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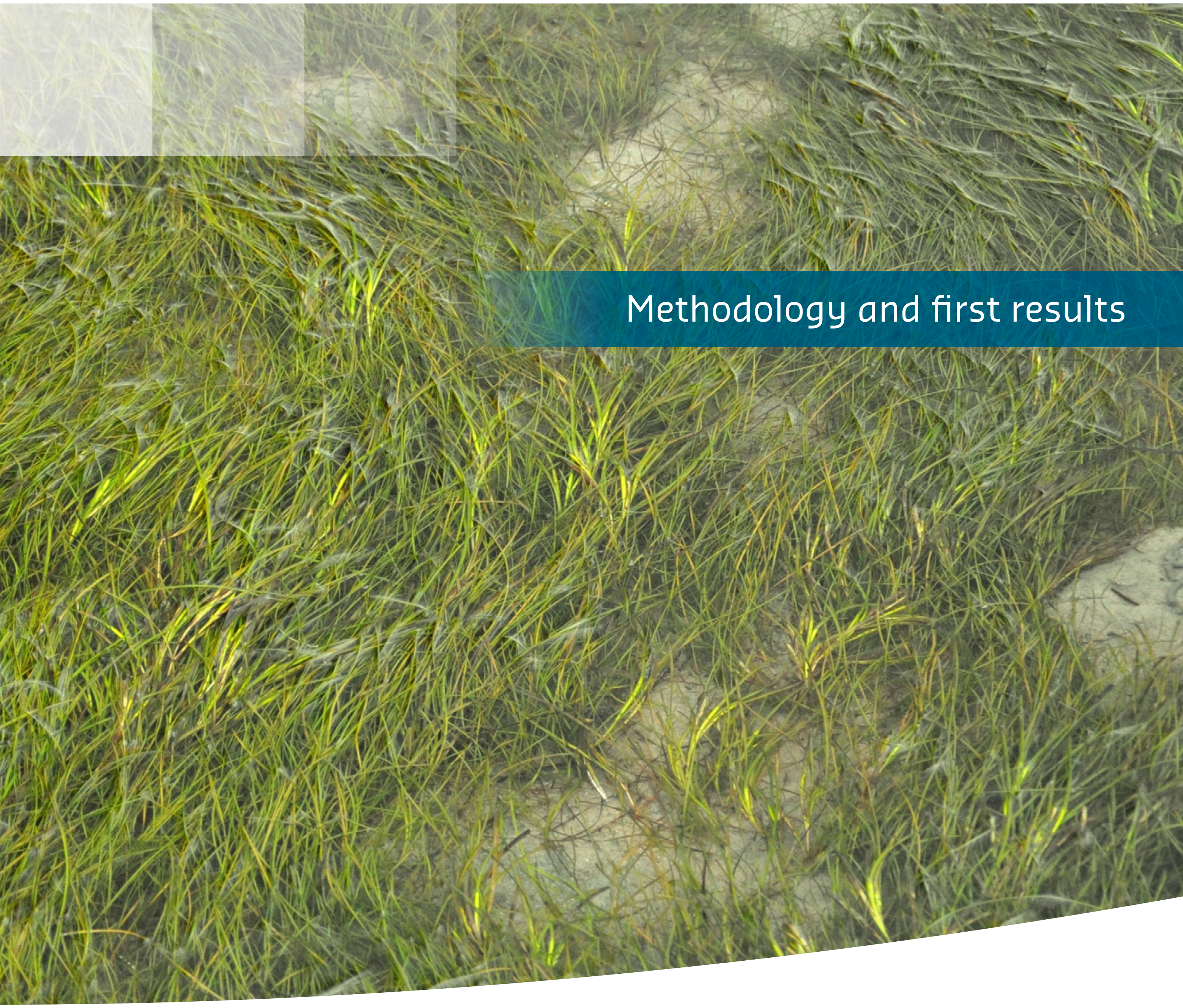
# Eelgrass restoration in the Dutch Wadden Sea



## Methodology and first results

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# Eelgrass restoration in the Dutch Wadden Sea

**Methodology and first results**

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Deltares

**Title**
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**Trefwoorden**
Eelgrass, seagrass, restoration, Wadden Sea, Water Framework Directive

**Samenvatting**
Before ca. 1930, Eelgrass (*Zostera marina*) was widespread throughout the whole of the Wadden Sea. Infrastructural works, disease, eutrophication and other factors have contributed to its demise. In the Dutch Wadden Sea Eelgrass has virtually disappeared. Within the European Water Framework Directive targets are set to increase its occurrence. With the reduction of nutrient runoff from land, the area of suitable habitat has increased. In Germany, Eelgrass has shown a remarkable recovery in the intertidal. In the Netherlands this has not been the case, even though models indicate that there is suitable habitat available. A hypothesis, that the lack of recovery is due to a lack of sufficient seed availability, is currently tested in a large-scale recovery project. The methodology is based on a technique developed in the U.S.A., where it has been successfully used, particularly on subtidal populations. The method was adapted to be used in the intertidal in the Wadden Sea. First results are encouraging, but there is no guarantee that the meadows are able to persist and increase. The various natural and anthropogenic changes in the system preclude the return to any historical reference situation. However, increasing the occurrence of a key species, characteristic for the Wadden Sea, may be possible.

| Versie | Datum | Auteur | Paraaf | Review | Paraaf | Goedkeuring | Paraaf |
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## Contents

# 1 Introduction, rationale

## 1.1 Eelgrass in the Wadden Sea

In the Dutch Wadden Sea, Eelgrass (*Zostera marina*) used to be very common, but has nearly disappeared since the nineteen thirties (Den Hartog 1994). The causes of the disappearance are not known exactly, but it is likely to be a combination of concurrent factors such as disease (*Labyrinthula*), effects of eutrophication, changes in flow velocities and wave exposition due to the closure of the Zuiderzee and changes in turbidity due to the changes in hydrodynamic regime (van Katwijk et al. 1999, Orth et al. 2006a, van der Heide et al. 2009, Dolch and Reise 2010).

In the species *Z. marina,* generally two types are recognised: a more robust, broader leafed type that occurs predominantly in permanently submerged habitats and reproduces predominantly clonally and a more flexible intertidal type. The intertidal ecotype of *Z. marina* is annual or semi-annual and has to re-grow every year from seed. The former type has completely disappeared from the Dutch Wadden Sea. The introduction of *Labyrinthula* and the closing off of the Zuiderzee by the Afsluitdijk have changed the habitat in the Western Wadden Sea to such an extent that return of the former large submerged populations is very unlikely in the near future. Analysis has shown that, according to the current state of knowledge, there ought to be several places in the Wadden Sea where the habitat is theoretically suitable for the annual intertidal ecotype of *Z. marina* (De Jong et al. 2005). However, in the Netherlands the species has failed to return also to these potentially suitable habitats.

Also in the German part of the Wadden Sea Eelgrass distribution was greatly reduced (Reise et al. 2008). However, in this part of the Wadden Sea the intertidal population has shown a remarkable recovery. Changes in nutrient dynamics and sediment dynamics are assumed to be more favourable now than in the period 1970-1990. (Dolch et al. 2012).

## 1.2 Earlier restoration attempts

In the past decade there have been various attempts to re-introduce *Z. marina* to the Wadden Sea by manually transferring plants from certain donor locations to various locations deemed suitable in the Wadden Sea (van Katwijk et al. 2000, van Katwijk et al. 2009). Some of these transplants managed to survive several years. However, although these transplants have yielded very valuable information regarding habitat suitability, none of these labour-intensive exercises have resulted in long-term return of intertidal populations. Very similar experiences can be found in the literature from other places in the world (Marion and Orth 2010).

## 1.3 Seed supply limitation

Due to its annual nature, the establishment of intertidal eelgrass meadows is strongly dependent on a sufficiently large supply of seed. In many places in the world where Eelgrass has disappeared, lack of seed supply has been identified as a severe bottleneck for the successful restoration of the species after habitat restoration has taken place. Seed production, even in a healthy population, varies substantially from year to year (Silberhorn et al. 1983, Orth et al. 2006b). A currently widely supported hypothesis regarding seagrass restoration is that for a stable population to develop, the population needs to have a certain critical size, to ensure that even in ‘bad’ years sufficient seed is produced to sustain the local population. This is probably a major factor in the failure of long-term seagrass recovery for the manual transplant experiments of plants. Even if many students and / or volunteers participate in the conservation effort, it is very difficult and costly to re-plant a sufficiently large area with seagrass plants. This is why in other locations in the world techniques have been developed to re-establish Eelgrass meadows by seeding, rather than by replanting (Harwell and Orth 2002, Erftemeijer et al. 2008, Marion and Orth 2010).

## 1.4 Project background

Under the water framework directive, the Netherlands is obliged to improve the habitat quality in the Wadden Sea and implement measures that increase the population of Eelgrass (*Z. marina*) (Rijkswaterstaat 2009). In 2010 a study was commissioned into the possibility to apply seeding techniques that have been successfully applied in the U.S. in the Wadden Sea (Erftemeijer and Van Katwijk 2010). This study established that for such a restoration effort it would be desirable to use Eelgrass seeds from stocks from other parts of the Wadden Sea, where populations have improved significantly over the past decade. The study also combined the habitat suitability maps (De Jong et al. 2005) with hydrodynamic models. The latter were used to assess which areas with suitable habitat would have the right conditions to ensure that seed-bearing shoots from an Eelgrass meadow would be retained in the area to promote next year’s crop. In spring 2011 Rijkswaterstaat, together with the environmental society, the “Waddenvereniging”, assigned a project to Deltares to carry out a two-year restoration project, followed by a 4-year monitoring effort in an attempt to restore *Z. marina* to the Wadden Sea.

