Estuarine, Coastal and Shelf Science 152 (2015) 109–115

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

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

Effects of livestock species and stocking density on accretion rates in grazed salt marshes

Stefanie Nolte [a,*], Peter Esselink [a,b], Jan P. Bakker [a], Christian Smit [a]

[a] Community and Conservation Ecology — Centre for Ecological and Evolutionary Studies, University of Groningen, PO Box 11103, 9700 CC Groningen, The Netherlands
[b] Puccimar, Boermarke 35, 9481 HD Vries, The Netherlands

ARTICLE INFO

Article history:
Received 7 April 2014
Accepted 15 November 2014
Available online 24 November 2014

Keywords:
cattle grazing
horse grazing
Wadden Sea
compaction
sedimentation
vegetation structure
inundation frequency

ABSTRACT

Coastal ecosystems, such as salt marshes, are threatened by accelerated sea-level rise (SLR). Salt marshes deliver valuable ecosystem services such as coastal protection and the provision of habitat for a unique flora and fauna. Whether salt marshes in the Wadden Sea area are able to survive accelerated SLR depends on sufficient deposition of sediments which add to vertical marsh accretion. Accretion rate is influenced by a number of factors, and livestock grazing was recently included. Livestock grazing is assumed to reduce accretion rates in two ways: (a) directly by increasing soil compaction through trampling, and (b) indirectly by affecting the vegetation structure, which may lower the sediment deposition. For four years, we studied the impact of two livestock species (horse and cattle) at two stocking densities (0.5 and 1.0 animal ha^{-1}) on accretion in a large-scale grazing experiment using sedimentation plates. We found lower cumulative accretion rates in high stocking densities, probably because more animals cause more compaction and create a lower canopy. Furthermore, a trend towards lower accretion rates in horse-compared to cattle-grazed treatments was found, most likely because (1) horses are more active and thus cause more compaction, and (2) herbage intake by horses is higher than by cattle, which causes a higher biomass removal and shorter canopy. During summer periods, negative accretion rates were found. When the grazing and non-grazing seasons were separated, the impact of grazing differed among years. In summer, we only found an effect of different treatments if soil moisture (precipitation) was relatively low. In winter, a sufficiently high inundation frequency was necessary to create differences between grazing treatments. We conclude that stocking densities, and to a certain extent also livestock species, affect accretion rates in salt marshes. Both stocking densities and livestock species should thus be taken into account in management decisions of salt marshes. In our study accretion rates were higher than the current SLR. Further research is needed to include grazing effects into sedimentation models, given the importance of grazing management in the Wadden Sea area.

1. Introduction

Coastal ecosystems around the world are under threat of inundation because of accelerated sea-level rise (SLR) (IPCC, 2007; Vermeer and Rahmstorf, 2009). The accelerated SLR is predicted to cause a loss of 5–20% of coastal wetlands worldwide by 2080 (Nicholls, 2004). Coastal wetlands such as mangroves (Krauss et al., 2010) and salt marshes (Morris et al., 2002) are among those threatened by accelerated SLR, and are in need of protection because of their valuable ecosystem services such as the attenuation of waves which increases coastal protection (Möller, 2006), carbon sequestration (Callaway et al., 2012) and the provision of habitat for a unique flora and fauna (Schmidt et al., 2012).

Salt marshes can be classified as either organogenic or minerogenic marshes. While in organogenic marshes accretion mainly depends on the accumulation of organic material, *e.g.* dead roots, accretion in minerogenic marshes is dominated by mineral deposition of sediments during inundations (Nolte et al., 2013a). Whether these minerogenic salt marshes are able to survive SLR is largely dependent on their ability to catch sufficient amounts of sediment which deposit on the marsh surface and thus add to the marsh accretion rate. The accretion rate is the vertical growth of the marsh in mm/year and includes compaction processes in the upper

* Corresponding author. Present address: Applied Plant Ecology, Biocenter Klein Flottbek, University of Hamburg, Ohnhorststr. 18, 22609 Hamburg, Germany.
E-mail address: stefanie.nolte@uni-hamburg.de (S. Nolte).

http://dx.doi.org/10.1016/j.ecss.2014.11.012
0272-7714/

soil layers (Nolte et al., 2013a), which are sometimes also referred to as shallow subsidence (Van Wijnen and Bakker, 2001) or auto-compaction (Cahoon et al., 1995; Bartholdy et al., 2010). When compaction processes in the deeper soil layers and tectonic processes are also taken into account, we speak of surface-elevation change in mm/year, which, in contrast to the accretion, is usually measured in relation to a local fixed benchmark level (Nolte et al., 2013a). If the vertical surface-elevation change is greater than or equal to local SLR, and lateral erosion, *i.e.* erosion on the seaward marsh edge, is not occurring, it is assumed that marshes are able to survive SLR. Surface elevation change and accretion rates are often comparable in marshes where the soil contains large percentages of mineral particles (French and Burningham, 2003), *e.g.* in the Wadden Sea area, as compaction only plays a small role there (Allen, 2000; French, 2006). Therefore, measurements of accretion rates can be used instead of surface elevation change to assess marshes susceptibility to SLR in minerogenic marshes.

