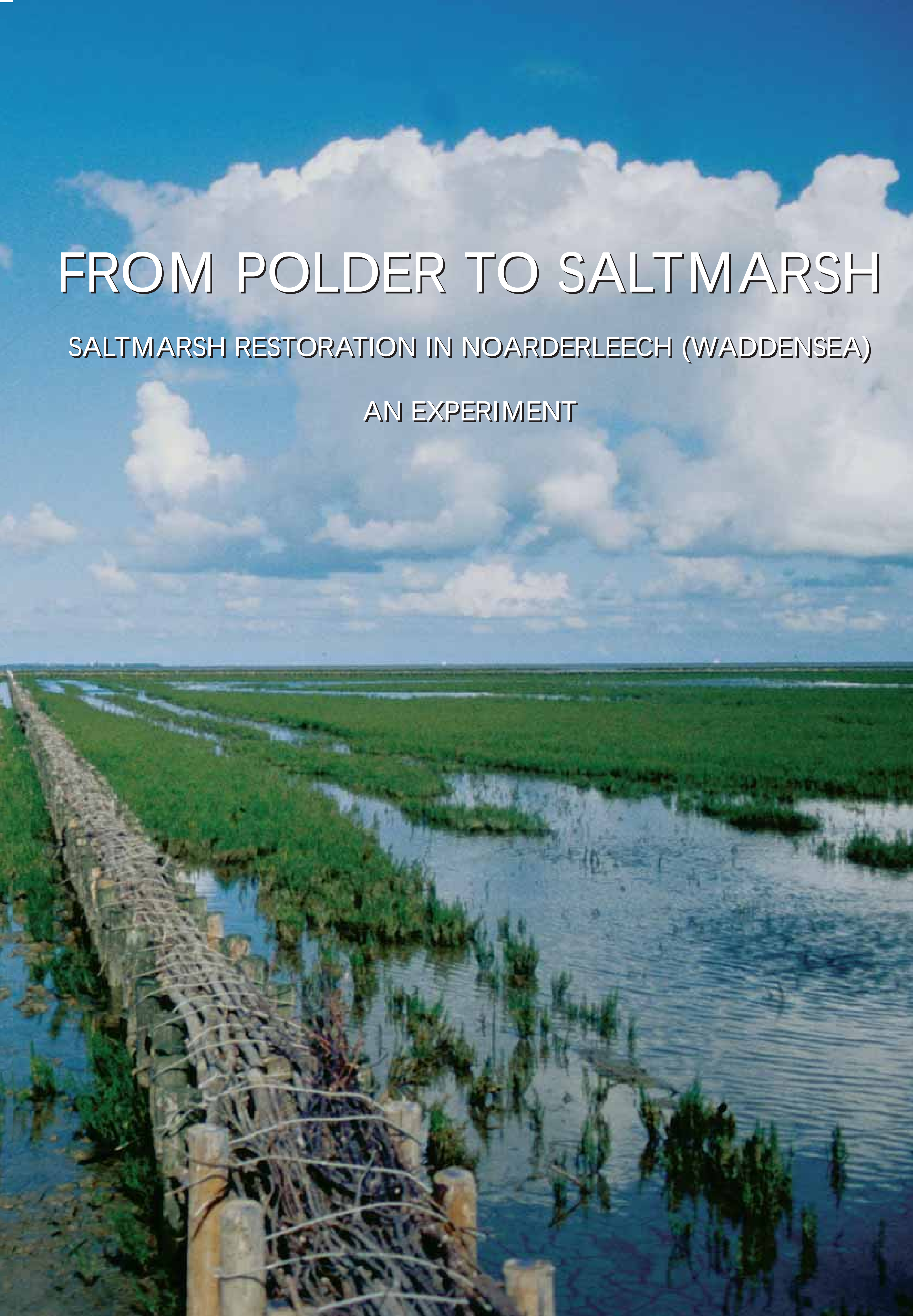
FROM POLDER TO SALTMARSH

SALTMARSH RESTORATION IN NOARDERLEECH (WADDENSEA)

AN EXPERIMENT



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AN EXPERIMENT.

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1 SUMMARY

Human habitation along the edges of the Wadden Sea dates back to long before Roman times. During the Middle Ages, the inhabitants of this region began to reclaim land from the Wadden Sea. From the seventeenth century onwards ditch systems were developed to stimulate accretion on the saltmarshes, and this essentially continued as a 'farmer's method' of land claim well into the twentieth century. By embanking the elevated saltmarshes, between 1897 and 1939 summer polders with an area of 1100 ha were created in Noarderleech. Land reclamation was undertaken in an ever more professional manner and, eventually, responsibility was assumed by the national Directorate-General of Public Works and Water Management, the *Rijkswaterstaat*. During the nineteen seventies and eighties, people's ideas and attitudes changed as land reclamation became increasingly expensive and the natural values of unembanked saltmarshes were appreciated more and more; so much so, that new large-scale targets were formulated to restore summer polders which had been reclaimed from the sea back into saltmarshes, and to open them up to tidal influence again. Noard-Fryslân Bûtendyks (North Friesland 'outside the dikes') would then become the largest saltmarsh area in Europe. Processes such as accretion and erosion in relation to the sediment balance of the whole of the Wadden Sea are very complex and rarely obvious. Because the consequences of saltmarsh restoration cannot be predicted with any certainty, the nature conservation society It Fryske Gea began an experimental saltmarsh project in 2001 in an area measuring 135 ha. Researchers carefully monitored the results until the end of 2005 to learn about future de-embankments, adding to the body of knowledge about saltmarsh restoration already gained in various countries around the world. It Fryske Gea would like to see rich and varied saltmarsh vegetation being created in Noard-Fryslân Bûtendyks with good foraging opportunities for geese; to achieve this a semi-natural grazed saltmarsh would be the most appropriate land use. In 2001, the summer dike was breached in three places after a very natural-looking but artificial winding creek system had been dug to stimulate the supply of seawater and sediment. Through these breaches, the area will be flooded fourteen times a year on average during storm tides.
A monitoring programme was set up to study the salinisation of the groundwater and soil and the vertical accretion in grazed and ungrazed conditions, in the abiotic environment. Monitoring of the biotic environment involved studying the vegetation development and assessing the numbers of wintering and staging geese and breeding birds in relation to trends in the wider environment.

Against all expectations, salinisation of the groundwater, soil and soil moisture proved to evolve only gradually. After four years the levels of salinity were still below those seen in the adjacent natural saltmarshes. There was no massive die-off of non-salt tolerant vegetation as a result of 'salt shock', and no salinisation was established in the adjacent summer polder. Vertical accretion varied from 0.3 – 36.7 mm per year. It was highest in the lower-lying parts of the trial area and higher in ungrazed areas than in grazed areas, because taller ungrazed vegetation traps more sediment. Vertical accretion in Noarderleech is more than adequate to keep pace with land subsidence and the rise in sea level.

Over time the vegetation gradually changed into that which is typical of a saltmarsh with many salt-tolerant species, resulting in a clear increase of the species targeted by the restoration project. Grazing has proved to be a very important factor in attaining the target scenario. In ungrazed areas (exclosures) the plant cover developed towards species-poor Couch-grass vegetation. The availability of food plants for Brent and Barnacle Geese still lags behind expectations and was lower than it was in the adjacent summer polders and saltmarshes. The food situation will probably recover as the saltmarsh vegetation continues to develop. No changes were observed in the numbers of breeding birds in the trial area.

In summary, the experimental saltmarsh restoration in Noarderleech can already be considered a success, and the prospects for continued saltmarsh restoration in Noarderleech and the rest of Noard-Fryslân Bûtendyks are good.

2 STRUGGLE AND RISE

Traditionally, the Dutch have had to fight the sea to survive and they are known for this characteristic all over the world. The motto of the province of Zeeland, *Luctor et emergo* – I struggle and rise – could well be their national motto; it is a source of national pride. The Dutch have been exporting their knowledge of drainage and land reclamation for centuries and Dutchmen are involved in drainage and embankment projects across the globe. But now, out of the blue, they are breaching dikes in several places in their own country to allow the sea into land that was reclaimed from it earlier at great effort and cost. How on earth can this be? It is no wonder that many people, especially in the Netherlands, find it hard to understand; and no wonder that, deep in their hearts, many people are hostile to it, especially those who live in places where it is happening, where families have striven for generations to claim and secure farming land, and where older people have sharp memories of catastrophic dike breaches and floods. We might just have a thing or two to explain to them.

