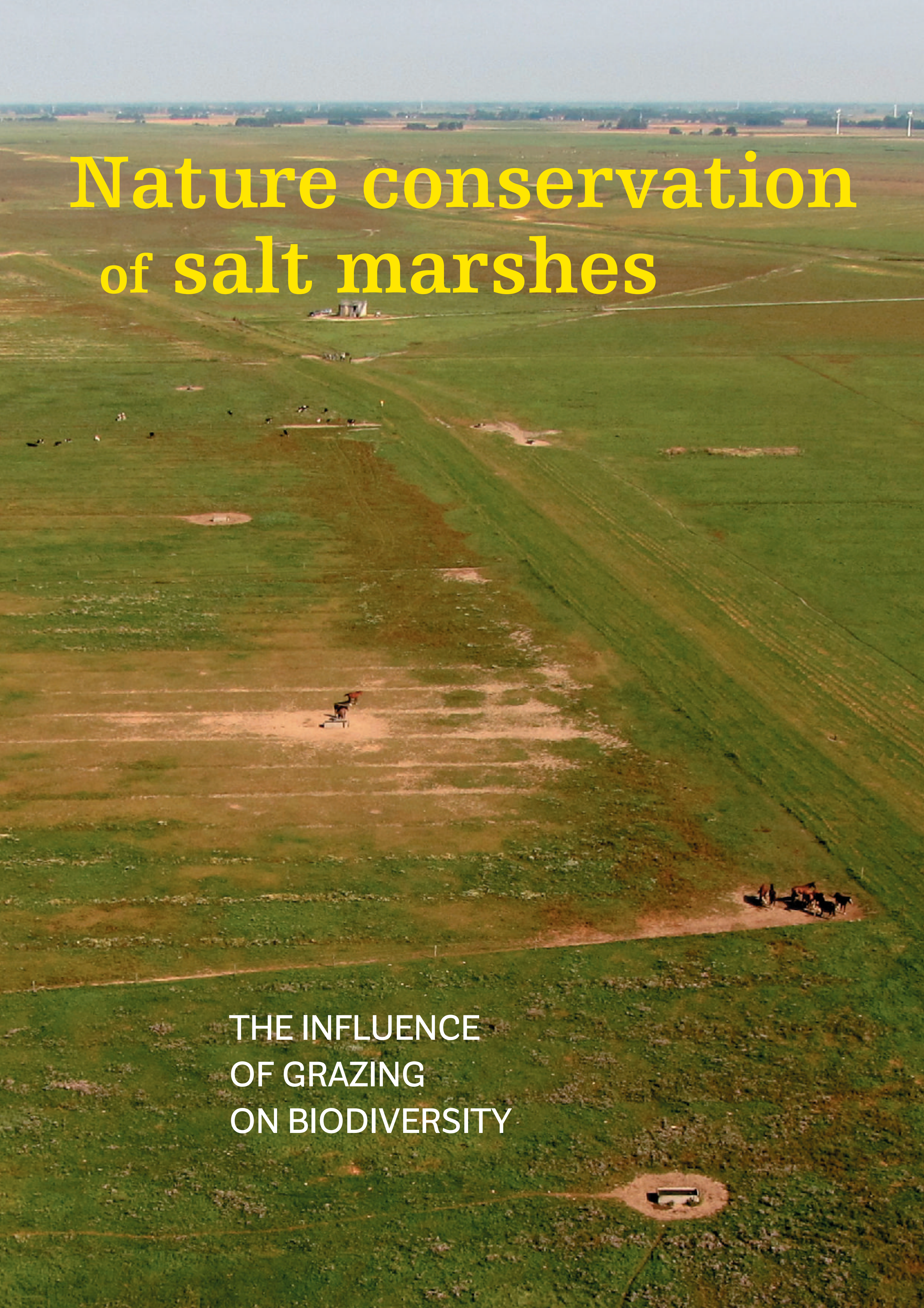
Nature conservation of salt marshes



THE INFLUENCE OF GRAZING ON BIODIVERSITY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Nature conservation of salt marshes

THE INFLUENCE OF GRAZING ON BIODIVERSITY

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The effects of grazing as seen from a height of 70 metres. In the upper right corner, a watering point from where livestock spread out over the salt marsh. The vegetation inside the rectangular field, from which animals are excluded, differs clearly from the surrounding area.

1 Summary

Background

Most of the salt marshes currently found along the mainland coast of the provinces of Groningen and Friesland The Netherlands have been developed since 1935 when the National Directorate-General of Public Works and Water Management (*Rijkswaterstaat*) undertook long-term coastal engineering projects in order to stimulate the development of salt marshes. Since around 1985, the management of the engineering works has become more focussed on nature conservation, and the term of 'land-reclamation works' has changed into 'salt-marsh works.'

Salt marshes can be grazed by cattle, sheep or horses for economic reasons but grazing can also be applied in the nature conservation management of salt marshes. The research project, *Biodiversity and nature management of mainland salt marshes*, aims to provide information to nature conservation organisations along the mainland coast so that they are able to make sound choices regarding different aspects of biodiversity during application of grazing, such as plants, birds and invertebrate animals. The project began in 2009, lasted for 5 years and was financed by the *Waddenfonds*, which is a source of government funding administered by the provinces of North Holland, Groningen and Friesland. This report forms a short overview on the results up to the beginning of 2013.

Research study

The research was largely carried out on the salt marsh of Noard-Fryslân Bûtendyks (North Friesland 'outside of the sea wall') and in a few comparable German salt-marsh areas in Schleswig-Holstein. In Noard-Fryslân Bûtendyks, experiments were conducted on grazing with horses and cattle in high (1 animal/ha) and low (0.5 animals/ha) densities, and using a rotational regime with alternating years of grazing (1 head of cattle/ha) and non-grazing. In Schleswig-Holstein, the effect of more than 20 years of grazing with different densities of sheep has been studied. Furthermore, data have been used from *Rijkswaterstaat* and *Sovon Vogelonderzoek Nederland* (Sovon, Dutch Centre for Field Ornithology) on all Dutch mainland salt marshes along the Wadden Sea.

Grazing affects the vegetation and has both direct and indirect effects on small invertebrate species (insects, spiders and the like) that live in the vegetation, as well as on birds. All these factors have been linked as much as possible in this study by conducting experiments at the same time and in the same areas.

Vegetation

For the vegetation, it appears that a clear difference between grazing with horses and cattle exists. Horses can tolerate more fibre-rich forage plants, move around much more and, move great distances from the watering points even at low stocking densities. Cattle stay more on the higher salt-marsh areas and graze mostly in the vicinity of the watering points.

Under light grazing regimes, a mosaic of shorter, grazed-down areas and taller, coarser patches develops. This structure is partly determined by the species of livestock used. Sea asters are sensitive to grazing and flower less even at low stocking densities. When an area remains ungrazed over multiple years, the Sea aster will quickly spread but then disappear for the most part afterwards and the diversity of the entire salt-marsh vegetation will also decrease.

In the ungrazed areas of Noard-Fryslân Bûtendyks, the rate of accretion reached almost 3 cm per year and was much higher here than in the grazed areas. In both the grazed and ungrazed areas, the yearly increase in elevation was sufficient to keep up with possible accelerating rates of sea-level rise in the future.

Insects and other invertebrates

The richness of insects, spiders and other small invertebrates is the lowest under grazed regimes. This results from a combination of competition for food (mostly for easily digestible plant species), a decrease in vegetation height, the amount of litter and, to a lesser extent, increased ingestion or trampling risks, and soil compaction. Areas under the rotational grazing regimes are very rich in invertebrates during the year that they remain ungrazed. Also, areas left ungrazed for long periods are clearly richer than grazed areas, despite their lower diversity of plant species. The encroachment of tall plant species is, however, not favourable for all species of invertebrates because there are also species that occur most frequently with grazing at low or high stocking densities. From research on Meadow pipits, it appears that these birds catch mostly caterpillars and big spiders to feed their young, leaving most of the other invertebrate species alone. In contrast to predictions, a positive effect of vegetation structure on habitat usage by Meadow pipits could not be demonstrated.

Birds

In Noard-Fryslân Bûtendyks, the highest number of birds was observed in experimental plots with grazing by high densities of horses. The number of species of birds, however, did not differ between the different grazing regimes and the number of breeding Oystercatchers and Redshanks were about the same in all the grazing regimes. The fact that there were no differences found in the density of breeding birds between the different grazing regimes could possibly have been due to the short duration of the experiment. In a study on vegetation and birds conducted in all the mainland salt marshes along the Dutch Wadden Sea, clear differences were indeed found. Ungrazed salt marshes were the richest in species but the difference between grazed and ungrazed areas decreased over time (from 1992 to 2008). The breeding success of birds was strongly negatively influenced by grazing with horses because horses, through their higher activity, trampled many more nests than cattle. Geese have a clear preference for grazed areas, with a preference in the autumn for areas that are grazed with a high density of livestock, resulting in short, homogenous vegetation.

Voles

Small mammals (especially voles) are mostly located on higher parts of the salt marshes with low stocking densities and ungrazed salt marshes. They form an important source of food for raptors such as harriers and Short-eared owls.

Conclusion

The conclusion of this research study is that the total diversity of salt marshes would be best realised by establishing and maintaining a spatial mosaic of different management regimes on the salt marsh: intensively grazed, lightly grazed, short-duration and permanently ungrazed areas.

2 Background and aim

Extensive salt-marsh areas are found along the Dutch mainland coast of the provinces of Friesland and Groningen, and along the shore of the Dollard bay on the border between the Netherlands and Germany. Salt marshes can be defined as areas with higher plants (herbs, grasses or low shrubs) that are subject to periodic inundation with salt water through the influence of tides. Salt marshes can extend from just below the level of mean high tide (MHT) up to the average highest water levels reached during storm tides (Figure 1). With increasing elevation, the number and duration of inundations decrease. Through the differences in the frequency and average duration of inundation, each salt-marsh zone is marked by characteristic vegetation.

The largest, continuous tract of salt marsh in the Dutch Wadden Sea lies in Noard-Fryslân Bûtendyks, which is called ‘Noord-Friesland Buitendijks’ in Dutch. This area consists of ‘summer polders’, which border the sea wall to the south and salt marshes to the northern, seaward side. The summer polders were developed from salt marshes that were reclaimed by private landowners between 1892 and 1956. Recently, a small proportion of these summer polders have been re-exposed to tidal influence, by breaching the summer dike, and reverted back into salt marshes. The total area of salt marshes in Noard-Fryslân Bûtendyks encompasses more than 2000 hectares. This includes a few hundred hectares of pioneer salt marsh in the transition areas leading to the intertidal mudflats. Almost all the salt marshes in Noard-Fryslân Bûtendyks and a large proportion of the summer polders are managed by the nature conservation society, *It Fryske Gea*, but there are also private landowners in the area. There are also a few other salt marshes along the Frisian coastline, the largest of which is the Peazemerlannen. This area is also managed by *It Fryske Gea*.

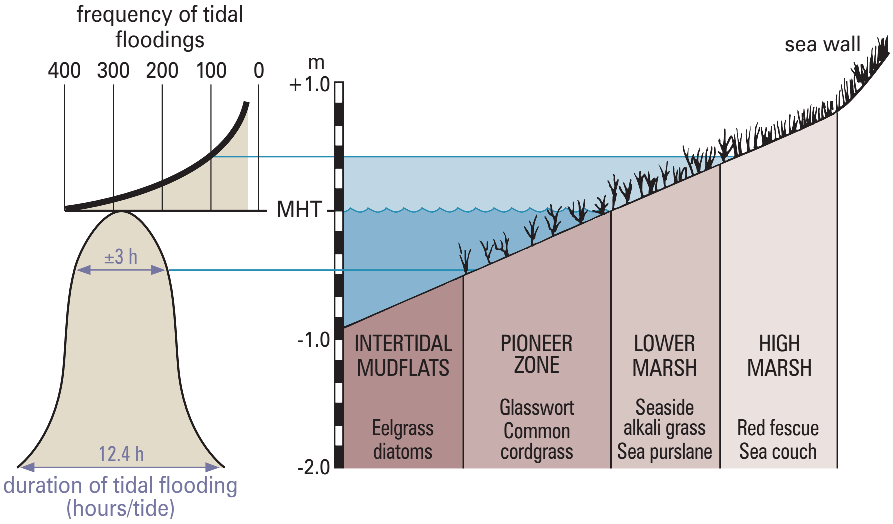


Figure 1 Schematic structure of a salt marsh with vegetation zones in relation to inundation duration and inundation frequency.

