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Utilisation of a coastal grassland by geese after managed re-alignment

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Full article

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Abstract

Purpose: In this study we evaluate the effect of coastal re-alignment on the utilisation of coastal grasslands by staging geese.

Methods: We assessed vegetation change and utilisation by geese using repeated mapping and regular dropping counts in both the restored marsh and adjacent reference sites. All measurements were started well before the actual re-alignment. In addition, we studied the effects of livestock grazing on vegetation and geese, using exclosures.

Results: The vegetation transformed from fresh grassland into salt-marsh vegetation. A relatively large proportion of the de-embanked area became covered with secondary pioneer vegetation, and the overall cover of potential food plants for geese declined. Goose utilisation had initially dropped to low levels, both in autumn and in spring, but it recovered to a level comparable to the reference marsh after ten years. Exclosure experiments revealed that livestock grazing prevented the establishment of closed swards of grass in the poorly drained lower area of the restored marsh, and thereby negatively affected goose utilisation of these areas during spring staging. Goose grazing in the restored marsh during spring showed a positive numerical response to grass cover found during the preceding growing season.

Conclusions: (1) The value of restored salt marsh as foraging habitat for geese initially decreased after managed re-alignment but recovered after ten years. (2) Our findings support the idea that the value of foraging habitats depends largely on the cover of forage plants and that this can be manipulated by adjusting both grazing and drainage.

Key words: Barnacle geese; Dark-bellied Brent geese; livestock grazing; salt-marsh restoration

Abbreviations

MHT mean high tide

MR managed re-alignment

NFB Noard-Fryslân Bûtendyks

IFG *It Fryske Gea*

1. Introduction

Coastal grasslands along the whole Wadden Sea serve as one of the main feeding areas for staging geese during fall and spring migration along their East-Atlantic flyway. The main goose species using these grasslands are Dark-bellied brent goose (*Branta bernicla bernicla*) and Barnacle goose (*Branta leucopsis*), which both breed in the Arctic or Subarctic (Madsen et al. 1999). They use both inland fresh grasslands, including summer polders, and salt marshes. Fresh grassland refers to grassland influenced by fresh, rather than salt water. In the Wadden Sea, summer polders are found particularly along the mainland coast of both Lower-Saxony, Germany, and the province of Friesland, the Netherlands (Esselink et al. 2009). Located in between the main seawall and the more seaward lying salt marshes, summer polders may be flooded irregularly, and for this reason their exploitation as productive farmland is not feasible.

Because of the centuries-long history of successive land claims, and the fact that the formation of new salt marshes could not keep pace with the rate of embankments, the current area of mainland salt marshes in the Dutch Wadden Sea is below any historic reference value (Dijkema 1987). These salt marshes, however, have an admitted value for nature conservation, and projects have been carried out to restore salt-marsh ecosystems and associated ecosystem and societal values all along the North Sea coast (Wolters et al. 2005). Such restoration projects, where formerly reclaimed land is re-exposed to tidal inundation through breaching of coastal embankments, is termed managed re-alignment (MR). Several reviews have evaluated the consequences of MR on plant communities (Garbutt and Wolters 2008; Hughes et al. 2009; Mossman et al. 2012a), environmental characteristics (Mossman *et al.* 2012b) or ecosystem services (Moreno-Mateos *et al.* 2012), but effects on staging geese have rarely been studied. A general conclusion of these studies is that salt-marsh plants are relatively rapid in colonising formerly reclaimed land after tidal flooding is resumed, but regenerated salt marshes often remain different in terms of species richness, composition and structure from reference salt-marsh communities (Garbutt and Wolters 2008; Mossman et al. 2012b).

The question of whether restoration aims are achieved in MR projects does not only depend on restoration of tidal influence, but also on the total package of environmental variables, conversion measures, and subsequent management. The latter may include livestock grazing. Many Wadden Sea salt marshes were traditionally exploited by livestock grazing but are managed for nature conservation nowadays. Livestock grazing may be applied as management tool in order to prevent species-poor vegetation types from developing or to facilitate goose grazing (Bakker et al. 2003). Under ungrazed conditions, salt-marsh vegetation may change due to natural succession (Bakker et al. 1993; Kiehl et al.

2000). During succession, tall plant species ultimately may become dominant, such as *Atriplex portulacoides* (nomenclature following van der Meijden (2005)) in the low marsh and *Elytrigia atherica* in the high marsh, both of which are unpalatable for geese (Jensen 1985; Olff et al. 1997; Bos et al. 2002; Barkowski et al. 2009). In contrast, livestock grazing favours short palatable grasses, such as *Puccinellia maritima* on the lower parts of the salt marsh and *Festuca rubra* on the high marsh (Kiehl *et al.* 1996; Bos *et al.* 2002). These short-grazed areas are preferred by Barnacle and Brent geese; thus, livestock grazing can facilitate goose utilisation of salt marshes (Aerts et al. 1996; Stock and Hofeditz 2000; van der Graaf et al. 2002; Bos et al. 2005). Salt-marsh swards in optimal state for grazing may accomodate many geese, but there is large variation depending on vegetation composition and management. High utilisation by geese is found at salt-marsh swards with high cover of food plants, which are often grasses (Madsen 1989; Stock and Hofeditz 2000) but also include *Plantago maritima and Triglochin maritima* (Prop 1991). Hardly any geese forage where unpalatable species dominate (Bos et al. 2005). The transformation from fertilised agricultural grassland to diverse salt-marsh vegetation is, therefore, assumed to decrease foraging opportunities for geese, but the magnitude of this effect will depend on vegetation composition and grazing management. For future restoration projects, and within the framework of goose-population management, it is relevant to what extent vegetation change will affect the capacity of areas that have been subjected to MR to accommodate geese. We, therefore, explicitly address this phenomenon and formulated the following hypotheses: H1) salt-marsh restoration from agricultural grasslands will result in decreased carrying capacity for geese; H2) livestock grazing will enhance goose utilisation of the restored salt marsh; H3) goose utilisation of the restored salt marsh will depend on cover by grasses, which are their staple food plants.