The world around us is changing, but it's not just that: we ourselves are changing as well and our views on nature, agriculture and water management have changed. In the Netherlands until half a century ago, nature was something that had to be overcome. Woods and heaths were described as 'waste lands', just lying there waiting to be cultivated. Moorland had to be excavated for peat extraction, stinking bogs drained and the sea kept in check. Mudflats were described as cheerless grey expanses where the only sounds heard were the dismal cries of the occasional shorebird, so … reclaim, impolder!

Towards the end of the twentieth century it became clear that nature, agriculture and water management could not be treated separately anymore. Nature was becoming scarce, was sought after and therefore precious; agriculture was no longer profitable in many places because of the rising cost of labour; and water management came into everything. If everybody continued to drain their land without limit – abroad as well, in the upper reaches of the main Dutch rivers – the Netherlands would soon be confronted with insoluble problems of excess water. For the first time, water management and water storage were thought about in relation to agriculture, nature and other uses, i.e., in terms of what we call integrated water management. Interestingly, and perhaps typically, the Dutch have managed to turn this into a global export product too, as other countries including the USA and China also have enormous water management problems; the Dutch 'poldermen' have again taken the lead in finding solutions as they continue to struggle and rise. It is in keeping with this change in attitude to breach dikes and expose agricultural land to the influence of rivers, estuaries and inland seas again, replacing polders by saltmarshes in a managed way, which is often referred to on the European continent as de-embankment (or depoldering, *ontpolderen* in Dutch).

Saltmarshes in the Dutch part of the Wadden Sea can be found on the mainland side of the Wadden Sea islands and along the mainland coasts of Friesland and Groningen. The largest continuous area of saltmarsh in the whole of the Wadden Sea lies in the Noard-Fryslân Bûtendyks area. It Fryske Gea has obtained extensive tracts of this area over the past few years for the purpose of improving their natural values. To achieve this, the plan is to breach summer dikes in certain places on a large scale to allow the Wadden Sea back into summer polders that were previously embanked. An experimental summer polder was opened in 2001 by breaching a dike in three places. Researchers have monitored the consequences for five years and their scientific findings have been set out in the report *Proefverkweldering Noard-Fryslân Bûtendyks* (Van Duin *et al*. 2007). The most important conclusions from this report will be presented in this research article.

3 HISTORICAL BACKGROUND

Human habitation of the Wadden Sea coast goes back to about the sixth century BC, when small settlements were founded on the higher levees along the many intertidal creeks in the coastal region of present-day Friesland and Groningen. The sea level was falling at that time, and so human occupation of the vast, expanding saltmarshes continued in a seawards direction. When the sea began to rise again in about the third century BC, the saltmarsh inhabitants found themselves under threat and responded by constructing mounds (*terpen*). Over the following centuries the sea ate its way deeper and deeper into the land, in particular, swallowing up sites where peat soils were farmed and where early drainage systems had been laid out, because these activities depressed the soil and made it easier for the sea to enter. Deep bays resulted such as the Zuiderzee, the Middelzee, the Lauwerszee and the Dollard.

The oldest summer dikes date from Roman times, but it was during the Middle Ages, when the threat of floodings became greater, that people began to construct simple dikes around the mounds on a larger scale to protect their farming land. An unintended side effect was that new saltmarshes were formed, because accretion took place on the seaward side of the new dikes. From the tenth century onwards longer dikes were built to protect the hinterland. By the thirteenth century, when the sea had stopped rising, all the mainland of the Northern Netherlands along the Wadden Sea coast had been diked with dikes following the contours of the inlets and inland seas. Subsequently, these inlets were also reclaimed, bit by bit, by embanking the saltmarshes. In Friesland, the main land reclamations in the Middelzee were carried out between about 1200 and 1500 AD. In the seventeenth century and the first half of the eighteenth century, some narrow polders were added which border onto the present Noard-Fryslân Bûtendyks area within the seawall.

In the seventeenth century, farmers on the Frisian coast began to stimulate accretion of the saltmarshes by digging ditches. It is not known exactly how these ditch systems developed, but it seems likely that the farmers discovered, first, that ditches in the vegetated part of the saltmarshes stimulated accretion between the vegetation and, then, that extending the ditches to the bare mud approximately 100 metres beyond the vegetation line fostered the accretion of the saltmarshes. In the nineteenth century in particular, elaborate systems of ditches running parallel to the coast and connected to shore-normal drainage channels evolved. The ditches had to be cleared every year. This method of claiming land, known as the 'farmers' method', continued well into the nineteen thirties.

The first summer polder in the Noarderleech area was made in 1897 outside the seawall by the construction of a summer dike. A summer polder only affords protection against floodings during the relatively calm summer season. During autumn and winter storms the sea may occasionally spill over the low summer dike so that the summer polder is flooded and a new layer of sediment is deposited. The grass sward is not harmed by these incidental winter inundations when the polder is empty of livestock. The construction of summer dikes continued until the year 1939, by which time the total surface area of all the summer polders amounted to 1100 ha.

During the first decades of the twentieth century, land claim by farmers tailed off because of socio-economic circumstances. Cheap labour was scarce and the prospects of making short-term profit from claiming land were not good. In addition, there were many legal disputes about the rights to the new land. Instead of accreting, in some places saltmarshes even

During the Second World War the land reclamation works came to a halt and much of the recently gained land was lost through erosion. The work was resumed in about 1946. Gradually, after 1950, most of the excavation work became mechanised. In the late sixties, the maintenance of the ditches became disproportionately expensive because of economic growth and rising wages, and in 1968 digging ditches was discontinued in the seaward facing rows of sedimentation fields. In the vegetated fields ditch maintenance was continued every two to six years instead of annually until the nineteen nineties. In 1980 a new target for the land reclamation works was added, namely, the protection and restoration of nature conservation values, and the term ‘land reclamation’ was replaced by terms like saltmarsh restoration or conversion, ecological restoration, etc.. Seaward expansion of the saltmarsh area is no longer the objective; the primary goal now is maintenance and preservation.

eroded, threatening the integrity of the seawalls. Then came the great economic recession of the thirties when, making a virtue of necessity, the government took land reclamation into its own hands and set large numbers of unemployed people to work in the heavy clay of the intertidal mudflats. A new method of claiming land was copied from Germany, the so-called Schleswig-Holstein method. Employing this method, sedimentation fields are constructed which are enclosed by light brushwood groynes consisting of double rows of stakes driven into the clay which are in-filled with brushwood fences. The top of the brushwood groynes usually stand approximately 30 cm above the mean high tide level. The advantage of using brushwood groynes is that seawater can flow through them freely so that no great differences of stress are caused on either side, whilst wave energy is dissipated which accelerates the settlement of silt and clay particles. The sedimentation fields used in Germany measured 200 x 400 or 200 x 200 m, but in the Netherlands larger fields of 400 x 400 m were made which extended beyond the vegetation line into the bare mud. Usually, two or three rows of fields were constructed behind each other. In the groynes running parallel to the coast, openings for water drainage were made at 200 m intervals.

The work in the heavy clay, often in severe weather conditions, was extremely hard and, in retrospect, there is general agreement that it was actually too hard for the less physically developed unemployed men from the big cities, who were in fact exploited.

4 RECLAIM AND RETREAT

The changed purpose of the saltmarshes and summer polders in Noard-Fryslân Bûtendyks did not come about without a struggle; the nineteen seventies and early eighties, in particular, were turbulent. As prescribed in the Delta Act, which was passed in 1958 following the 1953 flood disaster in Zeeland, all sea defences in the Netherlands including the embankments of all the major rivers had to be raised to a certain minimum safe height (the 'delta height') to prevent such disasters from recurring. In the early seventies it was the Frisian Wadden Sea coast's turn to be protected in this way, and a decision had to be made about how the Act should be implemented. The simplest solution was to just raise the existing seawall but, as the opportunity was there, a good alternative would be to construct a new dike surrounding the accreted saltmarsh area and thus reclaim a sizeable area of intertidal mudflats where seed potatoes could be grown. Four different designs were made, each with their own small band of supporters and opponents. Plan A consisted of raising the existing seawall, Plan B included the summer polders and a narrow strip of the vegetated saltmarsh outside them, Plan C included all of the vegetated saltmarsh, and Plan D envisaged a new dike being constructed all around the land reclamation plots, which would constitute an impolderment of some 4000 ha of saltmarsh.