No summer polders are present along the northern coast of Groningen; the salt marshes there begin directly adjacent to the sea wall. Occupying an area of over 1250 hectares (including pioneer salt marsh), these salt marshes are mostly managed by the farmers who own the farms on the landward side of the sea wall with a smaller proportion managed by the conservation society, *Het Groninger Landschap* (the Groningen Landscape). Lastly, a salt marsh of around 760 hectares lies along the Dollard. Around 65% of this area is managed by *Het Groninger Landschap*.

The aim of nature conservation management is to develop and conserve the value of natural environments. The diversity of all plants and animals existing in an area play a role in determining this nature conservation value; however, the greatest importance is attached to species that are characteristic of certain areas. In our case, this applies to all the plant and animals species that are dependent on salt marshes for their existence. Examples include plant species such as Seaside alkali grass (*Pucinellia maritima*), Sea plantain (*Plantago maritima*), Sea arrowgrass (*Triglochin maritima*), Sea lavender (*Limonium vulgare*) and Sea aster (*Aster tripolium*); birds such as the Brent and Barnacle goose; and hundreds of species of insects, spiders and other invertebrates.

Traditionally, salt marshes on the mainland were used for grazing livestock. For private landowners, this was a means to earn revenue. For optimal usage of the grass production, the stocking density was usually kept as high as possible. In the past, almost all the grazing was done by sheep and cattle but in the last decades, large herds of horses have also appeared on the marshes. For conservation management organisations, such as *It Fryske Gea*, grazing is a means to preserve or enhance the conservation value and biodiversity. Grass production is not an aim; the results are counted in geese, breeding birds, plants species and invertebrates interacting in a harmonious whole. For these managers, the important questions regard whether and where grazing should be applied, at what stocking densities and with which livestock species in order to best achieve a high nature conservation value.

The aim of this investigation was to experimentally quantify the effects of grazing on diverse aspects of ecology on the mainland salt marshes. These gains in insight can be applied to the sound management of these marshes from a nature-conservation perspective.

3 From land reclamation to salt-marsh works

The great majority of currently existing salt marshes on the Dutch mainland along the Wadden Sea were developed by coastal engineering works. The government began with these works during the Depression years around 1935 with the combined aims of reclaiming land and combatting unemployment. The technique was adapted from Germany (the so-called *Schleswig-Holstein* method) and consisted of installing sedimentation fields of 400 m × 400 m surrounded by a brushwood groyne: a double row of posts between which brushwood bundles are fastened. Each sedimentation field had an opening through which sea water could flow in and out. The brushwood groynes attenuated wave energy, through which sediment particles could more easily settle and become less vulnerable to resuspension during storms. In addition, ditches were dug to allow for better drainage, resulting in earlier establishment of pioneer plant species. The most important pioneer plants are Glasswort (*Salicornia europaea*) and Common cordgrass (*Spartina anglica*). Common cordgrass is a species that appeared in the 19th century in England through hybridization between the native species, Small cordgrass (*Spartina maritima*), and an introduced American species, Smooth cordgrass (*Spartina alterniflora*). Later on, this new species was planted world-wide, including in the Netherlands, to promote accretion of salt marshes and subsequently became naturalised. Further accretion of sediment predominantly occurred through the establishment of Seaside alkali grass followed by other salt-marsh species.

During the Second World War, work on the sedimentation fields almost came to a standstill but afterwards, work was resumed with vigour. In Noard-Fryslân Bûtendyks as well as in Groningen, a coastal belt of more than a kilometre in width was provisioned with brushwood groynes. These works were relatively successful because by 1990, a new strip of salt marsh had been created; this strip was 400 – 600 m in width at most places and sometimes even wider.

Since 1990, the development of salt marshes has continued, but at a slower pace. The aim of coastal engineering works in the intertidal area has evolved into the preservation of the extent of salt-marsh area (also important from the perspective of coastal defence) and the nature conservation value. Because land reclamation is no longer an aim, these long-term projects are currently addressed as salt-marsh works instead of land-reclamation works. The change in management goals means, among other things, that ditches are no longer maintained in order to achieve more natural drainage conditions and to increase the spatial variation in the vegetation by allowing areas with poor drainage to develop. Furthermore, the outermost brushwood groynes on the intertidal mudflats are no longer maintained. Thus, the outermost sedimentation fields have truly been given back to the intertidal flats. The remaining brushwood groynes, however, are now actually extra well maintained. This is necessary to prevent erosion of the salt marshes. An illuminating example of what can happen when brushwood groynes are not maintained can be seen to the east of the village of Wierum in Friesland; there, the salt marsh is eroding away. An extensive area of salt marshes exists along the mainland coast of Friesland and Groningen only because of this history of coastal engineering works to enhance sediment accretion. Although these marshes are modest in size compared to the situation of a few hundred years ago, they are large enough to be proud of and are consistent with the UNESCO World Heritage status of the Wadden Sea. The man-made salt marshes in the Wadden Sea form 10% of the total salt-marsh area found in West Europe. There is however a 'but'. Because of the large-scale of the construction design, these salt marshes are relatively uniform in structure. Thus, the task now is to manage them in such a way that all the potential richness of plants and animals that can exist in mainland salt marshes can be brought to fruition.

Brushwood groynes of the coastal engineering works in Noard-Fryslân Bûtendyks. In the shelter of the brushwood groynes, pioneer vegetation of the Common glasswort can easily develop.

Salt-marsh erosion near Wierum. Since maintenance of the brushwood groynes has been discontinued, this salt marsh is eroding away.

From high above in the sky, the structure of the former coastal engineering works in Noard-Fryslân Bûtendyks is clearly visible. Above left (light yellow), a part of the summer dike is visible. There, the start of the high salt-marsh zone is seen followed by the low salt-marsh zone, which terminates in the pioneer zone and bare sedimentation fields (below right). Below to the far right, a part of the intertidal mudflat is visible.

4 The research study

Much is already known about the effects of sheep and cattle grazing on salt-marsh vegetation, and it was clear quite in advance that grazing was necessary in order to maintain and increase the nature conservation value of mainland salt marshes. However, it was not clear whether grazing should always be applied everywhere and which stocking densities would be most effective. Moreover, there were some considerable gaps in knowledge: the effect of grazing with horses had never been researched; neither had the consequences of grazing on insects and other small animals; and a systematic analysis of the effects of grazing on birds was also absent.

These were reasons enough for It *Fryske Gea*, in cooperation with different research institutes under the umbrella of the University of Groningen, to submit a proposal to the *Waddenfonds* on research to fill these gaps in knowledge as much as possible. The grant was awarded in 2008 and research began in 2009 for a provisional period of five years (see box underneath). This brochure outlines the research that was carried out and gives an overview of the most important insights gained until now.

Organization of the research
For this research project, *It Fryske Gea* received a subsidy from the *Waddenfonds*. A smaller portion of the project costs were financed by *It Fryske Gea* and the University of Groningen (RuG).

Three Ph.D. candidates from the Community and Conservation Ecology Group (COCON) of the University of Groningen (RuG) were appointed to carry out this research: one plant ecologist (Stefanie Nolte) and two animal ecologists (Roel van Klink for the invertebrate animals and Freek Mandema for the birds). In addition to supervision by Jan Bakker as the primary supervisor, the Ph.D. candidates received support in their research from Joost Tinbergen (*Animal Ecology Group*, RuG), Bruno Ens, Kees Koffijberg, Julia Stahl (Sovon Dutch Centre for Field Ornithology), Michiel Wallis de Vries (The Butterfly Foundation; *De Vlinderstichting*), Rikjan Vermeulen (The Foundation of Willem Beyerinck Biologisch Station), Menno Reemer (the Dutch branch of the European Invertebrate Survey (EIS-NL), Kees Dijkema (Imares) and Peter Esselink (the ecological research and consultancy firm, PUCCIMAR). To facilitate a smooth cooperative relationship between the researchers and *It Fryske Gea* and also, to carry out monitoring of the project, a steering committee was formed. Simultaneously, the project was able to offer possibilities for internships and Master's research projects to students. In order to compile a number of datasets that spanned the entire length of the project, Petra Daniels and Remco Hiemstra were employed during the last two years of the project as field assistants.

It Fryske Gea, itself, made a significant contribution to the research project through the contributions of Gerrit van de Leest and Johannes Westerhof , who carried out the actual construction of the grazing experiment and kept a close eye on the livestock used in the experiment. The firm, PUCCIMAR, undertook the general organisation of the project and production of this brochure.

5 Study area Noard-Fryslân Bûtendyks

Figure 2 Overview map of the three experimental areas in Noard-Fryslân Bûtendyks. The view of the central experimental area has been enlarged and the management regimes of the five experimental fields are shown schematically. Each experimental field contains about 11 hectares of saltmarsh. One animal represents light grazing with 5 units of livestock per experimental field (0.5 animals/ha), two animals represent intensive grazing with 10 units of livestock per experimental field (1 animal/ha). In the far right experimental field, the rotational grazing regime was applied with rotations between one season of intensive grazing (1 head of cattle/ha) and 1 season of no grazing. The westernmost experimental area has six experimental fields because there was also a permanently ungrazed experimental field present there.

An important part of the research was carried out on the salt marshes of Noard-Fryslân Bûtendyks. Because of the large-scale method used to develop these marshes, this area is relatively homogenous and it was no trouble to find three easily comparable experimental areas. All three areas covered the range in elevation from a high salt marsh (0.6 – 0.8 m above mean high tide (MHT) to a low salt marsh (0.3 – 0.5 m +MHT).

Each experimental area was divided into five experimental fields of about 11 hectares in size (Figure 2). The southern portion of each experimental field always consisted of high salt marsh, covered with Couch grass (*Elymus repens*), Sea couch (*Elymus athericus*), Creeping bentgrass (*Agrostis stolonifera*) and Red fescue (*Festuca rubra*), which changed around halfway to the mudflats into low salt marsh with Seaside alkali grass. In the centremost experimental area, each experimental field included a small zone of pioneer marsh with Common glasswort and Common cordgrass on the seaward side.

In 2010, five plots in each experimental area were given the following treatments: intensive grazing regime with horses or cattle (1 animal/ha), light grazing regime with horses or cattle (0.5 animals/ha) and a more dynamic or rotational grazing regime (one year of intensive cattle grazing alternating with one year of no grazing, namely 2010 and 2012 respectively). Grazing only took place during the summers: the grazing season on the salt marshes of Noard-Fryslân Bûtendyks runs from around June 1st to October 15th. A drinking trough was present on the high elevation area of each field.

6 Study areas elsewhere

The Hamburger Hallig salt marsh under partial inundation with seawater after a high tide.

The salt marshes of Sönke-Nissen-Koog, Friedrichskoog and the Hamburger Hallig lie in the German National Park, *Schleswig-Holsteinische Wattenmeer* (Figure 3). Just as in the Netherlands, these salt marshes were developed largely from human intervention in the process of salt-marsh formation, *i.e.* the construction of sedimentation works using the *Schleswig-Holstein* method. Because of this, the structure of these marshes is very comparable to that of the mainland salt marshes along the Dutch Wadden Sea. The research areas in Schleswig-Holstein have been grazed with different stocking levels of sheep since 1989. Therefore, it was possible to conduct research there on the long-term effects of particular stocking levels, which included effects on the vegetation as well as the effects on insects, spiders and other invertebrates that live there. The salt marshes of Sönke-Nissen-Koog lie at a relatively low elevation (0.2 – 0.3 m +MHT) and are predominantly covered with Seaside alkali grass. The salt marshes of Friedrichskoog lie at somewhat higher elevations (0.5 – 0.6 m +MHT) and are mainly covered by Red fescue.

Finally, it must be mentioned that use was made of data collected on the vegetation and breeding birds of salt marshes along the whole Dutch mainland coast. Additionally, the salt marsh on the island of Schiermonnikoog was used as a reference site for research on the effects of grazing on invertebrates.

