Deltares

Enabling Delta Life

Eelgrass restoration in the Dutch Wadden Sea

Results 2013

Deltares

Eelgrass restoration in the Dutch Wadden Sea

Results 2013

dr. L.A. van Duren
dr. M.M. van Katwijk

1203892-000

Deltares

Title
Eelgrass restoration in the Dutch Wadden Sea

Client	Project	Reference	Pages
Rijkswaterstaat - WVL	1203892-000	1203892-000-ZKS-0040	19

Keywords
Eelgrass, seagrass, *Zostera marina*, restoration, Wadden Sea, Water Framework Directive

Summary
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. This report is an update with the latest monitoring data, collected in late summer 2013. At all three locations the Eelgrass population has increased substantially. Also two new locations have been identified with a substantial amount of eelgrass plants. These likely originate from the Uithuizen deployment location. This confirms the hypothesis that there is indeed suitable habitat for this species in the Wadden Sea. Whether this restoration effort is large enough for long-term reintroduction cannot yet be concluded.

Version	Date	Author	Initials	Review	Initials	Approval	Initials
	nov. 2013	dr. L.A. van Duren dr. M.M. van Katwijk		drs. J.A. van Dalfsen		drs. F.M.J. Hoozemans	

State
final

Contents

1 Background

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 since the nineties, the area of suitable habitat has likely increased. In Germany, Eelgrass has shown a remarkable recovery in the intertidal area. 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 (Pickerell et al. 2005, Marion and Orth 2010). The method was adapted to be used in the intertidal in the Wadden Sea.
In Van Duren et al. (2013) a full account has been presented with details of the methodology, the preliminary work, the results from the first monitoring campaign in 2012 after the first deployment etc. This report is an update of this report presenting the data of the eelgrass distribution observed in 2013, after the second year of deployment.

1.1 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*) and of Dwarf eelgrass (*Zostera noltei* formerly and more commonly known as *Z. noltii* (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.

1.2 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 takes 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 collections were carried out – 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 have been carried out in two consecutive years. The collection of inflorescences and the deployment of the seed bags were carried out by the Fieldwork Company and volunteers of the Wadden Vereniging, supervised by Deltares and Ecoscience. 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 has been monitored by a local research institute (the Alfred Wegener Institut on Sylt). This group also carried out the effect monitoring on Sylt. The two consecutive years of eelgrass harvesting has not resulted in any appreciable effect on the donor population (Van Duren et al. 2013).

2 Deployment locations (2011 and 2012)

Full details for the arguments supporting the location choices can be found in (Van Duren et al. 2013).

2.1 Uithuizen

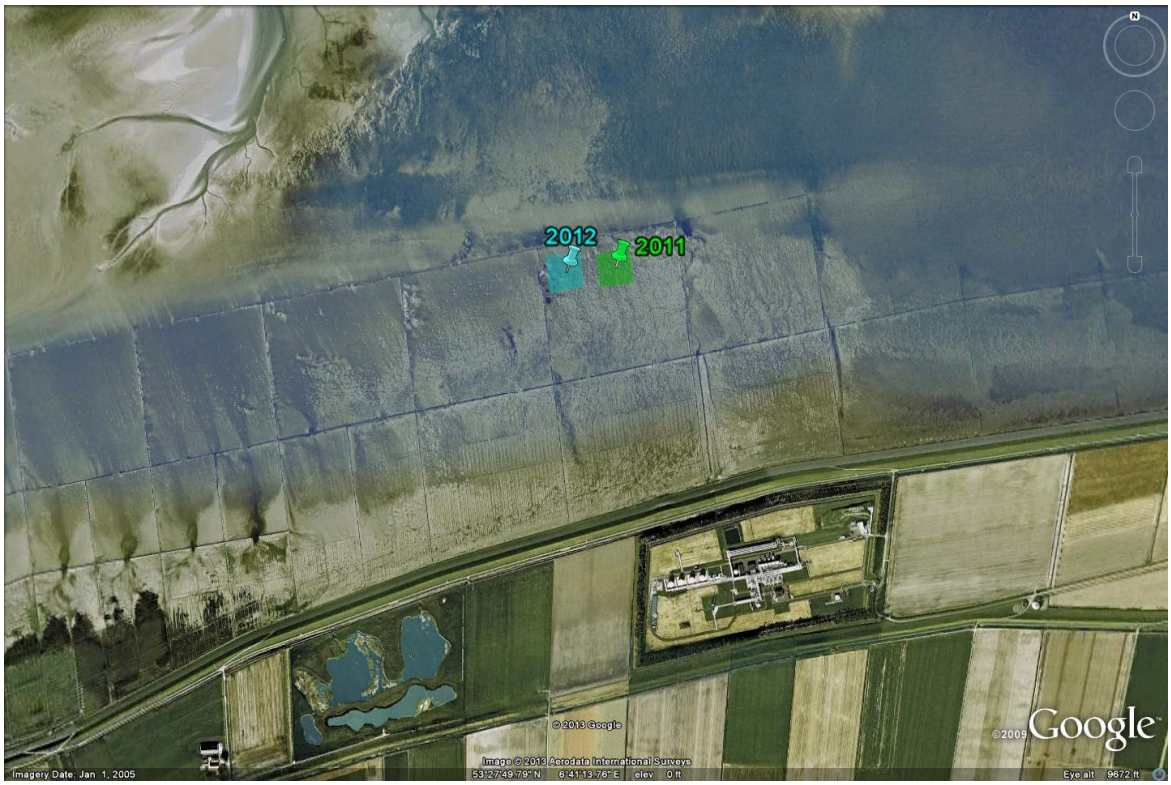

Figure 2.1: Locations at near the Saltmarshes in North Groningen. The green square indicates the 2011 deployment location, the light blue square is the deployment location used in 2012.

Near Uithuizen the 2011 a location site was selected 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''.
The choice for the 2012 deployment site was 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''.

2.2 Balgzand

Figure 2.2: Balgzand deployment locations, the 2011 area is indicated in green, the 2012 deployment is indicated in light blue.

The 2011 plot at Balgzand was 250 x 40 metres and the centre was located at N 52°55'30'' and E 4°47'59". For 2012, a deployment location slightly further south was selected. 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 rectangles 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.

2.3 Schiermonnikoog

Figure 2.3: Schiermonnikoog locations. The 2011 is indicated in green, the 2012 location in light blue.

The 2011 location at Schiermonnikoog 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 a little closer to the dike, with the centre at N 53° 28' 10.22'' and E 6° 10' 24.75''.

3 Data collection on Eelgrass distribution

3.1 Annual monitoring in the vicinity

A comprehensive seagrass monitoring within the national monitoring framework (MWTL) is carried out every 3 years. Specific monitoring following the same methodology is carried out annually in the immediate vicinity of the deployment sites. The first monitoring of 2012 indicated that there was a bit more dispersal of seagrass around the deployment site than was initially expected, based on the sinking velocity of the seeds. In the current (2013) monitoring the survey was carried out over a somewhat larger area than in 2012, taking wider margins surrounding the deployment areas.

A full description (in Dutch) of the surveying method can be found in the RWS-CIV reports. (Bergwerff and Buiks 2012, Pranger and Tolman 2013). The field work is carried out using a grid method. Each of the three areas is 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. noltei*, 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 are given in table 1.

In 2013 the monitoring was carried out by *Maatschap Pranger and Tolman ecologen*. This company will also carry out the subsequent monitoring in 2014 and 2015. The 2012 monitoring had shown a dispersal of eelgrass at a relatively large distance from the deployment area. In 2013 the monitoring covered a wider perimeter around the deployment areas, in order to be sure the full extent of the eelgrass cover around the deployments of both 2012 and those of 2011 was covered. Deltares and Ecoscience supplied some additional observations with respect to flowering and seed maturation.