In practice, Plans B and C did not receive much attention and debate focused on the pros and cons of Plans A and D. The supporters of Plan D regarded the occasion as a unique opportunity for concluding the land reclamation projects in style, and pointed out the advantages in terms of agricultural use, employment and other regional economic benefits. The advocates of Plan A emphasised the international importance of the area as a nature area within the Wadden Sea and questioned the agricultural significance and the increase in employment which was expected by their adversaries. The battle between them flared up at times and almost fifteen years of demonstrations and protest meetings followed. Stacks of thick reports were written which together would fill many desk drawers, and heated discussions took place between the local inhabitants and nature conservationists, but eventually feelings calmed down and people could see eye to eye again. At first it seemed as if all the parties would agree to Plan B, a compromise, but in the end the tenacity of the Wadden Sea Society *(Vereniging tot Behoud van de Waddenzee)* won out, and in 1986 the Council of State declared that: "There are no compelling reasons that would justify the impoldering of this nature area." So, Plan A it was: not potatoes but avocets.

The decision by the Council of State may seem surprising and partial, but it does not stand on its own. In December of 1979 the government had published its Key Planning Decision on the Wadden Sea *(Planologische Kernbeslissing Waddenzee, or PKB-Waddenzee)*, which was adopted by the Lower House of Parliament in January of 1980 (and has been revised several times since, lastly in 2006), and which states as its primary goal: ‘the sustainable protection and development of the Wadden Sea as a nature conservation area’. In Noard-Fryslân Bûtendyks the boundary runs along the toe of the seawall so that the whole area outside the seawall including the summer polders falls within the PKB area. This decision made by Parliament had, in fact, already virtually precluded the adoption of Plan D. The *Zeitgeist* was not with the farmers.

During the implementation of the PKB, throughout the nineteen eighties, the protected status of the Wadden Sea was elaborated in greater detail, adopted and placed within a legal framework at the national, provincial and municipal levels.

The protection of the Wadden Sea also has consequences internationally. The Netherlands have made a proposal that the Wadden Sea, including the summer polders and saltmarshes, be designated as wetlands of international importance under the Ramsar Convention; countries who are signatories to this Convention have a duty to protect wetlands with this designation. The area has also been designated an EC Birds Directive area and an EC Habitats Directive area, and the EU imposes a duty on its member states to protect areas that meet certain criteria in accordance with these Directives. The ministers of the three Wadden Sea countries involved (the Netherlands, Germany and Denmark) have also made agreements about the conservation of the Wadden Sea, the central concern being that Noard-Fryslân Bûtendyks is the largest continuous saltmarsh area in the whole Wadden Sea.

Large parts of the area have, in the meantime, been bought by It Fryske Gea with subsidies from the European Community, the Dutch government and the province of Friesland, to be managed by it as a nature conservation area. It Fryske Gea now oversees approximately 3500 ha of the 4000 ha of Noard-Fryslân Bûtendyks (saltmarshes plus summer polders), almost 90% of it. Converting the summer polders into saltmarshes is not automatic, and the local people quite naturally have shown resistance to it. For this reason, It Fryske Gea decided to first carry out an experiment by converting an area of 135 ha in size into a saltmarsh and to carefully monitor the effects over a number of years.

This research was carried out with financial contributions from the EU (the LIFE-Nature programme), the Ministry of Agriculture, Nature and Food Quality, the Directorate-General of Public Works and Water Management *(Rijkswaterstaat)*, the province of Friesland, the Prince Bernhard Culture Fund, the University of Groningen, and It Fryske Gea.

5 SALTMARSH DYNAMICS

As noted above, whatever is done in relation to water affects water management somewhere else, in the form of an excess or deficiency of water. To manage water sensibly all the various aspects (agriculture, nature, drinking water, safety, recreation, et cetera) must be considered in relation to each other, in other words, water management must involve integrated practise. The same applies to sand and silt. The Wadden Sea is a 'sand-sharing' system in which sand is transported by the wind, tides and currents, but in the end always retains more or less the same spatial distribution. A local excess of sand will eventually be distributed across the whole Wadden Sea, and the same applies to any local deficiencies. Thus, land subsidence (or sea-level rise) should lead to a chronic deficiency of sand resulting in receding coastlines. As we don't want the Wadden islands to shrink, what is done these days is to suck sand up from the North Sea to reinforce them (beach and foreshore renourishment). The law of the sand-sharing system then ensures that the excess sand from the Wadden islands is distributed across the whole Wadden Sea area during autumn storms.

Actual reality is, of course, more complex. The sand-sharing Wadden Sea is not a closed system. Along the whole of the Dutch North Sea coast, the dominant wind directions and sea currents cause net sand transport from the south-west to the north-east. Thus, sand enters the Wadden Sea from the west through the Marsdiep and other tidal inlets, and on the eastern side sand is carried on to the German and Danish parts of the Wadden Sea. If the supply and loss of sand balance each other out, the sand balance in the Wadden Sea is maintained. Unfortunately, the balance has been disturbed by the construction of Maasvlakte 2, a port and industrial zone near Rotterdam, which has resulted in an enormous area of sedimentation, called the Voordelta, which is now a beautiful nature area, but which has also caused a deficiency of sand supply in the Northern Netherlands.

That is not all. Following the natural sand flow, the Wadden islands ought to migrate towards the east and south, because they are subject to constant erosion on the exposed north-west side and accrete on the sheltered south-east side. On the island of Schiermonnikoog, for example, the village of Oosterburen ('oost' means east) now lies on the western side of the island, whilst Westerburen has ended up on the bottom of the sea halfway between Schiermonnikoog and the island of Ameland. In the eastern part of the Dutch Wadden Sea, Rottumeroog will in time fall over the edge of the deep channel which leads to the Dollard. On the western side, the Haaks shoals between the mainland city of Den Helder and the island of Texel are growing into a new Wadden island, although this is being obstructed because Texel is no longer migrating. Action has been taken to prevent Texel from being displaced, in the same way as the other islands are being kept in place, so that villages like Westerburen will disappear into the sea no more.

On the eastern sides of the Wadden islands, *Rijkswaterstaat* has constructed long sand-drift dikes to reinforce the coastal defence function of the islands. On the sheltered Wadden Sea side, beautiful 'natural' saltmarshes have formed, such as the Oosterkwelder on Schiermonnikoog and the Boschplaat on Terschelling. According to the sand-sharing law this should result in less accretion on the other side of the Wadden Sea, that is, on the coast of Friesland and Groningen.

By their nature saltmarshes are never stable. They are subject to constant change, growing through vertical accretion if sediment is withdrawn from the sand-sharing system, and shrinking when sediment is returned to the system through erosion. The relationship between accretion and erosion depends on the balance between the supply and discharge of sediment in the Wadden Sea as a whole, on phenomena such as sea-level rise and land subsidence, and on structural changes in weather patterns. At times the wind blows harder and more often from the north-west for a number of years, resulting in higher mean high water levels from damming up.

A natural saltmarsh forms if a mud or sand flat rises through vertical accretion until it lies just below the mean high water level so that it is submerged twice a day for several hours and is dry the rest of the time. If this is the case the flat will be colonised by primary vegetation – the pioneer plants Common Cord-grass and Glasswort. The zone where these plants grow is called the pioneer zone. When the tide rises, the plants standing in the water impede the flow of water and augment the sedimentation of silt particles. Next, Common saltmarsh grass may establish itself which promotes the trapping of sediment even further. This second zone, which lies just above the mean high water level and is not submerged at high water every time, is called a low saltmarsh. As the saltmarsh grows and becomes higher, it is flooded less and less often, and new plant species establish themselves until a middle marsh is formed which is flooded only occasionally during storm tides.

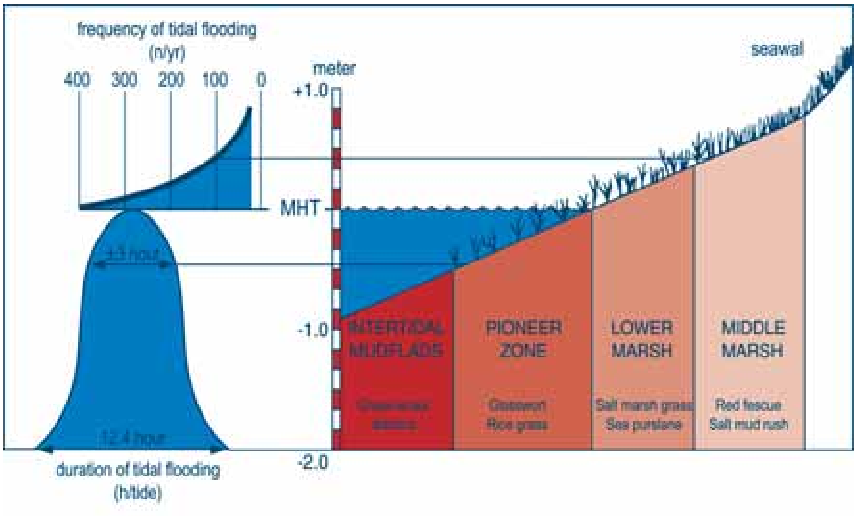

Figure 1. Section of a saltmarsh showing vegetation zones in relation to flooding duration and frequency.