In 2001, a 123-ha area of summer polder was de-embanked in the Dutch section of the Wadden Sea at Noard-Fryslân Bûtendyks (NFB) by the local nature conservancy *It Fryske Gea* (IFG). IFG was aiming to gain experience in MR in order to have a sound basis for a future, larger scale restoration project at NFB. In order to allow for proper evaluation of the changes in abiotic conditions, plants and birds, a monitoring system was put in place, which included vegetation mapping, goose counts and regular counts of goose droppings (Esselink et al. 2014). Now, after the first ten years following de-embankment, we are able to evaluate the change in goose utilisation of the area subject to MR from the results of these field activities.

2. Methods

2.1 Study area

The restored site is part of a larger area of summer polders and salt marshes at NFB (Fig. 1), which consists of about 920 hectares of fresh grassland outside the main seawall located in the summer polders, the restored site and another 2400 hectares of salt marsh. The summer polders are former salt marshes that were embanked between 1892 and 1956. They are generally grazed by cattle and horses from May until October, and from October until the following May, Barnacle geese are present in high numbers. The area is also important for Brent geese.

This complex of summer polders is generally used for pastures, but in the past also partly for arable fields. The site where we took our measurements, adjacent to the restoration site, has been managed as a nature reserve since1996. The grassland vegetation at this site is characterised by *Lolium perenne*, *Agrostis stolonifera* and *Alopecurus geniculatus*. From 1998 until 2006, this summer polder was not fertilised, but before 1996, it had been managed intensively and received either slurry manure (15 - 20 ton/ha/yr) , farmyard manure (5 – 15 ton/ha/yr) or artificial fertiliser (100-200 kg N/ha/yr), or combinations of these. After 2006 application of manure was resumed, but the use of artificial fertiliser was completely abandoned.

The restoration site had been one of the aforementioned summer polders until September 2001. In this summer polder, an area of 123 ha was embanked in 1909 and kept as grassland. The western part has a higher elevation than the eastern part, generally varying between 35 and 75 cm above Mean High Tide (MHT; 1.35 m and 1.75 m +Dutch Ordnance Level; van Duin et al. 2007). Fertilisation stopped in 1998, but seasonal grazing (from April or May - October) with cattle and horses continued in different paddocks at varying stocking densities over the years.

2.2 Managed re-alignment at the restoration site

In September 2001, three breaches of 20-40 m in width were made in the summer dike at the restoration site. At each breach in the summer dike, an artificial creek system with an initial width between 5 and 10 m was excavated to allow for the supply and discharge of seawater and sediment,. Since 1997 there had already been a limited tidal exchange of sea water through open valve culverts in the summer dike. In the framework of converting the area, the drainage became partly blocked temporarily by the end of 2000. In order to rewet the restoration site, small parallel ditches, 10 m apart, were mostly blocked off where they intersected with the artificial creeks. The management aim for Noard-Fryslân Bûtendyks is to create a diverse salt marsh which embraces also sufficient foraging opportunities for geese. In order to prevent an increase of tall-growing plant species such as Elytrigia atherica, the area was managed by seasonal livestock grazing.

2.3 Vegetation change

Vegetation development was described by repeatedly mapping the vegetation. We used existing vegetation maps from years -14, 1 and 7 relative to the de-embankment in 2001 (i.e. 1987, 2002 and, 2008; Directorate-General of Public Works and Water Management, Rijkswaterstaat) and mapped the vegetation ourselves in year 10 (2011). The vegetation in each map was re-classified according to typology developed within the Trilateral Monitoring and Assessment Programme (TMAP) in the Wadden Sea (Esselink et al. 2009).

2.4 Goose counts

Geese were counted at regular intervals in order to determine the species and number of geese present throughout the season. These counts were performed over the entire area of NFB (about 3300 ha of vegetated area outside the seawall) and also over 2500 ha of adjacent inland fields, in strictly defined units of area for goose counting. These counts were also used to evaluate the change in use of adjacent inland arable fields and grasslands over time. The goose counts did not allow for a precise comparison of change over time for the restored site, because the spatial scale at which geese numbers had been recorded was too coarse. Goose counting was done for three years before and ten years after de-embankment at regular intervals, i.e. once a month or every two weeks. Geese were identified to species by experienced observers equipped with binoculars and telescopes, who covered the area on foot or by car.

2.5 Changes in goose utilisation over time

We measured goose utilisation of the restoration site, the adjacent salt marsh and the permanent grassland in the adjacent summer polders. Goose utilisation was assessed at these three sites using dropping counts in the autumn (November- December) and spring (April - May) of years -3, 0, 1, 2, 3 and 10 relative to de-embankment (1998/99, 2001/02, 2002/03, 2003/04, 2004/05 and 2011/12). Dropping counts allow for statistically robust comparisons of differences in grazing pressure over space or changes in grazing pressure over time (Owen 1971; Ydenberg and Prins 1981; van der Graaf et al. 2002; Bos et al. 2004), although several factors may affect the dropping densities found at a given location at a given time (Bédard and Gauthier 1986; Bos et al. 2008). Droppings were counted and subsequently removed from 4m^2 circular plots at regular intervals of usually one week but occasionally longer. The plots were marked in the field with an inconspicuous 5-cm-long stick in the centre. The number of plots was between 75 and 85 per counting period, which were divided over transects of five plots each. Each site was sampled in a representative way with a minimum of four transects per site. No distinction was made between droppings of different species of geese, but droppings <3.5 cm length that could be identified as originating from Wigeon (*Anas penelope*) were counted separately.