## 1.5 Project outline

The basic idea behind the project is to import a large amount of seed bearing eelgrass shoots from healthy populations in Germany, where intertidal eelgrass populations have recovered nearly to their former extent. The seed-bearing shoots are deployed in mesh bags with a mesh size large enough to let the seeds fall through, but small enough to retain the grass shoots. The bags contain floats and the floats are anchored with rope to the seabed, allowing the seeds to ripen and distribute themselves in the immediate vicinity of the deployment location.

The aim is to populate a large enough area with seagrass that the meadow becomes self-sustaining with respect to seed production. Using donor material from other tidal basin in the Wadden Sea should reduce the risk of introducing alien, invasive species. The collection of inflorescences and the subsequent deployment should take place in the period that the seed is ripening and the shoots are beginning to be released. This occurs in the German Wadden Sea in the period of late August to late September. As the exact peak of seed production depends on weather conditions and is not predictable a long time in advance, per year two collection periods are scheduled – to diminish the risk of missing this peak of seed production. As there is in the field a large year-to-year variability in recruitment success, the collection and deployment of seed bags will be carried out in two consecutive years.

Although calculations in Erftemeijer and Van Katwijk (2010) indicate that the amount of harvested eelgrass material should not pose any risk to the donor population, the state of the donor populations will be monitored by a local research institute (the Alfred Wegener Institut on Sylt). This group will also carry out effect monitoring.

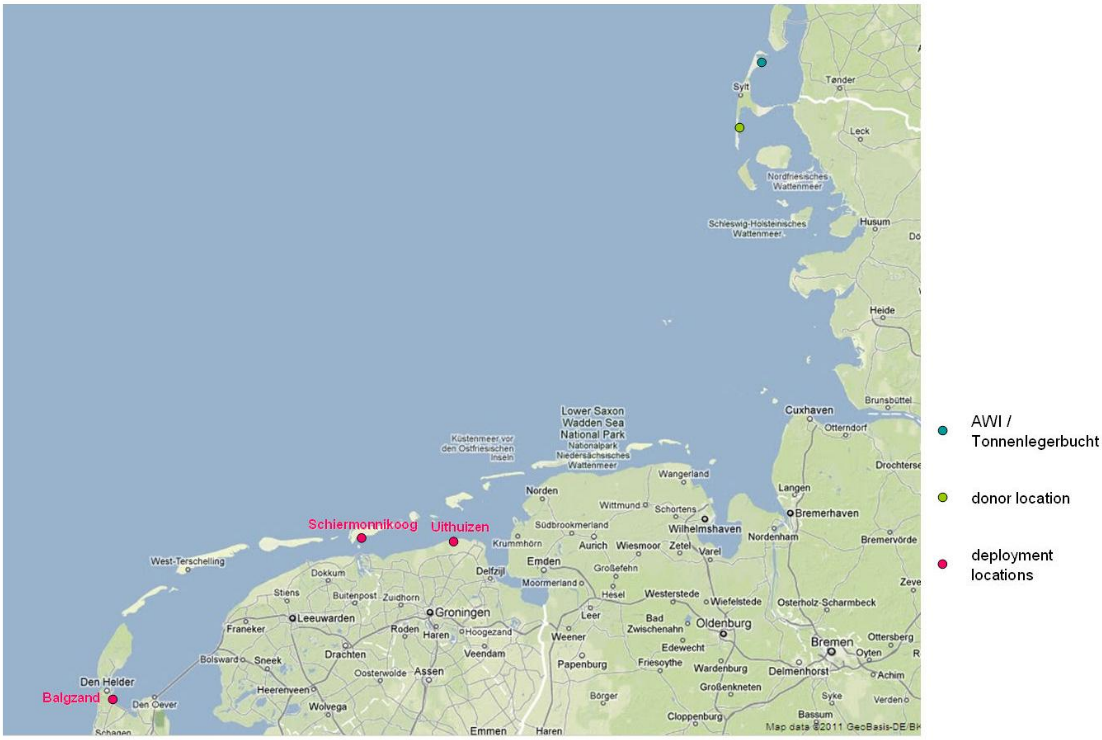


*Figure 1.1: Overview of the Wadden Sea area with indications of the donor location and the three deployment locations. See also detailed maps with the descriptions of the different sites.*

### 1.6 Acknowledgements

This project would not have been possible without the contribution of a great many groups and individuals. First and foremost we wish to thank Josje Fens and the volunteers of the "Waddenvereniging" who have braved the weather and worked very hard to produce the BUDs, collect material, help with the deployment and helped remove all materials from the field. Josje has also been excellent in raising the profile of this project through the press.
We are very grateful to all departments from the Dutch government, from the local area management in the Netherlands and from the German Nationalpark Wattenmeer, for being helpful in getting the necessary permits to carry out this project.
Several people have given helpful advice on the set-up of this project, as well as in the location choice. We particularly like to mention: Prof. Robert Orth, Dr. Paul Erftemeijer, and Dick de Jong have given very useful tips and advice. Finally we would like to thank Floris van Bentum for his efforts surrounding the management at the RWS-side.

# 2 Donor material and location

### 2.1 Location choice

The desk study preceding this project (Erftemeijer and Van Katwijk 2010) recommended using the healthy Eelgrass populations around Sylt (German Wadden Sea) as a suitable donor population. This recommendation was based on the following scientific and practical arguments:

1. Ecologically, the Wadden Sea can be considered to be one single system. Transport within the system is broadly speaking from west to east, preventing a sufficiently large transport rate of seed-bearing shoots to re-colonise the Dutch part of the Wadden Sea naturally, as the Dutch part is situated in the west of the system. However, there

is sufficient connectivity between the various tidal basins to ensure that introduction of unwanted exotic species of from the donor location is minimal.

2. The seagrass meadows around Sylt are well described and their recent developments are well documented by scientists from the Alfred Wegener Institute. The meadows are extensive and have been expanding over the past decade
3. There are logistical advantages exploiting these meadows as most of them are easily accessible, and the proximity of the AWI on the island ensures that there is also easy access to areas where seagrass can be temporarily stored, sorted and put in the mesh bags.

Initially a site very close to AWI was chosen: Tonnenlegerbucht. This is a relatively small area (around 2 ha) with a very dense 100% cover of *Z. marina*. Due to its peculiar semi-enclosed location, this area is not part of the Wadden Sea National park. The jurisdiction for Tonnenlegerbucht, i.e. the authority responsible for issuing permits, is the Schleswig Holstein Ministerium für Landwirtschaft, Umwelt und ländliche Räume (the ministry for agriculture, environment and rural areas). Obtaining the necessary permits to collect eelgrass at this site in time proved to be impossible.

A second, large seagrass meadow that falls under the jurisdiction of the Wadden Sea National park was therefore selected just south of Rantum. This site was further away from the institute and had a mixed population of predominantly *Z. noltii* with lower densities of *Z. marina*. This therefore required more care in selecting suitable plants and covering a much larger area to obtain the same amount of seed. However, the site had a major advantage over Tonnenlegerbucht of being very sandy. Tonnenlegerbucht consists of very soft sediment that would incur additional damage to the seagrass due to trampling. Trampling was no issue at all at the Rantum site. Eventually this site was chosen as a donor site in 2011. As this site contained a large enough supply of seed and was logistically favourable, the same site was selected in 2012.


*Figure 2.1: Southern part of Sylt with the Puan Klent meadow (south of Rantum) indicated in green.*

## 2.2 Inventory of the donor location

In summer 2011 and 2012 the donor sites were sampled for *Zostera marina* cover, number of seed bearing shoots per plant and number of seeds per shoot. Erftemeijer and Van Katwijk (2010) had estimated that for 3 deployment locations of 1 Ha each a total of 3.750.000 seeds would be required.

### 2.2.1 2011

The 2011 surveys at Rantum had indicated that over the whole area the cover averaged 93.75 plants $m^{-2}$. Each plant carried on average 3 inflorescences, each inflorescence carried on average 5 seeds. Based on the available area it was clear that less than 0.5% of the available inflorescences of this meadow was required per annum to provide the material for this project.

### 2.2.2 2012

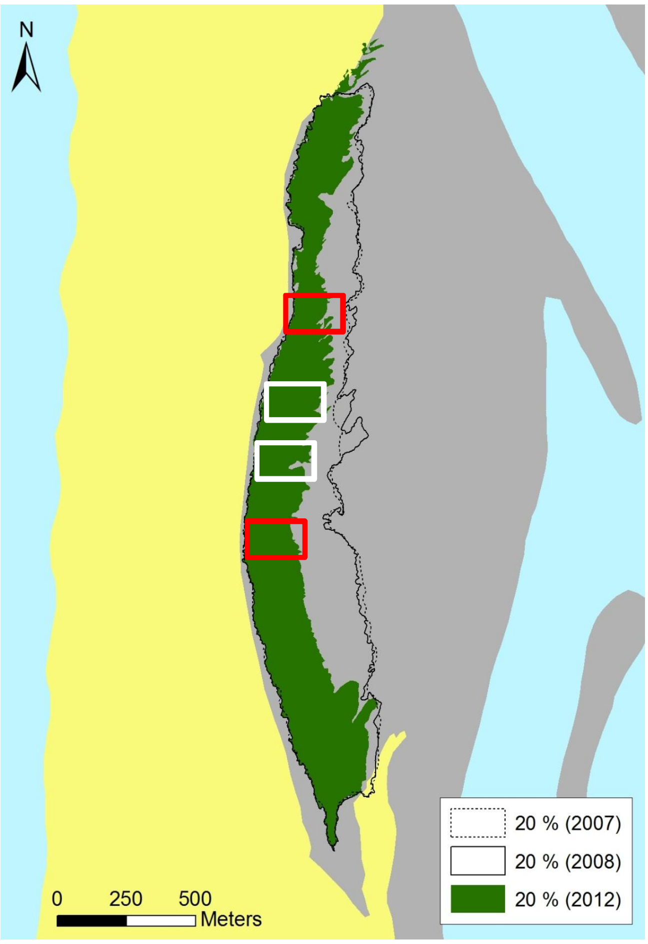


*Figure 2.2 Seagrass bed (green) composed of mixed Zostera noltii and Z. marina in the intertidal zone (grey) between Puan Klent and Hörnum at the eastern shore of the island of the island of Sylt (yellow). The area of the bed (>20% coverage) at July 21, 2012 is given in green. For comparison, 20%-contour lines of the bed in 2007 and 2008 are given when the bed extended further seaward. Shoot density of Z. marina has been estimated at plots harvested in 2011 (red rectangles) and control areas (white).*