Code	Cover (%)	Surface area (m^2)
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

3.2 Eelgrass observations reported by the public via the RWS website

The targeted monitoring only gives data with respect to the distribution of eelgrass in the immediate vicinity of the deployment areas. In 2012, the first year after a deployment, it was unlikely that seagrass from our project would emerge at any great distance from the deployment sites. However, as the eelgrass was observed to produce inflorescences with healthy looking seeds, these were expected to disperse naturally and have the potential to end up at significant distances from their origin.

In order to get some additional information about dispersal of eelgrass, Rijkswaterstaat has on their websites a notification form where members of the public can report sightings of eelgrass. This form can be found at:
https://www.rijkswaterstaat.nl/formulieren/aanmeldformulier_zeegras.aspx.

The Waddenvereniging has throughout the season given some extra publicity to the existence of this site and several notifications have been received there. Although it is clearly not possible to definitively link these sightings to the eelgrass that developed in 2012 at the 2011 deployment sites, it does give valuable additional information – certainly on the availability of suitable eelgrass habitat.

4 Monitoring observations

On all three locations a good crop of eelgrass was observed in 2013. As the exact location of the 2012 deployment on Balgzand was separated from the 2011 location by several hundreds of meters, it was interesting to observe that the 2011 locations were still recognisable in the field on the basis of the eelgrass dispersal. On Schiermonnikoog the original 2011 location was also still discernible by having the highest densities.

4.1 Uithuizen

4.1.1 Cover

This location was surveyed on 12-13, 17-18, 28-31 August and 1, 4 and 7 September.

Uithuizen		
	2012	**2013**
Number of surveyed cells	980	5098
Number of cells containing *Z. marina*	297	2884
Number of cells containing *Z. noltei*	751	not recorded
Number of cells containing *R. maritima*	0	0

In 2013 a five times larger area was surveyed than in 2012. The blue lines in Figure 4.1 indicate outline of the extent of the eelgrass cover in 2012. Note that in 2012 the cover at the edges was rather patchy and the surface area within the indicated blue line contained quite a few empty cells. In 2012 it was clear that not the full extent of the distribution was recorded, although the cells furthest away from the deployment area had very low densities. The full area of eelgrass cover in 2012 may therefore have extended slightly further – particularly to the north east, but even taking that into account, it is safe to say that the area where eelgrass occurred had increased in comparison to the previous year.
Generally cover falls in the category, but the two cells with densities of up to 5% were located within the perimeter of the 2012 deployment area.

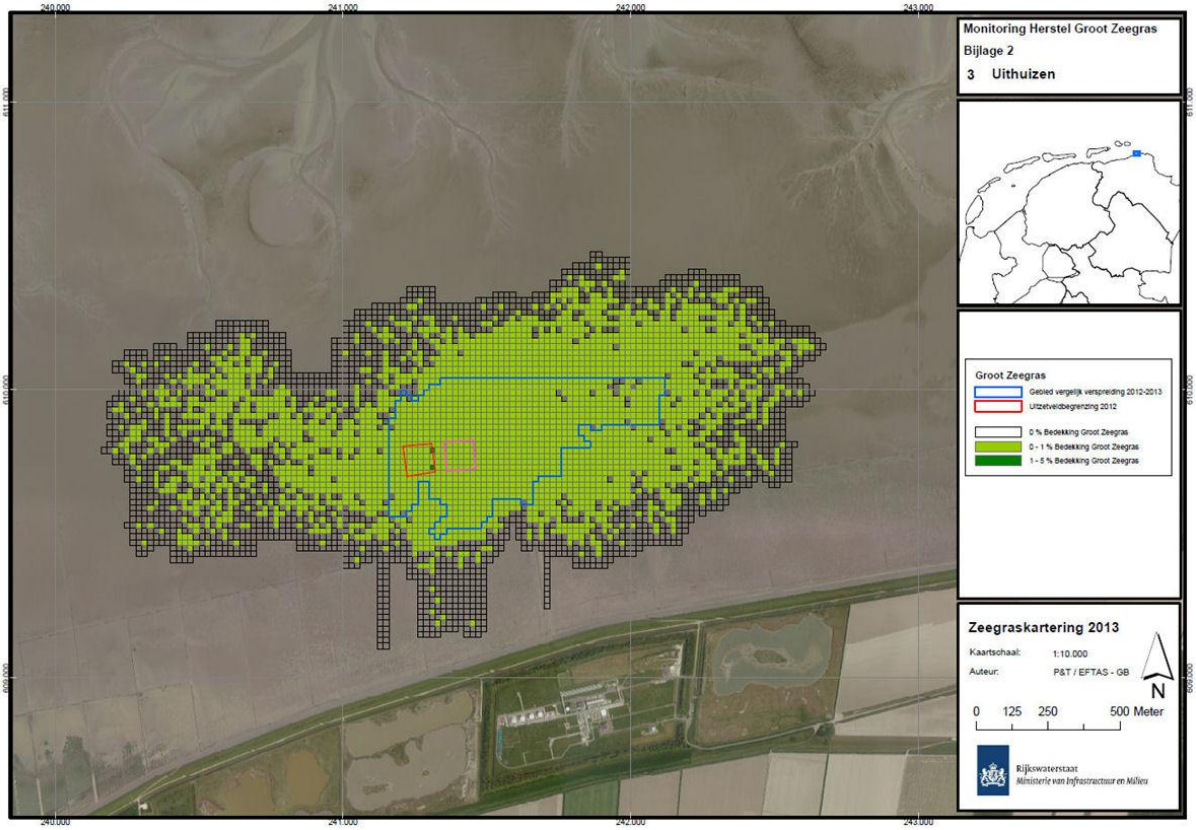

Figure 4.1: Surveyed area at Uithuizen. Light green patches represent 0-1% cover; darker green represents 1-5% cover. The blue line indicates perimeter of the extent of the eelgrass cover in 2012. The red box indicates the deployment locations of 2012, pink represents the 2011 deployment.

The Uithuizen site is characterised by a significant population of dwarf eelgrass (*Z. noltei*). Dwarf eelgrass prefers a slightly higher elevation, but part of the meadow consists of a mix of *Z. marina* and *Z. noltei*. Contrary to 2012, no quantitative data had been collected on dwarf eelgrass. Qualitative observations indicated a good crop of dwarf eelgrass with at least a similar or slightly larger cover than in 2012.

4.1.2 Vitality and seed development

All plants looked healthy, ranging in size from 20-70 cm (Figure 4.2). Early August plants were still flowering and little evidence of seed development was seen. Late August the presence of seed was recorded, and early September there were clear signs of senescence in the plants (brown colouring).

Figure 4.2 A: Uithuizen, 14 August 2013, locally high plant densities, B: Plants looked healthy and vigorous, although closer inspection revealed that flowers seemed to decay before seeds were ripe. Photos: Marieke van Katwijk.

4.2 Balgzand

This location was surveyed on on 15-16 August. Similar to 2012, this location was characterised by large amounts of macroalgae, specifically *Ulva lactuca* and filamentous algae. Cover of these macro algae far outweighs the cover of Eelgrass.