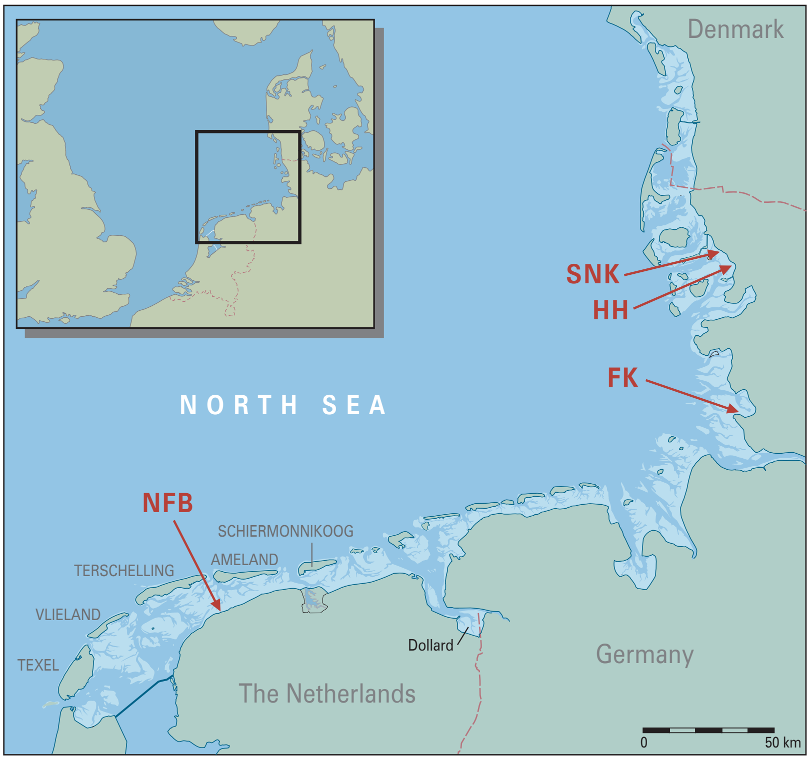


Figure 3 The locations of the most important research areas in the International Wadden Sea: Noard-Fryslân Bûtendyks (NFB), the salt marshes of Sönke-Nissen-Koog (SNK), Friedichskoog (FK) and the Hamburger Hallig (HH).

7 Grazing and vegetation

Fieldwork during the study on the diet of horses.

7.1 Cattle and horses: their diet and behaviour

Cattle and horses differ from each other in a number of aspects. Cattle are ruminants and thus have extremely efficient digestion systems. Horses are not ruminants, are less efficient in their digestion of food and, therefore, require more food per unit of body mass than cattle. However, their digestion system is more flexible: this means that when horses are forced to ingest food of low quality or palatability, they are also able to excrete this food more quickly. Because horses often eat more high-fibre food than cattle, they must also eat more. Cattle and horses also differ in the way that they graze. Cattle wrap their tongues around their food and subsequently cut or pull it off with the teeth in their lower jaw. As a result, a few centimetres of grass always remain standing. Horses have incisors in both their upper and lower jaws and can bite off their food almost to the ground.

These differences were also found in Noard-Fryslân Bûtendyks. Horses ate relatively more Couch grass, Sea couch and Seaside alkali grass, which are grasses with high fibre content. Cattle ate relatively more Creeping bentgrass, a grass with somewhat lower fibre content, and also more Sea aster.

The horses were more active than cattle and also spread themselves more over the whole experimental field. Thus, no grazing gradient developed. With cattle, a grazing gradient was formed from the watering point on the high salt marsh to the low salt marsh under both low and high stocking densities.

The differences between cattle and horses in behaviour and diet choice led to the conclusion that the grazing patterns of cattle are easier to manage through the positioning of watering points. However, for controlling tall, relatively unpalatable vegetation, horses are more suitable.

7.2 Cattle and horses: diversity in the vegetation

Would the number of plant species increase or decrease with grazing, depending upon the livestock species and stocking density? The time frame of the experiment appeared to have been too short for plant species to disappear from or completely colonise an experimental field, although shifts in the numbers of plant species were observed to take place in permanent quadrats of 4 m × 4 m.

After three years of the experiment, Sea couch was generally more common under cattle grazing than under horse grazing. Probably part of the reason for this was that horses require more food than cattle.

By grazing with 1 head of cattle/ha, a spatial mosaic has been formed at this place with patches of Scentless chamomile (white flowers) alternating with short lawn.

Also, Sea aster was more abundant under cattle grazing than horse grazing after three years. This same pattern holds for both Sea wormwood (*Artemisia maritima*) and Spear-leaved orache (*Atriplex prostrata*). These last two species were not eaten very often by cattle and horses but they are probably sensitive to trampling. Particularly under light grazing by cattle, several plant species did relatively well on the high salt marsh: these include the Sea barley (*Hordeum marinum*) and Scentless chamomile (*Tripleurospermum maritimum*), which are species limited to coastal habitats.

On average, the permanent quadrats in the plots subjected to the rotational grazing regime were less rich in plant species than the other plots after three years. This could be attributed to the increase in the tall, competitive species, Sea couch, during the years without grazing. It must be noted that only one complete cycle of this treatment took place.

Based on these results, it can be provisionally concluded that horses are more effective in reducing the cover of Sea couch but cattle grazing is probably more suitable for maintaining a high diversity of plant species.

The alternations in vegetation height were measured with the help of a styrofoam disk of about 25 cm in diameter (weighing 75 grams) that could slide down a ruled measuring stick. The height at which the disk remained resting on the vegetation is used as the value for vegetation height.

7.3 Vegetation patterns

Through grazing, patterns may appear where places with taller vegetation alternate with short, grazed-down parts of the terrain. These ‘patches’ (places which are distinguished from their surroundings by either a higher or a lower canopy) are able to remain in this condition because plants, once grazed, produce young, more nutritious shoots that can be grazed down again. Through this feedback process, such places remain attractive for animals to return to, whereas ungrazed patches continue to remain ungrazed because no new, protein-rich shoots are formed here.

Sometimes, the formation of patches can be partly attributed to the presence of unpalatable plants. Palatable plants can remain untouched when standing between their unpalatable neighbours, thus profiting from this protection. An example of an unpalatable plant species is Sea wormwood. When salt marshes are not too heavily grazed, then stands of Sea wormwood often remain.

As expected, it appeared that the average vegetation height was dependent on stocking density: higher stocking density resulted in shorter vegetation. The livestock species used for grazing also had an effect: under both density treatments, horses kept the average height of the vegetation shorter than cattle. This can be attributed to the fact that horses require more food than cattle and also trample the vegetation more. Under light grazing regimes, spatial patterns in the vegetation were formed under horse as well as cattle grazing. However, the size of the patches differed between horses and cattle: under horse grazing, patches were almost twice as large.

A spatial mosaic of patches with short, grazed-down vegetation alternating with patches of taller, less shortly kept vegetation usually appears under light grazing.

7.4 Grazing and Sea asters

The Sea aster is a very conspicuous plant species. On the salt marshes of Groningen and Friesland, they can grow to a height of one metre and on brackish marshes, such as in the Dollard, they can grow up to even two metres in height. Around the end of August, salt marshes with Sea aster can become covered in a carpet of purple flowers.

Sea asters can form carpets of purple flowers around the end of August, especially on ungrazed salt marshes that had been grazed during previous years.

Sheep, cattle and horses all find Sea aster to be very palatable. Thus, the effect of grazing is that shorter individuals with fewer flowers remain. In addition, Sea aster plants are also sensitive to trampling. As an important plant for many insect species in salt marshes, it was important to particularly address the effects of grazing on Sea aster during this research project. Furthermore, Sea aster may serve as a model species for other, shorter and less conspicuous salt-marshes plants.

As predicted, Sea aster plants survived the best and produced the most flowering heads when they remained ungrazed by livestock for a year, as was the case during the rotational grazing regime. In this case, more than 1000 flowering heads per square meter were formed (Figure 4). The damage increased with increasing grazing pressure. At the stocking density of 0.5 horses/ha, the number of flowering heads decreased to around 500 flowering heads per square metre; at the stocking density of 0.5 cattle/ha, only around 50 flowering heads per square metre were produced. At the stocking density of 1 head of cattle or horse/ha, the number of flowering heads was also around 50 per square metre.

In an experimental field grazed with 0.5 cattle/ha (foreground) stand many Sea asters with Seaside alkali grass in between (not visible in the photograph) and some Common cordgrass. In the bordering experimental field grazed with 1 horse/ha, there is grazed-down Seaside alkali grass and an unpalatable species, Annual seablite (Suaeda maritima), which turns red during late summer.

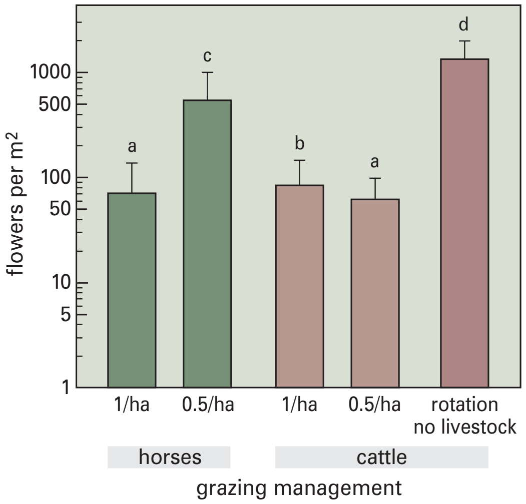


Figure 4 Effect of the grazing regimes on the flowering of Sea aster measured by the number of flowering heads per square metre. Letter symbols are used to show significant differences.

At the present, the conclusion seems to be that in order to encourage abundant flowering of Sea asters, it is best not to apply grazing! Actually, this conclusion is only valid over the short term because ungrazed areas subjected to the rotational grazing treatment in this experiment were only left ungrazed for one year. Sea asters were already present in these areas, and could grow without impediment into large plants with many flowering heads during the year without grazing. It is known that with long-term lack of grazing, other plant species, such as Sea couch, can become dominant (see the following paragraph), thus suppressing Sea aster.

7.5 Vegetation under grazing with different sheep densities

The salt marsh of Sönke-Nissen-Koog lies at a relatively low elevation, whereas the salt marsh of Friedrichskoog lies at a higher elevation (Chapter 6). Both areas have been divided into five experimental fields of about 12 hectares. One field remained ungrazed during the whole experimental period; the other four fields were grazed each summer with stocking densities of 1.5, 3, 4.5 and 10 sheep/ha respectively. In each of the plots, a watering point was present close to the sea wall.

Through the many years of consistent grazing management, the effect of differences in grazing pressure is very clear. Under no grazing or a grazing density of 1.5 sheep/ha, a tall vegetation dominated by Sea couch developed; under grazing densities of 3 and 4.5 sheep/ha, this only happened at the local scale. Under a grazing density of 10 sheep/ha, a homogenous short-grass vegetation appeared. The low-elevation salt marsh of Sönke-Nissen-Koog was dominated by Seaside alkali grass (that is also mostly found elsewhere on low, grazed salt marshes) and on the higher elevation salt marsh of Friedrichskoog, Red fescue dominated (a species that is characteristic of grazed, high salt marshes).

Seaside alkali grass has a higher growth rate than Red fescue. This explains why the vegetation on the salt marsh of Sönke-Nissen-Koog was taller, on average, with a smaller proportion of short vegetation than on the salt marsh of Friedrichskoog. In both salt marshes, a clear relationship between the canopy height and distance to the watering point was found, with a shorter canopy found closer to the watering point.

Thus, in both areas, the vegetation development appeared to be easily ‘steered’ by the means of controlling livestock density, also over the long term.

7.6 Grazing and sediment accretion

Under higher water levels, especially with north-westerly winds, salt marshes are flooded with sea water. This water transports sediment particles that become suspended by the action of currents or waves in tidal creeks and on the bordering intertidal mudflats. Above the salt marsh, the turbulence of the water drops, and a large part of the sediment in the water column may be consequently deposited. Vegetation may play an important role in this process: the turbulence is decreased by vegetation, through which more sediment particles may be

Examples of the German salt marshes with sheep grazing applied at high and low stocking densities, and an ungrazed salt marsh.

deposited. This buffering effect increases with vegetation height. When the vegetation is kept shorter by grazing, this could lead to less sediment deposition and lower accretion rates on the salt marsh. This effect can be strengthened by the greater soil compaction found under grazing, due to trampling effects. How strong are these effects and would grazed salt marshes under conditions of increased sea-level rise be able to accrete enough sediment to keep up with sea-level rise?