Before harvesting there a second time in September 2012, the bed was mapped and density of Z. marina shoots was estimated at 4 plots in July 21, 2012.
Compared to 2007 and 2008, the seagrass bed has retreated at its seaward side (Figure 2.2). This phenomenon is similar to other seagrass beds at Sylt studied previously (Dolch and Reise 2010): and is interpreted as a response to decreasing sediment stability. In July 2012, coverage by seagrass was generally close to 100%. *Z. noltii* dominates and *Z. marina* takes a share of 30-40%.
*Z. marina* shoots with inflorescences tend to be of a lighter green and blades are twice as wide as those of *Z. noltii*. This allows counting these shoots per unit area (0.25 m², n = 80). Their density is patchy and varies with water coverage during the phase of low tide exposure. Residual water is maintained during low tide by the dense cover of the seagrass itself. Average density of *Z. marina* shoots was 53.4 $m^{-2}$.
Counting was performed at each of 4 plots, two of which were used for harvesting in 2011 (Figure 2.2). At the northern plot, conspicuous sand waves penetrate the seagrass bed from the seaward side and disturb the coherent seagrass cover in 2012 (see northern end of seagrass beds in Figure 2.2).

This entails a low seagrass coverage and low *Z. marina* shoot density (7.2 ± 4.0 per 0.25 m², range 0-15; n = 20). At the other three plots density was more than twice as high and similar between plots (from north to south: 16.9 ± 5.4, 14.5 ± 3.1 and 14.9 ± 3.4).
Conclusions:

1. There is sufficient *Zostera marina* to sustain harvesting shoots at the chosen site.
2. There is no indication that *Zostera marina* seed-bearing shoots are less abundant at plots where shoots were harvested in the previous year.
3. Due to low density of seagrass at the northern one of the four investigated plots, it was recommended to shift next harvesting to the two former control plots in the middle of the range.

*Figure 2.3: areal photograph of the southern part of the seagrass meadow at Puan Klent (South of Rantum)*

# 3 Deployment sites, locations and dimensions

In 2011, the deployments sites were selected on the basis of 3 criteria:

- The habitat suitability map (De Jong et al. 2005)
- Dispersal modelling of eelgrass shoots, selecting for areas with a relatively high retention of water (Erftemeijer and Van Katwijk 2010)
- Visits to the areas with experts.

In 2012 the deployment sites were selected on the basis of where eelgrass occurred with respect to the deployment sites in 2011. The rationale being that both deployments should be in the same area, but the second deployment should not damage the plants resulting from the first one.

### 3.1 Uithuizen (Groningen)

#### 3.1.1 Eelgrass occurrence in previous years and probability of occurrence.

The seagrass monitoring carried out under the national monitoring program (MWTL) has indicated that on the seaward side of the salt marshes of the land reclamation work on the coast of Groningen there is a fairly healthy population of the seagrass species *Zostera noltii*. In years before 2008 occasionally individual plants of *Zostera marina* have been observed. Relatively close to this location are the offshore mudflats “Hond” and “Paap” and the small onshore mudflat “Voolhok”. These are the areas where in the Wadden Sea in recent years relatively substantial populations of Eelgrass have been observed.

#### 3.1.2 Location choice

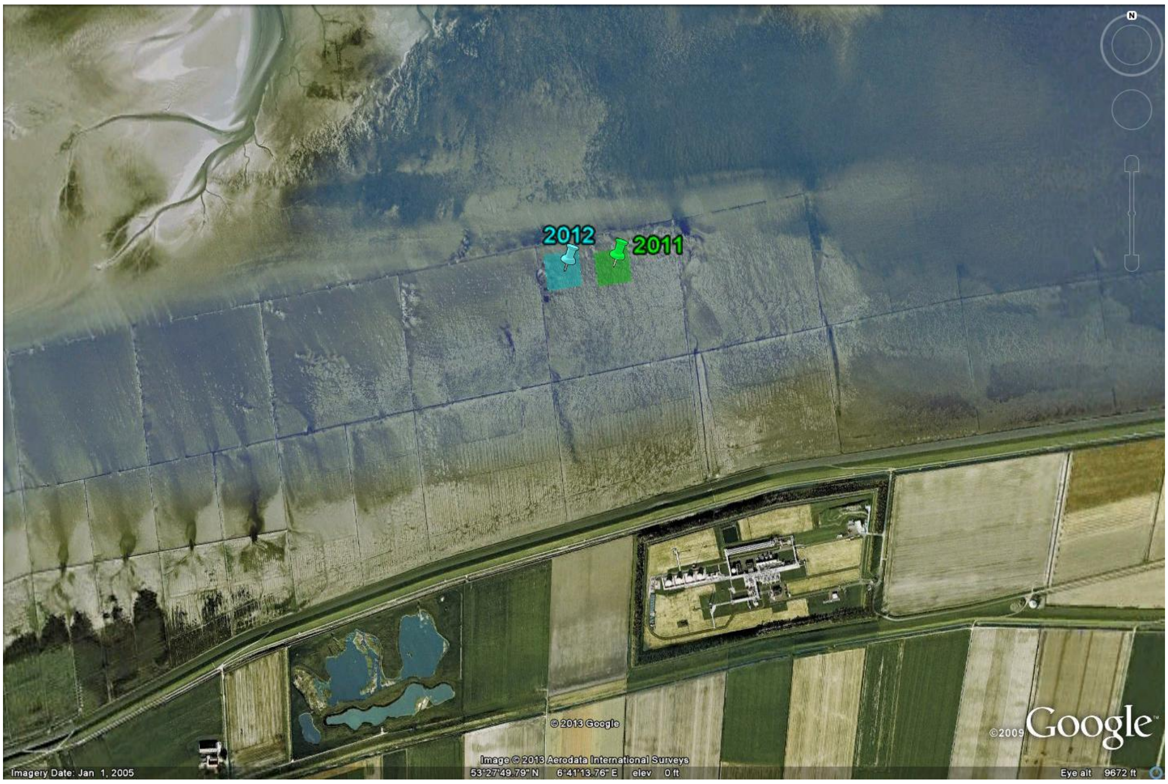


*Figure 3.1: Locations at near the Saltmarshes in North Groningen. The green square indicates the 2011 deployment location, the light blue square is the deployment location used in 2012.*

Near the land reclamation sites in North Groningen, initially 2 locations were indicated as potentially suitable. The first location is near Uithuizen, near the gas works (between the green markers). This site has a healthy *Zostera noltii* population closer to the saltmarsh and looks suitable for a deployment on the seaward side of the *Z. noltii.* The other site near Noordpolderzijl does not have any seagrass and appears to have changed significantly over the past years. This site was reportedly a very silty site, but during the visit on the 16$^{th}$ of June 2011, the site was remarkably sandy, indicating an increased hydrodynamic exposure. This seems not favourable for seagrass.
The location for deployment is therefore near Uithuizen 100 m long and 100 m deep (running parallel to the saltmarsh land reclamation plots). The centre of the 2011 plot was: N 53°28’02’’, E 6°41’17’’.
Eelgrass developed around the site in 2012 (see chapter 6). More plants were observed to the east of the original deployment site. In the vicinity of the site the habitat appears to be

fairly similar along the dike. Hence the choice of locating the 2012 deployment site just west of the 2011 site: close to the original one and with limited chance of trampling emerging eelgrass plants. The centre of the 2012 plot was: N 53°28'01.92'', E 6°41'10.41''.

## 3.2 Balgzand (Noord-Holland)

### 3.2.1 Eelgrass occurrence in previous years

### 3.2.2 Location choice


*Figure 3.2: Balgzand deployment locations, the 2011 area is indicated in green, the 2012 deployment is indicated in light blue.*

Attached to the dyke at Balgzand there is a small saltmarsh area (indicated in dark purple). Field surveys in June had indicated that the most favourable habitat could be found just north of this saltmarsh. However, this small area is an important roosting area for wading birds during high tide. The local management requested in 2011 to keep a minimum distance of 800 m. between the deployment site and the saltmarsh to avoid disturbing roosting birds. Subsequently, the area indicated in green was selected close to the dyke, where the elevation is close to 0. The proposed plot is 250 x 40 metres and the centre is located at N 52°55'30'' and E 4°47'59".
In 2012 a substantial amount of eelgrass was observed to grow around this location. In order not to trample the emerging new seagrass and the lack of suitable habitat at a sufficiently large distance from the small saltmarsh area an alternative location had to be found for the 2012 deployment. During the work of 2011 it became clear that at Balgzand all fieldwork could be carried out during low tide, when the birds are not using the saltmarsh. On this basis we obtained permission from the local management to switch to our preferred location in 2012. Due to local topography (the presence of a small gully in this area, the 2012 location was split into two adjacent sections, the total surface area remained 1 Ha. The centres of the

two squares were located at: N 52°55’11.28’’, E 4°48’10.20” and N 52°55’09.05’’, E 4°48’14.18” respectively.

