = 0.87$) and ungrazed (1 sample *t*-test: $P = 0.16$). Marsh zone was removed from the model as it was not significant.

4. Discussion

Our study focussed on the effect of rotation grazing on salt marsh vegetation as a potential management tool for biodiversity conservation in comparison with more traditionally used grazing regimes. We found that six years of rotation grazing resulted in similar effects on turnover and cover of *Elytrigia* as the more traditionally used regimes, while we

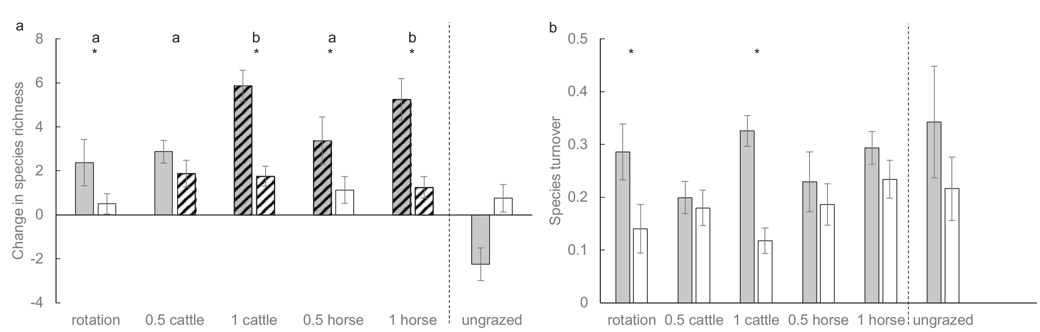

Fig. 2. Effect of different grazing regimes on (a) change in plant species richness and (b) species turnover, after 6 years between 2009 and 2015 at the high (grey bars) and low salt marsh (open bars) in Noord-Friesland Buitendijks, The Netherlands. Error bars represent mean ± 1SE; significant differences among grazing regimes are indicated with letters, and between marsh zones with '*'. Shaded bars in 2a indicate changes which were positively different from zero (the changes in non-shaded bars are neutral or negatively different from zero). $N = 16$ for each grazing regime, except ungrazed ($N = 8$). The ungrazed regime has been presented graphically as a visual reference, and data from this regime were only analysed to determine if the change within the regime was genuine (different from zero).

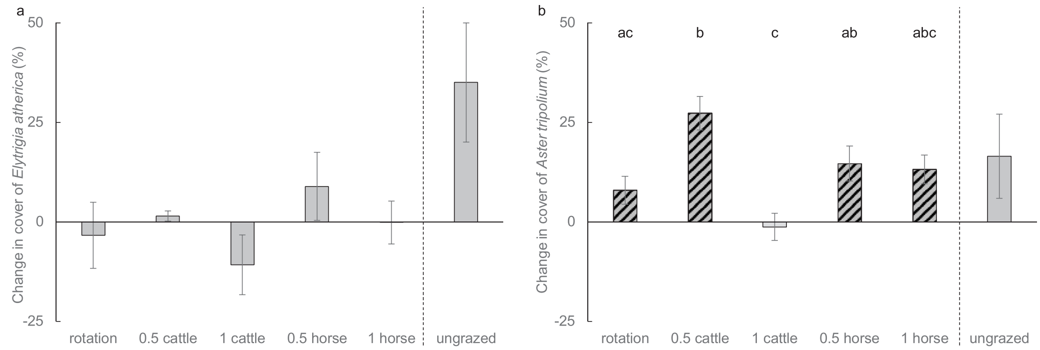

Fig. 3. Change in cover of (a) *Elytrigia atherica* and (b) *Aster tripolium* after 6 years under different grazing regimes in Noord-Friesland Buitendijks, The Netherlands. Error bars represent mean ± 1SE. Significant differences among grazing regimes are indicated with letters. Changes which were positively different from zero are indicated with shaded bars with change being neutral or negative indicated by non-shaded bars. $N = 16$ for each grazing regime, except ungrazed ($N = 8$). The ungrazed regime has been presented graphically for visual comparison, and data from this regime were only analysed to determine if the change within the regime was genuine (different from zero).

found lower species richness and different species composition in rotation than in the high density grazing regimes, and less increase in *Aster* within the rotation regime than with low density cattle grazing.