In theory, one would expect the vertical accretion rate to decrease as the saltmarsh gains elevation, because the frequency and duration of inundations decrease, but in reality things are more complex. Because vegetation traps sediment much better than bare mud does, accretion is not greatest in the lowest zone but a little higher up where there is more grass. As a result, the saltmarsh's slope towards the sea becomes steeper; which is not a problem until the saltmarsh becomes so steep that wave action cuts a cliff in it. If this happens, undercutting will cause the steep saltmarsh edge to retreat more and more inland. The saltmarsh is eaten up by the sea and in time may disappear. Sometimes this process stops halfway and a new saltmarsh forms in the lower zone on the seaward side of the cliff edge.

The sedimentation pattern is also subject to seasonal effects. All the sediment which collects during the calm summer months within and just outside the pioneer zone may be stirred up during autumn and winter storms and be deposited on the saltmarsh.
A natural saltmarsh is characterised by a highly branched creek system, which the seawater flows back through into the sea after high tide. During high tide, seawater enters these creeks so that the water spills over the banks, depositing coarser sediments just outside the banks and more finely grained sediments farther away. Thus levees are created, just as they are along rivers. Levees originate at two different levels of scale. Apart from the small-scale levees which form along the creeks, storm surges may form broad levees consisting of coarser sediment along the full length of the saltmarsh parallel to the outer coastline.

The Frisian saltmarshes, which have resulted from land reclamation projects, are less complicated. Instead of having natural creeks, they are drained by means of ditches during the falling tide. When the ditches silt up, they are cleared and the mud is dispersed evenly over the plots. Differences in elevation caused by levees are therefore absent.

Finally, the role of animals must be mentioned in connection with the vertical accretion process. Above the mean high water level, plants assist sedimentation and below this line molluscs lend a hand. They filter enormous amounts of seawater as they hunt for the digestible organic particles which they feed on. Most suspended particles which they ingest, however, are indigestible clay or silt particles which they need to eject again and which they do in the shape of pseudofaeces: tiny mud excretions packaged in a slimy mucus layer. They are not real faeces because they have not passed through a digestive tract, hence the name pseudofaeces. These tiny mud packages settle more easily than individual silt or clay particles do and if they are stirred up from the bottom of the sea by a storm they behave more like coarse sediment, which settles more rapidly.

6 SALTMARSH RESTORATION ELSEWHERE

The experimental saltmarsh restoration undertaken by It Fryske Gea is not the first instance of saltmarsh restoration and does not stand on its own. Saltmarsh restoration is also receiving attention elsewhere in the Netherlands as well as abroad, where it may also be referred to as managed realignment or managed retreat, often with an emphasis on coastal defence, which is not the case in the Dutch situation. The Dutch may have been at the forefront internationally for centuries in the art of land reclamation and, as noted above, are the leaders with regard to integrated water management, but they have some catching up to do vis-à-vis countries such as Great Britain and the United States of America in terms of the practical implementation of saltmarsh restoration.

In England, for example, managed realignment has been implemented on the Essex coast as an economic and sustainable solution for coastal defence against erosion and the risk of flooding in the event of sea-level rise. In many cases, the intertidal habitats in question originate from accidental dike breaches that were not repaired. In these areas the level is raised by vertical accretion, which provides better protection of the hinterland against storm tides. Another aspect which is important nowadays is compensation of lost habitats.
An essential difference between the English and Dutch situations in general is that in England the coastal strips which are protected by the dikes are very narrow: only 175 metres on average! This means that, because of the cost of labour, maintaining the dikes far exceeds any revenue from the narrow strip of arable land protected by it. In the Netherlands, the area protected by dikes against flooding is usually a lot larger and so, generally speaking, dikes are far more precious. In England saltmarshes are being developed because they provide good resistance to wave action, they keep up with sea-level rise, require little maintenance and are widely accepted as green nature areas.

In the USA many saltmarsh conversion projects are carried out within the framework of the Mitigation Act. Under this Act, preventing damage to wetlands is a requisite precondition for getting planning permission or, if this is not possible, any damage caused must be compensated. Many saltmarsh conversions, such as those in San Francisco Bay, have resulted from such compensation schemes. In the past, only the surface area of the re-flooded area was taken into account in relation to the disruptive intervention but, increasingly, measurable nature conservation outcomes are set as a requirement which are based on specific losses in the affected areas. In consequence, there is a tendency to restructure the lost habitat exactly as it was by copying the relief using machinery, by planting the desired plant species, often applying intensive fertilisation, and by introducing animals. But on the whole, there is little understanding of the dynamics and the natural processes in these areas.

In the Netherlands and Belgium, the de-embankment of polders, or 'depoldering', is a highly sensitive subject, especially in the south-western province of Zeeland where the disastrous flood of 1953 is a living memory. The problem centres on the Western Scheldt, because the EU has attached certain conditions to the intended deepening of the shipping channel to Antwerp; compensation measures must now be taken if any natural areas are affected, and returning polders to the sea is seen as the main tool. The EU is making many millions of euros available, but this is scorned as a mess of pottage in the region. Returning land to the sea is almost a taboo topic in Zeeland. Still, one case of de-embankment has taken place within the Western Scheldt, when a dike in the Selenapolder was not repaired after it had been breached. The area was bought by the regional nature conservation organisation Zeeuws Landschap which has developed it into an intertidal nature area with a surface area of 100 ha called Sieperdaschor.
De-embankments are also under consideration along the banks of the Western Scheldt on the Belgian side, however, mainly for safety reasons because the risk of flooding is increasing as a result of sea-level rise, reduced floodwater storage capacity because of embankments, and the increasing frequency of hard westerly winds.

In the north of the Netherlands, two polder areas on the north-east coast of Friesland have been restored to saltmarsh. After the dike of one of the two summer polders in the Peazemerlannen nature area was breached during a storm surge in 1973, it was agreed that the breach should not be closed and that the polder should be allowed to develop into a natural saltmarsh of about 100 ha. At the pier at Holwerd a small polder measuring 37 ha was deliberately exposed to tidal action by opening three tide gates permanently from 1989 onwards, another breach in the summer dike being added in 1995. The experience gained from these two polders has been very important for the set-up of the

7 MANAGEMENT OF NOARDERLEECH

experimental saltmarsh in Noarderleech.
It Fryske Gea's management aims for Noard-Fryslân Bûtendyks are to create sufficient foraging opportunities for geese, to prevent the increase of tall-growing plant species and to delay the ageing of the saltmarsh as much as possible by grazing horses, cattle and sheep on it during the summer. These animals behave very differently from each other and thus have different effects on the vegetation. Together they create a varied pattern of vegetation.

If spring grazing is applied there is always an uneasy balance between grazing livestock and breeding birds. Grazing is necessary to maintain the breeding habitat but trampling of the nests is inevitable. Horses cause most damage because they have a way of charging across the fields in groups now and again, covering great distances and leaving many footprints in proportion to their gazing needs. Horses are a particular threat in areas with gregarious birds, because it almost seems as if they enjoy charging right through the bird colonies, causing a lot of damage on the way. Cows are much calmer animals with behaviour which is much more predictable, and they trample the least number of nests proportionately although young cattle can also run riot at times. Sheep also trample few nests individually and they have smaller hooves, which reduces the chance of their hitting nests, but because more (small) sheep are needed than (big) cows to achieve the same grazing density, the damage from trampling caused by sheep is greater than that caused by cows.

In principle, the grazing season in the summer polders of Noarderleech runs from 15 May to 15 October, but the animals are put out to pasture later in some places where management agreements in the context of the Nature Management Subsidy Scheme *(Subsidieregeling Natuurbeheer 2000)* are in place. These agreements protect the nests of meadow birds during the nesting season. Grazing may also be delayed by bad weather or flooding. The grazing season in the Noarderleech saltmarsh runs from 1 July to 1 October.

The grazed saltmarsh areas have never been treated with manure or fertiliser, but the summer polders created by private farmers are treated intensively with combinations of liquefied manure, fertiliser and dung. On the parcels of land leased to private farmers by It Fryske Gea, treatment is less intensive and no fertiliser is used. The summer polders managed by It Fryske Gea have not been treated since 1998; this also applies to the trial saltmarsh.