## 3.1 Schiermonnikoog (Friesland)

### 3.1.1 Eelgrass occurrence in previous years

The MWTL database as well as local observations by the area management indicated that on either side of the marina occasional Eelgrass plants have been found. One exceptional year was 2009, when there were reports of a few hundred plants. These plants did not manage to expand the following year. It is unknown where the seeds that sprouted these plants originated from. However, the proximity of the marina, with small boats that visit other parts of the Wadden Sea makes that a likely source.

### 3.1.2 Location choice

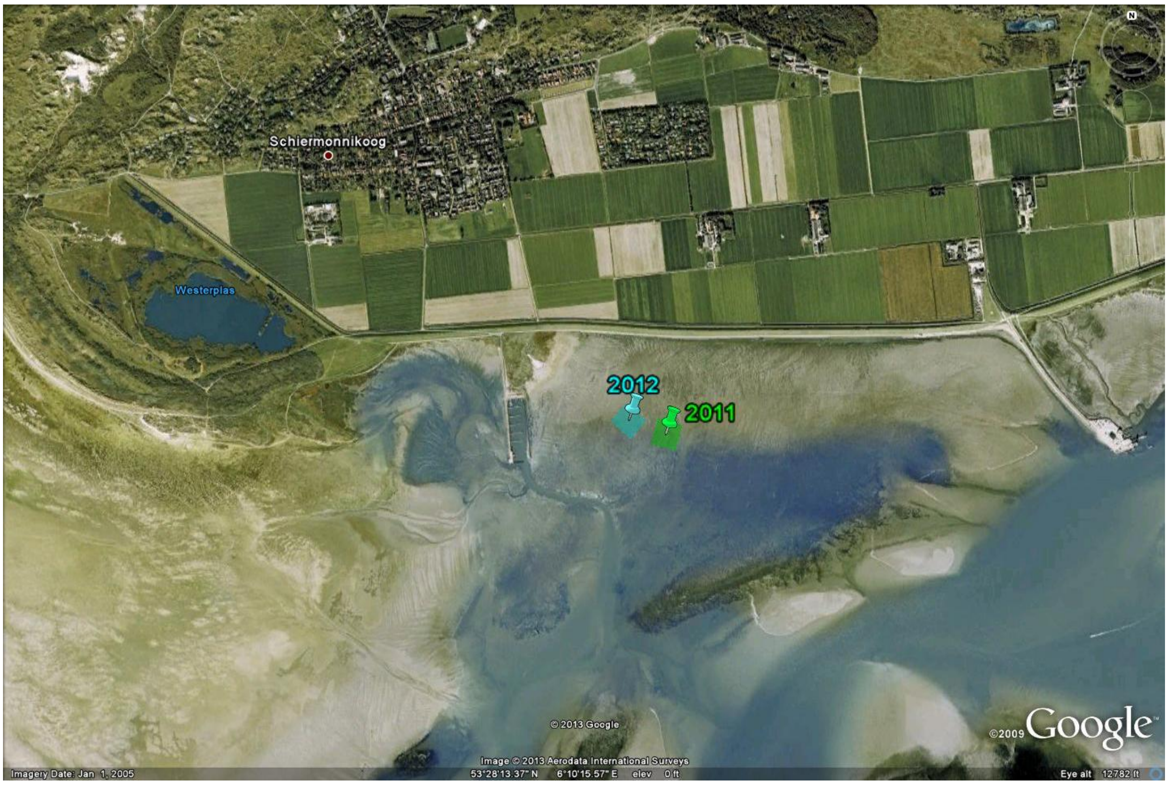


*Figure 3.3: Schiermonnikoog locations. The 2011 is indicated in green, the 2012 location in light blue.*

Locations on either side of the marina at Schiermonnikoog looked suitable. Further to the east there are locations in use by other research projects, such as Waddensleutels and Mosselwad. In recent years eelgrass has occurred near both locations.
The responsible authorities for managing this area (Natuurmonumenten) favours the eastern location due to the fact that in the future a link may be established between the Westerplas and the Wadden Sea, which would be hampered if there would be a substantial seagrass population on the western side. As both locations appeared suitable, we have chosen to locate the deployment area on the eastern side.
The 2011 location was square (100 x 100m) with the centre at N 53° 28’ 08’’ and E 6° 10’ 33’’.
In 2012 most eelgrass appeared to the north of the 2011 location and changes appeared to have occurred with respect to sediment composition and elevation. Based on the occurrence

of eelgrass and local bed elevation the 2012 location was situated closer to the dike, with the centre at N 53° 28' 10.22'' and E 6° 10' 24.75''.

# 4 Methodology

The method is based on the "buoy-deployed seeding method" (BUD-method), extensively described by experts in the U.S. (Pickerell et al. 2005, Marion and Orth 2010, Orth et al. 2010). In short, this method is based on

- the collection of Eelgrass inflorescences from a suitable donor location.
- putting these seed-bearing shoots in mesh bags, with mesh small enough to retain the shoots but large enough to allow the seeds to fall through the mesh
- deploying these mesh bags with a float, attached to an anchoring construction at suitable deployment sites.

*Figure 4.1: A mesh bag with Eelgrass shoots, a float and a stainless steel hook*

The section below describes the adaptations of this general methodology to the specific sites in the Wadden Sea, as well as the arguments for choosing specific donor sites and deployment sites.

## 4.1 BUD construction

Due to the fact that the deployment areas are all very muddy, concern arose that soft mesh bags might accumulate too much sediment over a few weeks that buoyancy would be compromised. Over summer a number of trials were carried out to check if this was the case, and if so, if a rigid, but slightly more expensive design would mitigate the problem. The tests with several designs indicated that although bags with seagrass did accumulate some sediment, this was not to such an extent that buoyancy was compromised.
The material for the mesh bags was chosen on the basis of:

- Measurements of seed sizes from the donor location. The intertidal *Z. marina* from the area around Sylt appears to be relatively small in comparison to the same species from other locations around the world. The maximum length of the seeds around Sylt did not exceed 0.8 mm.
- Measurements of seagrass shoots, to ensure that the shoots would remain inside the bags.

The material that was ultimately chosen was commercially available, flexible mesh. The mesh size with new material, dry and not stretched is around 1.5 mm. When the material is submersed in water for a few days and stretched by e.g. wave-action the mesh size can stretch to around 2 mm.
Each of the two years, each site was supplied with 180 seed bags, i.e. 540 bags for all three sites together.
The BUDs are constructed by volunteers prior to the field campaigns. After the material is collected in the field, the BUDs are immediately filled with around 700 g of seagrass material. They are closed with cable tiers and transported in plastic crates, each crate containing no more than 8 BUDs to prevent compression. The crates are subsequently transported in a

temperature controlled trailer, as the quality of the seed rapidly diminishes if temperatures are allowed to exceed 15° C.

### 4.2 Anchoring and deployment

Two weeks prior to the deployment of the seed bags, cables were anchored at each of the three sites (Figure 4.2). Attached to these cables 5m long ropes were attached with floats at the ends and a metal hook.

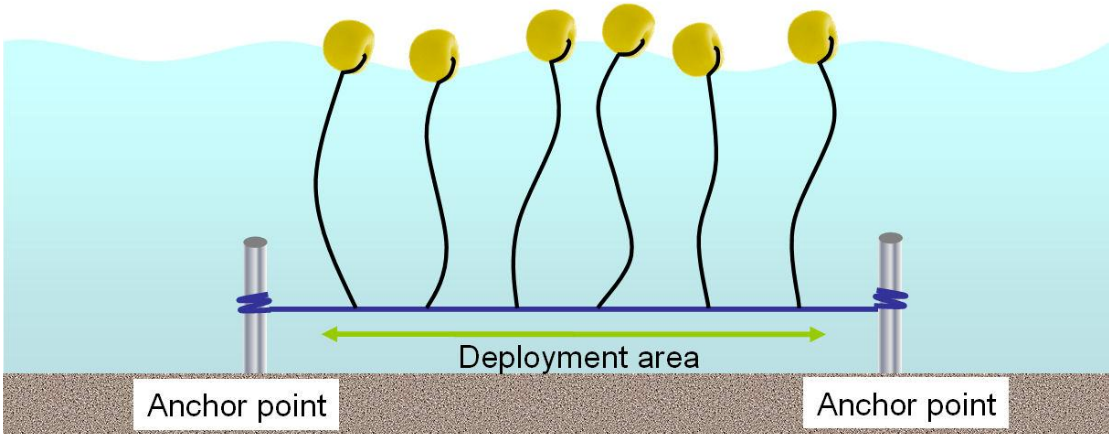


*Figure 4.2: Schematic drawing of the anchoring of the floats, to which subsequently the BUDs (also containing a float) were attached. In reality the distance between the floats is proportionally larger than suggested in this drawing.*

*Figure 4.3: Attaching BUDs to moorings in high wind on Schiermonnikoog, September 2011*

The BUDs can then either be attached by walking onto the mudflat at low tide, or by manoeuvring close to the floats during high tide using a small vessel and attaching the BUDs from the vessel.

After the BUDs have been deployed in the field, they are left there for 5-6 weeks, until all the seed material has disappeared from the bags. The bags, floats, and all the anchoring material is subsequently removed, so no material is left behind.

