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Effects of vegetation patterns and grazers on tidal marshes

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Summary

INTRODUCTION

A large part of the global terrestrial area is covered by grasslands and they are being grazed by both wildlife and domestic livestock, resulting in very high grazing pressures. These grazers will have a large impact on the local vegetation and can alter important ecosystem functions. Furthermore, due to changing environmental conditions and human impact, populations of native grazers are reducing in some ecosystems, while they are increasing in others. With these global changes in grazing pressures, it is important to gain understanding on how they impact vegetation characteristics, the interactions between grazers and vegetation, and the effects on important ecosystem processes. In this thesis I studied this, using tidal marshes as a model ecosystem.

THE IMPACT OF GRAZERS ON IMPORTANT MARSH DYNAMICS

Throughout the year, many small grazers use marshes as feeding habitats. Migratory birds are present in European marshes during winter. Other small grazers, such as hare and rabbits, are present throughout the entire year. Next to these small grazers, we also find livestock on many European marshes. The effects of livestock grazing on the marsh vegetation have been studied intensively in ecology. They are known to reduce vegetation height and increase plant diversity. By bringing back younger successional plant species in mature marshes, they are known to facilitate for small grazers. However, their impact on many important ecosystem functions has not received a lot of attention so far. In this thesis, I found that the impact of a grazer within an ecosystem depends for a large part on their body size as well as forage mechanism.

In **chapters 2 and 3** we studied the impact of small grazers (Barnacle goose, Brent goose and hare) and large grazers (cattle), which graze on above-ground plant parts. We measured their effect on vegetation height, sediment deposition, marsh accretion rates and carbon accumulation in the marsh soil. We found that both small grazers and large grazers reduced the vegetation height significantly. However, this did not affect sediment deposition (**chapter 2**). Additionally, small grazers had no effect on marsh accretion rates (**chapter 2**) or carbon accumulation in the marsh soil (**chapter 3**). Based on our results, we concluded that the impact of small grazers on the functioning of tidal marshes were fairly limited. In contrast, we found that cattle had a negative impact on marsh accretion rates (**chapter 2**), while they positively affected carbon accumulation in the marsh soil (**chapter 3**). Through trampling, they increased the bulk destiny and this reduced the marsh accretion rates. Furthermore, by increasing the bulk density in the soil, they also reduced the oxygen availability and therefore the organic carbon decomposition by the microbial community. This enhanced carbon sequestration in the marsh

soil. These effects of large-bodied grazers on soil properties in tidal marshes has been largely neglected so far, but need to be considered when we want to introduce livestock to ungrazed marshes.

Next to above-ground grazing, we also find small grazers that grub for below-ground storage organs in tidal marshes. This type of grazing removes the entire plant and it is therefore much more difficult for the vegetation to regenerate. This grubbing behavior generally causes bare patches to form within the marsh vegetation. In extreme cases, it can lead to large marsh areas to become degraded. We studied the regeneration of these local bare patches created by grubbing Greylag geese (**chapter 5**). Additionally, we studied ecosystem development on a landscape scale. Within our study site, a large population of Greylag geese is reducing in size and we hypothesized that geese grubbing on a local scale or ecosystem development on a landscape scale, is in fact reducing their food supply. We found that the bare patches regenerated back to a similar vegetation type within about 12 years. Therefore, the geese do reduce their food supply, but only shortly and very locally. Very interestingly, we found an increase in plant diversity as young-successional plant species established in these bare patches during regeneration. On a landscape scale, we found a very high accretion rate that outpaced the rising sea-level. Their preferred food source, *Bolboschoenus maritimus*, reduced in cover, while *Elytrigia atherica* was increasing in cover. *Bolboschoenus maritimus* is generally limited to the lower elevated depressions between the creek banks, whereas *Elytrigia atherica* dominates op top of the creek banks. An increase in elevation would allow *Elytrigia atherica* to expand towards the depressions and *Bolboschoenus maritimus* to reduce in cover. Therefore, we concluded that the natural development of the marsh on a landscape scale is causing the Greylag geese to get evicted from the ecosystem and not due to local degradation by the geese themselves. Additionally, and in contrast to other studies showing the negative effect of grubbing small grazers, we concluded that grubbing geese can positively affect plant diversity through a local set-back of the plant succession.

THE IMPACT OF LARGE GRAZERS AND HETEROGENEITY ON SMALL-GRAZER ABUNDANCE

In tidal marshes, small grazer abundance is known to change with increasing productivity. At young successional stages, where productivity is still low, limited biomass production limits the amount of small grazers that can forage within the system. As the marsh develops and productivity increases, then the abundance of small grazers increases as well. However, at mature marshes the cover of nutritious plant species get replaced by unpalatable ones and the small grazers reduce in abundance again. Large grazers are known to facilitate for small grazers by bringing back the nutritious plant

species again. In line with these previous studies, we also found an increase in the abundance of small above-ground grazers when cattle were introduced in mature marshes. However, we did not find any evidence for the cattle facilitating for below-ground grubbers (**chapter 6**). As mentioned previously, we found a reducing population of Greylag geese in our study site due to natural succession. In contrast to the small above-ground grazers, we did not find an increase in the abundance of small below-ground grubbers when cattle were present.

Next to the effect of the large grazers, we also found an effect by small-scale heterogeneity in the marsh platform on small grazer presence (**chapter 4**). We studied a small-scale topographic heterogeneity (of a few square metres) that consisted of higher elevated hummocks alternating with lower elevated depressions. By comparing the soil characteristics underlying the heterogeneity in four European marshes, we concluded that this pattern is formed in the pioneer stage, before marsh formation starts and fine-grained sediment accumulates on the marsh platform (**box 1**). Throughout ecosystem development, ranging from pioneer to mature marshes, this heterogeneity increased plant diversity (**chapter 4**). Additionally, we found a very high grazing pressure by hare on top of the higher elevated hummocks, which was especially higher in the young successional stages of 15 and 30 yrs-old marsh compared to homogeneous marsh (**chapter 4**). Although limited primary production in young marshes generally limits the abundance of grazers, presence of higher elevated hummocks increased local primary production and the hare could profit from these local elevated patches.

MANAGEMENT IMPLICATIONS

Many European marshes are grazed by wildlife as well as by livestock, to maintain plant diversity. For management purposes, we need to understand the impact of these different types of grazers on the vegetation and on important marsh dynamics. The results in this thesis showed that small above-ground grazers reduced the vegetation height, but their effects on important marsh dynamics (that were studied in this thesis) were very limited (**chapters 2 and 3**). Below-ground grubbing geese had a large impact on the vegetation composition and this increased plant diversity in tidal marshes, although this effect was only present for a limited period of time until the bare patches regenerated (**chapter 5**). With respect to cattle, these large-bodied animals had a very large effect through trampling of the soil. Trampling by cattle reduced the marsh accretion rates (**chapter 2**), while it enhanced the carbon sequestration rate in the marsh soil (**chapter 3**). Whether the positive impact of large grazers on biodiversity and carbon sequestration, outweighs the negative impact on marsh accretion rate will be very site specific, depending on the problems the marsh are facing. Marshes with high sedimentation

rates will be less affected by a reduced accretion rate. Hence, livestock grazing on these sites could be used to provide increased carbon sequestration rates next to an increased biodiversity. These impacts of grazers on both vegetation and soil characteristics should be taken into account in future studies that use models to estimate whether coastal habitats can cope with an accelerated sea-level rise.