At the end of spring, in June of years -3, 1,2, 4 and 11 relative to de-embankment (1998 – 2012), we assessed plant cover per species at each dropping plot by visual estimation according to the decimal scale (Londo 1976). With these data we calculated the average cover of plants that are considered edible for geese per site. Based on goose-diet studies in salt marshes in the Wadden Sea by Aerts *et al.*(1996) and van der Wal *et al.*(2000), the following species were defined as 'edible for geese': *Agrostis stolonifera, Alopecurus* *geniculatus, Elytrigia repens, Festuca rubra, Lolium perenne, Puccinellia maritima, Plantago maritima* and *Triglochin maritima*.

2.6 Effect of livestock grazing on food availability and goose utilisation at the restoration site

In order to study the impact of livestock grazing on the vegetation dynamics in the restoration site, we installed twelve exclosures measuring10 m × 25 m; three permanent plots of 4 m × 4 m were installed inside and three control plots outside each exclosure. Locations for the exclosures were selected in the catchment area of each artificial creek to vary in distance to the breach and the creek, so that the effect of hydrology could be incorporated into the design. In order to evaluate the effect of livestock grazing on goose utilisation of the restoration site during spring, goose droppings were counted in a 4 m^2 circular plot placed in the centre of each permanent plot during the first week of May, 2012, which was eleven years after the de-embankment. Droppings had accumulated at these plots as a result of goose grazing (and defecating) inside and outside the exclosures during the period since the last inundation, which was not sharply defined. The last high flooding that possibly could have removed droppings from the plots had occurred on 24 February, 2012, i.e. more than two months earlier. Goose utilisation inside and outside the exclosures were evaluated relative to vegetation cover at the permanent plots during late summer of the previous year, 2011. The grazing season for livestock starts during the 2^{nd} half of May, which means that there is hardly any overlap between livestock and goose grazing. However, in order to avoid any possible interactions, plots in one catchment area were not recorded, because horses had been released there already more than one month earlier, from 1 April,2012, onwards.

2.7 Statistical analyses

The results of the repeated dropping counts were recalculated as the number of droppings/m^2/day. Counts from intervals longer than ten days, or otherwise obviously invalidated (e.g. by flooding), were disregarded. For the season 2011/12, we tested whether differences in grazing pressure were related to season (autumn or spring), site or their interaction. This was done using a Generalized Linear Mixed Model with gamma distribution (in SPSS version 20); individual counts per plot and week were treated as repeated measures for each transect in order to prevent pseudo-replication.

Correlation was calculated between data for the cumulative dropping counts inside and outside the exclosures in the eleventh year and total grass cover in the previous summer. The groups of plots at each exclosure were separated into two classes: ‘low' and 'high' elevation marsh. The effects of livestock grazing, elevation and distance to the creek were tested in a linear mixed model with group as a random variable. Goose counts were recalculated for the total number of goose days per species per year for the areas outside the seawall and the adjacent inland counting areas. We assessed whether there was a change over time in the use of inland counting areas using linear regression.

3. Results

3.1 Vegetation change

Fourteen years before de-embankment, the restoration site had been entirely covered with the vegetation type of *Lolium perenne* and *Agrostis stolonifera*, and classified as fresh grassland. One year after de-embankment, the cover of this vegetation type had been reduced to only 35% of the area, and was restricted to parts with higher elevation in the west. After seven years it had declined further, and after ten years the area was too small to be mapped (Fig. 1). At the expense of fresh grassland, vegetation types of the high and low marsh increased and covered about 25% and 17%, respectively, after ten years. Most apparent, however, was the sheer dominance of the vegetation type with *Salicornia* and *Suaeda* developing under waterlogged conditions. Because this pioneer vegetation was found at a relatively high elevation, and in order to discriminate it from primary pioneer salt marsh that forms around MHT, we classified this as 'secondary pioneer vegetation'. The vegetation in the restoration site had thus changed from a state dominated by fresh grassland to a salt marsh representing all the characteristic major zones of salt-marsh vegetation. A relatively large proportion (60%) of the restoration site became covered, however, with secondary pioneer vegetation.

3.2 Goose counts

Barnacle and Brent geese were both numerous at NFB, but the Barnacle goose dominated with 91% of the total number of goose days. Brent geese accounted for 5% of the total number of goose days (Fig. 2a). The number of goose days spent at NFB was 2200 goose days/ha on average per season (July-June) for the two species together. The number of geese was higher in spring than in autumn or winter, with a maximum monthly average of 71,000 Barnacle geese in April and 34,000 in November. The relative number of geese foraging in the adjacent strip of inland fields was limited and fluctuated around 3% of the total number observed (87 goose days/ha per season). There has not been a significant change in goose utilisation of these inland sites during the period from five year before de-embankment up to 11 years afterwards (linear regression $F_{1,13} = 0.89$, n.s.).