# 5 Effect monitoring at the donor location

All initial assessments have indicated that harvesting this amount of Eelgrass seeds should not in anyway affect the donor population. Specifically the site at Rantum has the additional benefit over other Eelgrass sites around Sylt that the sediment is very sandy. This would also limit any damage due to trampling by the harvesters. However, to ensure that no appreciable damage has been done to the donor population a post campaign check was carried out. A quantitative sampling of the seagrass between harvested and reference sites in 2011 and with the new population in 2012 would be very labour intensive. Therefore an alternative monitoring strategy, using the exploitation of the seagrass meadows by birds as a proxy for habitat quality was devised. In September 2011 and September 2012 AWI has carried out a survey of the use of the seagrass meadows at Rantum by Brent Geese (*Branta bernicla*) and widgeon (*Anas penelope*). The assumption is that if there is a significant effect of the eelgrass harvesting on the meadow, this will result in a diminished use of the exploited sites by birds.

### 5.1 Effect monitoring 2011

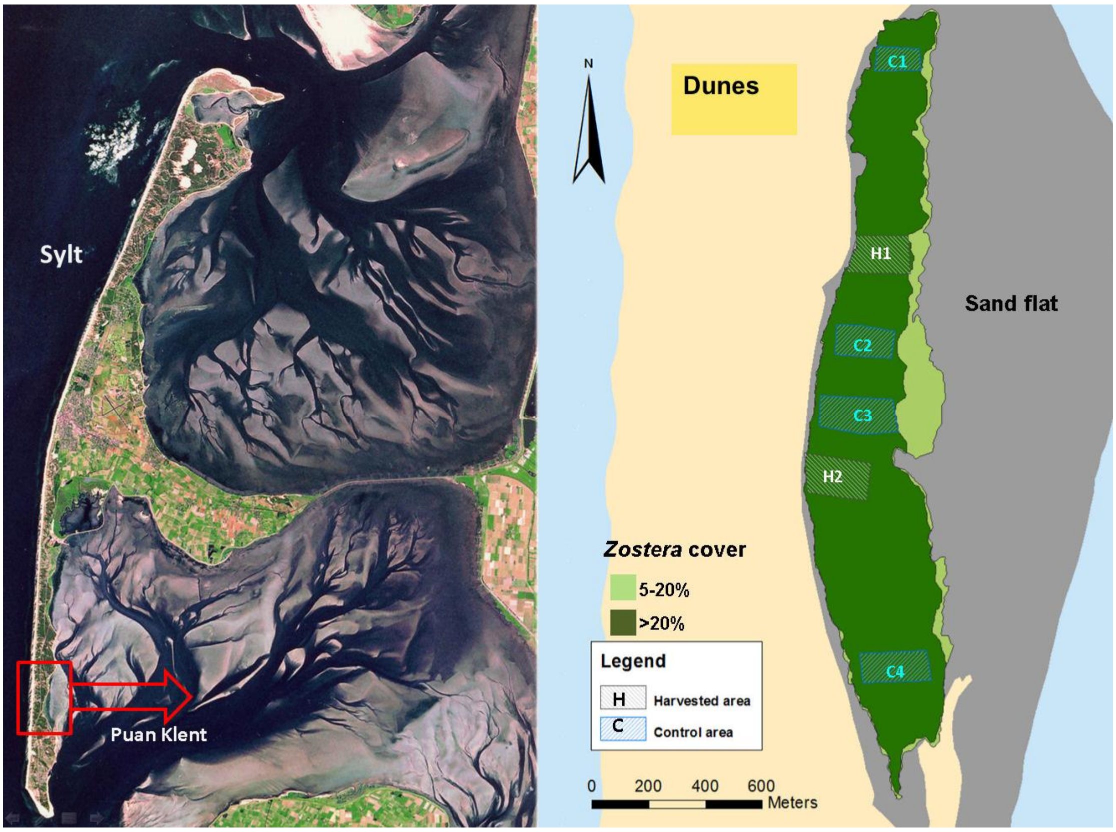


*Figure 5.1: Locations of harvesting sites and control sites on the Puan Klent meadow, south of the village of Rantum.*

In 2011 material was harvested from 2 areas (H1 and H2) on the seagrass meadow, while 4 areas were used as a reference site (C1-4, Figure 5.1). In September 2011 large flocks of Brent geese (*Branta bernicla*) arrived and were feeding on the seagrass. On 4 and 7 October 2011 observations were made on the exploitation of the harvested and control sites.

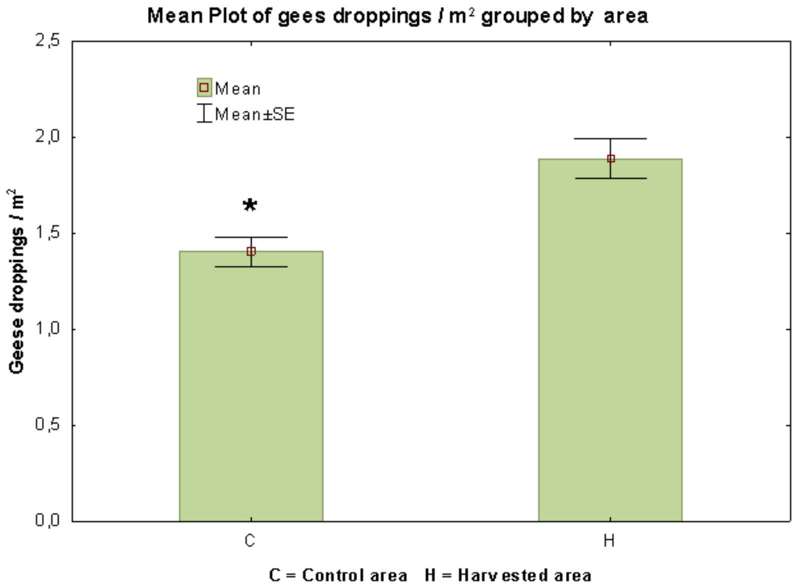


*Figure 5.3: bar graph representing the average density of geese droppings observed on the harvested and control locations. Shown are means with ± SE for replicates (n = 297 + 297)*

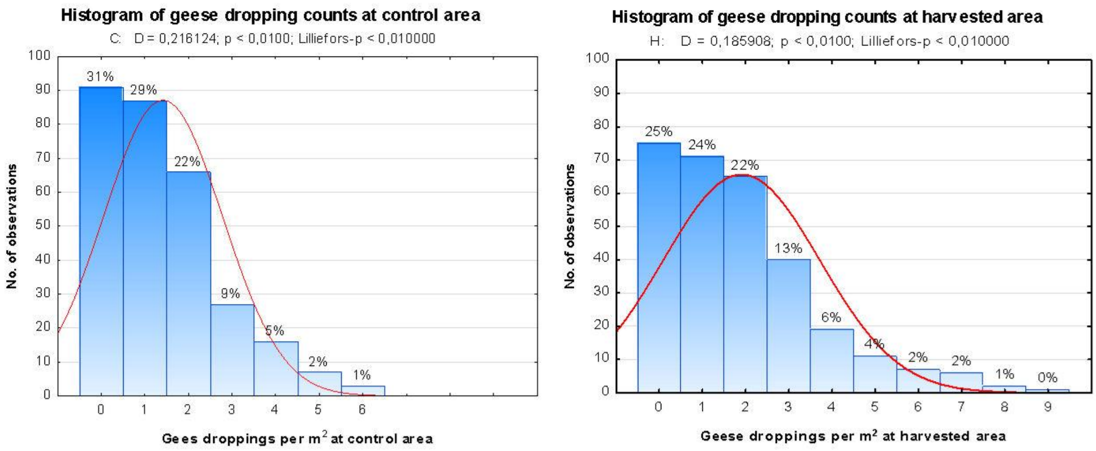


*Figure 5.2: histograms of the distribution of observations on geese droppings per m² at the control and the harvested site.*

The number of geese droppings per unit area were counted at all sites and compared statistically. Mann–Whitney U tests revealed that significantly ($p < 0.05$) fewer droppings were found at the control sites (n=4) than at the harvested plots (n=2), indicating that site preferences of the harvesters and brent geese were alike. The lay-out of the control and reference sites did not allow for a pair-wise comparison that could rule out effects of topographical differences or north-south gradients in the seagrass cover. The results certainly indicated no negative effect of the harvesting. For 2012 it was recommended to change the design of harvest and control plots.

## 5.2 Effect monitoring 2012

The summer survey of seagrass abundance had already indicated that there did not appear to be any difference in seagrass abundance or density of inflorescences between the sites that were harvested in 2011 and the reference sites (see also section 2.2.2.)

To avoid the statistical problems of 2011, in 2012 we changed the lay-out of the harvest and control plots to a pair-wise design of 5 1-hectare harvest plots and 5 control plots. Each plot was divided into a control and a harvest site. As there are reported differences in seagrass cover between the north and south part of the meadow, the southern part having a better seagrass cover. To avoid effects of a gradient in the pair-wise comparison, care was taken to alternate the location of control and harvest sites.