In the summer polders, thistles are combated mechanically. The polders are drained by a system of drains and ditches which connect to tide gates in the summer dike. In several places, however, outside the trial saltmarsh as well, the tide gate flaps have been lost and have not been replaced so that seawater can also enter into other summer polders in a small-scale way without the dikes needing to overflow.

8 THE INTERVENTION

The plan for Noard-Fryslân Bûtendyks involves the creation of one of the largest saltmarsh areas in Europe by de-embanking 1100 ha of summer polders. The plan is co-funded by the EU LIFE-Nature programme with additional funding from the national and provincial governments. The aim is to restore the natural character of the area as much as possible, but expressly without excluding human influence. From the preceding chapters it should be clear that to strive for a wholly natural system in this area would be a utopian dream, because the whole area would be lost through erosion if the influence of the restored saltmarshes were removed. The human influence which must be maintained is the continuation of the restored saltmarshes on a modest scale, and the grazing. Research in the Netherlands and Germany has shown that without grazing, saltmarsh vegetation develops into a dense and monotonous vegetation dominated by Sea Couch. Such vegetation is poor in biodiversity and is unattractive to many bird species including typical saltmarsh breeding birds, such as the Avocet, Common Redshank and Common Tern, and grazing flocks of geese during the winter season. It Fryske Gea envisages a semi-natural, grazable saltmarsh where managed natural processes can take place as much as possible and which is of a sustainable character.

Noard-Fryslân Bûtendyks as a whole can be described as a 'semi-natural landscape intended to hold a varied vegetation cover containing as many plant and animal species as possible that naturally belong in saltmarshes'. The qualification 'semi-natural' is essential for the making of management choices.

Three basic principles apply to the trial saltmarsh project:

- Tidal water must be able to flow into and out of the trial area freely so that typical halophytic vegetation grows up. However, the experiment may not lead to a higher water level in the adjacent areas or to their salinisation, because the owners of the adjacent summer polders must not experience any disruption.
- Sufficient vertical accretion must take place to meet the target scenario and to keep up with soil compaction, sea-level rise and land subsidence, but not too much or the vegetation will age too soon and exhibit less biodiversity. The saltmarsh fronting the trial area may not suffer any adverse effects from the changed sediment balance.
- Safety must be guaranteed. The flooding frequency and duration in the adjacent summer polders must not change, and the breaches in the outer summer dike must not erode any further.

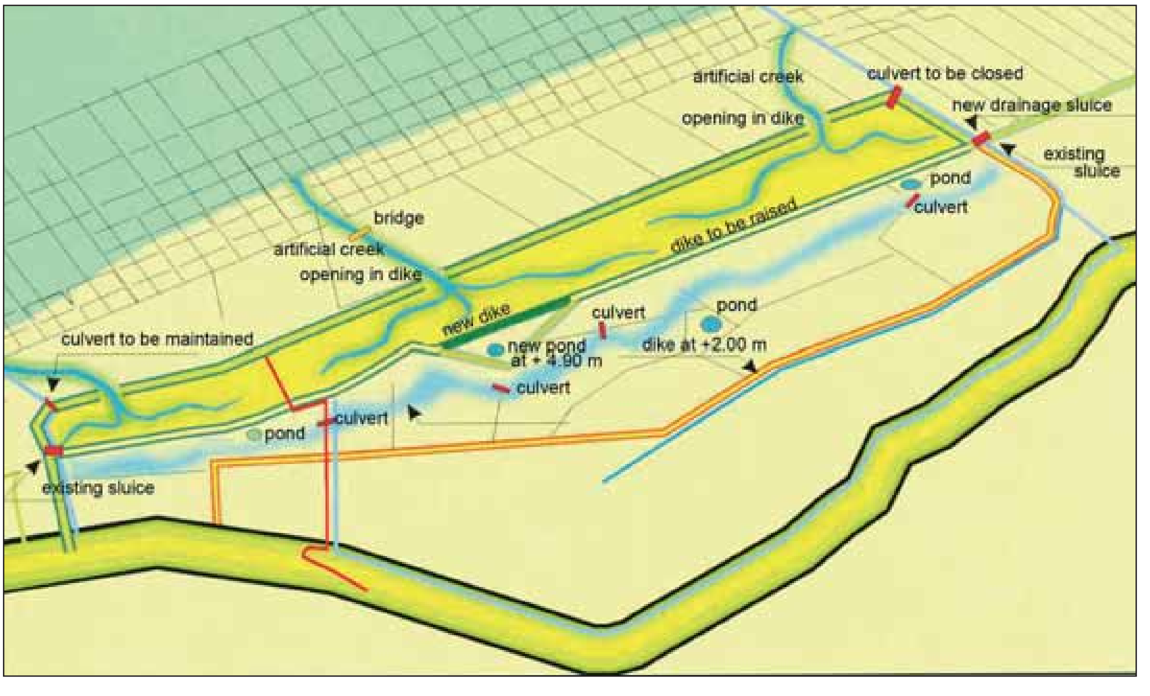

Figure 2. Plan for the experimental saltmarsh in Noard-Fryslân Bûtendyks undertaken by It Fryske Gea. After a drawing by Oranjewoud.

In preparation for the experiment, the tide gates in the summer dike have been open permanently since 1997. Since that time, therefore, the inflow of salt water has been higher and, along with it, the inflow of seeds and the vegetative parts of saltmarsh plants. Small sluices exist at both ends of the summer polder. The one on the west side is open permanently and the one on the east side has been closed.

In the course of the year 2000 the drainage channels which connected to the former tide gates were filled up and three artificial creek systems were dug which were to have a role in the supply and discharge of seawater and sediment. The creeks were designed in a winding pattern to give them a natural appearance. Their initial width was between 5 and 10 m. The soil dug up was used to raise the dike behind the saltmarsh along the adjacent summer polder in case of an increased risk of flooding.

The summer dike was finally breached on 14 September 2001. It was dug away to ground level in three places over a width of 20-40 m at the mouths of the creeks dug earlier. At the centre breach, the initial opening of the 5-10 m wide creek was later limited to 2 m by means of a culvert. A bridge has been built across the creek mouth of the western breach which, however, does not directly affect the flow opening.

9 RESEARCH

The formation of a saltmarsh is a complex process which is always attended by insecurity about (the rate of) vertical accretion and vegetation development. Many developments may seem likely but nevertheless cannot be predicted with any certainty. Similarly, it is not possible to know in advance what effect a saltmarsh conversion will have on the fronting lower saltmarsh or how the changes in the area will affect its use by geese and breeding birds. The Noarderleech trial saltmarsh was, therefore, regarded as an important experiment which was to provide insight into the process of saltmarsh conversion and its impact on the flora and fauna in the area. Because the insight gained can inform and support other saltmarsh restorations in the future, it was very important to monitor the trial project carefully, and a comprehensive monitoring research programme was set up which was continued until the end of 2005.

The research, which was commissioned by It Fryske Gea, was undertaken by a collaboration between Alterra-Texel (since 2006: Wageningen IMARES), the ecological research consultancy Koeman en Bijkerk, Altenburg & Wymenga (A&W) ecological consultants, and the Wadden Sea Birds Working Group *(Wadvogelwerkgroep)* of the Frisian Society for Field Biology *(Fryske Feriening foar Fjildbiology, FFF)*. Alterra coordinated the research, the results of which have been published in the report by Van Duin *et al*. (2007) referred to above. The influx of plant seeds by floodwater was studied by the University of Groningen.

The principal objective of the saltmarsh trial was: "To gain insight into the abiotic and biotic changes that occur when a summer polder is converted into a saltmarsh." This led to the following research question being formulated for the monitoring programme: "Do the proposed design and management measures, i.e., de-embankment, cessation of manuring, abandonment of ditch maintenance and extensification of grazing, allow a varied saltmarsh vegetation to develop in the trial saltmarsh?"

In addition to the principal objective, the following ancillary objectives were formulated:

- The project must provide insight into the development of the elevation and the vegetation in the trial saltmarsh;
- The project must provide insight into the possible effects of the conversion on the adjacent natural and man-made saltmarshes;
- Any effects of the saltmarsh conversion on adjacent (agricultural) areas/summer polders must be recorded;
- The project must provide insight into the effects on the fauna, focusing in particular on staging geese and breeding birds;
- Experience with this kind of nature development must be gained to enable advice to be given on the design and management of future saltmarsh restoration projects and to enable making predictions about them.