3.3 Changes in goose utilisation over time

Goose utilisation was higher in spring than in autumn of each goose wintering season (Wald $Chi^2 = 4.6$, $P = 0.03$; Fig. 2b). In the last year of measurement, the restoration site and the adjacent salt marsh had lower goose utilisation than permanent grassland in the summer polders (GLM, Wald $Chi^2 = 87$, $P < 0.001$). Especially in spring the differences were prominent; the grazing utilisation strongly increased in the summer polders but not in the restoration site or the salt marsh that last year. Also in other years, we found lower goose grazing utilisation in the restored site after de-embankment, with the lowest values directly after the start. In autumn, goose grazing utilisation increased in the restoration site as of year 2 and was not lower in year 10 than it was before de-embankment. There was also no statistical difference between the restoration site and the salt marsh in that last year of measurement.

3.4 Cover of potential food plants

The cumulative cover of edible plant species ranged from 40 to 97 % in the summer polders and salt marsh, but this cover never reached this same level in the restoration site during the first eleven years after de-embankment (Fig. 3). At the restoration site, *Agrostis stolonifera* was the most important edible species with 34 % ± 1 s.e. and 27 % ± 12 s.e. in the first two years after de-embankment. This species had declined to 13% ± 3 s.e. by year 11 after de-embankment. In year 11, the cover of *Puccinellia maritima* and *Elytrigia repens* had increased up to 12% ± 25 and 10% ± 18, respectively. The only grass species that should be categorized as a non-food plant, namely *E. atherica*, was either absent or present at low abundances with only a small share of the total grass cover. The restoration site was especially characterised by bare soil in spring: on average 51% ± 11.

3.5 Effect of livestock grazing on food availability and goose utilisation at the restoration site

The effects of livestock grazing, elevation and distance to the creek were all relevant in explaining variation in grass cover (Fig. 4a, linear mixed effect model: three-way interaction t=5.2, df = 36, $P < 0.001$). In the livestock-grazed low marsh, away from the creeks, grasses were virtually absent. In the plots ungrazed by livestock under the same conditions, however, a grass sward of predominantly *Elytrigia repens* had firmly established. These results were strongly reflected in the goose dropping densities. There was also a significant three-way interaction between livestock grazing, elevation and distance to the creek in explaining goose utilisation (Fig. 4b, linear mixed effect model: t=4.1, df = 36, $P < 0.001$). Thus, at low elevations in the back marsh, livestock grazing had a strong negative impact on both grass cover and goose utilisation, which resulted in a strong correlation between goose utilisation and grass cover within the grazed plots (Fig. 5).

4. Discussion

4.1 Main developments at the restored site

Analogous to many cases of MR elsewhere (Garbutt and Wolters 2008; Barkowski et al. 2009), the vegetation in the restoration site quickly changed. Salt-marsh plants colonised the site, and soon all the major vegetation zones that are characteristic of salt marshes were present, and the fresh grassland had disappeared. In comparison to the reference salt-marsh, a large area was covered by a secondary pioneer vegetation type dominated by *Suaeda maritima* and *Salicornia europaea*. This secondary pioneer vegetation type developed at an elevation around 0.4 m above MHT, at which grasses immediately started to dominate if the vegetation was released from livestock grazing.

Goose utilisation strongly dropped in the first years after de-embankment. It recovered to levels that were still lower than that found in the fresh grasslands of the summer polder (0.18 ± 0.03 s.e. versus 0.8 ± 0.07 droppings/m^2/day), but which could not be distinguished statistically from those in the adjacent salt marsh in the last season. We note, however, that these levels of goose utilisation are also lower than what has been recorded on well developed swards of salt-marsh vegetation dominated by grass. Under this type of condition, values between 0.7- 0.9 droppings/m^2/day have been recorded during the same two spring months in, for example, the Hamburger Hallig (Stock and Hofeditz 2000), Ameland (van der Graaf et al. 2002) or at NFB itself (this study).

The forage available for geese, in terms of cover of potential food plants, was estimated to be lower at the restoration site in comparison to the situation before MR and to the adjacent summer polders. The restoration site was especially characterised by bare soil in spring, but on the elevated parts, there was a good cover of grasses. In autumn *Suaeda maritima*, which has never been reported in the diet of geese, was very apparent in the vegetation. Within exclosures, however, grasses became firmly established, even at the low-elevation parts of the restoration site. Here we found elevated dropping densities and, thus, a positive correlation between grass cover and dropping densities. Given these experimental results, we suggest that forage availability was the main reason behind lower average goose utilisation after restoration.

The results are consistent with our first two hypotheses in that salt-marsh restoration from agricultural grassland resulted in a decrease of carrying capacity for geese and that goose utilisation of the restored salt marsh is dependent upon cover by grasses as their staple food plants. The third hypothesis however is rejected. Livestock grazing did not enhance goose utilisation of the restored salt marsh. Rather, it prevented the establishment of a suitable grass sward and thus reduced foraging opportunities for geese.

The goose counts illustrated that NFB as a whole was, and still is, a very important area for staging geese, mainly Barnacle and Brent. The restoration of a relatively small site, considering the size of NFB as a whole, has neither affected that function, nor the relative amount of geese foraging in adjacent inland sites.

4.2 Goose facilitation by livestock grazing on salt marshes

Many studies have demonstrated the facilitative effects of livestock on goose utilisation in salt marshes, by affecting either forage quality, sward structure or species composition of plants (Aerts et al. 1996; van der Graaf et al. 2002; Bos et al. 2005). In this study we found a contradictory result in that dropping densities were higher in the absence of livestock grazing in the low-lying parts of the restoration site, and there were no clear positive effects in the higher parts. This is related to the fact that, within the first ten years after MR, unpalatable species had not reached dominance in the ungrazed situation at the higher parts. In the low-lying parts, the presence of livestock prevented the establishment of grass. The fact that this only happened in the low-lying back marshes indicates a trampling effect interacting with waterlogged conditions.