4.2.1 Cover

Balgzand		
	2012	**2013**
Number of surveyed cells	256	981
Number of cells containing *Z. marina*	118	467
Number of cells containing *Z. noltei*	0	1
Number of cells containing *R. maritima*	1	4

The distribution of eelgrass on Balgzand is shown in Figure 4.3. There are clearly two centres with high distributions, corresponding to the deployment locations in 2012 and the one from 2011. Although there are sporadic observations of individual plants between the two areas, the density in the area halfway between the two successive deployments is very low.

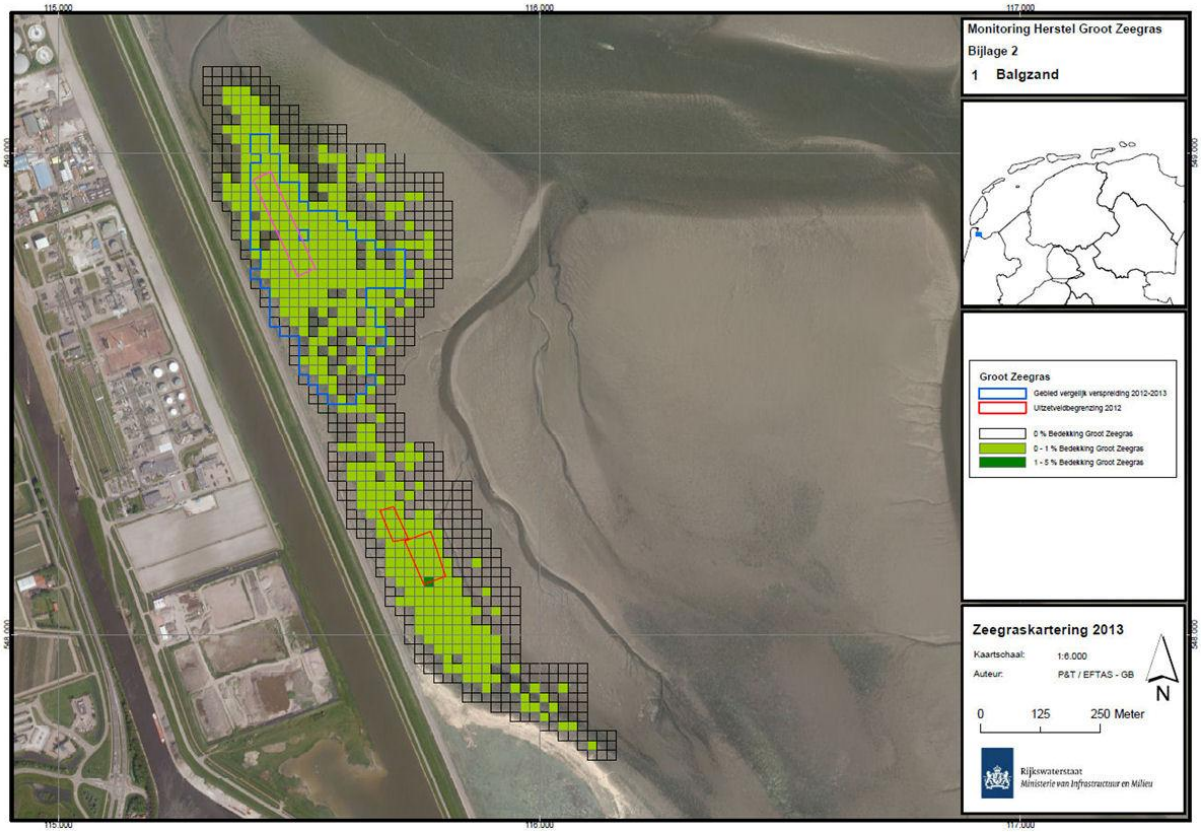

Figure 4.3: Surveyed area on Balgzand. Light green patches represent 0-1% cover; darker green represents 1-5% cover. The blue line indicates perimeter of the extent of the eelgrass cover in 2012. The red box indicates the deployment locations of 2012, pink represents the 2011 deployment.

4.2.2 Vitality and seed development

Plant vitality varied considerably on this location. The smallest plants were estimated to be about 15 cm, the largest individuals were around 60 cm. Mid-August many plants already showed signs of early decay. As in 2012, plants appear to be in worse condition at this site compared to the other two, probably due to the large amount of algae, partly smothering the eelgrass meadow (Figure 4.4A).

Very little seed development was observed. Although no quantitative observations were made, female inflorescences seem to outweigh male ones by a significant margin. Many unfertilised flowering plants were observed relatively late in the season, unlikely to produce mature seeds before the end of the growing season (Figure 4.4B)

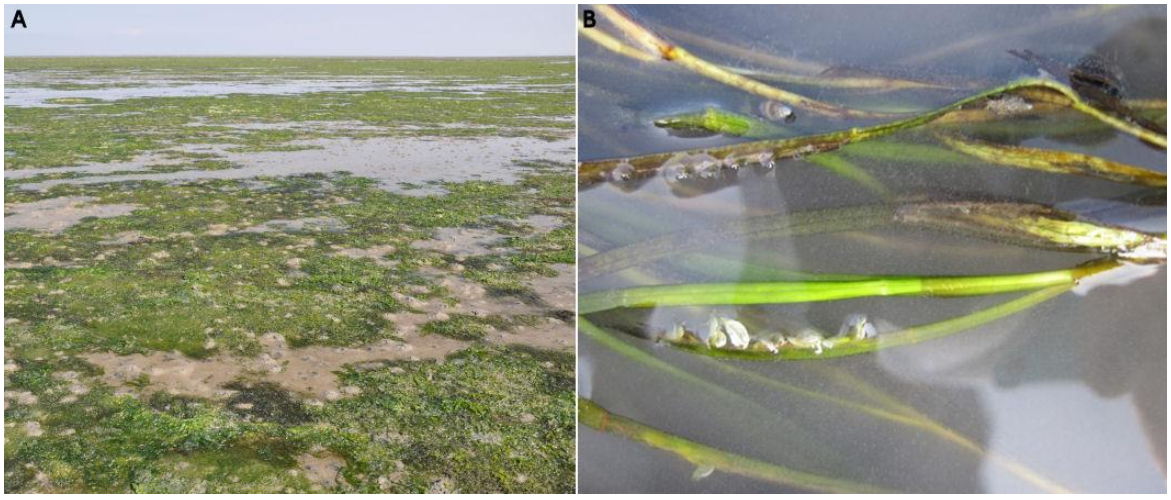

Figure 4.4: A: 4th of September at Balgzand near the 2011 deployment area. Very high cover with Ulva *and filamentous green algae, Eelgrass plants often covered by algae (Photo Luca van Duren). B: Male inflorescences were rarely encountered during visits mid-August and early of September. In contrast, female inflorescences (with styles touching the water surface) were flowering frequently, but often the (unfertilised) flowers were seen to decompose without signs of seed formation (Photo Marieke van Katwijk)*

4.3 Schiermonnikoog

This location was surveyed on 14 and 29 August.

4.3.1 Cover

Schiermonnikoog		
	2012	**2013**
Number of surveyed cells	271	1620
Number of cells containing *Z. marina*	140	1077
Number of cells containing *Z. noltei*	0	29
Number of cells containing *R. maritima*	0	0

The cover of eelgrass appears to have extended in comparison to the 2012 survey, although in 2012 the survey almost certainly did not cover the full extent of the dispersal around the deployment location. During the 2013 survey, a substantial amount of plants was observed relatively close to the dyke, an area that was not surveyed the previous year. Despite the fact that the eelgrass cover may have extended a bit further towards the north in 2012, it is clear that the eelgrass population has expanded considerably in 2013.