Surface elevation change and accretion in salt marshes, as well as factors affecting it, have been widely studied in both organogenic (Cahoon and Turner, 1989; Baustian et al., 2012) and minerogenic marshes (Dijkema, 1990; Bellucci et al., 2007). Factors which were found to influence accretion rates in tidal marshes are, for example, elevation affecting inundation frequency and duration (Richard, 1978; Stoddart et al., 1989; Temmerman et al., 2003b), the suspended sediment concentration (SSC) of the inundating water (Kirwan et al., 2010), the distance to the sediment source such as creeks or the marsh edge (Esselink et al., 1998; Reed et al., 1999; Bartholdy et al., 2004) and the physical vegetation structure. The physical vegetation structure is assessed in different ways, *e.g.* the number of stems per m^2 (Leonard and Reed, 2002; Bouma et al., 2005; Neumeier and Amos, 2006), the above-ground biomass (Bouma et al., 2005; Neumeier and Amos, 2006) or simply the canopy height (Neumeier and Amos, 2006). A tall and dense vegetation structure slows down the current of the inundating water and thereby promotes sediment deposition (Neumeier and Amos, 2006; Viles et al., 2008; Fagherazzi et al., 2012). An important factor that strongly affects these physical vegetation structure indices in salt marshes is livestock grazing (Andresen et al., 1990; Neuhaus et al., 1999; Stock, 2011; Suchrow et al., 2012).

Livestock grazing in salt marshes can be found in South America (Di Bella et al., 2013), Asia (Yang et al., 2008) and has a long tradition in European salt marshes, especially in the Wadden Sea area (Esselink et al., 2000, 2009). While in the past livestock grazing mainly had agricultural purposes, it is currently also frequently used as a tool for nature management (Andresen et al., 1990; Bos et al., 2002; Bakker et al., 2003; Kleyer et al., 2003). Despite this, nature management decisions to date hardly took into account possible effects of grazing on accretion rates. Strong evidence for a reduction of accretion rates in grazed marshes was found in various studies (Andresen et al., 1990; Neuhaus et al., 1999; Stock, 2011; Elschot et al., 2013). In contrast, Nolte et al. (2013b) did not find any overall clear effect of grazing on accretion rates. In addition to the comparison of grazed *vs.* ungrazed marshes, the stocking density was also found to influence accretion rates with lower rates at higher stocking densities (Andresen et al., 1990; Neuhaus et al., 1999; Stock, 2011). The effect of stocking density is of great importance for nature management (Dumont et al., 2007; Scimone et al., 2007; Dumont et al., 2009), as it is necessary to choose a stocking density to reach management goals (*e.g.* high biodiversity by preventing dominance of a tall species). Furthermore, nature managers need to choose a livestock species for grazing (Rook et al., 2004) although the way in which different livestock species affect accretion rates is thus far unknown.

Grazing is supposed to affect accretion rates in salt marshes in two ways: directly by increasing soil compaction (by trampling) and indirectly by altering the vegetation structure (Elschot et al., 2013; Nolte et al., 2013b). Soil compaction was found to be increased by livestock grazing in salt marshes (Olsen et al., 2011; Schrama et al., 2013), and this compaction probably directly reduces accretion rates, especially during the summer months when livestock is present. Indirectly, livestock grazing is assumed to affect accretion rates by altering the vegetation structure (Andresen et al., 1990; Stock, 2011). A dense vegetation, such as a high number of stems per m^2, was found to increase sediment deposition and accretion by tempering current velocities of the inundation water (Fagherazzi et al., 2012). The physical vegetation structure, *i.e.* canopy height and tiller density, is reduced by livestock grazing (Andresen et al., 1990; Berg et al., 1997; Elschot et al., 2013) and therefore livestock grazing is expected to reduce sediment deposition and accretion rates. We expect to find this effect especially in winter, when most of the sediment deposition takes places during storm events or strong floods (Roman et al., 1997; Fagherazzi et al., 2012; Schuerch et al., 2012). In winter the compaction effect can be excluded because livestock is not present. How different livestock species affect accretion rates in salt marshes is unknown. We would expect different livestock species to vary in their effect based on behavioural differences between species. For example horses, in comparison to cattle, have higher forage requirements per day and walk longer distances (Duncan et al., 1990). This behaviour might lead to a higher compaction of the soil and a stronger reduction of vegetation structure (Nolte et al., 2014), both of which are assumed to reduce accretion rates (Elschot et al., 2013; Nolte et al., 2013b).

We tested the effect of horses and cattle grazing in two stocking densities on accretion rates in a grazing experiment in a salt marsh situated at the Dutch mainland coast. We hypothesize that 1) high stocking densities lead to lower accretion rates compared to low densities, and 2) that based on behavioural differences between livestock species, horses lead to lower accretion rates compared to cattle. To investigate whether effects are caused directly, by differences in compaction, or indirectly, by differences in sediment deposition, we analysed cumulative accretion rates for different seasons: direct effects are expected to take place in summer when animals are present, while indirect effects are probably more pronounced in winter, when sediment deposition takes place during storms.

2. Materials and methods

2.1. Study area

The research area ‘Noord-Friesland Buitendijks’ (NFB) is a mainland salt marsh situated on the north coast of the Netherlands (53°20′11″, 5°43′40″) and exposed to a tidal range of about 2.1 m. The intertidal flats in front of the marsh area are generally not eroding. The region is characterized by a temperate climate with an average yearly precipitation of 820 mm and an average yearly temperature of 9.5 °C. Based on the data from the tide gauges at Harlingen and Lauwersoog (Rijkswaterstaat), which are situated approximately 30 km to the west and east of the study area, we calculated the mean high tide (MHT) to be 99.5 cm above NAP (Dutch ordnance level). Most mainland salt marshes in the Wadden Sea, including NFB, originate from man-made sedimentation fields. These sedimentation fields were installed to enhance sediment deposition on the marsh. The building of sedimentation fields also included the digging of straight drainage ditches which led to marshes with relatively flat topography. The flat topography and regular shape of ditches is the ideal starting situation to install a large-scale experiment to test the effects of livestock grazing on accretion.