Research was undertaken to measure accretion rates during the last decades in grazed and ungrazed salt-marsh areas in Noard-Fryslân Bûtendyks as well as three areas along the mainland coast of Schleswig-Holstein. For this, the depth at which traces of the radioactive fallout from the Chernobyl nuclear disaster (1986) was taken as a reference (Figure 5): the sediment layer above this depth has grown since then. Using this technique, a large difference in accretion rates was found between grazed and ungrazed salt marshes in Noard-Fryslân Bûtendyks (13.4 mm/year *vs*. 29 mm/year). Over all four salt-marsh areas, the accretion rate was 11.6 mm per year on average and taking all sites into account, no significant difference was found between grazed and ungrazed marshes. In all the areas, the accretion rate was much higher than the current rate of sea-level rise (an average of around 2 mm per year over the last 100 years in the Netherlands).

In another study carried out in Noard-Fryslân Bûtendyks, the accretion as well as sediment deposition rates during the last ten years could be compared between grazed and ungrazed conditions. Also, a much lower accretion rate was measured under grazed conditions than under ungrazed conditions (7.6 mm/year vs. 15.2 mm/year) but no significant difference was found in the amount of sediment deposition between the treatment conditions. The difference in accretion rates could be fully explained by the influence of trampling on soil compaction under grazed conditions.

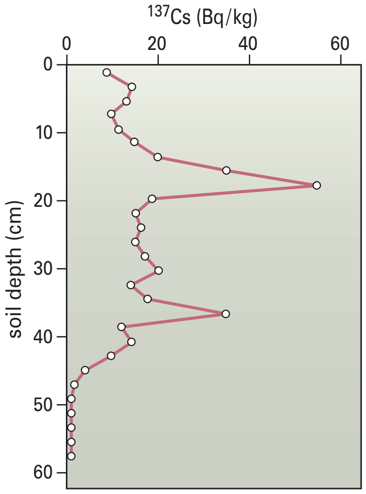


Figure 5 Activity of radioactive caesium per 2 cm-layers in a salt-marsh soil. The sharp peak at the depth of 18 centimetres was caused by the nuclear disaster at Chernobyl in 1986; the smaller peak at 37 cm in depth was caused by atomic-bomb testing during the 1960s.

8 The effects of grazing on insects, spiders and other invertebrates

8.1 What is already known from other areas?

Salt marshes, but also other grassland areas, are grazed world-wide by domestic livestock or large, wild herbivores. Through grazing, re-forestation of land is kept in check or at least delayed. In these cases, the insects, spiders and other invertebrates found in grassland areas are dependent over the long term on grazing. On European salt marshes, however, this process does not play a role; no trees can grow in salt marshes in our climate. However, the vegetation is much changed by grazing, which always results in consequences for invertebrate species.

A direct effect always found with grazing is that insects and other invertebrates are incidentally eaten; especially slow animals and animals that cannot get away because they live in the stems and leaves of plants. Slow animals sitting on the plants can sometimes escape by letting themselves drop from the plants. However, a lot of time is needed before they can climb back up again.

As a result of grazing, vegetation becomes shorter and many plants are no longer able to reach their full height. Consequently, a more open environment develops where other, and also more, plant species can be found. Given that almost all of the many plant species host their own assembly of characteristic insect species, it could be predicted that the species richness of invertebrates would also increase. However, in most of the many publications on this subject, this does not seem to be the case. The shorter, and possibly more species-rich, vegetation resulting from grazing is usually lower in species richness of invertebrates than higher, ungrazed vegetation in the same area. This is caused by the fact that species are no longer able to make use of different layers in short vegetation, and above all, no litter layer is formed, upon which many species

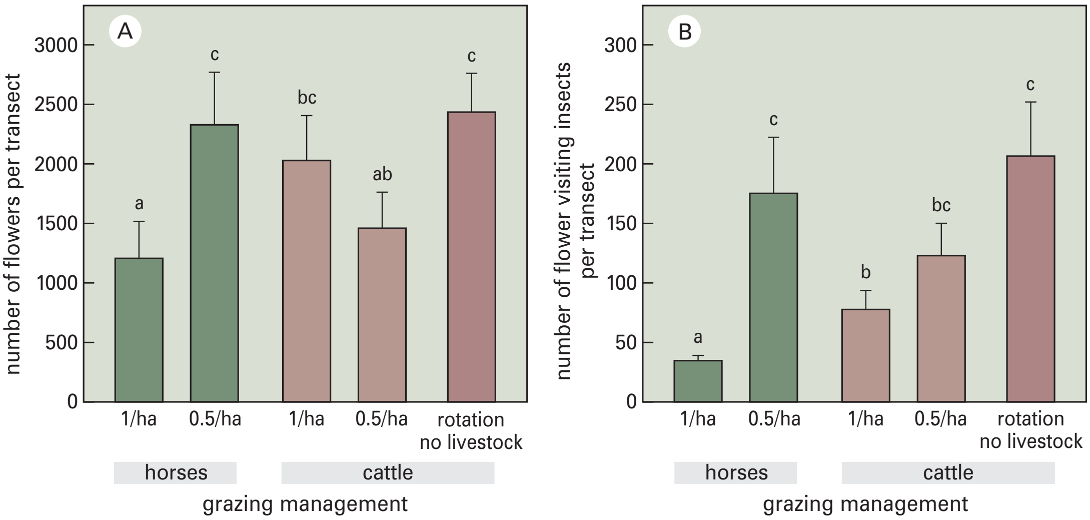


Figure 6 Comparisons between flower availability (left) and the number of flower-visiting insects per transect (right) in the five management regimes in the grazing experiment during a year without livestock grazing in the rotational grazing treatment (2012). The number of flower-visiting insects was the highest with the rotational grazing treatment, but this was not significantly different from the numbers attained by 0.5 horses/ha or cattle/ha. Lower-case letters are used to show significant differences.

depend. Also, plant structures that are important for insects are eaten up (such as flowers and stems) so that the insects that live in or live on these structures no longer have a chance.

Another direct effect of grazing is trampling. Trampling can be a direct cause of death for many small animal species but the force applied by the hooves of livestock also has an indirect effect, leading to the compression of the litter layer and the upper layers of soil. For the many animals that live in the litter layer and soil, this is a big disadvantage and their numbers drastically decline under grazing. These are the reasons why it is important to measure precisely how insect, spider and other invertebrate communities on salt marshes respond to different grazing regimes.

8.2 Sea asters, grazing and insects at Noard-Fryslân Bûtendyks

Hoverflies, bees and butterflies are directly influenced by grazing on salt marshes because they are on the lookout for flowers with pollen and nectar. Depending on the level of grazing intensity, the available flowers could be from short, small plants such as the Greater and Lesser sea-spurrey (*Spergularia media* and *Spergularia salina*) or from large, high plants such as Scentless chamomile (*Tripleurospermum maritimum*) and Sea aster. In particular, the Sea aster has an enormous attractive power for flower visitors.

The flower availability changed over the season: Sea milkweed (*Glaux maritima*) and Silverweed cinquefoil (*Potentilla anserina*) were the most important flowering plants in May and June, whereas Creeping thistle (*Cirsium arvense*) and both species of sea-spurries were in the most important in July. In August and September, the tall and abundantly flowering Scentless chamomile and, in particular, the Sea aster bloomed. Because of this, the most flower-visiting insects were observed during the late summer.

As was already written in section 7.4, Sea asters are eaten by livestock and the number of flowering heads decreases with grazing. This had a direct influence on the number of flower-visiting insects (Figure 6). The number of flower-visiting insects was the lowest with grazing with 1 animal/ha, both with horses and with cattle. In particular, this was due to the lower number of hoverflies and butterflies. The rotational grazing treatment resulted in high numbers of flower visitors in the year without livestock

The Essex skipper (*Thymelicus lineola*) is one of the many flower visitors found on the flowers of Sea aster.

A few dozen insect species live on Sea asters. Examples include the leaf-miner flies, whose larvae live in foliage and leave behind typical discolouration patterns caused by their appetites. The small gall fly, *Campiglossa plantaginis*, lays its eggs on emerging flower buds.

grazing (Figure 6) but in the year with grazing, the number of flower visitors was just as low as with continuous cattle grazing.

In 2010, the effect of grazing on insects that use Sea aster as a forage plant was measured. For this purpose, 20 flowering Sea asters were collected from three different grazing regimes: long-term (at least for 20 years) ungrazed, grazed with 1 animal/ha and the rotational grazing treatment during the year of no grazing. The horse-grazed salt marsh was not included in this study.

There were significantly more species of insects found per plant during the ungrazed year of the rotational grazing treatment than on the ungrazed salt marsh or the salt marsh grazed with 1 head of cattle/ha. The most important factor that determined the number of species occurring per plant appeared to be the size of the plant. It appeared that under grazing with 1 head of cattle/ha, at least seven times the number of plants were needed to harbour the same richness of insects as found under ungrazed conditions. Remarkably, the diversity of insects was the highest in the salt marsh under the rotational grazing treatment, thus higher than in the salt marsh left ungrazed for at least 20 years. This could be due to the sparse plant cover, especially in the low-elevation parts of long-term ungrazed salt marsh in winter. Many insects, such as the flies and small moths that live in the flower heads of Sea aster, actually survive the winter in the soil, nestled between the plant roots.

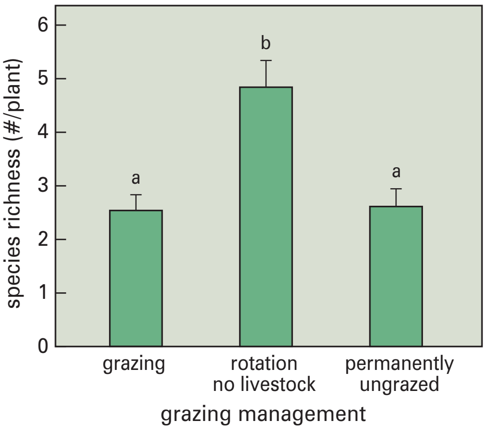


Figure 7 The number of insect species that could be found on one Sea aster plant is strongly dependent on the size of the plant. The plants in grazed areas were partially eaten by the livestock, through which they remained small and could shelter fewer insects. The plants in the areas that were left ungrazed for a year were the largest and had the most insect species per plant. Plants in the permanently ungrazed areas had about as many species of insects as plants in the grazed areas. Letter symbols are used to show significant differences.

Grazing with 1 horse/ha or 1 head of cattle/ha, thus, resulted in fewer flower visitors on Sea aster, which was to be expected. Furthermore, grazing with 1 head of cattle/ha resulted in fewer species of herbivorous insects present on Sea aster.

8.3 Insects and spiders in relation to grazing with sheep

The study on insects and spiders on salt marshes grazed over the long-term (more than 20 years) by sheep was carried out on the mainland salt marshes of Schleswig-Holstein (see Chapter 6). The densities of grazing sheep varied from 0 to 10 animals per hectare.

Tall vegetation on both the ungrazed salt marsh and the salt marsh grazed with 4 sheep/ha appeared to be the most species rich. Additionally, the densities of invertebrate species were also the highest there. This was especially due to the presence of species that also occur inland. At places with short vegetation resulting from grazing, there were clearly fewer species of invertebrates, especially because fewer inland species were found (Figure 8). Thus, the conclusion is that there is about the same number of salt-marsh specialists occurring on the grazed as on the ungrazed salt marsh. The spatial variation of

The insects, spiders and other invertebrates were captured by first setting a plastic cylinder on the ground and then sucking up all the animals on the plants by using a strong vacuum (a reversed leaf blower). Afterwards, the plants were cut to a height of 3 cm from the soil and the litter and the soil layers were also vacuumed.

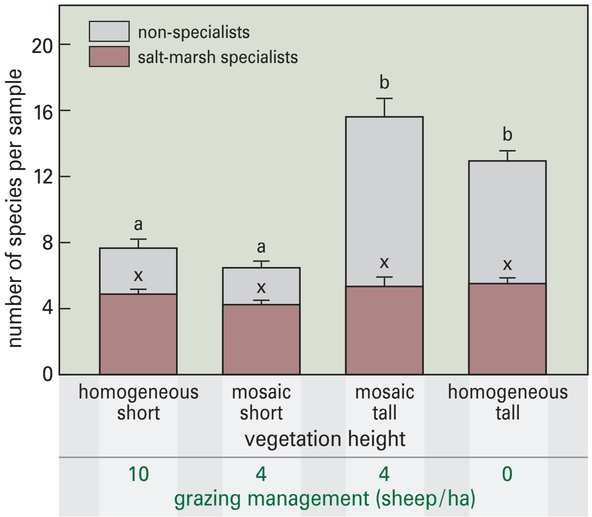


Figure 8 The number of invertebrate species on the German salt marshes in relation to the height of the vegetation and the variability in vegetation height. About the same number of salt-marsh specialists (dark shading) were found in the different categories of vegetation structure. In addition, many invertebrate species that are also found in non-saline environments were found in the high vegetation (ungrazed places in the experimental fields with 3–4 sheep/ha and completely ungrazed experimental fields). The different letters indicate significant differences.

short and tall vegetation does not lead to more salt marsh specialists, whereas non-characteristic species appear to profit from it.