4.3 Drainage measures and food for geese

At the restoration site, the well-drained creek sides were all covered by grasses (see vegetation map in Fig.1). The digging of creeks enhanced the variability of the abiotic environment at the restored site. Overall, however, the restored marsh was very flat, due to its former use and developmental history. This explains why blocking off the former drainage system affected such an extended area, resulting in waterlogged conditions and the development of extensive secondary pioneer vegetation. The combination of livestock grazing and increased waterlogging resulted in similar effects in the Dollard salt marshes (Esselink et al. 2000; Esselink et al. 2002) where the cover of halophytic annuals increased. There, *Elytrigia repens* almost disappeared outside exclosures, but could recover inside. The conservation or the construction of a more extended drainage system in the lower parts of the restored marsh would have enhanced, even under livestock grazing, the cover of grasses and, thereby, would have added to the value of the area for geese. Mossman et al. (2012b) also acknowledged the value of drainage at MR sites, while Ewanchuk and Bertness (2004) demonstrated experimentally that waterlogged soils limit the success of otherwise competitively dominant clonal turfs. We expect, nonetheless, that the secondary pioneer vegetation will slowly be replaced by grass-dominated vegetation once a natural drainage pattern develops, or if livestock grazing would temporarily be stopped, as was found by Hughes et al. (2009) for the vegetation at two ungrazed managed realignment sites in the Blackwater estuary, UK. For the time being, the results are in line with those of Mossman et al. (2012b), who generally found that the community composition of managed realigned MR sites was significantly different from reference salt-marsh sites in the UK, with early-successional species remaining dominant.

4.4 Implications for management

Our understanding of the mechanism behind the developments implies that management can affect goose utilisation of MR sites by influencing livestock grazing and drainage. For this particular restoration site at NFB, adjustment of livestock grazing and drainage may stimulate the establishment of grasses. By doing so, it should be possible to further enhance the value for wintering geese. The managed re-alignment of agricultural grasslands, in general, will lead to a lower carrying capacity for geese, unless an optimal salt-marsh sward with high grass cover can be developed. Higher grass cover can be achieved by either abandoning livestock grazing in low marshes, at least temporarily, conserving a greater part of the former drainage system during conversion of the restoration site, or digging an adequate, new drainage network. We recommend that the potential effects of MR on the carrying capacity for winter staging geese should also be addressed in other study areas.

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Figure captions

Figure 1. (a) Position of Noard-Fryslân Bûtendyks (white borderline) in the Dutch Wadden Sea and the Netherlands. (b, c) The location of the restoration site with adjacent summer polders and salt marshes. (c) The three artificial creek systems, which were dug for the supply and discharge of seawater and sediment, are given in blue. (d) Vegetation map of restoration site ten years after de-embankment. Classification of vegetation into main vegetation-zones follows the TMAP classification (Esselink et al. 2009). The community of *Salicornia* and *Suaeda* has been classified as secondary pioneer vegetation, in order to distinguish it from the primary pioneer marsh vegetation that develops at lower elevations at the transition between the intertidal mudflat and salt marsh. For technical reasons bare soil was assigned to the category of secondary pioneer vegetation.

Figure 2. (a) Cumulative number of goose days per season for Barnacle and Dark-bellied Brent geese at Noard-Fryslân Bûtendyks based on goose counts. (b, c) The development in average goose utilisation (droppings/m^2/d) at the restoration site compared to two neighbouring sites, the salt marsh and grassland in the summer polder. The panels give data for the autumn and spring of the same wintering seasons for geese as panel a. Error bars represent the standard error of the mean over the different transects within agricultural grassland in the summer polder (n = 5), salt marsh (n = 4), restored site (n = 6), respectively. Letters indicate significant differences within the season 2011-12 for autumn and spring separately. Data left of the dotted line refer to the period before de-embankment.