Seven hypotheses were formulated which were to be verified on the basis of the results of the monitoring research:

- De-embankment will cause a 'salt shock' in the trial saltmarsh, which will lead to the die-off of the halophobic vegetation and create opportunities for saltmarsh plants to establish themselves. During the transition phase the lower-lying eastern part of the saltmarsh will temporarily be poorly vegetated and wet.
- After the de-embankment, rapid vertical accretion will take place on the low eastern part of the trial saltmarsh because of the high inundation frequency in this area. The inundation frequency in the higher-lying western part of the polder will be lower so a lower rate of vertical accretion is expected there.
- Vertical accretion in the trial saltmarsh will not affect the development of the surface elevation of the adjacent natural and man-made saltmarshes.
- Surface elevation and the degree of drainage will be adequate for the formation of grassy saltmarsh vegetation.
- Vertical accretion will also be influenced by the vegetation structure and, thus, indirectly, by the kind and intensity of grazing too.
- The establishment of saltmarsh vegetation is conditional upon the influx of seeds with floodwater (research by the University of Groningen).
- Use of the converted summer polder by geese and breeding birds will not diminish.

10 MONITORING

Biological fieldwork consists, to a large extent, of making accurate counts and measurements which must be repeated *ad infinitum*. A brief outline of what was counted and measured in the trial saltmarsh follows below.

A vegetation survey involves marking out plots and then meticulously recording the composition and number of plant species occurring in them. A plot which is monitored annually is called a Permanent Quadrat (abbreviated as PQ). In the Noarderleech trial saltmarsh 72 PQs, each measuring 4x4 m, were marked out. Vegetation surveys were carried out in these PQs for five years in combination with vertical accretion measurements so that changes in surface elevation could be monitored. In addition, three transects were set up to obtain a better picture of the development of the vegetation in the whole area. In these transects a total of forty individual plant species were mapped. Twenty of them were designated as 'target species' for the new saltmarsh.

To measure the effects of grazing, exclosures were made. An exclosure is a small piece of land within a grazed area which is fenced to keep the livestock out.

To monitor groundwater salinisation, salinity wells (pipes) were placed in the trial saltmarsh and the adjacent summer polder to measure groundwater levels and water salinity. Changes in salinity were also measured in the top 5 cm of the soil and in the soil moisture contained in this top layer.

Changes in surface elevation were measured using a so-called Sedimentation/Erosion Bar in the following way. Two stakes were driven firmly into the soil and the sandy subsoil, 2 m apart and with their tops exactly level at *ca.* 35 cm above the soil surface. To take the readings an aluminium bar was placed across the tops of the stake heads, a rod was placed through holes in the bar and the height was measured from the top of the bar to the soil surface. Vertical accretion was also measured using so-called sedimentation plates: steel 30 x 30 cm plates which were placed in the soil horizontally at a depth of 10 cm. Using a thin iron ruler, the depth of the plates to the surface could then be read.

Goose counts of Brent and Barnacle Geese which were taken every two weeks in the 1996/97, 1997/98 and 1998/99 seasons, form the basis for the baseline situation. After the breach creating the saltmarsh had been made in 2001, counts were carried out in 2001/02, 2002/03, 2003/04 and 2004/05.

To determine the effects of the saltmarsh conversion on the geese more accurately, pellet counts were carried out. Because geese defecate at very short and regular intervals, the density of the droppings within a fixed circle (a pellet plot) is the measure of the geese's grazing pressure. In total, 105 pellet plots were used. Because the species composition of the grass sward is important for the geese's choice of food, additional vegetation surveys were carried out in the pellet plots.

Nests and habitats of breeding birds in and around the saltmarsh conversion were mapped from 1999 up to and including 2005.

11 TIDAL FLOODING AND SALINISATION

Inundation frequency in the trial saltmarsh was not measured directly but can be deduced from the information we have about the height of the summer dike before and after the intervention, in combination with the automated water level measurements performed every ten minutes by *Rijkswaterstaat* at the Nes station on the island of Ameland. From these measurements the high water levels have been selected for the period from 1997-2005, that is, starting more than four and a half years before the intervention on 14 September 2001 and continuing until almost four and a half years after it, a total of nine years.

Before the intervention, the lowest point of the outer summer dike stood *ca.* 2.72 m above Amsterdam Ordnance Datum. At all tides above 2.7 m, salt water could therefore flow into the polder, which would have happened only three times during the four and a half years before the intervention started. During the four and a half years after the intervention not a single tide was high enough to wash over the dike. Since the intervention, the polder is flooded completely at water levels exceeding *ca.* 1.9 m above Amsterdam Ordnance Datum. In the period preceding the intervention, 62 tides would have been high enough.

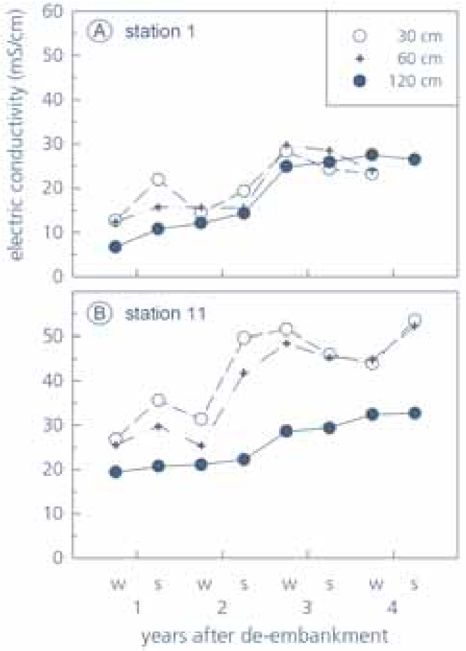

Figure 3. Increase of the EC value of the groundwater in the trial saltmarsh near the dike breaches in the western (Location 1) and eastern parts (Location 11), during the first four years after the de-embankment.

From the date of the intervention until 31 December 2005, in theory 64 inundations took place so that, on average, the polder was, and will be, inundated about fourteen times a year.

Against all expectations, the inundations which in fact took place after 14 September 2001 did not cause a salt shock; salinisation proved to proceed very gradually. In the low-lying eastern part of the saltmarsh, the shallow groundwater became more saline at a faster rate than the groundwater in the higher western part, and no levelling off could be observed after four years. In the drier western part, levelling off was observed from the third year onwards. In the deeper groundwater (120 cm) the increase in salinity levels, measured in terms of electrical conductivity (EC values), was very gradual (Figure 3).

In the top 5 cm of the soil and in the soil moisture contained in it, salinity content also increased only very gradually. After four years, chloride concentrations were about 60% of the values for natural saltmarshes (Figure 4). Changes in soil moisture, in particular, are relevant with regard to the vegetation.

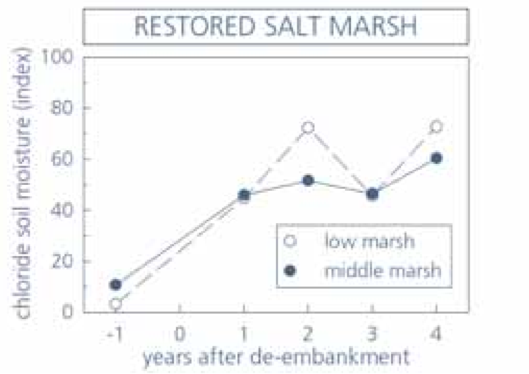

Figure 4. Changes in the chloride concentrations in the soil moisture, indexed by the value for natural saltmarshes.

No indications were found that any salinisation occurred in the adjacent summer polder as a result of the saltmarsh conversion. In a number of places, a decrease in salinity was even observed, in particular, in the deeper groundwater.

12 VERTICAL ACCRETION

The measurements using the Sedimentation/Erosion Bar show that vertical accretion in the lower eastern part of the trial saltmarsh occurred more rapidly than in the higher western part. Vertical accretion was more pronounced close to the artificial creeks than it was farther away from them. Grazing had great effect. Vertical accretion clearly took place more rapidly in ungrazed conditions than in grazed conditions (because of sediment trapping by taller vegetation). In grazed areas the rate of vertical accretion varied from 0.3 mm/year to 31.5 mm/year, while the rate in ungrazed areas was 10.7 mm/year to 36.7 mm/year.

As a result of new sediment being deposited, the buried sedimentation plates gradually came to lie at a deeper level. In the summer period (April – August), when normally no inundations occur, surface elevation decreases as a result of soil compaction. During the storm season (September – March) an increase occurs as a result of sedimentation and, perhaps, the swelling of the wet soil. Figure 5 describes the progression of the depths of the sedimentation plates at one of the locations. Conditions at the various locations differed but, on the whole, observations throughout the whole area showed a similar trend.