The herbivorous insect species did not all show the same response to grazing. In Figure 9, they are divided into four categories: the first category (28 species) showed a decline with increasing livestock density (negative response); the second category (11 species) showed a positive response to increasing livestock density; the third category (6 species) showed an optimum with light grazing of 3 – 4 sheep/ha; and the fourth category (9 species) showed no reaction (neutral response) to livestock density. Of the salt-marsh specialists, ten species showed a negative response to increasing livestock density and five species showed no response to livestock densities of 0 – 10 sheep/ha.

Ungrazed salt marshes are, thus, the richest in invertebrates, also when considering the salt marsh specialists. However, there are also salt-marsh specialists that appear to have a preference for grazed salt marshes: some prefer salt marshes with low stocking density; others prefer more intensively grazed salt marshes.

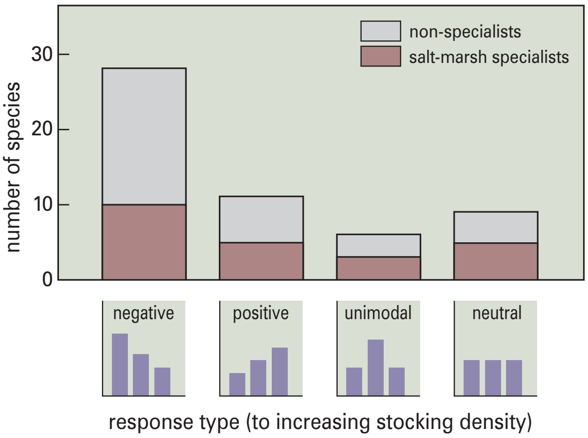


Figure 9 On the salt marshes of Schleswig-Holstein, it appears that many species of invertebrates are more common in places without grazing (negative reaction to grazing). Smaller numbers of species had a preference for intensive grazing (positive reaction) and light grazing (with an optimum between ungrazed and intensively grazed). There were also species that responded similarly to ungrazed, lightly grazed and intensively grazed treatments (neutral reaction). Inland invertebrate species were present in all grazing treatments, but they were most numerous at ungrazed sites.

9 Grazing and birds

9.1 Birds in the experimental fields of Noard-Fryslân Bûtendyks

To what extent do the stocking density and the species of livestock influence the breeding and staging migratory birds on the salt marshes of Noard-Fryslân Bûtendyks? To get to the bottom of this, birds were counted every two weeks for the whole duration of the research project (October 2009 to December 2013) in the experimental fields of Noard-Fryslân Bûtendyks. This was carried out by walking once along the length of each experimental field and counting all the birds that were sitting in, flew out of or landed in each field. These bi-weekly bird counts have been analysed for the first three years of the research project (up to December 2012). The staging geese in the area were consciously left out of the analyses because they can fly here and there in enormous flocks on the experimental fields, strongly influencing the bird count. For geese, a much better method was used in order to estimate how habitat use is correlated to grazing by livestock: namely, dropping counts. This will be addressed later on.

The number of birds varied strongly per season. The bird counts during the last winter period were clearly (and significantly) the highest in the experimental fields with 1 horse/ha: an average of 14 birds per count (Figure 10). Clearly, all the other grazing regimes scored lower, on average between 4 and 7 birds per count. During the previous periods, there was little difference in the bird counts between the different grazing regimes. Also the species composition of the observed birds did not differ between the different management regimes.

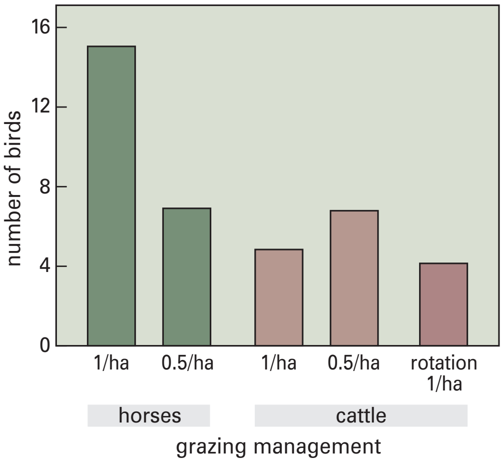


Figure 10 The average number of observed birds per experimental field and per round of counting in the grazing experiment in the winter period of 2011/12 (second year of the experiment). In general, there were not any big differences in the number of birds between the different management regimes. Only a relatively high number of birds were observed in the experimental fields grazed by 1 horse/ha.

Actually, many more changes in the bird world had been expected because of the differences that appeared in the vegetation due to the differences in grazing. Perhaps the site fidelity of breeding birds played a role in this result (section 9.3).

Anyway, it is possible that three years was just too short to observe clear changes, because the study in the following section showed that changes in grazing over the long-term are actually correlated with changes in the bird community.

9.2 The breeding bird populations of Dutch mainland salt marshes and the height of the vegetation

To find out how the density of breeding birds on salt marshes is related to the grazing in previous years, the breeding bird population of all Dutch mainland salt marshes along the Frisian and Groningen coast, including the Dollard, were compared to the percentage of tall vegetation and short vegetation in this area. The percentage of tall vegetation increased when a salt marsh was left ungrazed for a longer period. For this research project, the vegetation maps of *Rijkswaterstaat* and the bird inventories of *Sovon Vogelonderzoek Nederland* between 1992 and 2008 were used.

Bird species from different groups are present on the salt marshes. They include waders, such as Redshanks, Oystercatchers and Pied avocets, and passerines, such as Skylarks, Meadow pipits and Reed buntings. In addition to Pied avocets, other colonial breeding birds such as gulls and terns also come regularly to breed (especially Black-headed gulls and Common terns). Harriers and Short-eared owls also sometimes breed there. All the inventoried birds were accounted for in the calculations of the total number and diversity of species. Six species appeared abundant enough to support individual analyses, namely the Pied avocet, the Oystercatcher, the Redshank, the Skylark, the Meadow pipit and the Reed bunting.

When data for all the years were pooled together, the species richness was about evenly divided between waders (average of 4.2 species per counting area), passerines (average 4.5 species per counting area) and the other species (3.8 species per counting area).

The result from the analyses pooling all species per group (waders, passerines and other birds) was that the species richness and the breeding bird density increased with the percentage of tall vegetation that was present on a salt marsh (Figure 11). However, the effect became less robust over time.

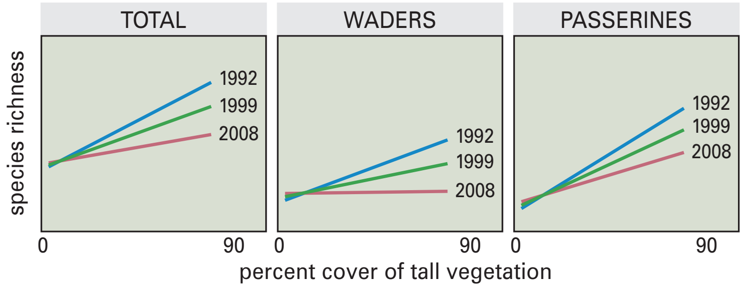


Figure 11 The species richness of breeding birds on Dutch mainland salt marshes in the Wadden Sea (calculated per counting area) between 1992 and 2008; the larger the percentage of tall vegetation, the greater the number of species. However, that link became less apparent as time passed (1992 to 2008), mostly because waders (particularly Oystercatchers) declined in tall vegetation. Passerines appeared to have a preference for taller vegetation but this preference became less apparent over time from 1992 to 2008.

For the waders as a group, there was no longer a positive relationship between the percentage of tall vegetation and the breeding bird density in the final years. This general relationship did not hold for all the groups separately and certainly not for individual species (Figure 12). With regard to the waders, the number of Oystercatchers and Redshanks (Oystercatchers in the past only) indeed increased as the percentage of tall vegetation increased, but the number of Pied avocets actually decreased. Of the passerines, Skylarks did not like encroachment by tall vegetation, Reed buntings preferred tall vegetation and Meadow pipits were somewhere in between.

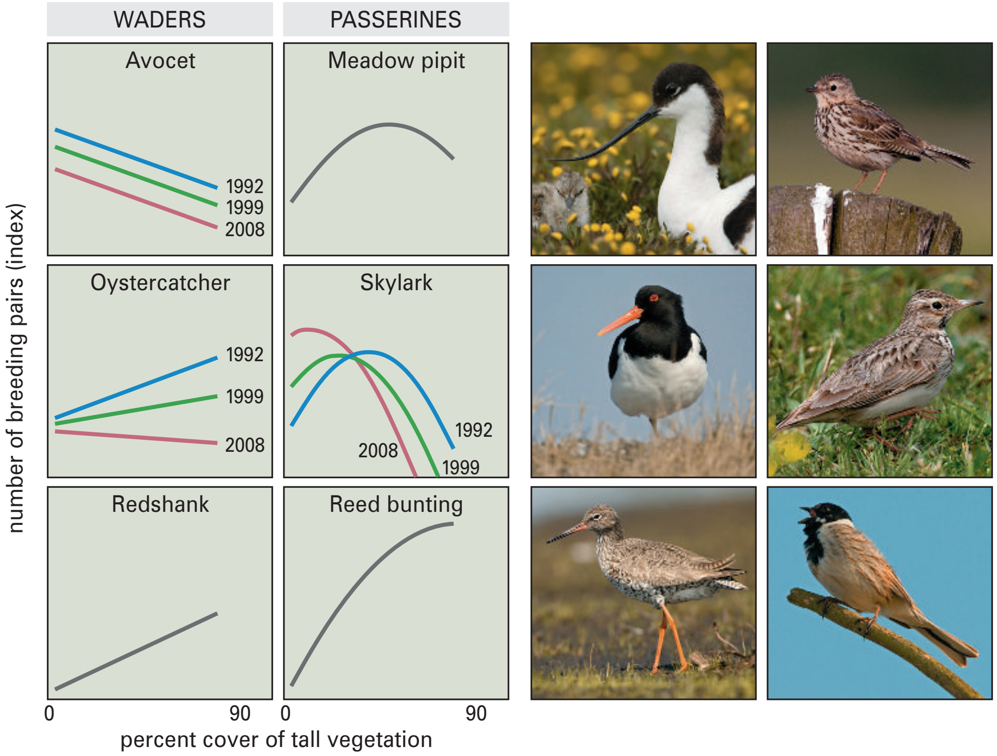


Figure 12 This figure shows the relationships between the percentage of tall vegetation per counting area and the number of breeding pairs for six different species of breeding birds for three different years.
Left: Waders in relation to the proportion of tall vegetation per counting area. Pied avocets breed mostly in areas with short vegetation and decreased in numbers from 1992-2008. Oystercatchers were more common in 1992 in areas with a high percentage of tall vegetation, but that changed over the course of time. In 2008, the numbers in tall vegetation had strongly decreased while the density in short vegetation remained the same. Redshanks had a clear preference for taller vegetation.
Right: The density of passerines in relation to the percentage of tall vegetation per counting area. Meadow pipits reached a maximum density in areas with an average percentage of tall vegetation. In 1992, Skylarks bred mostly in areas with an average or somewhat lower percentage of tall vegetation, but this preference shifted in the direction of areas with a relatively high percentage of short vegetation in 2008. Reed buntings showed a preference for areas with a high percentage of tall vegetation.

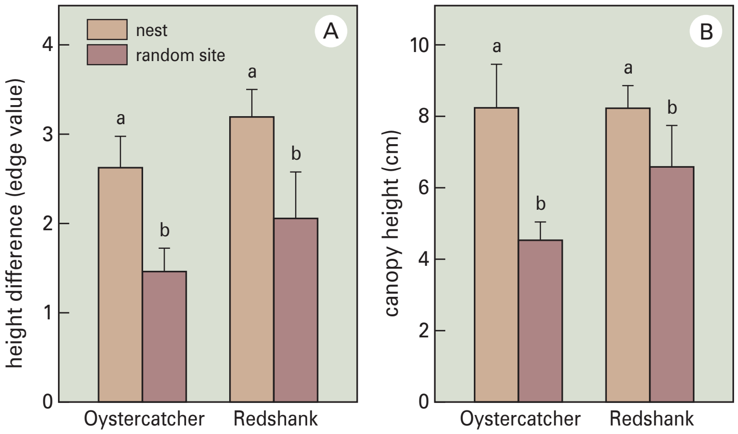


Figure 13 IIn comparison with random sites, Oystercatchers and Redshanks breed in sites with greater variation in vegetation height (left) and above all, in sites where the vegetation is higher than in the rest of the area. Significant differences are indicated by lower-case letters.