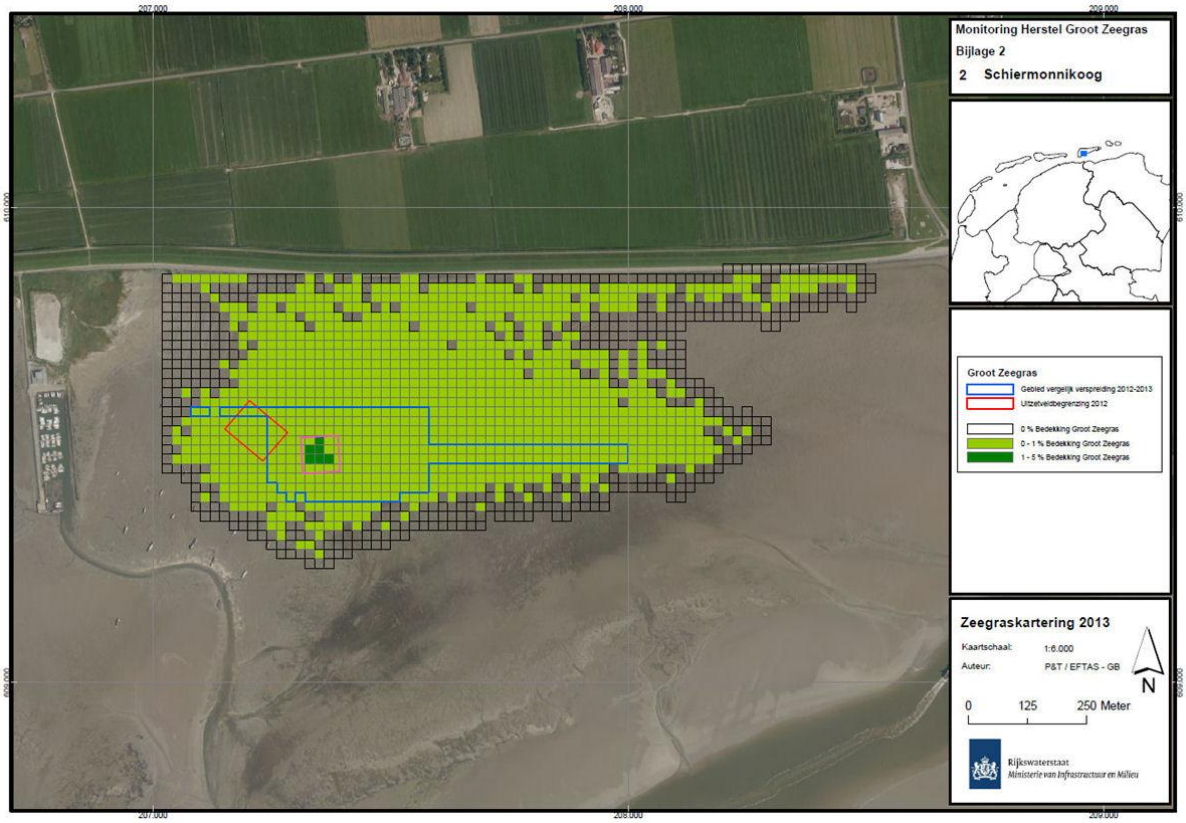

Figure 4.5: Surveyed area on Schiermonnikoog. Light green patches represent 0-1% cover; darker green represents 1-5% cover. The blue line indicates perimeter of the extent of the eelgrass cover in 2012. The red box indicates the deployment locations of 2012, pink represents the 2011 deployment.

Figure 4.5 shows the distribution on Schiermonnikoog. It is striking that the highest densities are found exactly within the perimeter of the 2011 deployment location (i.e. a location where in the previous year no seed bags had been deployed, Figure 4.6A).
Maximum densities ranged around 150 tussocks per survey cell (one tussock may contain one or several plants).

At this site 29 cells were observed to contain *Z. noltei*, all these cells were within the 2012 deployment perimeter. In previous years this species has not been observed at Schiermonnikoog, and it is virtually certain that these plants originate from dwarf eelgrass at Sylt, as the donor location is a mixed meadow.

4.3.2 Vitality and seed development

All plants at this location appeared healthy, the smallest plants measured around 20 cm and the largest ones 70-80 cm. Seed development was observed, although as in the other sites, development was late and fewer mature seeds were observed. From late August signs of senescence where observed, also in plants with seeds that has not reached maturation (Figure 4.6B).

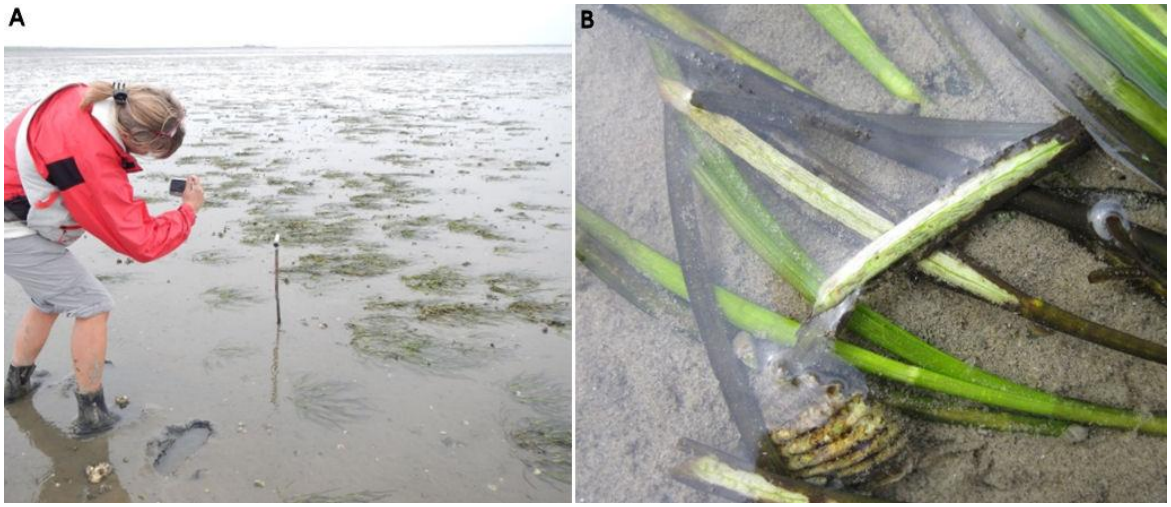

Figure 4.6 A: at Schiermonnikoog (15 August 2013), eelgrass reached high densities in the deployment location of 2011 (Photo Brigit van Tussenbroek). B: Three inflorescences with the base of the inflorescence visible (whitish green), because the shielding outer tissue (dark brownish) has degraded. This was also observed at Uithuizen on 14 August, and at Balgzand on 4 September (Photo Marieke van Katwijk).

4.4 Comparison with 2012

4.4.1 Cover

Despite the fact that in 2012 not the full extent of the eelgrass distribution was covered by the survey, it is very clear that there is an extension of the cover in 2013 in all three locations. A comparison has been made between the cells that were surveyed in 2012 and the same cells that were surveyed in 2013. The latter therefore being a sub-set of the full dataset of 2013.