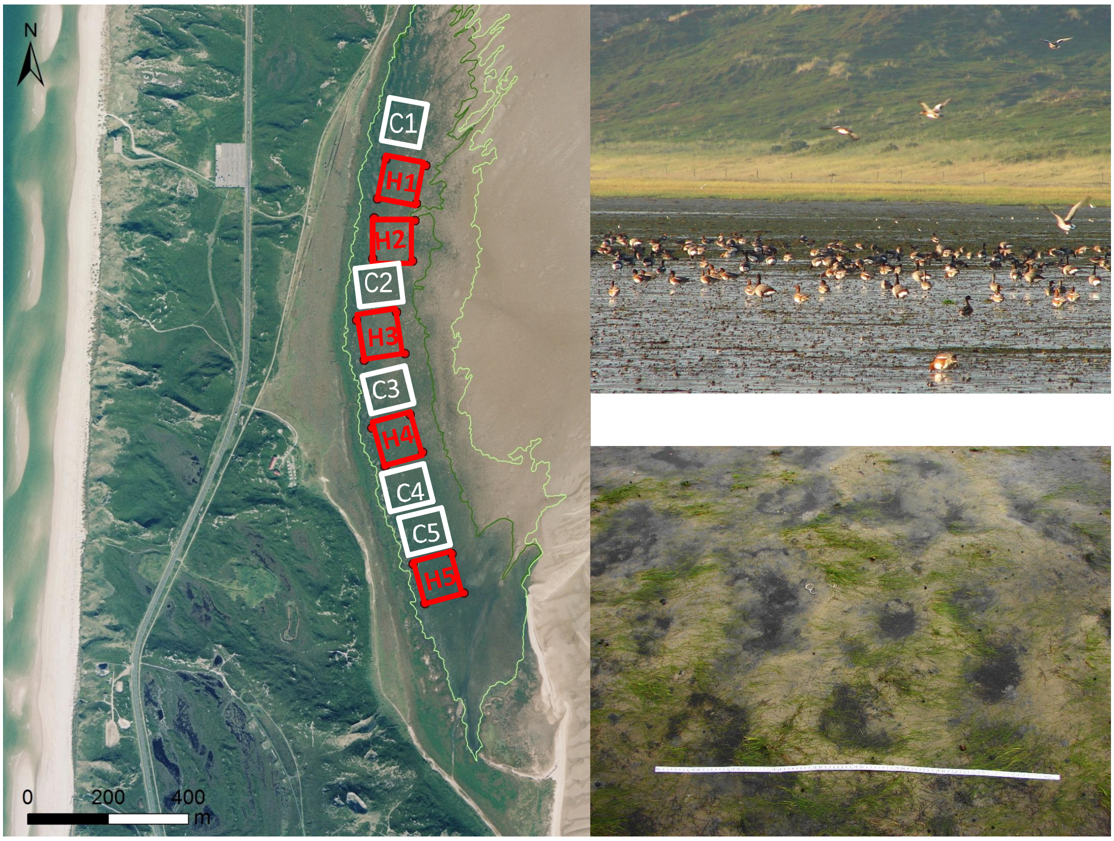


*Figure 5.4 Seagrass bed adjacent to a dune and saltmarsh area south of Puan Klent at the Wadden side of the island of Sylt. Seaward contour line for >20% (dark green) and >5% coverage (light green) were assessed July 21 in 2012 with GPS. The landward contour lines fall together. Harvesting of seed bearing inflorescences of Zostera marina took place at 5 hectares (H1-5 in red) in August 25 and September 8, 2012.Feeding pits of wildfowl have been assessed at H1-5 and control hectares (C1-5 in white) Sept. 27. 2012. Aerial photograph from 2010 provided by LKN-SH. Upper right: Widgeon (Anas penelope) and Brent geese (Branta bernicla) feeding on seagrass. Lower right: Feeding pits of wildfowl with 1-m scale. Both photographs from September 27, 2012 (K. Reise).*

In September (8, 24 and 27.09.12) large flocks of Widgeon *Anas penelope* (>2000 birds) were observed grazing on eelgrass with only a few groups of Brent geese *Branta bernicla* (about 100 birds) among Widgeons. Counting droppings to assess feeding activity was hampered by strong rain fall, disintegrating the faecal strings. Instead, feeding pits were counted per m² in September 27, 2012. Harvested plots and control plots were located by GPS, recording corner positions of one hectare areas.
Mean depth of these feeding pits was 23 ± 6 mm (n=30) and mean maximum diameter was 0.28 ± 0.07 m (n=75). Occasionally adjacent feeding pits merged and then the mean diameter served to judge on the number of individual pits. Pits were dark because of anoxic sediment (fresh pits) or because of accumulating plant debris (older pits). Direct observation showed that both, Widgeon and Brent geese, dug out pits to feed on eelgrass rhizome.

The number of feeding pits ranged from 4 to 9 $m^{-2}$ (n=200) with means for 5 harvested plots (H 1-5; each n=20 m²) of 6.21 ± 0.38 $m^{-2}$ and 5 control plots (C 1-5; each n=20 m²) of 6.31 ± 0.46 $m^{-2}$. The difference was not significant (ANOVA: df 1, F = 0.139, p = 0.719; Tukeys Honest Significant Difference Test, homogenous variances p > 0.05).

Pits are assumed to have originated from feeding activities of the wildfowl during the preceding 2-3 low tides, thus averaging patchy occurrences of feeding flocks. Birds move gradually while grazing, and occasionally over large distances when landing after the flock had been flying a few circles over the seagrass bed.

Concluding we can say that wildfowl - mainly Widgeon - intensively grazed on eelgrass on an elongated bed parallel to the shore between Puan Klent and Hörnum (Sylt) in September 2012. Counting the well-discernible feeding pits at 5 one-hectare plots and interspersed 5 control plots revealed no evidence, that grazing birds recognized a difference. Thus it may be concluded that harvesting inflorescences of *Z. marina* within a bed dominated by *Z. noltii* had no negative ecological impact.

# 6 Results of the first deployment of 2011

After the deployment of seed bags in 2011, the weather conditions in autumn and winter were quite a-typical for the Netherlands. Autumn and early winter were relatively warm and stormy, while there was a 3 week period with very sharp frost and minimum temperatures below -15°C, followed by heavy ice floes. Despite these destructive forces on the seabed, all three deployment locations yielded a crop of eelgrass in May 2012. In summer 2012 (31st July and 1st and 2nd of August) the sites were surveyed by the team of RWS-Data – ICT-Dienst.

## 6.1 Survey method

A full description (in Dutch) of the surveying method can be found in the report by the RWS-Data-ICT-Dienst report. (Bergwerff and Buiks 2012). The field work is carried out using a grid method. Each of the three areas are divided in grid cells of 20x20 m. Each area is subsequently surveyed on foot and per grid cell occurrence of seagrass species, notably: *Z. marina*, *Z. noltii*, and *Ruppia maritima* are recorded on hand held computers (PDAs). The codes for the different levels of cover and the corresponding area within a 20x20 m grid cell is:

| Code | Cover | Surface area |
|---|---|---|
| 1 | >0-1 | >0-4 |
| 2 | 1-5 | 4-20 |
| 3 | 5-10 | 20-40 |
| 4 | 10-20 | 40-80 |
| 5 | 20-30 | 80-120 |
| 6 | 30-40 | 120-160 |
| 7 | 40-50 | 160-200 |
| 8 | 50-60 | 200-240 |
| 9 | 60-70 | 240-280 |
| 10 | 70-80 | 280-320 |
| 11 | 80-90 | 320-360 |
| 12 | 90-100 | 360-400 |

In nearly all cases the cover in the surveyed grid cells fell in the lowest category (1). Due to the very high sinking velocity of viable seed, the initial expectation was that the seeds would remain in the immediate vicinity of the deployment areas. The surveys therefore started at distances of approximately 100 m of the edge of each deployment location and systematic transects were followed until no more plants were encountered. On hindsight there must have been significant sediment transport on each location, which has also resulted in transport of the seeds buried in the sediment. At all locations plants were found at considerably higher distance from the deployment locations than can be expected on the basis of the local maximum depth, flow speeds and sinking velocity.

On average 2-4 plants were recorded per grid cell, however in extreme cases this number exceeded 170 plants per cell.

Subsequently the data from the PDAs was downloaded on a computer and the data were transformed into maps using ArcGIS.

## 6.2 Results

### 6.2.1 Uithuizen

- Number of surveyed cells: 980
- Cells containing *Z. marina*: 297
- Cells containing *Z. noltii:* 751

*Z. marina* has spread from the deployment location towards the east and north east over a distance of at least 700 m. It is possible that eelgrass has emerged at even larger distances from the deployment location as this was the limit of the area covered. Spreading towards the other directions appeared to be less (Figure 6.1). Although the area towards the dike is not extensively covered, it is unlikely that eelgrass will be able to grow in these areas with a higher elevation.

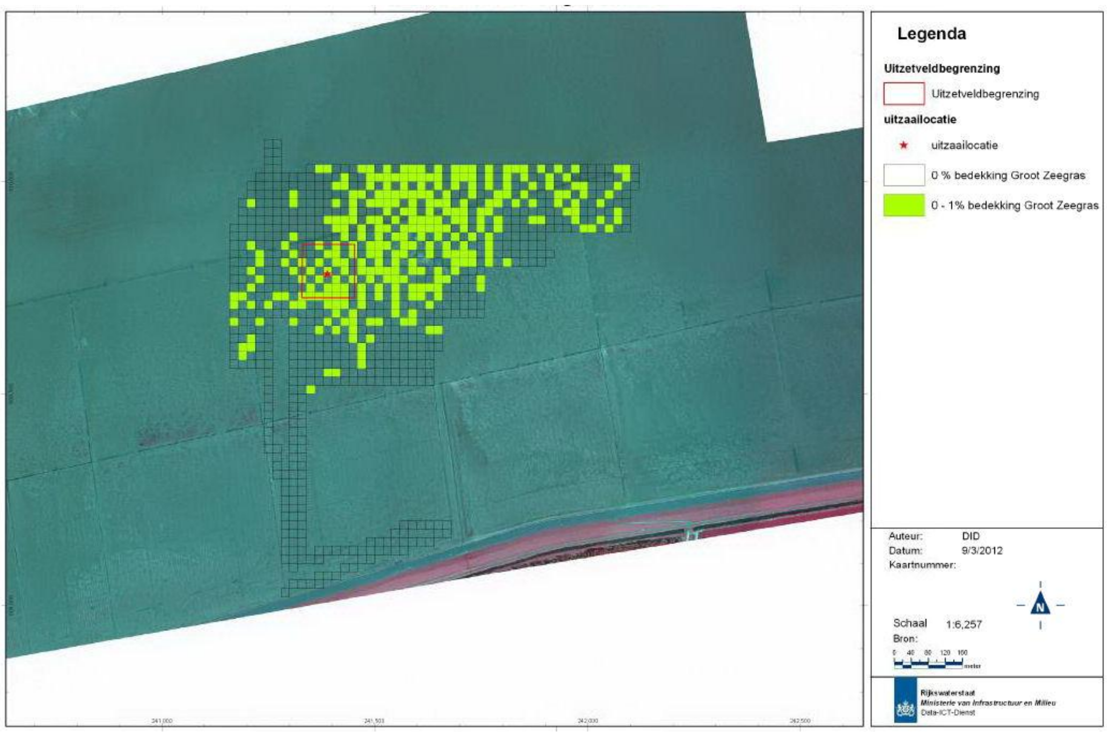


*Figure 6.1 Distribution map of Z. marina at Uithuizen*

This location has a substantial presence of the smaller seagrass species *Z. noltii*. This species has its highest cover slightly higher up, closer towards the dike (Figure 6.2). *Z. noltii* was already present here in previous years and is clearly unrelated to the deployment of Eelgrass in this project.