When searching for an optimum for all species together, the conclusion is that the increase of tall vegetation on salt marshes is initially favourable, but not over the long-term. When the vegetation remains tall after discontinuing grazing, the ongoing process of succession changes the species composition of the vegetation. When regarding the individual bird species, there are also species that do not prefer tall vegetation. This holds in any case for Pied avocets. Skylarks already reach an optimum at a relatively low percentage of tall vegetation,

9.3 Choice of nesting site for Redshanks and Oystercatchers

Do breeding birds on salt marshes prefer a certain vegetation height and variation in the vegetation? This was studied in greater detail for Oystercatchers and Redshanks in the experimental fields at Noard-Fryslân Bûtendyks.

A total of 29 Oystercatcher nests and 22 Redshank nests were found in the experimental fields. Both Oystercatchers and Redshanks appeared to breed at places with significantly taller vegetation, on average, and more variation in vegetation height than the average elsewhere in the same experimental field (Figure 13). The variation in vegetation height around Redshank nests was a little higher than around Oystercatcher nests but this difference was not significant.

Both livestock species and stocking density caused differences in vegetation structure, which could be relevant for the suitability of the marsh as nesting habitat for breeding Redshanks and Oystercatchers. After one year of grazing, the height and the variation in height of the vegetation were significantly higher with 0.5 animals/ha or the rotational grazing treatment (one year with grazing, one year without) than with 1 horse or 1 head of cattle/ha. However, these differences in the vegetation did not lead to differences in the nesting density between the difference management regimes, also not during the second year of the study.

Redshanks (left photograph) mostly hide their nest securely in tussocks and count on camouflage. When in danger, they remain as long as possible on their nest. Shorter vegetation around the nesting sites gives a better vantage point for possibly approaching predators and can be used to flee during danger. Oystercatchers (right photograph), however, make their nest in relatively open vegetation and try to distract predators as much as possible; if necessary, they attack. For them, it is less important to hide their nest.

After a clay pigeon was placed in a shallow core hole, it was covered with the grass plug from the sod corer.

Clay pigeons

Actually, it had been expected that Redshanks would have a clearer choice for somewhat taller and more variable vegetation than Oystercatchers, and that relatively more birds would breed in the experimental fields with light grazing regimes during the second year of the study. However, there were apparently enough suitable nesting sites to be found in the experimental fields with 1 animal/ha. Additionally, the fidelity of birds to nesting sites could have played a role in this result. A shift in preference for plots with 0.5 animals/ha could thus occur over the long-term through the death of old birds and establishment of young birds breeding for the first time.

9.4 Trampling losses of nests estimated by using clay pigeons

Birds that have a preference for the vegetation structure of grazed areas run the risk of their nests being trampled by livestock, and naturally, this chance will increase as the stocking density increases. Furthermore, there could be an effect of the livestock species and of the location of the watering point on the risk of trampling. The animals must repeatedly walk to these watering points to access drinking water, through which arises a higher chance of being trampled in the vicinity of watering points. The questions for this part of the study were: how high is the chance of a nest being trampled under different stocking densities of cattle and horses, and is there an effect of the location of the watering point?

In order to study these questions, artificial nests in the form of buried clay pigeons were used. Clay pigeons are baked clay disks of about 10 cm in diameter that are used as targets in shooting sports. Clay pigeons are very brittle, and shatter into pieces when they are hit by a pellet of birdshot or when

Horses walk more than cattle, often run after each other on the salt marsh and do not need to ruminate. In general, cattle behave very calmly, and lie down for a part of the day to ruminate.

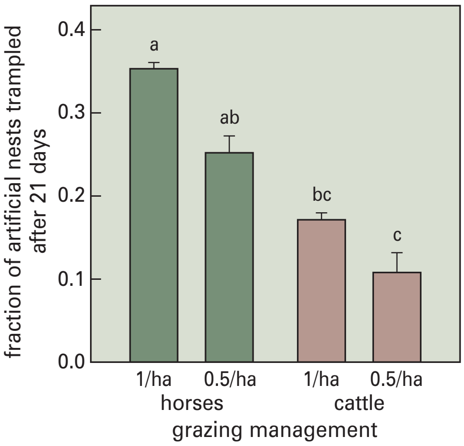


Figure 14 The proportion of the artificial nests in the form of buried clay pigeons that were trampled by livestock. More nests were trampled under horse grazing than under cattle grazing. The chance of trampling is also dependent on the stocking density. Thus, intensive grazing with horses resulted in the highest chance of trampling (36%), and light grazing with cattle, the lowest (10%). Different letters indicate significant differences.

stepped on by cattle or horses. The size of a clay pigeon is quite comparable to the nest size of Redshanks or Oystercatchers. Distributed over each experimental field, 50 clay pigeons were buried to a depth of 10 cm using a sod corer After the clay pigeon was placed in the hole, the space above was filled up with the grass plug from the corer (see photograph). Because of this, the clay pigeons were not visible to the livestock, but close enough to the soil surface that they would break when an animal stood upon them. Clay pigeons have been used already in other trampling studies, and offer the advantage that much more data can be collected than when real nests must be used.

The clay pigeons were searched for after three weeks, which is about as long as the breeding period of most of the waders. Of the 600 clay pigeons that had been installed, 524 were found back after three weeks. Of these, 118 had been broken.

There seems to be a clear difference depending on the species of livestock and the stocking density. Horses trampled more than twice the number of clay pigeons as cattle, and trampling increased with increasing livestock density (Figure 14). There was also an effect of the watering point: the closer to the water point, the greater the chance was of being trampled.

These results merge seamlessly with the observations from the vegetation study: horses walk much more than cattle and this is also the explanation for the greater number of clay pigeons that were trampled. In order to restrict the chance of bird nests being trampled, grazing with cattle, thus, is preferable.

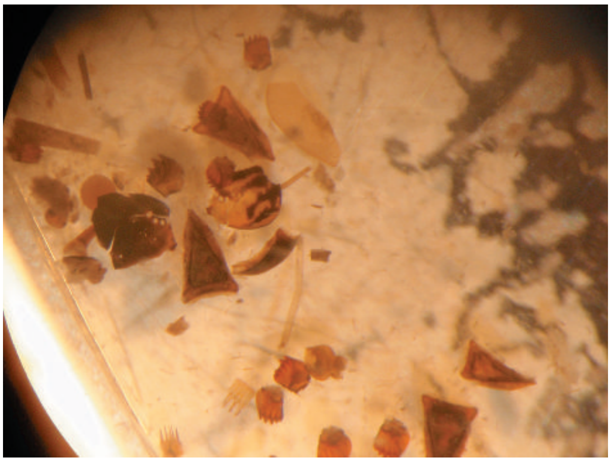
9.5 Meadow pipits, vegetation and the food that they gather for their young

The few passerine species that breed on salt marshes are dependent for their food on the insects and spiders that live there. For Meadow pipits, it was studied where they preferred to get their prey from in order to feed their young and also, which prey was selected from the total availability. This study was possible through the cooperation of experts in the areas of vegetation, insects and birds, and this also can be seen as one of the strengths of the entire research study, in which different aspects could be studied at the same time.

In order to see where Meadow pipits caught their prey, observation towers of 3 metres in height were set up to provide a good overview of the marsh. From here, the nests were detected and it could be observed where the parent birds foraged. In order to see what Meadow pipits subsequently fed their young, droppings of nestlings were collected from the nest. Nestlings that were picked up from their nest mostly produced droppings very quickly. When

Young Meadow pipits in their nest.

Microscopic image of prey remnants from droppings of young Meadow pipits.



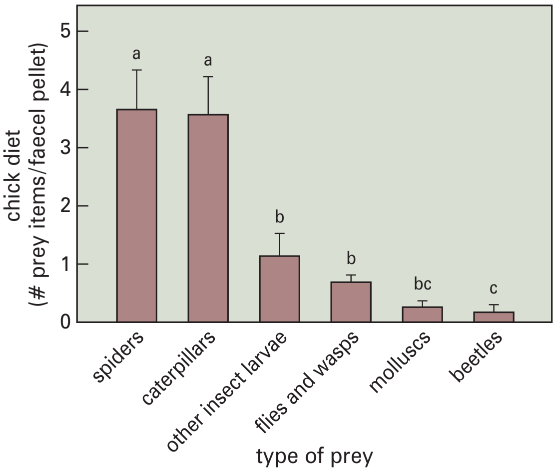


Figure 15 Meadow pipits in Noard-Fryslân Bûtendyks mostly feed their chicks with big spiders and caterpillars. Small spiders and most mature insects were present in the area but were not fed to the young. Letter symbols indicate significant differences.

this did not happen within 10 minutes, the nestling was put back into the nest in order to prevent disturbance of the brood. In total, 23 droppings were collected in this manner.

At the same points where the adult birds had searched for food, invertebrates were sampled in short (<10 cm), slightly taller (10 – 20 cm) and tall (>20 cm) vegetation. In this way, the availability of prey animals in the birds' feeding habitat could be determined. Afterwards, through the comparison of prey parts in the droppings, it could be established which prey out of the total food supply were selected.

In the droppings, it appeared that all the hard parts of the eaten prey animals could be found back: legs, jaws, and pieces of the armour. It was not possible to identify to which animals these parts had belonged when using some body parts, such as legs and all sorts of small fragments. Therefore, hard unbroken parts of which each prey item had only one or two, such as the jaws of caterpillars and beetles, and the sexual organs of spiders, were sought after. These were used to determine the species by comparing these parts with those of species that had been captured in the same area.

The greatest proportion of the prey animals that were fed to young Meadow pipits were rather large spiders and caterpillars (each 38%). Other types of prey were much lower in abundance (Figure 15). A few times, small snails and shells were found and every once in a while, remnants of a beetle. The spiders were almost all bigger than 5 mm, and the caterpillars were about 2 cm long. Relatively, the percentage of larger spiders, caterpillars and other insect larvae was higher than that available in the vegetation. Small spiders, small beetles, cicadas, froghoppers, true bugs, soldier beetles (soft and rather large beetles) and ladybird beetles were, in contrast, under-represented in the diet. These were evidently too small or not attractive with respect to taste or nutritional value. Contrary to expectations, Meadow pipits did not show a preference for sites with a high variability of vegetation height and they also did not have a preference for very short vegetation.

9.6 Geese and grazing

Geese live on young, nutrient-rich grass shoots and from other plants such as Sea plantain and Sea arrow-grass. Such plants can only be found in older salt marshes when these marshes are grazed. But how much grazing is minimally required to maintain an adequate food supply on salt marshes, and would it make a difference which species of livestock is used for grazing?

Large numbers of Brent and Barnacle geese forage on the salt marshes of Noard-Fryslân Bûtendyks. The Barnacle goose is the most abundant; between October and May, there are tens of thousands, with a peak in March-April (Figure 16). Their numbers in Noard-Fryslân Bûtendyks have increased over the last 20 years, partially due to the increase of the entire world population (from 267,000 in the 1990s to 770,000 in 2010). Brent geese are most abundant in May, just before they fly back to their breeding grounds in the high north.

In order to know how many geese have foraged in a specific area, use can be made of the number of droppings that they have let fall. Geese eat, namely, throughout the whole day and continually produce a fresh dropping every few minutes. The more droppings that lie on a specific area, the more time the geese have spent foraging there.