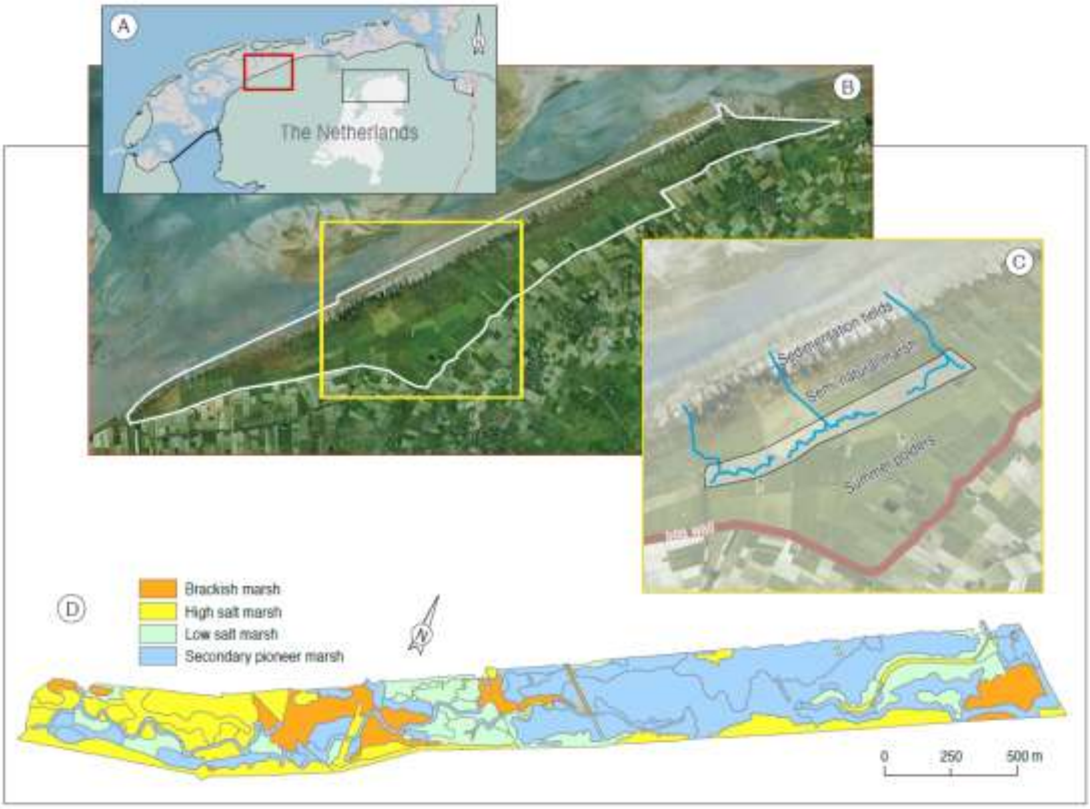
Figure 3. The average cover of plants considered as 'edible' for geese at the restoration site, the salt marsh and adjacent summer polders. Error bars indicate standard error of the mean (for sample size, see text in Fig. 2). Data left of the dotted line refer to the period before de-embankment.

Figure 4. (a) Average percentage of grass cover in permanent plots in the exclosure experiments in the high and low marsh zones along creeks and in the back marsh, 10 years

after de-embankment. Note the virtual absence of grasses in the livestock grazed low marsh in the absence of creeks. (b) Distribution of foraging geese, as measured by the number of cumulative droppings in the same permanent plots as in panel a during the subsequent spring. Note that geese did not visit the low marsh in the absence of creeks.

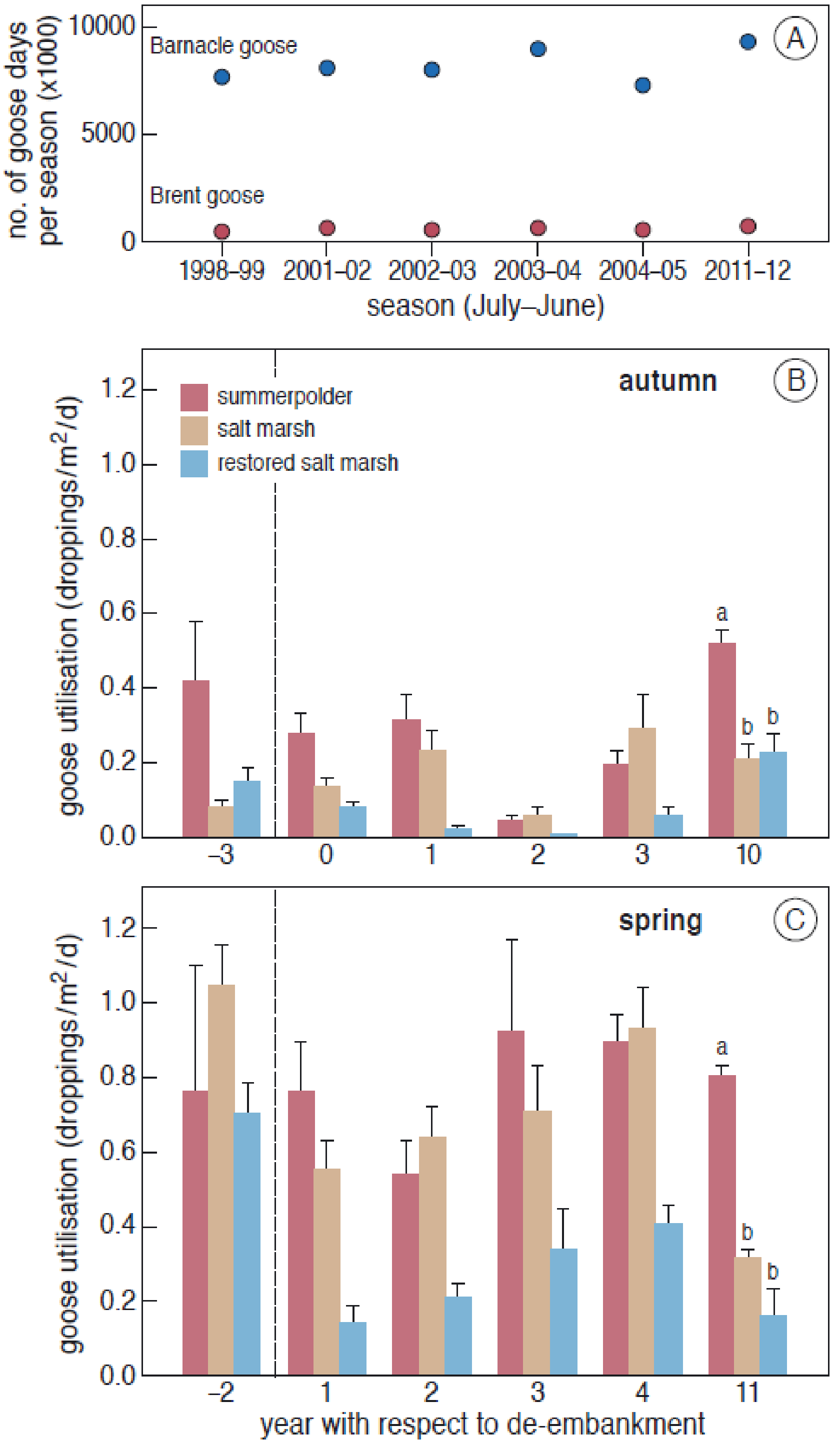
Figure 5. The relationship between grass cover in late summer and goose grazing during the subsequent spring, dependent on livestock grazing management. For the ungrazed plots, the relation was not significant in contrast to the grazed plots, where the relationship was highly significant.