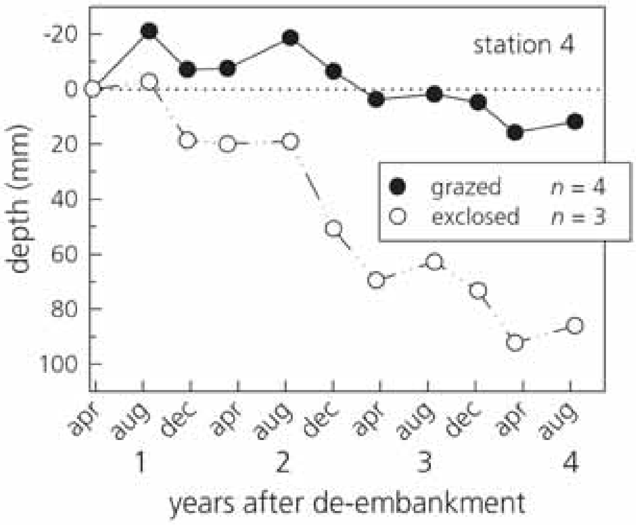

Figure 5. Progression of the depth of the sedimentation plates. For clarity's sake, the depth in the baseline situation has been set at 0.

On the basis of the specific volume and the vertical accretion figures, a rough estimate can be made of the annual sediment supply in the trial saltmarsh. In the higher part of the area, vertical accretion amounted to 6.0 mm/year at a sediment supply of 4.8 kg per square metre per year. In the lower part of the saltmarsh it was 14.8 mm/year at 10.4 kg. In both cases, the rate of vertical accretion was more than adequate to keep pace with phenomena such as land subsidence and sea-level rise. The level of the mean high tide shows an upward trend of approximately 2.6 mm per year, allowing for changes in weather systems.

13 VEGETATION

Rapid changes occurred in a number of individual plant species after the de-embankment, but the vegetation as a whole changed only very gradually. It was expected that the salt shock resulting from exposure to seawater would lead to the die-off of vegetation and would cause bare patches, but this did not happen. Even after four years, changes are gradual and in keeping with general trends.

running off through the creek. Creeping Thistle declined strongly and, in the course of only a few years, has virtually disappeared from two of the three transects. Interestingly, Red Bartsia and Strawberry Clover established themselves in some parts of the old, higher 'farmer's method' salt-marsh.

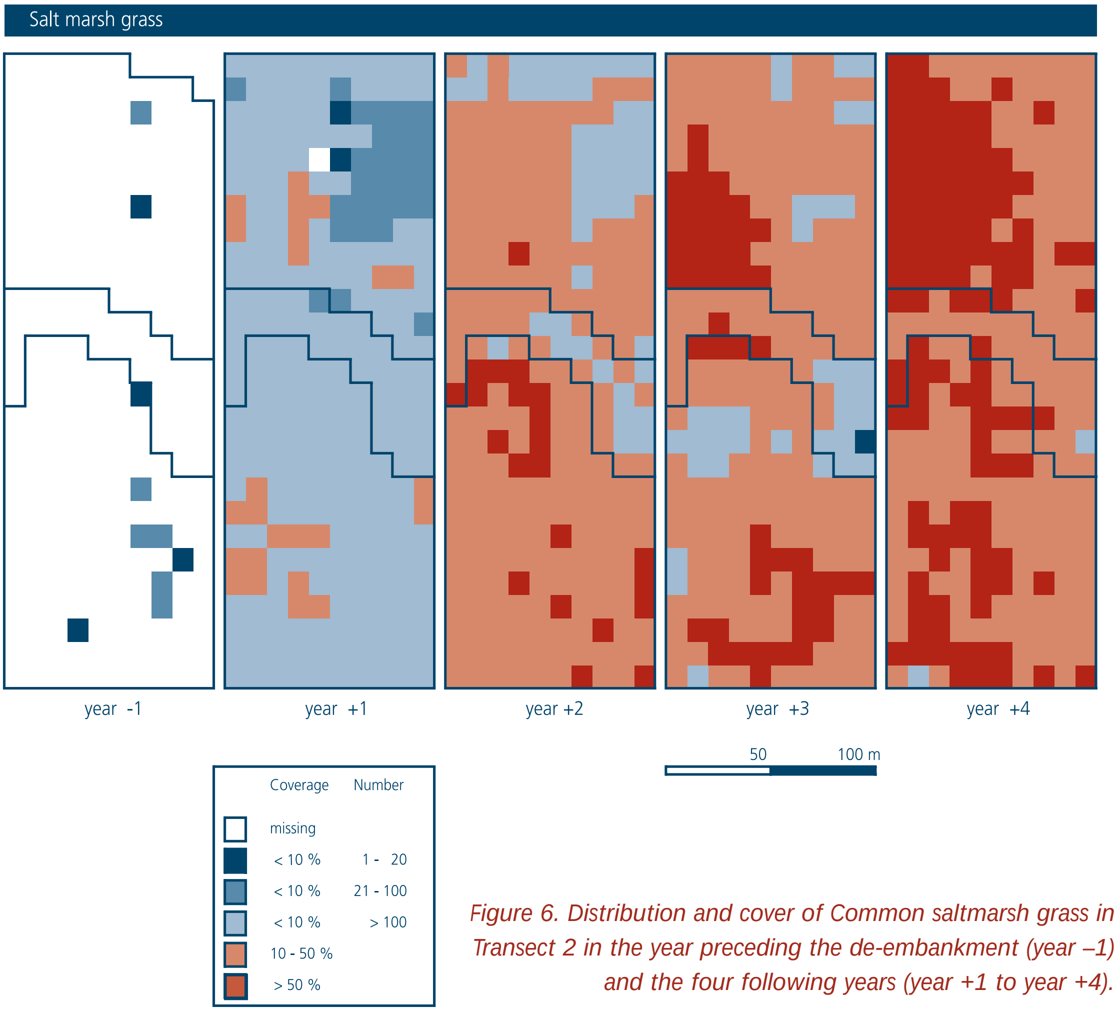

Figure 6. Distribution and cover of Common saltmarsh grass in Transect 2 in the year preceding the de-embankment (year –1) and the four following years (year +1 to year +4).

The salt-intolerant species (glycophytes) and the more salt-tolerant species (brackish) species showed a large, gradual decline compared to the baseline situation. A remarkable appearance in the first and second years after the de-embankment was Sea Clubrush, which was seen in the creek dug in the highest transect, but in the third and fourth years it was not found here anymore, probably because of the continuing salinisation of the groundwater

Salt-tolerant species (halophytes) established themselves soon after the de-embankment and spread. The majority of these species, in the baseline situation, were already present on a modest scale in or along ditches and, in particular, near tide gates that had already been removed in 1997. After the dike had been breached they spread rapidly in the fields, where they had not occurred before.

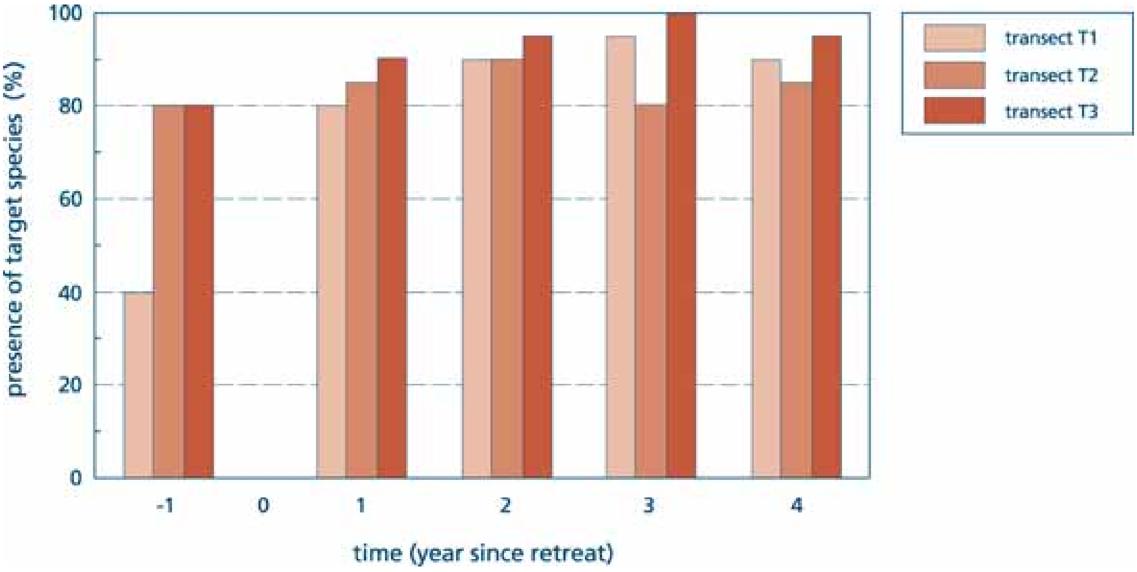

Figure 7. The percentage of target species found per transect from one year before de-embankment until four years after.