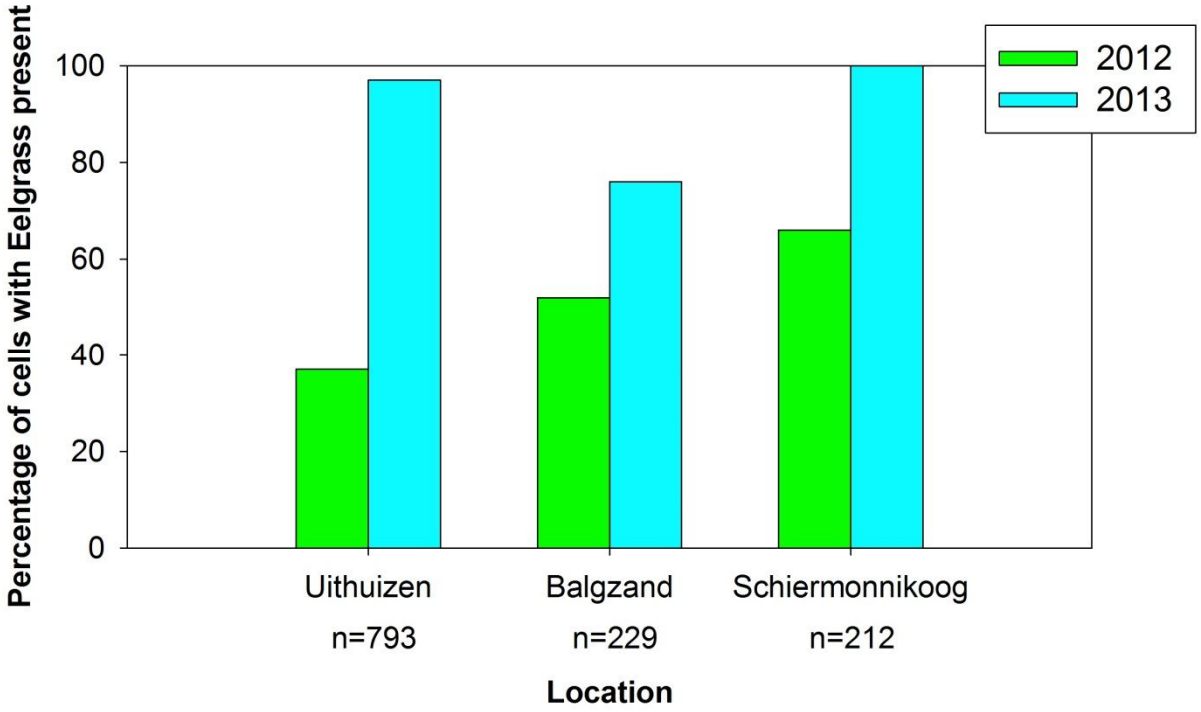

Figure 4.7: Comparison between 2012 and 2013 in terms of proportion of cells containing eelgrass; 100% being the total number of cells surveyed in both 2012 and 2013.

Figure 4.7 shows that there is a clear increase in all three locations, indicating that the cover in 2013 was less patchy than in 2012. Particularly for Balgzand this is remarkable, as on this site, the 2011 and 2012 deployments were several hundreds of metres apart. Here, the increase is therefore likely due to an expansion of the 2011 population, rather than an influence of the remote seeding from the 2012 deployment.
Only the odd cell that contained eelgrass in 2012 did not contain eelgrass in 2013 at any of the sites.

4.4.2 Vitality and seed development

In both years most plants appeared predominantly healthy and vigorous. Balgzand is a bit of an exception as it tends to have a relatively high proportion of plants with discolourations, almost certainly due to the large amount of decaying algae at this site. There was no indication that the condition of the leaves or the average size of the plants showed marked differences between the years.
Although neither in 2012 or 2013 seed development was quantified, all observations indicate that seed development in 2013 was conspicuously later and also less than in the previous year. There seemed to be relatively few male inflorescences at all sites in 2013.

5 'New' eelgrass locations reported via the website

5.1 Eilanderbalg

After receiving a notification of several *Z. marina* plants near buoy EB7 at Eilanderbalg, employees of RWS CIV (formerly DID) decided to carry out a preliminary inventory, in order to assess whether this location ought to be taken up in the regular monitoring program. Figure 5.1 indicates the route taken for location with respect to other landmarks in the Wadden Sea, see Figure 5.5.

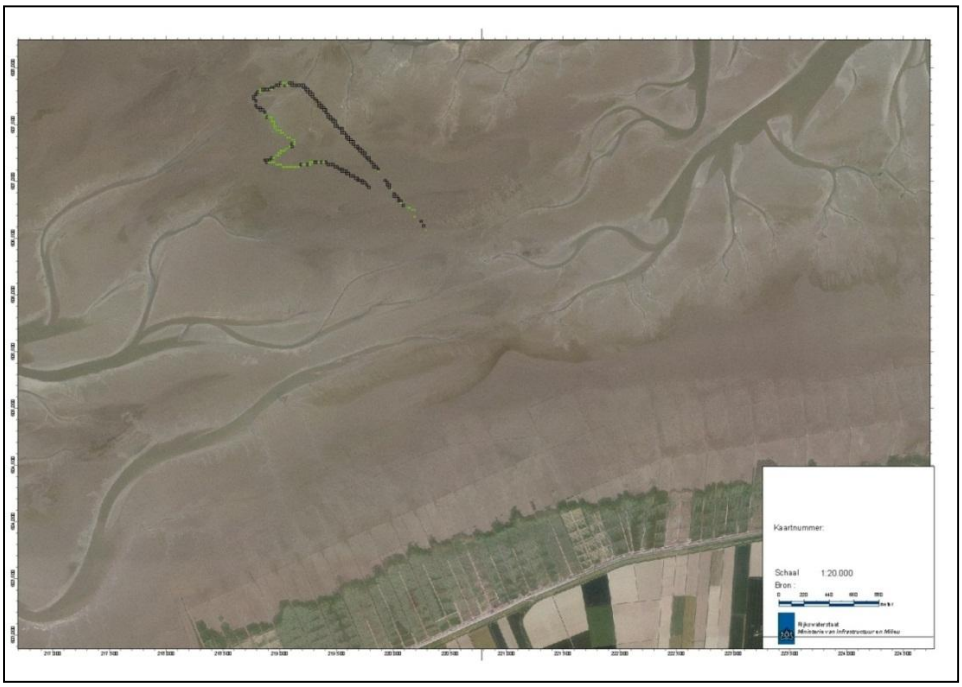

Figure 5.1: surveyed area by the CIV team for location of this area with respect to other locations in the Wadden Sea see figure 5.5. Green cells indicate the presence of eelgrass plant, empty cells are surveyed but did not contain any plants.

The area was not comprehensively surveyed. In total 211 cells have been surveyed and in 72 cells Eelgrass plants were observed. A small field with a few plants was observed slightly further south towards the saltmarsh and a larger field (roughly estimated at 400 x 600 m, i.e. 24 Ha, Figure 5.2).
The larger patch was very diverse in terms of density, ranging from 1 to 50 plants per survey cell. Based on an estimate of the average cover and the total area, the team estimated the total number of plants at this location between 1000 and 1500.

