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Effects of grazing management on biodiversity across trophic levels–The importance of livestock species and stocking density in salt marshes

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ABSTRACT

European coastal salt marshes are important for the conservation of numerous species of specialist plants, invertebrates, breeding and migratory birds. When these marshes are managed for nature conservation purposes, livestock grazing is often used to counter the dominance of the tall grass *Elytrigia atherica*, and the subsequent decline in plant species richness. However, it remains unclear what is the optimal choice of livestock species and stocking density to benefit biodiversity of various trophic levels.

To fill this knowledge gap, we set up a triplicate, full factorial grazing experiment with cattle and horse grazing at low and high stocking densities (0.5 or 1 animal ha^{-1}) at the mainland coast of the Dutch Wadden Sea. Here, we present the results after 4 years and integrate these with previously published results from the same experiment to assess effects of livestock grazing on various trophic groups.

Stocking density affected almost all measured variables: high stocking densities favoured plant species richness and suppression of *E. atherica*, whereas low stocking densities favoured abundances of voles, pollinators and flowers. Densities of different functional groups of birds showed no significant response to the regimes, but tended to be somewhat higher under 0.5 horse and 1 cattle ha^{-1}.

Choice of livestock species had fewer and smaller effects than stocking density. Horse grazing was detrimental to vole density, and showed an interactive effect with stocking density for Asteraceae flower abundance. Multidiversity, a synthetic whole-ecosystem biodiversity measure, did not differ among regimes. These results are discussed in the light of other results from the same experiment.

Because of these contrasting effects on different trophic groups, we advise concurrent application of different grazing regimes within a spatial mosaic, with the inclusion of long-term abandonment. High density horse grazing, however, is detrimental to biodiversity.

1. Introduction

To maintain high plant species richness and to counter the encroachment of tall, competitive plant species, livestock grazing is a frequently used management tool in European semi-natural grasslands. It is becoming increasingly clear, however, that not all trophic groups respond equally positively to this type of management. Grazing is often beneficial to plant species richness (Olff and Ritchie, 1998), but detrimental to species richness of many arthropod groups (Foster et al., 2014; van Klink et al., 2015), molluscs (Boschi and Baur, 2007) and small mammals (e.g. Villar et al., 2014), while mixed effects are reported for species richness of meadow birds (e.g. Atkinson et al., 2005; WallisDeVries et al., 2007). Holistic management approaches, designed to benefit

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various trophic and taxonomic groups are therefore urgently needed (WallisDeVries et al., 2002).

Coastal salt marshes in north-western Europe represent a case in point. These ecosystems are of high conservation interest because of the numerous plant- and invertebrate species confined to this specific habitat, some of which are endemic to the region, and therefore protected under the EU Habitats Directive (Doody, 2008; EC Habitats Directive, 1992). Additionally, salt marshes are of high importance to large numbers of breeding and migratory birds, among which several species classified as vulnerable on the Dutch, German and British red lists, such as Redshank (*Tringa totanus*) and Oystercatcher (*Haematopus ostralegus*).

Mainland salt marshes have been used for livestock grazing for millennia, because of their productive clay soils. However, over the past 50 years many marshes fell to abandonment as livestock grazing became less profitable (Bakker et al., 2002). Abandonment usually results in a dominance of competitive plant species such as the tall-statured Sea couch grass (*Elytrigia atherica*) on higher salt marshes, Sea purslane (*Atriplex portulacoides*) on lower marshes (Bos et al., 2002; Wanner et al., 2014), or Common reed (*Phragmites australis*) on brackish marshes (Esselink et al., 2000). Such encroachment endangers populations of short-statured plants (Bos et al., 2002) and some invertebrate species (van Klink et al., 2013), and changes nesting and foraging conditions for birds, which are key issues according to the EU Habitats Directive. Livestock grazing can maintain species-rich plant communities and prevent, or decrease, the dominance of *E. atherica* (Bakker et al., 2002), but will under high stocking densities create a homogeneous short-grazed vegetation structure, which is unfavourable to many species of invertebrates (Pétillon et al., 2007; Rickert et al., 2012) and breeding birds (Mandema et al., 2015; Norris et al., 1998). Therefore it remains unclear, how grazing can best be implemented with respect to stocking density and livestock species, to benefit various trophic and taxonomic groups, and to prevent the dominance of competitive plant species. To fill this knowledge gap and to optimise salt-marsh conservation management, we installed a four-year grazing experiment on a mainland salt marsh at the Dutch Wadden Sea coast, using cattle and horse grazing at 0.5 and 1 animal per hectare, each. Here, we present new findings on plant, bird, pollinator and vole communities at the field scale, and compare these to previously reported results on vegetation structural complexity, nest survival, staging geese, survival of flowering forb *Aster tripolium*, and sediment accretion.