Only Common Cord-grass and Sea Purslane were absent in the baseline situation, but established themselves after the de-embankment. The most surprising and remarkable new arrival was Common saltmarsh grass, which appeared 'out of the blue' immediately, and *en masse*, during the first year after the new saltmarsh was created. Figure 6 shows the change in cover density in Transect 2.

With the exception of Grass-leaved Orache, all the mapped halophytes can be classed as target species for the saltmarsh restoration programme. Figure 7 shows how the percentage of target species increased in the three mapped transects.

In grazed sites in the higher parts of the trial area, the types of vegetation characteristic of a saltmarsh edge (the natural transition zone from the middle marsh to the hinterland) continued to dominate for some time after the de-embankment. The Perennial Ryegrass type was replaced by the Silverweed type and a relatively species-rich type of Couch grass. In the lower sections the vegetation types of the saltmarsh edge were replaced by typical saltmarsh vegetation much more quickly.

In ungrazed situations the variety of vegetation types was less. In the third year after the de-embankment, Perennial Ryegrass vegetation had largely been replaced by a species-poor type of Couch grass from the middle marsh. It is expected that Couch grass will eventually give way to Sea Couch. The natural final stage of an ungrazed saltmarsh is a monotonous, species-poor vegetation dominated by Sea Couch. Sea Couch was first observed in the trial saltmarsh in the second year of the experiment, but by the fourth year it already covered almost 20% of the ungrazed permanent quadrats. This is evidence that grazing is an important management tool for the management of a varied, species-rich saltmarsh.

14 BIRDLIFE

Wintering geese (Brent and Barnacle Geese) use the salt-marshes, the summer polders and the adjacent land within the dikes. To get an overview of the availability of a feeding habitat for geese, cropping plan maps from 1996 and 2004 were compared which proved that the saltmarsh conversion was not the only change in the geese's habitat. A marked shift towards agriculture took place in the area within the dikes at the expense of cultivated grassland. In the summer polders, a spectacular shift from 'cultivated grassland with low vegetation' to 'cultivated grassland with tussocky vegetation' occurred when large parts of the area came into the ownership or management of It Fryske Gea, after which extensification took place and fertilisation was stopped. Cultivated grassland was replaced by saltmarsh vegetation in the trial saltmarsh, as described above.

Brent and Barnacle Geese are both abundant in Noard-Fryslân Bûtendyks with average seasonal maximums of 18,000 and 93,000, respectively, in the period 2000-2005. Converted into goose days, the number of Barnacle Goose days was 4 to 5 times higher than the number of Brent Goose days. Brent Goose numbers peaked in April and May, accounting for 70% of the total number of goose days. Barnacle Goose numbers peaked twice, in October-November and in March-April, the latter peak being the highest.

In the period from 1996-2005 the number of Brent Goose days in Noard-Fryslân Bûtendyks gradually decreased every winter season from over one million to fewer than 200,000. This development followed the national trend. The number of Barnacle Goose days in the same period was lowest in 1996/97, at fewer than 6 million. In the following years the number fluctuated between 9 and 7.5 million. Brent Geese favoured the saltmarshes, while Barnacle Geese visited both the saltmarshes and the summer polders, reaching their highest densities in the summer polders.

To date, the food supplies available for geese have declined because of the saltmarsh experiment. The cover of plant species which are important for geese lay between 65 and 80% in the summer polders and between 45 and 85% in the saltmarshes. In the trial saltmarsh, however, the cover did not exceed 37% during the first years after the intervention. This may change as the saltmarsh vegetation continues to develop.

Despite the temporary deterioration of available food, the changes in the summer polder have not led to large numbers of geese moving to areas within the dikes.

The differences in food availability between the saltmarsh, cultivated grassland and the trial saltmarsh are reflected in the grazing pressure, which was measured by means of pellet counts (expressed as the number of droppings per square metre per day). The pellet counts do not allow any differentiation between Brent and Barnacle Geese. Figure 8 shows the grazing pressure for the various habitats, which is higher in spring than in autumn.

Birds breeding in the summer polders were chiefly the Avocet, Lapwing and Oystercatcher and, in some years, a lot of Black-Headed Gulls. The numbers of breeding birds remained fairly stable

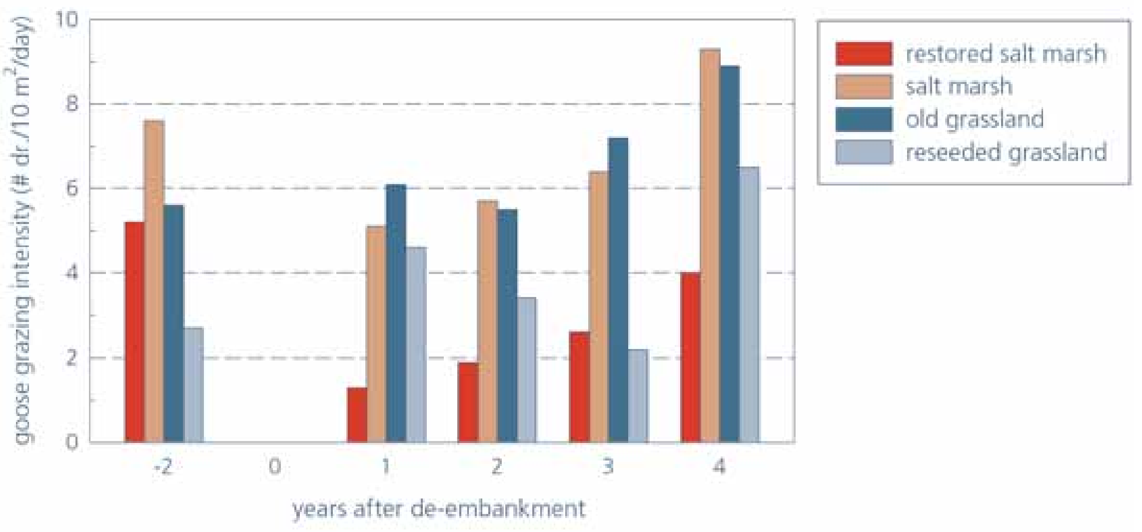

Figure 8. Grazing pressure in spring in various habitats, measured by droppings density.

over the years. In the saltmarsh, Avocets and Oystercatchers were the most numerous, with large numbers of Black-Headed Gulls and Common Terns breeding there in some years. The Godwit was rare, and Meadow Pippits and Lapwings occurred only in low numbers. Remarkably, Larks increased, going against the national trend.

Avocets and Oystercatchers were the most abundant birds in the trial saltmarsh. Oystercatcher numbers remained constant, as did the numbers of Godwits, Larks and Meadow Pippits. The number of Avocets fluctuated strongly without any clear trend. The Common Redshank appeared to be recovering after an initial decline following the saltmarsh conversion. The Common Tern declined in numbers, but they were not numerous in the first place and the decline was slight.

In general, the numbers of breeding birds in the trial saltmarsh remained more or less stable. It was expected that Lapwings, Godwits and Larks would decline in number and that Avocets, Common Redshanks, Black-headed gulls, Common Terns, Arctic Terns and Meadow Pippits would increase, but this was not borne out by reality as the number of breeding species decreased slightly in the trial saltmarsh.

15 EVALUATIONS AND PERSPECTIVES

To what extent have the predictions that were formulated at the start of the research come true? The main outcomes are, in brief summary:

- In the first year after de-embankment, the vegetation changed considerably but, because no salt shock occurred no massive die-off took place. In many species the change was so gradual that the changes still followed trends in the fourth year.

- Vertical accretion in the western part of the area was lower than in the eastern part. In ungrazed situations the difference was 11 mm annually. Differences in sediment supply caused by the creek forms may have played a role.

- Vertical accretion was less in grazed areas. In the higher part of the trial saltmarsh, sediment trapping in ungrazed conditions exceeded that in grazed conditions. In the low-lying part no greater sediment trapping was measured in the exclosures.

- There are no indications that vertical accretion in the trial saltmarsh had an effect on the surface elevation development in the adjacent natural and man-made saltmarshes.

- Compared to the existing grazed saltmarshes, the use of the trial saltmarsh by geese in autumn was considerably less. Use by geese in spring has increased substantially since 2001/02. No trend can be observed as regards the number of breeding birds.

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