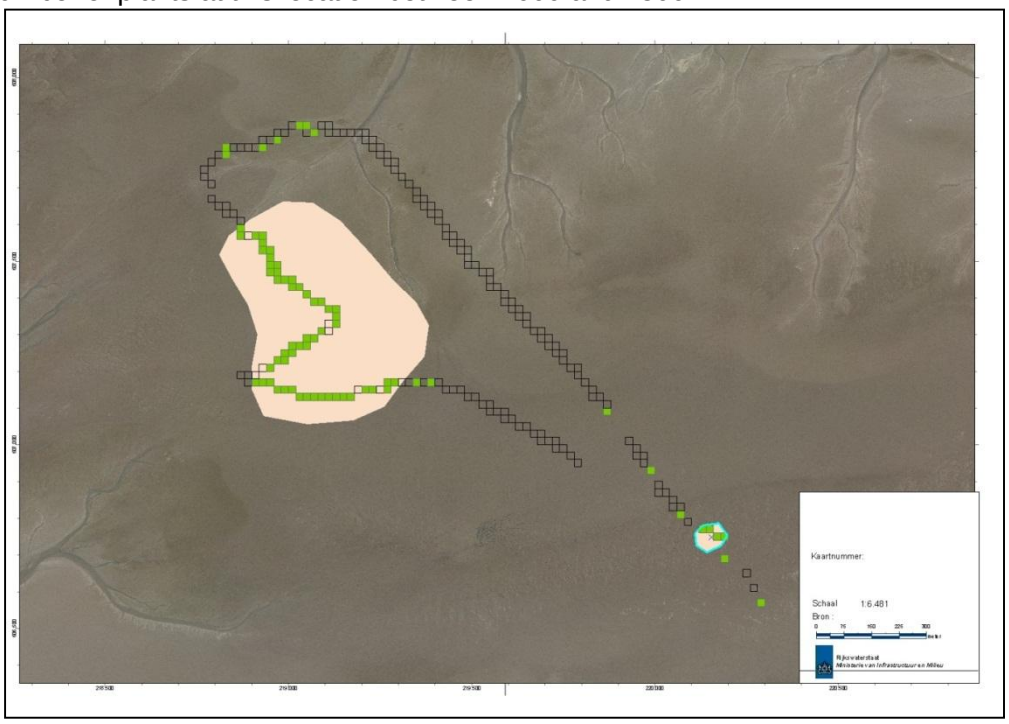

Figure 5.2: Detail of the surveyed area with a qualitative indication of the extent of the eelgrass patches. Green cells indicate the presence of one or more plants of eelgrass

The plants appeared healthy, with dense leaves Figure 5.3. Smaller plants were ranging between 10 and 15 cm, the largest ones reaching up to 1m. Some seed development was observed.

Figure 5.3: Plants with inflorescences at EB7 buoy, photo RWS-CIV

5.2 Observations Norbert Dankers at Rottum

Several plants of *Z. marina* were observed on the 25th of September 2013 at Rottum by a group of researchers from IMARES. The plants were on average 20-50 cm in size and appeared healthy. They also contained ripening inflorescences. The locations of some individual plants are indicated in Figure 5.4.

Figure 5.4: Locations of observed plants on Rottum

5.3 Other sightings

There have been a few other incidental reports on the seagrass sight, but these all concerned reports of individual plants. These sightings have not been followed up.

5.4 Locations with respect to deployment sites

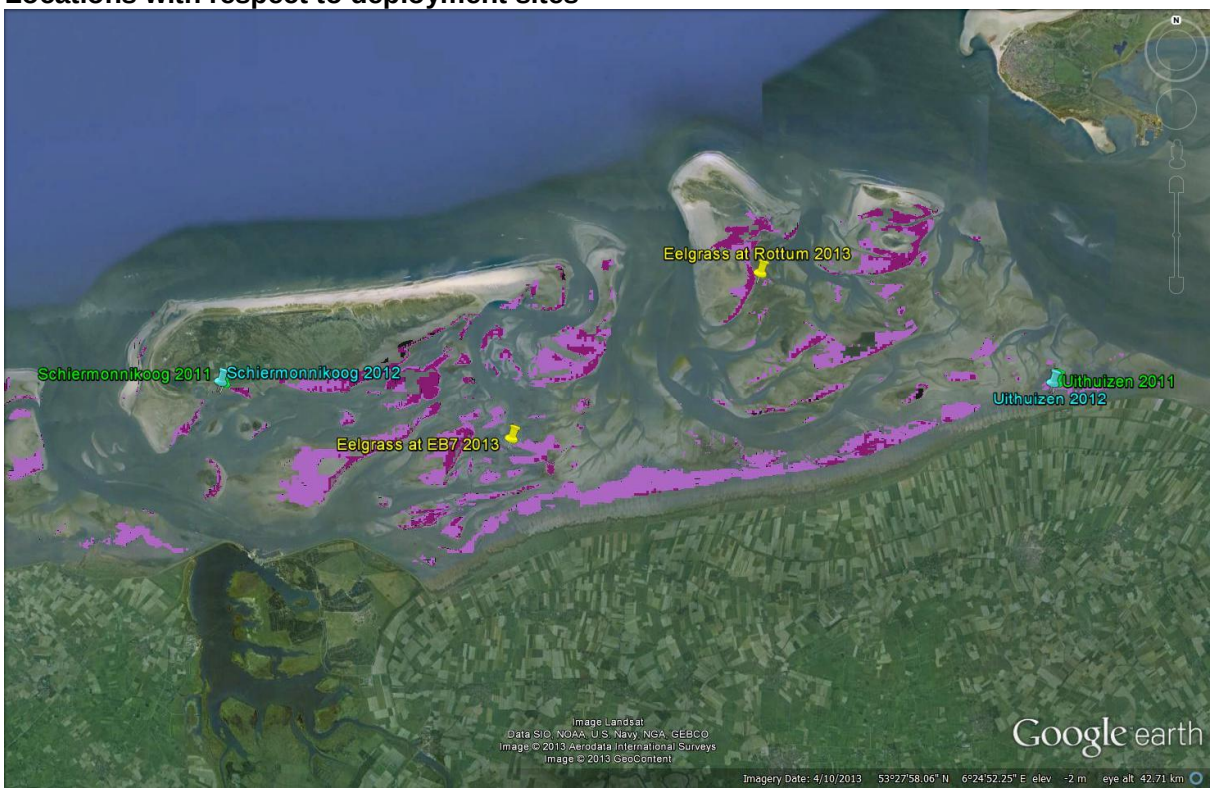

Figure 5.5: Two "new" eelgrass locations with respect to the two nearest deployment locations and with the habitat suitability map plotted in the background. Purple colours indicate locations that are on the basis of models and expert judgement deemed to be suitable for seagrass.

Both reported 'new' eelgrass sites are located between the Uithuizen deployment and the Schiermonnikoog deployment. Both sites are also very near sites that were identified in 2006 as "suitable or partially suitable for eelgrass"(De Jong et al. 2005).

6 Discussion

6.1 Habitat suitability

It is clear that the locations that were chosen based on the habitat suitability maps and expert judgement in the field are indeed suitable. The fact that the two observed "new" locations are also very close to sites that according to the habitat suitability map ('*zeegraskansenkaart*', De Jong, 2005), indicates the value of this map. One of the factors determining habitat suitability for eelgrass is elevation. As the Wadden Sea is a highly dynamic area with shifting gullies and mudflats one has to observe some level of caution in using such a map from 2006. On a very small scale (tens of metres) suitable areas may have shifted. However, on a larger (hundreds of metres) scale we still expect locations that were deemed suitable in 2006 to be in roughly the same location.

Another important parameter of the habitat suitability map is wave exposure. Certainly for future reference it may be good to be aware that the 2006 map was made with a fairly crude flow and wave parameterisation. Currently there are better hydrodynamic models available. As the Wadden Sea area is dynamic and because certain other parameters determining habitat suitability, such as nutrient loading are gradually changing over time, it is probably sensible to update these habitat suitability maps every 10 years or so. This would also give an indication if the potential habitat for eelgrass is increasing or decreasing. It would also indicate if large-scale changes are taking place with regard to suitable areas. Identification of very specific sites (e.g. new deployment areas for other restoration projects) will still have to be done in the field. Even with better and more accurate models, predictions on the scale of tens of meters will not be feasible.