On salt marshes, the most important mechanisms by which livestock grazing affects biodiversity are biomass removal (defoliation) and trampling (Bakker et al., 1985). The impacts of both these processes increase with stocking density, but can also be expected to differ between livestock species due to differences in digestive system and mouth morphology. Horses, as hind-gut fermenters, have higher food intake rates than ruminants of the same size, and are able to digest more low-quality, high-fibrous grasses (Illius and Gordon, 1992; Menard et al., 2002). Additionally, horses can forage closer to the ground and are more active than cattle (Menard et al., 2002). Therefore, we hypothesise that the effects of horse grazing on the system will be greater than those of the more placid cattle.

The direct effects of livestock on their habitat can be expected to cascade up the food-chain (Evans et al., 2015). We hypothesise that plant species richness benefits from higher stocking densities as grazing opens the canopy and decreases light competition (Borer et al., 2014). Such a short and open vegetation canopy will be beneficial for spring staging geese, as these small herbivores require high-quality forage (Mandema et al., 2014b). By contrast, protective cover for voles will decrease under high stocking densities (Villar et al., 2014), hence, voles are hypothesised to be more abundant under low stocking densities. Also pollinators can be expected to be more abundant under low stocking densities, as their most important floral resource, *Aster tripolium*, is sensitive to grazing (Kiehl et al., 1996; Nolte et al., 2013). The thus expected high abundance of invertebrates and seeds under low stocking densities should in turn be attractive for breeding and wintering birds foraging on the salt marsh. By contrast, birds that forage on the intertidal flats, but roost on the salt marsh, are hypothesised to utilise the more heavily grazed marsh, because of the higher detectability of predators. Raptors and owls, in turn, can thus be expected to forage mostly in plots with low stocking densities, where their vertebrate prey, such as voles, are expected to be most abundant (Baker and Brooks, 1981). Our aim was therefore to determine which grazing regime (i.e. species and stocking density) is most optimal in terms of biodiversity.

2. Material and methods

2.1. Study area and experimental design

We established a triplicate grazing experiment in 2010 (year 1) on the salt marshes of Noord-Friesland Buitendijks at the mainland coast of the Dutch Wadden Sea (N53°20′, E5°43′). The site is a typical example of a Western European mainland salt marsh, which has established on marine clay deposits (up to 80% clay and silt) within man-made sedimentation fields. The average yearly temperature is 11 °C, with an average yearly rainfall of 785 mm (2005–2015; Royal Dutch Meteorological Institute). The study area is characterised by a distinct vegetation zonation from the frequently flooded pioneer zone, over the low marsh, to the higher elevated and seldom flooded high marsh, and is managed for nature-conservation purposes. The historic management of the experimental area was cattle grazing at relatively high densities (Esselink et al., 2009), with several rotations per year. This management type was continued until the start of the experiment in the central and eastern replicates, but in the western replicate grazing was ceased for eight years prior to 2009. In 2009 (year 0), high-density grazing was installed in the western replicate for one season to enhance comparability with the other two replicates at the start of the experiment in 2010.

Each replicate was subdivided into five paddocks of approximately 11 ha (Fig. 1), in each of which a different summer grazing regime (June-October) was installed: horse and cattle grazing at two stocking densities each (0.5 and 1 animal ha^{-1}), and a rotational grazing regime (one fallow year followed by 1 cattle ha^{-1}; not considered here due to limited data). Livestock were obtained from local farmers. Cattle were all 2–3 year old non-lactating cows (breed: Holstein-Friesian; ca. 600 kg). The horse herds consisted of animals of both sexes, all above 2 years of age (breed: Dutch Warmblood (KWPN); ca. 700 kg). The regimes were randomly assigned to the paddocks, with the restriction that horse grazing was not applied to two adjacent paddocks to avoid interactions between the two herds. Ungrazed paddocks were not included in the experiment, since the effects of grazing cessation on various biotic groups have been studied extensively elsewhere (e.g. Ford et al., 2013; Irmler and Heydemann, 1986; Kiehl et al., 1996; Wanner et al., 2014). In addition, the ecological changes are most pronounced under such a severe management regime, making it an ineffective control. The high density cattle grazing regime thus best reflects the historic management, and can be regarded as control regime.

2.2. Data collection

2.2.1. Vegetation

The spread of *E. atherica* was assessed by vegetation mapping of each paddock in year 0 and 4, based on aerial photographs.