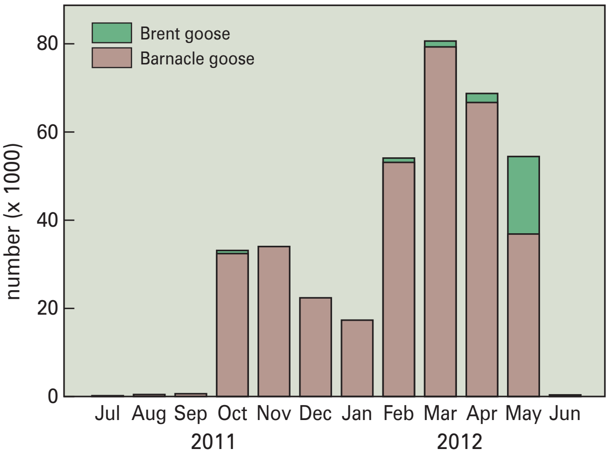


Figure 16 The numbers of Barnacle and Brent geese in Noard-Fryslân Bûtendyks during the period from July 2011 to June 2012.


Brent geese


Barnacle geese


Goose droppings

The geese of Noard-Fryslân Bûtendyks appeared to have a preference for grazed, higher elevation parts of the salt marsh. On the basis of the dropping counts, it can be established that it does not matter to geese whether an area is grazed with cattle or with horses. However, the stocking density does matter: in the autumn, there was a preference for plots with 1 animal/ha. In the spring, this preference was not present; experimental plots with 0.5 and 1 animal/ha attracted about the same number of geese (Figure 17). Only in the autumn was a stocking density of 1 animal/ha favourable for geese. Contrary to expectations, this difference was not caused by the difference in vegetation height because fields with shorter vegetation had about the same number of droppings as fields with somewhat taller vegetation.

A possible explanation for the differences between autumn and spring is that in autumn, mostly old plants are present. During this season, young shoots only sprout continuously when the plants are defoliated by grazing. The greater the stocking density, the stronger this effect is. In the spring, all plants make new shoots, even when the vegetation has not been grazed down during the previous year. Because of this, the livestock density in the previous year has less effect on food availability for geese in spring.

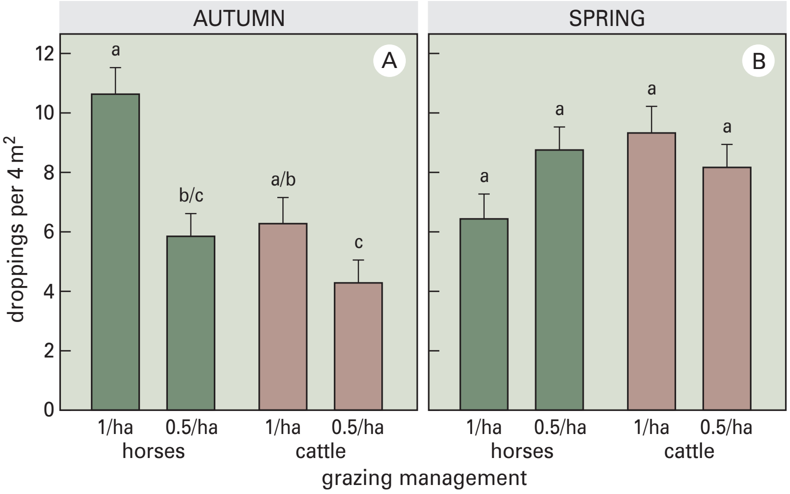


Figure 17 The average number of goose droppings that were counted on a weekly basis in 4 m^2 plots in four different grazing regimes divided into (A) the autumn and (B) spring periods. In the autumn, geese had a preference for experimental fields with high stocking densities. In the spring, there was no difference between the four shown management regimes. Letter symbols above the bars indicate which values were statistically significant per season.

10 Grazing and voles

On the high salt marsh of Noard-Fryslân Bûtendyks, smaller and larger burrow entrances of voles can be found. The small burrow entrances indicate that a burrow probably belongs to either the Common vole or the Field vole; the larger entrances indicate that a burrow probably belongs to a larger vole species, *i.e.* the European water vole. In Noard-Fryslân Bûtendyks, the number of burrows were counted along five transects of about 250 m long and 9 m wide. The data are only available from one year and one experimental area. The results give a first impression of the differences in vole density among the different grazing regimes.

With 1 horse/ha, there was almost no trace of voles found (one occupied burrow for five transects; Figure 18). With 1 head of cattle/ha, the equivalent of 20 burrows per hectare were found; with 0.5 horses/ha or cattle/ha, 34 burrows per hectare. The rotational grazing treatment in the year without grazing with 1 head of cattle/ha was somewhere in between with 28 burrows per hectare. Evidently, the voles could withstand some level of grazing but their numbers decreased with densities of 1 head of cattle/ha and they could not withstand a density of 1 horse/ha.

How high the density of burrows would have been after a longer period without grazing cannot be extrapolated from the currently known data. However, it is known from long-term ungrazed salt marshes, such as the northern part of the Peazemerlannen, that high densities of voles can occur despite the rather uniform vegetation of Sea couch.

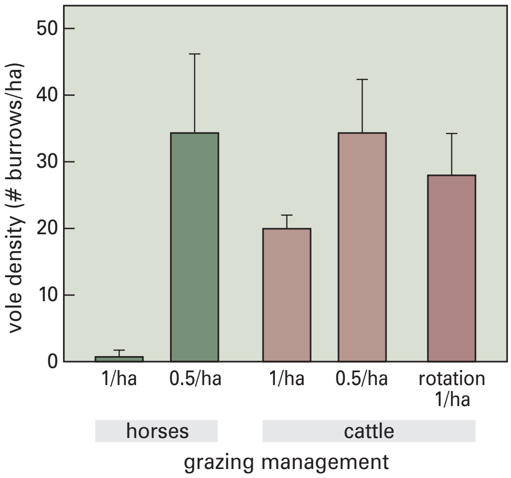


Figure 18 The number of voles found in autumn on high salt marshes with different grazing regimes. The bar chart gives the average number of occupied burrows (± standard error) per hectare over five transects per management regime in the central experimental area (Figure 2).

Left: In the high elevation areas of the salt marshes of Noard-Fryslân Bûtendyks, there were many burrows of voles to be seen, mostly when the grazing was not too intensive. Right: Vole in Noard-Fryslân Bûtendyks.

11 Synthesis

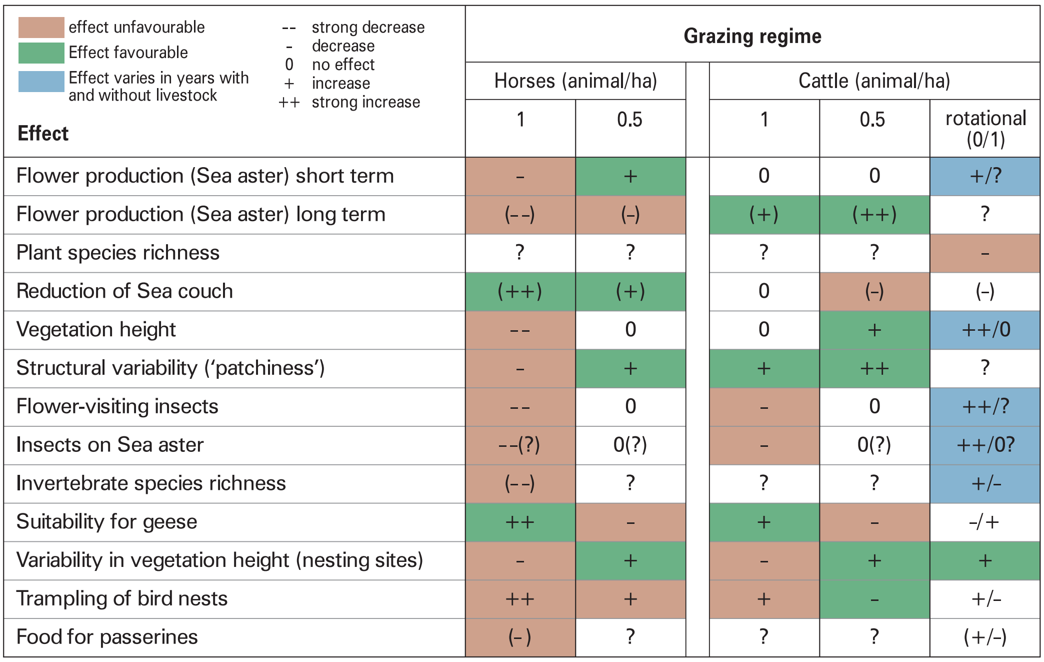
Grazing: at which stocking densities and with which livestock species? These were the central questions of this research study, in which the effects of grazing on vegetation, invertebrate animals and birds were studied.

The effects of different grazing regimes in the grazing experiment on Noard-Fryslân Bûtendyks is summarised in Table 1. Therein, it can be seen that the effects of grazing are dependent on both stocking density and livestock species. The effects of the rotational grazing regime over the long-term are not yet clear; therefore a few cells in the far right have not been filled in.

The differences that are given Table 1 were caused by differences in stocking density, in combination with differences in the behaviour and food uptake of horses and cattle. Horses are more active than cattle, and they also have a slightly different choice in diet. On the scale of the experimental fields we used, no grazing gradient appeared with horses but did appear with cattle. It is however possible that such a gradient could also appear with horses, but then only when the scale of the area is large enough. The higher activity of horses leads to the consequences that more nests are trampled and that the soil becomes more compacted. The different diet choice of horses means that they are more inclined to eat fibre-rich plants. Nature conservation organisations can make use of this last feature when they are aiming to decrease the proportion of Sea couch in the vegetation.

For the formation of patterns and diversity in the vegetation structure, grazing with stocking densities of 0.5 animals/ha is favourable. In this study, structural diversity was highest with stocking densities of 0.5 animals/ha and patch size was found to be smaller with cattle grazing than with horse grazing. In principle, enhanced structure of the vegetation meant enrichment for invertebrate animals because more and other species could exist in parts with tall vegetation than in short, grazed-down areas. Structurally diverse vegetation can also be favourable for birds; it was demonstrated in this study that Oystercatchers and Redshanks have a preference for nesting sites with more structure in the vegetation than was found on average in the surroundings.

In general, grazing appeared to have a negative effect on the diversity of invertebrates, which is consistent with the scientific literature. Ungrazed salt



🟫 effect unfavourable
🟩 Effect favourable
🟦 Effect varies in years with and without livestock

-- strong decrease
- decrease
0 no effect
+ increase
++ strong increase

Effect	Grazing regime				
	Horses (animal/ha)		Cattle (animal/ha)		
	1	0.5	1	0.5	rotational (0/1)
Flower production (Sea aster) short term	-	+	0	0	+/?
Flower production (Sea aster) long term	(--)	(-)	(+)	(++)	?
Plant species richness	?	?	?	?	-
Reduction of Sea couch	(++)	(+)	0	(-)	(-)
Vegetation height	--	0	0	+	++/0
Structural variability ('patchiness')	-	+	+	++	?
Flower-visiting insects	--	0	-	0	++/?
Insects on Sea aster	--(?)	0(?)	-	0(?)	++/0?
Invertebrate species richness	(--)	?	?	?	+/-
Suitability for geese	++	-	+	-	-/+
Variability in vegetation height (nesting sites)	-	+	-	+	+
Trampling of bird nests	++	+	+	-	+/-
Food for passerines	(-)	?	?	?	(+/-)

Table 1 Overview of how different grazing regimes studied in the grazing experiment affect potential management targets using a five-category ordinal scale. Question marks indicate that the effect is not yet clear because of the short duration of the experiment. Effects placed between brackets indicate that they have not been proven, but would probably be found. The background colours in the cells indicate whether an effect would be seen as favourable or unfavourable. With the rotational grazing treatment, effects are different between the years with and without grazing.

marshes can be categorised into salt marshes that have only been ungrazed for a short time and salt marshes that have been left ungrazed for longer periods. However, there were also invertebrate species with a positive response to light grazing (0.5 animals/ha) or to the intensive grazing with 1 animal/ha. Through the differences in preference, the total diversity of an extensive area of salt marsh could thus be the greatest with a spatial mosaic: areas with stocking densities of 1 animal/ha, areas with 0.5 animals/ha, temporarily ungrazed and permanently ungrazed areas.

The diversity of breeding birds on the Dutch mainland salt marshes in the Wadden Sea appeared the highest in areas without grazing, but this effect became less apparent after a period of almost 20 years without grazing (1992 – 2008). This might be attributed to different stages of vegetation development after the cessation of grazing, which had ultimately ended in a rather monotonic stage dominated by Sea couch. However, an increase in the number of Foxes and possibly also in other ground predators in the salt marshes could also have played a role. As is found with invertebrates, there are also birds that have a preference for livestock densities of 0.5 and 1 animal/ha. Therefore, the total diversity of invertebrates and breeding birds benefits from a spatial variation between parts with livestock densities of 1 animal/ha, parts with 0.5 animals/ha, temporarily ungrazed and permanently ungrazed parts.