6.2 Hypothesis of seed limitation

This project was started on the basis of the hypothesis that there is currently in the Wadden Sea much more suitable habitat for Eelgrass than the distribution in 2010 showed. The reason for the lack of recovery in the Netherlands compared to the German Wadden Sea was assumed to be limitation of seed availability, as the intertidal variety of *Z. marina* for the most part has to regrow from seed every year. Although it is too early for a firm acceptation of this hypothesis, the current data are certainly in support of this theory.

6.3 Dispersal

6.3.1 Around the deployment locations

The fact that the original deployment locations of 2011 are still recognisable in the field (on Balgzand as a distinct location, spatially separated from the 2012 one; on Schiermonnikoog as the location with the highest local density of plants) indicates that a substantial proportion of the produced seeds actually very locally and do not disperse at all. This may be a different in permanently submerged eelgrass populations.

This is in terms of a restoration technique very promising. On one hand, the aim of the exercise is of course for the created eelgrass meadows to act as a source population for further dispersal. On the other hand, good local retention assures that also the original site will be repopulated the subsequent year.

6.3.2 Origin of the two “new” sites.

As the only definitive proof of origin would be DNA testing, we cannot state categorically that eelgrass on the site on Rottum and the site near the EB7 buoy originate from our 2011 deployment sites. However, when we look at the results of the dispersal models from the study of Erftemeijer and Van Katwijk (2010) it appears most likely that they both originate from the Uithuizen location (Figure 6.1). Although the EB7 site is closer to Schiermonnikoog than to the Uithuizen location, it is actually just on the other side of the tidal division (Figure 6.2). There is a net sediment flux across the watershed, but transport of water across the tidal division is limited. Although it is possible that some floating material from Schiermonnikoog makes it across, the dispersal models indicate that material from Uithuizen is much more likely to end up in this area. Certainly for the EB7 site, it seems very unlikely that this patch originates from anywhere else than one of the 2011 deployments (most likely Uithuizen), as there are no known other sources in the vicinity.

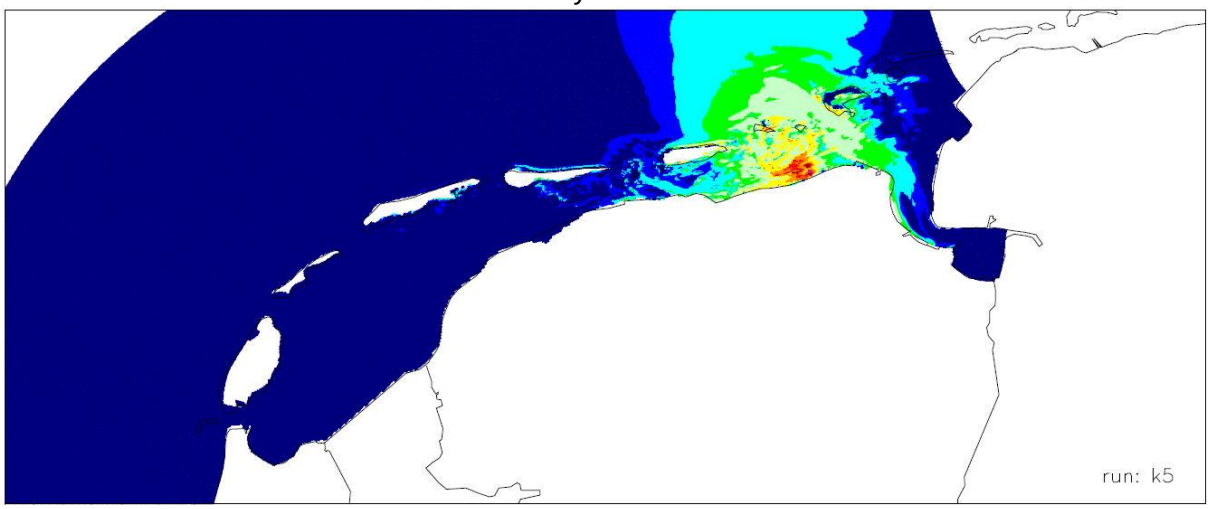

Figure 6.1: dispersal model results with seeds released at Uithuizen (Erftemeijer and Van Katwijk 2010).

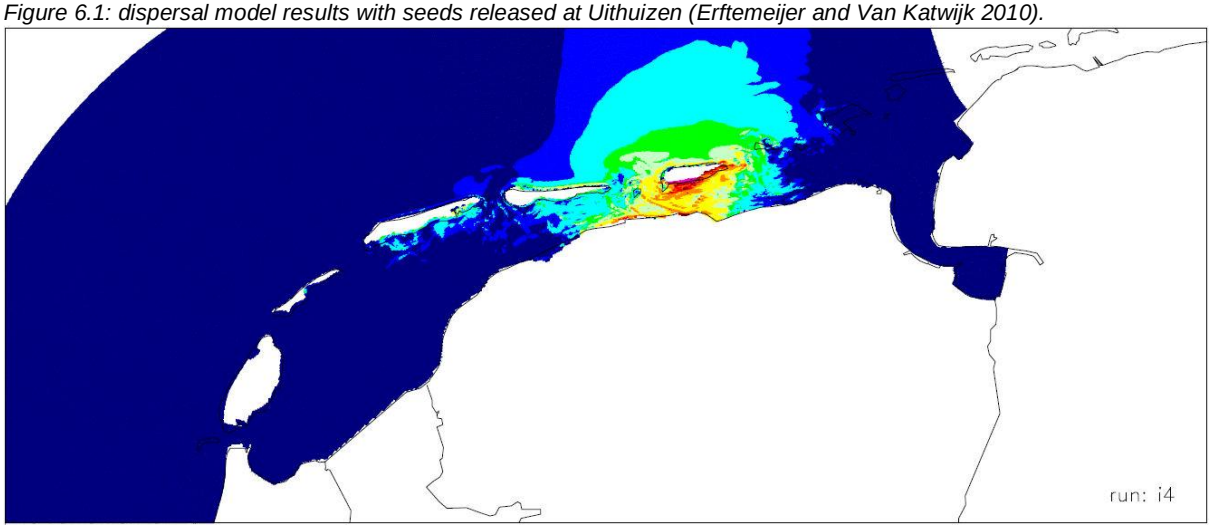

Figure 6.2: dispersal model results with seeds released at Schiermonnikoog (Erftemeijer and Van Katwijk 2010).

Also the Rottum site is right in the area where floating material from Uithuizen is most likely to end up (Figure 6.1). However, for these plants it is possible that they originate from the Dollard area, e.g. from the Hond and the Paap, where until 2009 the last significant population of *Z. marina* was observed. These sites were in decline over the past few years, but have not been surveyed since 2011. Another option is that it originates from German sites across the border

6.4 Seed development – outlook for next year

In 2012 there was a brief period with very sharp frost (<-15 °C for several nights) in February, resulting in ice floes. This cold spell only lasted a couple of weeks. The spring was mild and eelgrass developed relatively early in the Dutch Wadden Sea and also in the German Wadden Sea around Sylt (Karsten Reise pers. Comm). Although temperatures were not so extremely low in the winter 2012/2013, there was a very long protracted period of cold weather in spring. From mid-January until late March – early April, daily average temperatures ranged around freezing point and night time temperatures were rarely above freezing (Figure 6.3).