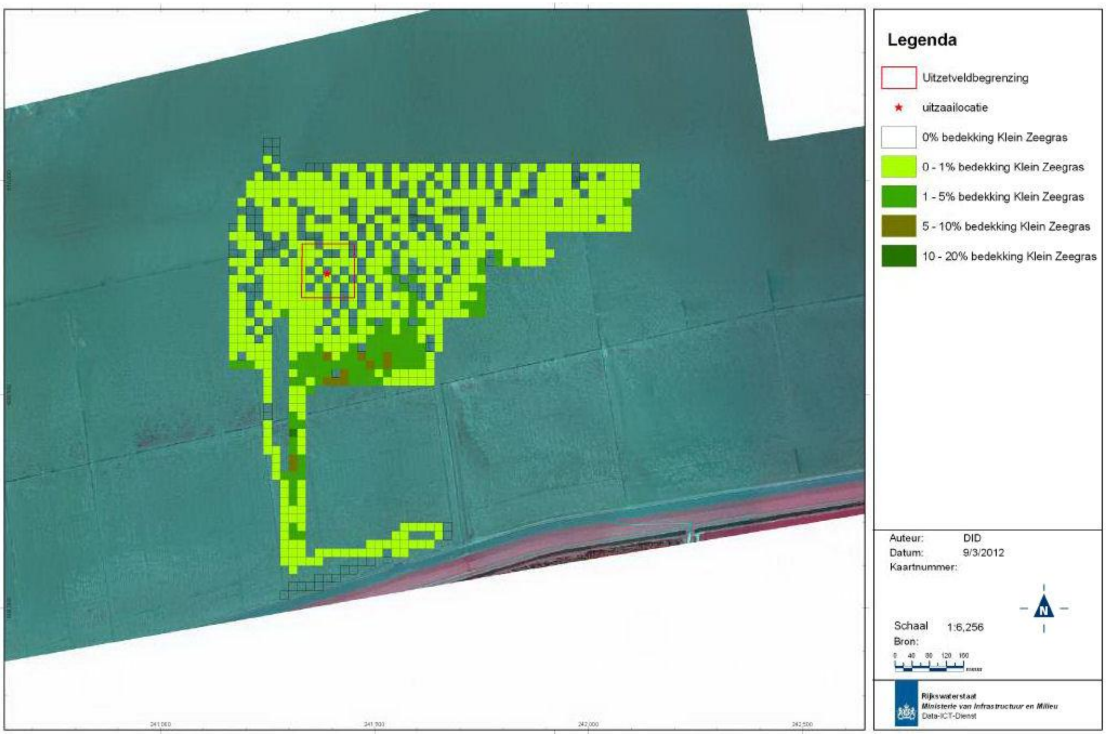


*Figure 6.2: Distribution of Z. noltii at Uithuizen.*

At Uithuizen the maximum cover observed was around 30 tussocks per 20 x 20 m grid cell. A single tussock consists of one or more individual plants. Closer to the original deployment location the density tended to be higher, while cells further away from the deployments site often had only one or two plants.

All plants appeared to look healthy. Smaller individuals measured about 20 cm, while the largest ones were estimated to be up to 60-70 cm. Seed bearing shoots were observed (Figure 6.3), although no attempt was made to quantify the occurrence of inflorescences.

*Figure 6.3: Development of inflorescences.*

### 6.2.2 Balgzand

- Total number of cells surveyed: 256
- Number of cells with *Z. marina: 118*
- Number of cells with *Z noltii*: 0
- Number of cells with *R. maritima*: 1 (indicated in blue on the map)

Plants of *Z. marina* were observed at a maximum distance of about 100 m. in a northerly direction and a westerly direction. Spread toward the south extended slightly further (Figure 6.4). It is possible that the distribution extended further towards the north east. However, the sediment composition changes in that direction and becomes sandier. A visual inspection of a few (not geo-referenced) transects indicated that further spread in this direction was minimal. Also at this location the density diminished further away from the deployment location.

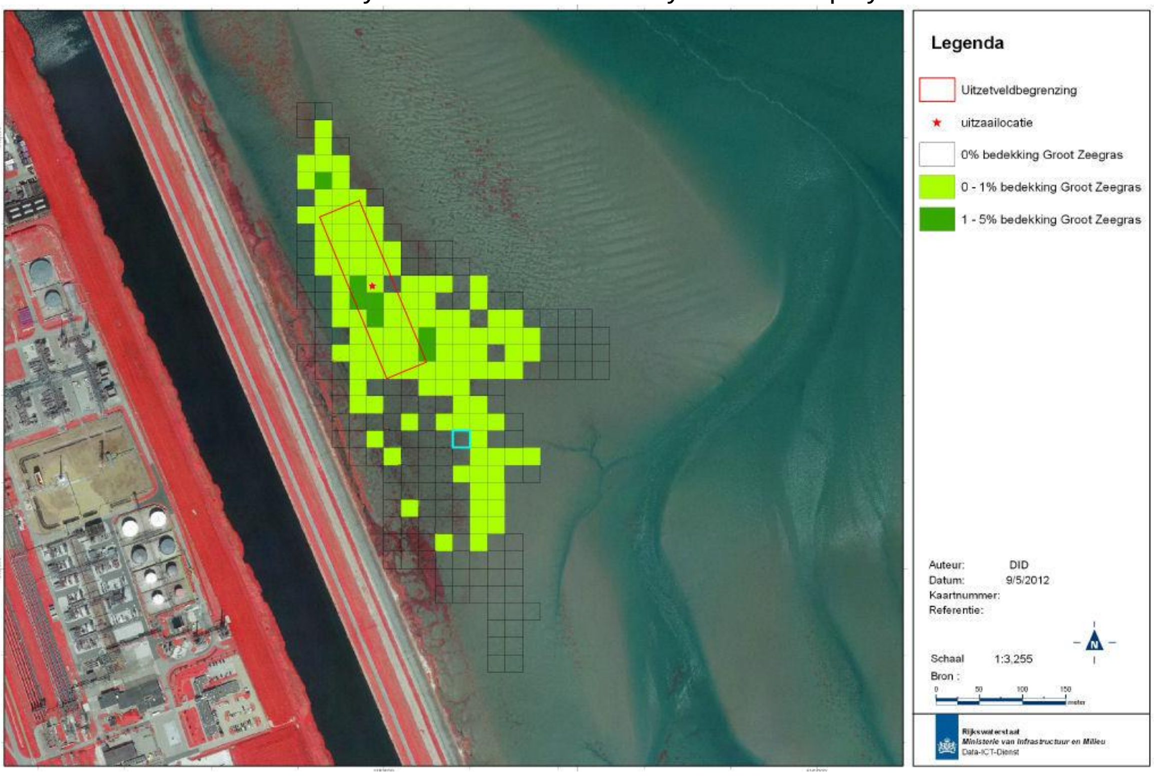


*Figure 6.4: Distribution map of Z. marina at Balgzand.*

At Balgzand several grid cells had a significant cover, although sometimes exact cover was difficult to estimate due to the large amount of algae, such as filamentous algae, *Ulva lactuca*, *Sargassum muticum* (Japanese brown alga) and other brown and green algae.
The maximum number of plants at this location has not been determined, although in all cases cover was less than 5%.
Most plants appeared healthy, although at Balgzand several individuals were observed with black or white discolourations. This was especially prominent in areas with large amounts of filamentous algae. Small plants measured about 20 cm; the largest individuals measured up to 70 cm. Also here seed development was observed.

*Figure 6.5: High cover with eelgrass and filamentous algae at Balgzand.*

### 6.2.3 Schiermonnikoog

- Total number of cells surveyed: 271
- Number of cells with *Z. marina: 140*

- Number of cells with *Z. noltii*: 0

Eelgrass was observed to grow at a distance of at least 600 m east of the original deployment location (Figure 6.6). It is quite possible that the spread extended over even larger distances. Spread towards the west was clearly less.