For the diversity of staging migratory birds, no conclusion can be drawn on the basis of this study. However, grazing had effects on Brent and Barnacle geese. Especially in the autumn, geese showed a strong preference for the short, grazed-down salt marsh resulting from 1 animal/ha treatments. In the spring, the vegetation is short almost everywhere and no clear preference by geese for a specific grazing regime could be measured.

For the diversity of plants in the vegetation, cattle appeared to score somewhat higher than horses. However, the experiments in Noard-Fryslân Bûtendyks lasted for too short a period to say conclusively whether this would hold over the long term.

For the diversity of invertebrates, the effect of soil compaction was studied, but only for grazing with cattle. Soil compaction appeared negative for the litter layer and the soil structure, and thus for the invertebrates that live in these layers. It is therefore plausible that grazing with a stocking density of 0.5 animals/ha is better than with a density of 1 animal/ha, and that grazing with cattle is better for organisms that live in the litter and soil layers than grazing with horses.

A Short-eared owl hunting for voles over a salt marsh encroached by tall vegetation.

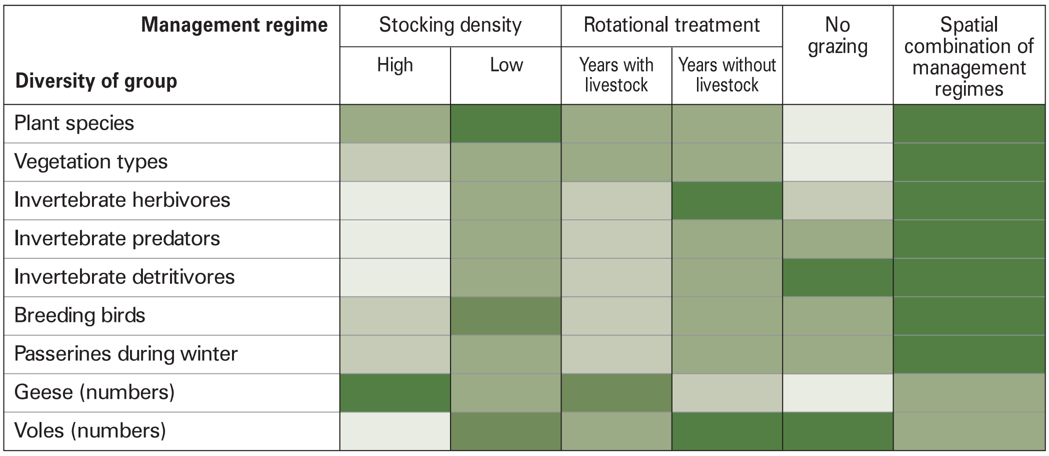
For the diversity of birds in Noard-Fryslân Bûtendyks, no significant differences between grazing with cattle and horses or between different stocking densities were found for either migratory birds or for breeding birds. It is, however, quite possible that those differences could arise over the long term.

Voles can subsist in high-elevation salt marshes, which in turn can attract harriers and Short-eared owls. The vole density in the experimental area was highest in treatments with a stocking density of 0.5 animals/ha and halved by a density of 1 animal/ha. In an experimental field with 1 horse/ha, almost no voles were present. Voles evidently do the best with stocking densities of 0.5 animals/ha or possibly with no grazing at all.

12 Management advice

The general result of the experiment in Noard-Fryslân Bûtendyks is that the effects of grazing are species specific. This means that making a management choice for one (target) species could result in the loss of another species. Table 2, which is partly based upon the research carried out till now, shows the effect of different management regimes. The effects of horses and cattle have not been specified separately in this table. In order to allow all aspects of diversity to reach their full potential, multiple grazing regimes must be maintained next to each other in space: a part left ungrazed, a part with lower stocking density, a part with higher stocking density and a part with a rotational grazing regime. Cattle offer more advantages than horse but the use of horses remains a possibility. It is expected that horses are more suitable for reducing Sea couch.

Given the grand scale of the mainland salt marshes, it is possible, on one hand, to work with land units of considerable size and, on the other hand, to maintain a certain diversity over the entire marsh area. For nature conservation organisations, it is now of importance to choose management goals on the basis of the results seen in this study and to apportion the different management regimes in a way that is also attainable in practice. Of course, the protection of a particular species can also play a role if that is desirable to the organisation.



Management regime	Stocking density		Rotational treatment		No grazing	Spatial combination of management regimes
Diversity of group	High	Low	Years with livestock	Years without livestock		
Plant species	▒	█	▒	▒	□	█
Vegetation types	░	▒	▒	▒	□	█
Invertebrate herbivores	□	▒	░	█	░	█
Invertebrate predators	□	▒	░	▒	▒	█
Invertebrate detritivores	□	▒	░	▒	█	█
Breeding birds	░	▓	░	▒	▒	█
Passerines during winter	░	▒	░	▒	▒	█
Geese (numbers)	█	▒	▓	░	□	▒
Voles (numbers)	□	▓	▒	█	█	▒

Table 2 Global overview of the diversity of salt-marsh plants and animals in relation to the management regime. Darker shading indicates a higher number of species (With geese and voles: darker shading indicates higher numbers of individuals). For birds and invertebrates, every regime has its own characteristic species. From a large-scale perspective, diversity can be maximized by using a spatial mosaic of different management regimes. The index values for passerines in the winter are based on estimates.

13 Gaps in the knowledge that cannot be filled yet

This study has greatly increased insights into the effects of different grazing regimes, especially because it addressed the differences between grazing with cattle and horses in different densities for the first time and because, in addition to the vegetation and the birds, invertebrates were also studied. With respect to the study method in Noard-Fryslân Bûtendyks, this experiment is unique in that the grazing regimes were neatly partitioned over the different vegetation types, thereby allowing grazing to be considered as the true source of the measured effects on the vegetation, birds and invertebrates. The integrated character of this study allows It Fryske Gea and other nature conservation organisations of mainland salt marshes to get the big picture when considering how to reach an optimal strategy in nature conservation management through grazing. This holds for both choice of livestock species and stocking density (for most aspects, a preference for cattle and for low stocking densities was shown).

However, follow up studies are still needed in the coming years. The most important unanswered questions are:

1. As was already indicated a few times in the text, the duration of this study was too short to predict how the effects of different management regimes will turn out over the longer term. Examples include the behaviour of birds and the shifts in the species richness of the vegetation. However, there are indications that shifts will occur over the longer term, but they could not be confirmed during a 3 to 5 year period.
2. Despite the fact that initial results for the rotational grazing treatment are very promising, there remain many questions in particular for this grazing regime. The experience gained over the past few years is insufficient to judge the real value of this management form. Moreover, due to the limited available time, short alternations between only one-year periods were used. It is possible that longer cycles of several years might be better because some plant species, such as Sea aster, may thrive for a couple of years before domination by other species results in the loss of diversity of plants, invertebrates and birds.
3. It is not yet clear if, or at which cycle length, the rotational grazing regime can suppress the abundance of Sea couch over the long term. If it cannot succeed in this role, or insufficiently, a rotational grazing system would not work over the longer term.
4. Does the quality of ungrazed vegetation decrease for birds as time passes, or does it only appear to do so and is this appearance caused by the increase in predators?

For nature conservation organisations, the question now is how the recommendations arising from this study can be realised in practice. What is the best level of partitioning between the different grazing regimes? Is it necessary to determine the minimum areas needed for successful implementation? Would it be feasible to work primarily with cattle? Answers to these questions will depend upon the chosen management targets and must be approached from a research perspective as well as through the lens of practical experience.

14 Acknowledgements

Many hands make light work. Without the help that this project received during the last few years, we would never have reached the point that we are now. At this time, we would like to give thanks the following people for assistance in the field and data analysis: Irene Lantman, Adriënne Verburg, Josée de Jager, Christa van der Weyde, Nils Buisman, Wouter van Looiengoed, Mark Eerkens, Sietse Kooijstra, Frank Groenewoud, Emma Penning, Jelle Loonstra, Eric Brüning, Corinna Rickert, Maarten Schrama, Fons van de Plas, Petra Daniels and Remco Hiemstra. A project like this cannot exsit without good logistical support. Jan Jelle Jongsma took care of the agreements with the farmers of It Fryske Gea for sufficient occupancy of livestock in the experimental fields, while Johannes Westerhof and Gerrit van de Leest supervised the care and maintenance of the livestock and always placed and removed the temporary grids.

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15 References

The information in this brochure was drawn from the scientific publications and dissertations that originated from this project, as well as unpublished data from the project.

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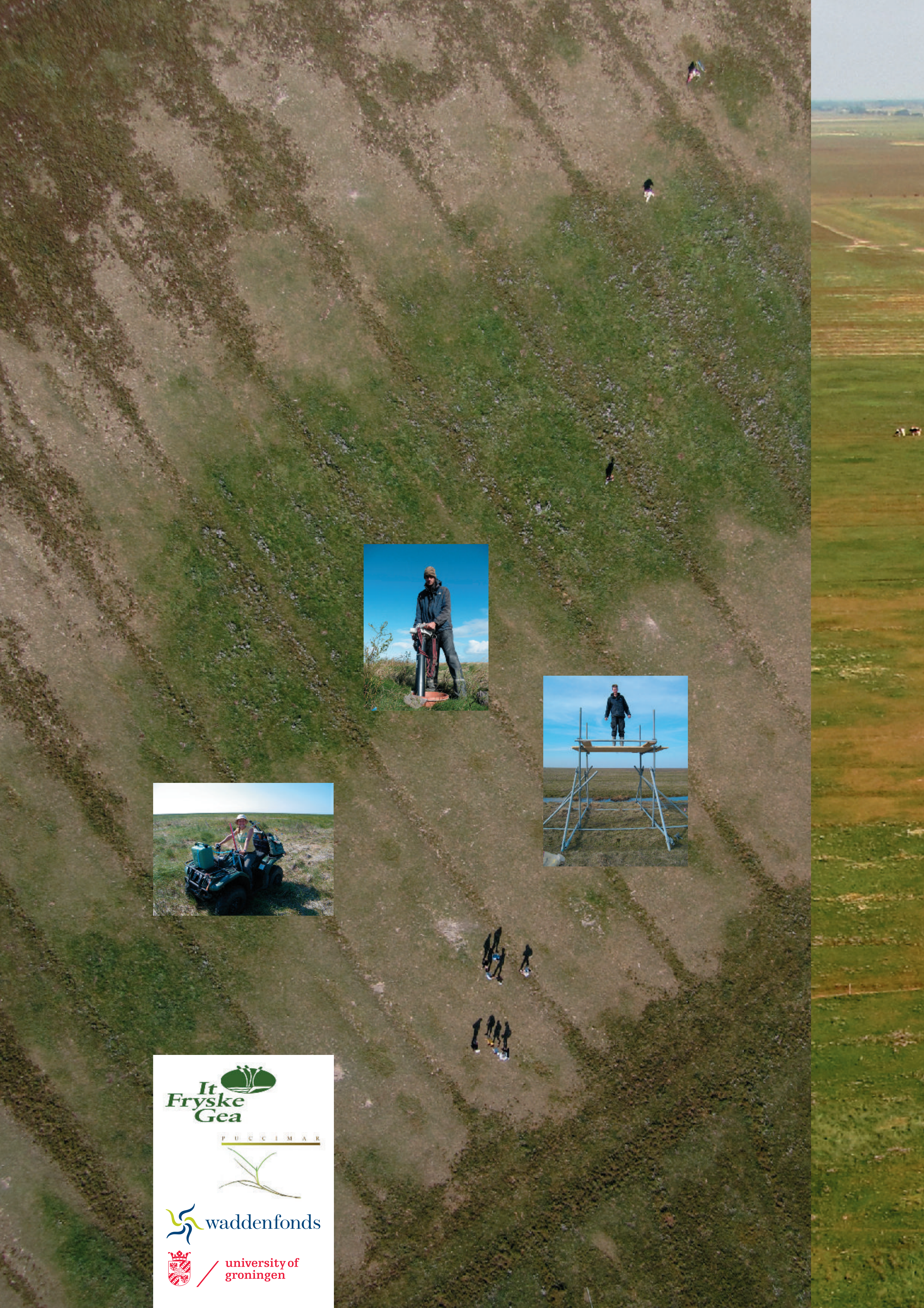

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