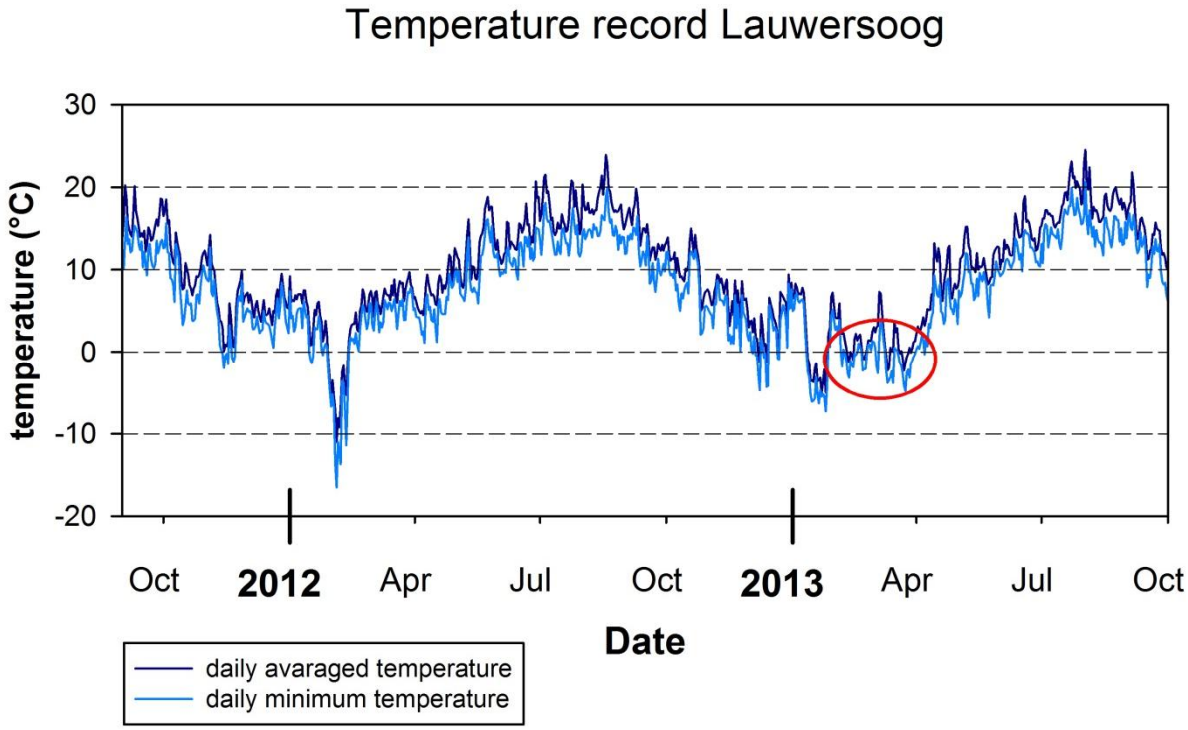

Figure 6.3: temperature record at Lauwersoog from 1 September 2011 – 1 October 2013; red oval indicates cold spell in spring 2013)

This cold spring appears to have resulted in a very late development of seeds. Whereas seeds were already well-developed in late July 2012, only halfway through August was the first seed observed in the Dutch Wadden Sea in 2013.

Figure 6.4: Picture taken on the 4th of September, eelgrass flowers on a plant showing signs of decay. Photo: Luca van Duren; see also similar pictures in section 4.

During visits in Augusts to Uithuizen en Schiermonnikoog and during a visit in September to Balgzand several plants were observed to still have flowers, rather than inflorescences with seed. Older flowers seemed to decay rather than develop seed. During these visits, very few male flowers were encountered, although no quantitative observations were made on the sex-ratio of flowers. It is possible that many flowers remained unfertilised due to pollen deficiency, but this remains speculative. Very few well-developed inflorescences with (nearly) ripe seeds were seen.

In 2012 ripe seeds were observed much more frequently. Inspection of plants that were collected in Sylt, mid-September 2013 (for a different restoration project in Zeeland) also showed more mature seeds and no signs of unfertilised, decaying flowers.

As the monitoring indicated that eelgrass plants on Balgzand were generally in a worse condition than the plants on Uithuizen or Schiermonnikoog, the after-effect of the cold spring may have affected this site stronger than the other sites. However, as development on the other sites was also relatively late, it is to be expected that a significant proportion of the 2013 seed production will not come to full maturation. In other words: we may have to be prepared for a lower success rate in 2014.

6.5 Critical mass hypothesis

The other main hypothesis that this project is testing is that in order to ensure long-term survival of Eelgrass any restoration effort needs to be large-scale. Recruitment varies strongly year-to-year. A restoration site needs to be large enough to survive a few successive ‘bad’ years. It will take several years to assess whether the effort from the current project has been large enough to create sufficient critical mass.

In 2013 no new seed bags were deployed in the Wadden Sea. It currently looks like the cold spring may cause limited recruitment in 2014. Purely from a restoration point of view, it would have been much more desirable to have a number of consecutive 'good' years to build up the eelgrass population before it has to overcome a bad recruitment year. From a scientific point of view is interesting to see if the recent success in establishing a population is sufficient for a long-term return of Eelgrass. If 2014 indeed turns out to be a poor year in terms of recruitment, next year should yield very valuable information with respect to the robustness of such restoration efforts.

The initial success of this project has received a lot of attention and there are a number of initiatives and ideas among NGOs and managing authorities (national and local) to expand the restoration effort to other areas. A consortium of NGOs has submitted a proposal to the "Waddenfonds" for additional restoration efforts in the vicinity of the current deployments.

From a strictly scientific point of view it would be advisable to wait and see how the current population develops over the next few years. However, from a conservation point of view, the current success might be too good an opportunity to miss. The impetus created by the publicity surrounding this project may facilitate obtaining grants for new projects and new initiatives should be welcomed. However, for the evaluation of the longer term effect of this project it would be advisable to refrain from new deployments too close to the ones from the current project. Certainly, any new initiatives need to be well communicated and discussed with the current project team.

7 References

Bergwerff, J. W. and J. Buiks. 2012. Monitoring Herstel Groot Zeegras Waddenzee 2012. RWS - Data-ICT-Dienst.

De Jong, D. J., M. M. van Katwijk, and A. G. Brinkman. 2005. Kansenkaart Zeegras Waddenzee: Potentiële groeimogelijkheden voor zeegras in de Waddenzee. RIKZ.

Erftemeijer, P. L. A. and M. M. Van Katwijk. 2010. Zeegrasproef Waddenzee. Grootschalig zeegrasherstel in de Nederlandse Waddenzee door middel van zaadverspreiding. Deltares, Delft.

Marion, S. R. and R. J. Orth. 2010. Innovative techniques for large-scale seagrass restoration using *Zostera marina* (eelgrass) Seeds. Restoration Ecology **18**:514-526.

Pickerell, C. H., S. Schott, and S. Wyllie-Echeverria. 2005. Buoy-deployed seeding: Demonstration of a new eelgrass (*Zostera marina* L.) planting method. Ecological Engineering **25**:127-136.

Pranger, D. P. and M. E. Tolman. 2013. Monitoring Herstel Groot zeegras Waddenzee 2013. BM13.22, Rijkswaterstaat CIV, Delft.

Rijkswaterstaat. 2009. Programma Rijkswateren 2010-2015, Uitwerking Waterbeheer 21e eeuw, Kaderrichtlijn Water en Natura 2000. Rijkswaterstaat, Lelystad.

Van Duren, L. A., M. M. Van Katwijk, J. Heusinkveld, and K. Reise. 2013. Eelgrass restoration in the Dutch Wadden Sea; Methodology and first results. 1203892-000-ZKS-0033, Deltares.

www.deltares.nl

Deltares