4.1. Species richness, turnover and composition

Species richness increased in the rotation regime, but the greatest increase occurred in the two high density grazing regimes. While we did find species richness to increase over time independent of the grazing regime, it decreased in absence of large grazers, which is in line with several other studies (Dupré and Diekmann, 2001; Hickman et al., 2004; Olff and Ritchie, 1998). This is attributed to decreasing competition for resources after grazing, such as light and nutrients, creating opportunities for other plant species to persist, and so increasing richness (Guretzky et al., 2007; Olff and Ritchie, 1998). Therefore, we suspect that the applied grazing pressure within rotation (i.e. 1 cattle ha^{-1} for 1 year, followed by 1 fallow year) was too low to create these optimal establishment conditions. Turnover rates, on the other hand, were similar across regimes, indicating that while compositional changes based on species identity did take place, these were not severe in any of the regimes. This was also reflected in the species compositional analysis, which takes into account both species identity and abundances. While the more traditional regimes with high and low density cattle or horse grazing were similar in species composition, rotation differed from 1 cattle and 1 horse ha^{-1}, but was similar to the low density grazing regimes. This indicates that grazing with 1 cattle ha^{-1} or 1 horse ha^{-1} is indeed of sufficient density to induce greater spatial heterogeneity for species to establish. To achieve similar results with rotation grazing concerning plant species composition and species richness, grazing density likely needs to be increased (i.e. > 1 animal ha^{-1}) during the grazing phase of the rotation cycle.

4.2. Elytrigia and Aster

Elytrigia had not increased in cover in the rotation regime, indicating that rotation grazing with one year of summer grazing with 1 cattle ha^{-1} once every two years is sufficient to halt the spread of *Elytrigia*. Six years of traditional grazing management also did not significantly change the cover of *Elytrigia*. However, it seems that cattle (but not horses) prefer and halt the spread of *Elytrigia* (Veeneklaas et al., 2011). It is also evident from our experiment that in permanent absence of grazing *Elytrigia* increases in cover (35% during our study), with a concomitant decrease in species richness (i.e. mean of 4.0 species compared with 7.8–10.2 species in the grazed regimes in 2015). Thus, spread of *Elytrigia* decreases plant diversity values within salt marshes as indicated by other studies (Bakker et al., 2003; Pétillon et al., 2005; Veeneklaas et al., 2013), but we show that rotation grazing may present an important alternative tool to the more traditionally used grazing regimes to cease the spread of *Elytrigia* and resulting mono-specific vegetation (Rupprecht et al., 2015).

Aster generally responded positively to grazing (except for 1 cattle per ha^{-1}), but not more favourably in rotation as we had expected. Release from grazing during the fallow year thus does not provide a long enough window of opportunity for *Aster* to proliferate and expand in cover to counter the effects of grazing in the following year (unpublished data). In addition, cattle in low density grazing increases basal cover of *Aster* through stimulating lateral compensatory growth after feeding on the *Aster* flowers and growing tips (Nolte et al., 2013). On the other hand, cattle in high density may even feed on *Aster* regrowth resulting in lower cover. Therefore, for the conservation of *Aster* a rotation regime with low cattle grazing densities and a longer period of grazing release (> 2 years) is recommended, however this would then also be dependent on the response of *Elytrigia* to the prolonged period of grazing release.

4.3. Applicability of rotation grazing

Besides impacts on diversity, it is important to consider feasibility of rotation grazing for conservation managers. Potentially, rotation grazing can save time and finances in comparison with the more traditional regimes where grazing takes place on a yearly basis. Whether rotation is practical also depends on the ratio between available livestock (species) and grazing area. In The Netherlands, livestock for nature areas is typically obtained from local farmers as most conservation areas do not own herds of livestock, and thus number and type of livestock is dependent on what is offered. A high ratio is less suitable for rotation grazing due to shortage of grazing grounds compared with high number of livestock (i.e. high grazing pressure). Contrary, a low ratio would be more favourable for rotation grazing, as there is sufficient grazing area available.

5. Conclusions

The effects of a rotation regime after three completed cycles on vegetation, in which one year of summer grazing is followed by a fallow year, are relatively similar to grazing regimes with cattle or horses in low densities (i.e. 0.5 animal ha^{-1}). The concurrent application of several traditional grazing regimes in salt marshes has been proposed by others (van Klink et al., 2016; Wanner et al., 2014), due to the idiosyncratic effects on different biotic target groups. The inclusion of a spatially and temporally explicit management scheme such as rotation may provide a window of opportunity for other biotic groups, such as birds, voles and invertebrates to persist, thereby enhancing biodiversity. However, it is yet unclear how rotation will affect these groups in the short- or long-term, as the cascading effects of the rotation regime are still unknown. Depending on the responses of these groups the grazing pressure of rotation can be increased, which will also likely favour biodiversity within the plant community. Grazing in productive ecosystems, such as salt marshes, generally increases biodiversity in the area (Olff and Ritchie, 1998) and we therefore expect our findings to be applicable to other productive ecosystems. However, the implementation of the rotation regime over the more traditionally used regimes remains to be decided by the conservation body depending on its applicability in terms of available grazing areas and livestock, and overall conservation goals.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.agee.2017.05.023.

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