Fig. 1.



A
The Netherlands
B
C
Sedimentation fields
Semi-natural marsh
Summer polders
D
Brackish marsh
High salt marsh
Low salt marsh
Secondary pioneer marsh
N
0
250
500 m

Fig. 2.



no. of goose days per season (x1000)
10000
5000
0
Barnacle goose
Brent goose
A
1998–99
2001–02
2002–03
2003–04
2004–05
2011–12
season (July–June)
goose utilisation (droppings/m2/d)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
summerpolder
salt marsh
restored salt marsh
autumn
B
a
b
b
–3
0
1
2
3
10
spring
C
a
b
b
–2
1
2
3
4
11
year with respect to de-embankment

Fig. 3.

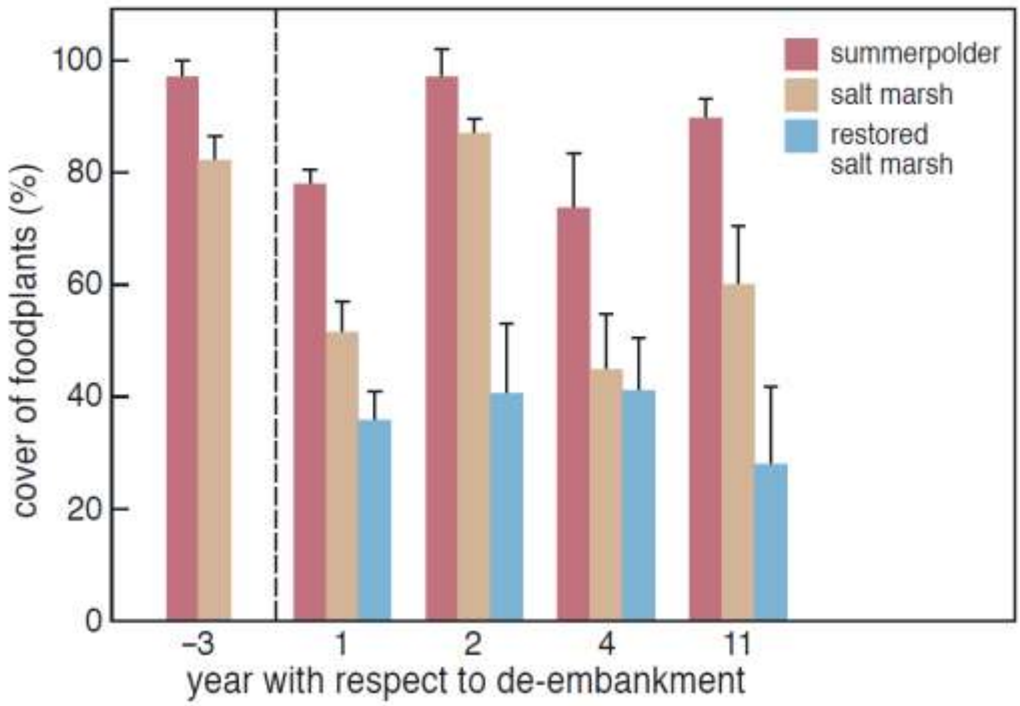

summerpolder
salt marsh
restored
salt marsh
cover of foodplants (%)
100
80
60
40
20
0
–3
1
2
4
11
year with respect to de-embankment