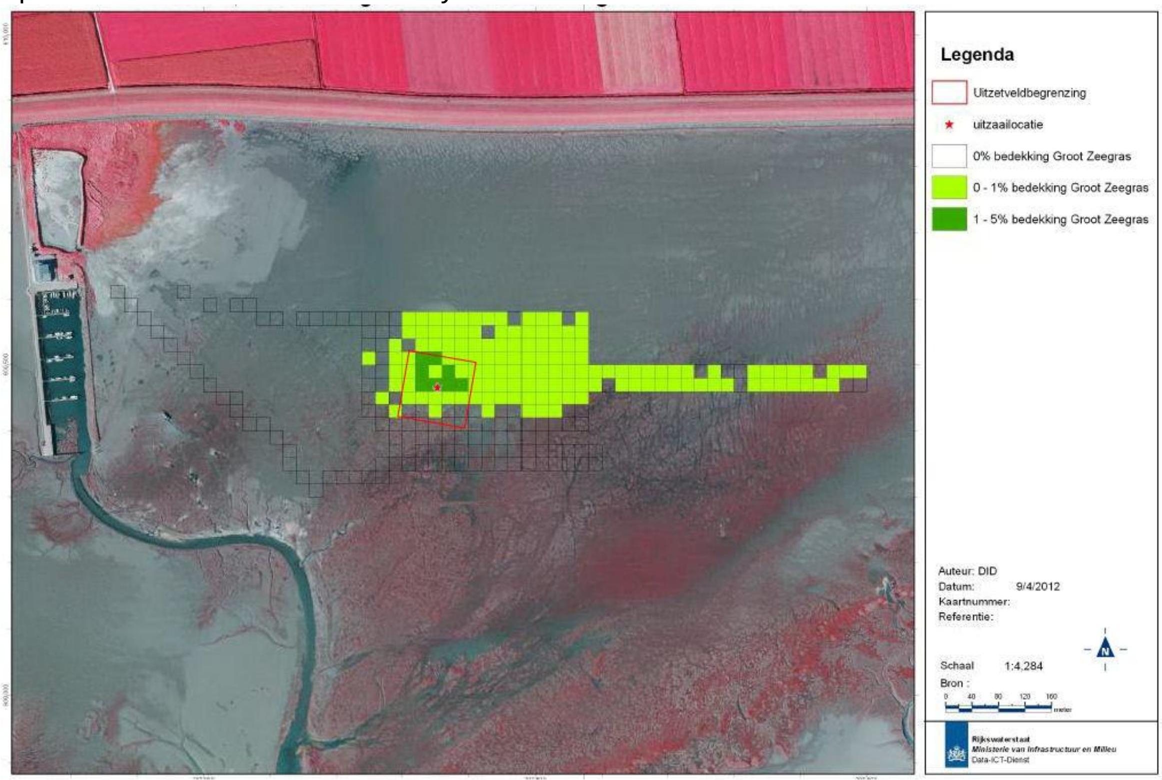


*Figure 6.6: Distribution map of Z. marina at Schiermonnikoog*

The maximum density observed per grid cell was 170 tussocks. Such levels of cover were interpreted as 1-5%. Tussocks may consist of one or more individual plants. The plants all appeared healthy, smallest individuals ranging around 20 cm long and the largest ones 70 – 80 cm in length. Also at this location development of inflorescences was observed.

### 6.3 Plant morphology

*Z. marina* on Sylt appears to be relatively small in comparison to the same species observed in other parts of the Wadden Sea and indeed elsewhere. Both at Tonnenlegerbucht and at the meadow at Rantum are most Eelgrass plants around 30 cm in length and the leaves tend to be 2-3 mm wide, while in the Dutch part of the Wadden Sea this species is often more than 50 cm long and the leaves tend to be slightly wider as well (4-5 mm). Our inventories of the plants and seed availability indicated that on Sylt the plants produce 2-3 inflorescences per plant, with about 5 seeds per

*Figure 6.7: Tussock Zostera marina at Schiermonnikoog of about 50 cm in length (Photo RWS-DID).*

inflorescence. That is less than is generally seen for this species. The study by Erftemeijer and Van Katwijk takes 100 seeds per plant as an average. Although no attempt was made to quantify the occurrence of inflorescences in the eelgrass at the deployments sites, Figure 6.3 gives a qualitative indication that some plants certainly produce a fair number of seeds per inflorescence.
There are known to be genetic differences over the different populations of the Wadden Sea, particularly over distances of more than 150 km (Ferber et al. 2008), although connectivity within the Wadden Sea is deemed to be relatively high.
The eelgrass that was observed in summer 2011 on the deployments sites and clearly originated from the seed imported from Sylt, had the morphology that is typical for eelgrass seen in the Netherlands, i.e. larger than this species is generally seen on Sylt. It is clear that the morphological differences are unlikely to be a result of genetic differences between the Dutch and northern German part of the Wadden Sea. Instead these must be a consequence of environmental factors.

# 7 First conclusions

## 7.1 Habitat suitability

Results from the 2012 deployment are at this moment yet unknown. The eelgrass distribution observed in the summer of 2012 clearly originates from the deployment of eelgrass seed bags in 2011. It is highly unlikely that the substantial amount of Eelgrass observed around the deployment locations originate from another source than the seed in the seed bags. The fact that at all three sites substantial amounts of eelgrass developed, is of course extremely encouraging. It confirms at least two things:

1. The method of sowing eelgrass worked as it was supposed to work. The materials selected (mesh size of the bags, the floats, the anchoring method) were all appropriate for the job. Particularly the mesh size of the bags had earlier raised some questions, as it appeared quite small for eelgrass seeds. However, the eelgrass plants, as well as the eelgrass seeds on Sylt, appear to be relatively small in comparison to the same species growing elsewhere. This mesh appeared to be appropriate for this particular application.
2. The site selection, at least as far as habitat suitability is concerned, was appropriate and that the deployment locations had been positioned in areas with the right combination of habitat factors.

So the first important hurdles have been taken successfully. As in all three deployment locations small numbers of eelgrass plants had been observed regularly, it perhaps should not be a great surprise that with such a large number of eelgrass seeds released in these locations at least some plants managed to develop. However, Eelgrass recruitment is notoriously variable. The rather extreme weather conditions that followed the first deployment with high temperatures and strong winds in autumn and a short period with sharp frost and in some parts heavy ice floes in February, certainly gave rise to some concern. The forces exerted on the seabed by ice floes can be quite considerable. Close to the Balgzand deployment an observation hut was totally destroyed by the moving ice sheets. The 2011 deployment site on Schiermonnikoog was partly selected because of its relatively sheltered position behind a mussel bed. This mussel bed was destroyed in the autumn storms and the area appears to have been subjected to a large amount of sediment transport from the sea side towards the dike. This is supported by the fact that there was significant spread of seagrass north and eastward and hardly any seagrass development in the southern part of the deployment area. This may be a consequence of the sediment with the seeds having

shifted. It is also possible that the seeds that remained within this plot were buried too deep in very silty sediment. Qualitative observations showed that at spring the original deployment site substantial deposition of very fine sediment had taken place.
As the current eelgrass distribution originates from the deployments and not from natural dispersal, we cannot draw any conclusions yet regarding the quality of the model predictions regarding the relatively high retention of seed around the deployment locations.

## 7.2 Recruitment percentage

From the monitoring data it is very difficult to calculate the actual recruitment success. In total plants were recorded in 555 of the grid cells. The maximum number of tussocks observed in a single grid cell was 170, but each tussock may be comprised of several single plants, i.e. the result of more than one seed. On Balgzand, due to the large amount of filamentous algae it was not possible to make an accurate assessment of the number of tussocks per grid cell. It is therefore not possible to assess the percentage of seeds that have produced adult plants. We are certainly talking about "several thousand plants", but much closer than this qualification one cannot realistically get. After previous restoration projects, a maximum of 800 plants developed in 2003 at Balgzand (van Katwijk et al. 2006), so in that light this first year of the project has been reasonably successful.
If we take a conservative wild stab at an average of 5 germinated seeds per grid cell and a total of about 4 million seeds that were distributed over the three sites, the percentage of seeds resulting in adult plants would be just under 0.1%. In the study by Erftemeijer and Van Katwijk (2010) summarise a list of possible causes of seed loss: such as losses by deep burial, removal of seed out of the sediment, reduced germination, loss of seedlings and losses in summer due to e.g. smothering by algae. At Balgzand the latter may have contributed to the loss and at Schiermonnikoog the high levels of sedimentation may have resulted in burial of seeds.

## 7.3 Donor site

The surveys on birds and the surveys on eelgrass in summer 2012 before the second campaign have indicated that this level of exploitation of the donor area has not resulted in significant damage to the donor site.
If at any point in the future similar or even larger campaigns are contemplated, it would be worthwhile performing similar preliminary calculations and taking the bed composition of the donor site into account.

## 7.4 Eelgrass and the Water Framework Directive

Currently, the Wadden Sea (excluding the Ems-Dollard tidal basin) scores very low on the targets for Seagrasses (STOWA 2007). Although no quantitative details are known for a reference situation without dykes, a 5-10 % cover with seagrass meadows of the total area is assumed. This is a combination of *Zostera marina* and *Zostera noltii*. Within meadows a cover of 60% *Z. noltii* and / or 30% *Z. marina* are required for a "good" status. Currently less than 3% of the total area consists of seagrass meadows, resulting in a "bad" or "insufficient" status.
The success of the first deployment is obviously not a guarantee for the long term. The acid test will be the development and spread of eelgrass over the coming years. As the eelgrass has been observed to produce inflorescences, the main question is now, if a sufficiently large part of the eelgrass can re-establish itself over the coming years.
Eelgrass recruitment is known to vary strongly from year to year (van Katwijk et al. 2006). The heavy ice floes of February 2011 are not indicative of 2011 being an exceptionally good year for seagrass development, but due to the lack of reference data for the Dutch Wadden Sea, it

is difficult to evaluate the success on the basis of this one year. The results of the 2012 deployment in 2013 should provide more information.
Whether or not a “good” status regarding Seagrass is achievable under the current criteria of the Water Framework Directive will have to be evaluated over the next few years.

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