Fig. 4a,b

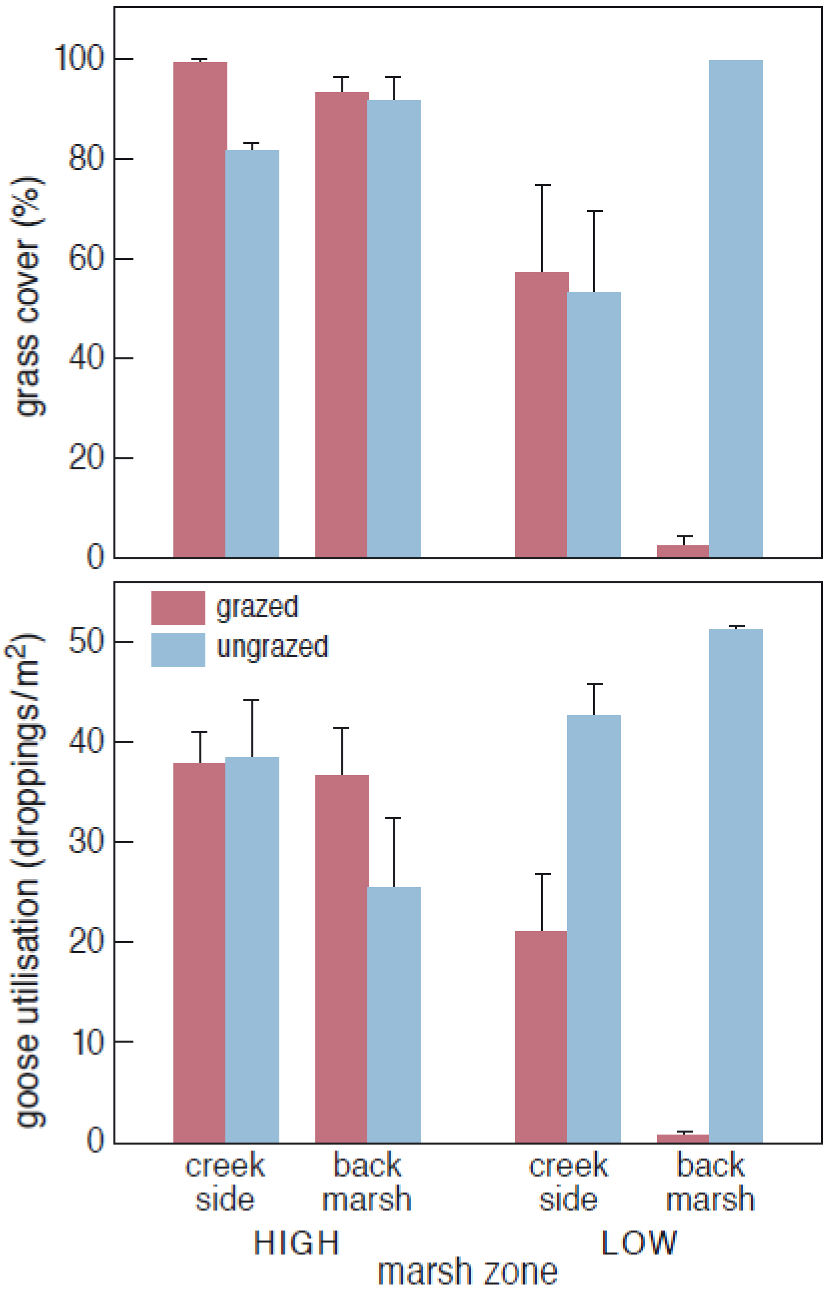
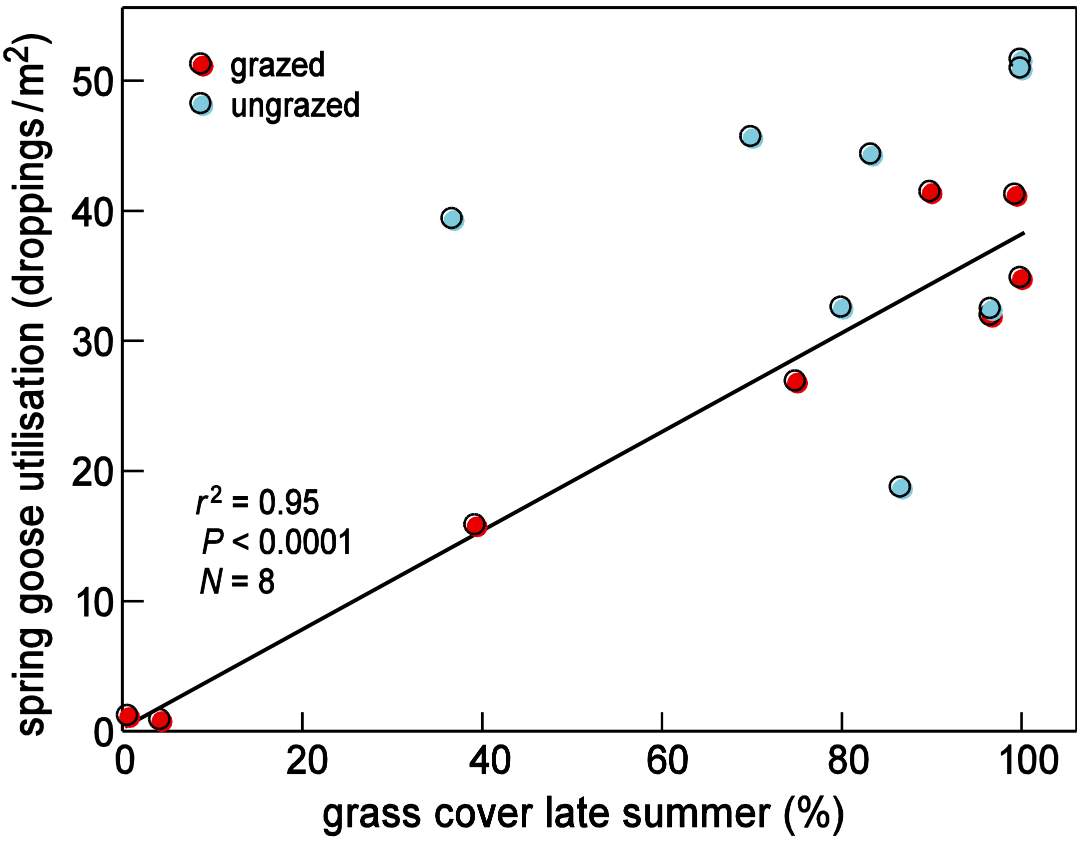

grass cover (%)
100
80
60
40
20
0
grazed
ungrazed
goose utilisation (droppings/m2)
50
40
30
20
10
0
creek side
back marsh
creek side
back marsh
HIGH
LOW
marsh zone

Figure 5



grazed
ungrazed
r2 = 0.95
P < 0.0001
N = 8
spring goose utilisation (droppings/m2)
grass cover late summer (%)
0
10
20
30
40
50
0
20
40
60
80
100