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# Eelgrass restoration in the Dutch Wadden Sea

## Results 2014

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**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 2014 monitoring data of the 2011 and 2012 deployments in the Dutch Wadden Sea. At all three locations the Eelgrass population has decreased substantially compared to the 2013 distribution. This is likely due to the diminished seed development observed in 2013. The results so far indicate that although there appears to be sufficient suitable substrate in the Dutch Wadden Sea, seed supply is restrictive for the natural recovery of the species. The restoration efforts within this project have probably been insufficiently large to ensure the long-term re-establishment of the species in the Dutch part of the Wadden Sea

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# 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. In a subsequent report the results of 2013, after the second year of deployment were reported (Van Duren and Van Katwijk 2013). This current report is an update presenting the data of the eelgrass distribution observed in 2014. This is the first year in this project where in the previous season no active restoration efforts were carried out.

## 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 noltii or Z. nana* also known as *Z. noltei* (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

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’’ (Figure 4.1).

## 2.2 Balgzand

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 (Figure 4.4).

## 2.3 Schiermonnikoog

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’’ (Figure 4.7).

# 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 2013 monitoring the survey was carried out over a somewhat larger area than in 2012, taking wider margins surrounding the deployment areas. The current 2014 survey covered the deployment locations and a minimum distance of 100 m surrounding the deployment locations until at least 2 empty cells were detected at the periphery. In 2014 also the full MWTL survey covering all Eelgrass locations in the whole Wadden Sea has taken place. This report concentrates on the targeted monitoring around the deployment sites and some additional observations at “Eilanderbalg, where in 2013 a new relatively large area with eelgrass was observed that likely originated from the 2011 deployment.

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, Tolman and Pranger 2014). 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. 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 are given in table 1.

| 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 |

In 2013 the monitoring was carried out by *EGG consult Pranger & Tolman ecologen*. This company will also carry out the subsequent monitoring in 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. This was continued in the 2014 monitoring.

In 2013 an additional location site was observed where eelgrass had established itself, likely originating from eelgrass that emerged after the 2011 deployment. In 2013 some extra observations were carried out to get a rough estimate of the size of the patch. This patch was revisited in 2014 (Bergwerff 2014).

## 3.2 Eelgrass observations reported by the public via the RWS website

In 2013 Eelgrass was reported by members of the public and researchers from IMARES at other locations via the RWS web-form:
https://www.rijkswaterstaat.nl/formulieren/aanmeldformulier_zeegras.aspx.
In 2014 no new locations have been reported.

# 4 Monitoring observations at deployment locations

On all three locations some eelgrass was observed in 2014, but in all cases considerably less than in 2013. Likely due to the extremely long protracted period of frost in spring 2013, seed development in 2013 was very late and very low. A reduced distribution and density was therefore expected. There were however very large differences in the sizes of the remaining populations.
The report below concentrates on the targeted monitoring around the deployment areas.

## 4.1 Uithuizen

### 4.1.1 Cover

This location was surveyed on 7, 12,13,14,16,30 and 31 July 2014.

| **Uithuizen** | | | |
|---|---|---|---|
| | **2012** | **2013** | **2014** |
| Number of surveyed cells | 980 | 5098 | 624 |
| Number of cells containing *Z. marina* | 297 | 2884 | 29 |
| Number of cells containing *Z. noltii* | 751 | not recorded | 264 |
| Number of cells containing *R. maritima* | 0 | 0 | 0 |

In 2014 eelgrass cover was very severely diminished at this location compared to 2013. Also the density within survey cells was low; the maximum number of eelgrass clumps within a grid cell was 2. The spread of eelgrass is predominantly due eastward with respect to the deployment locations.

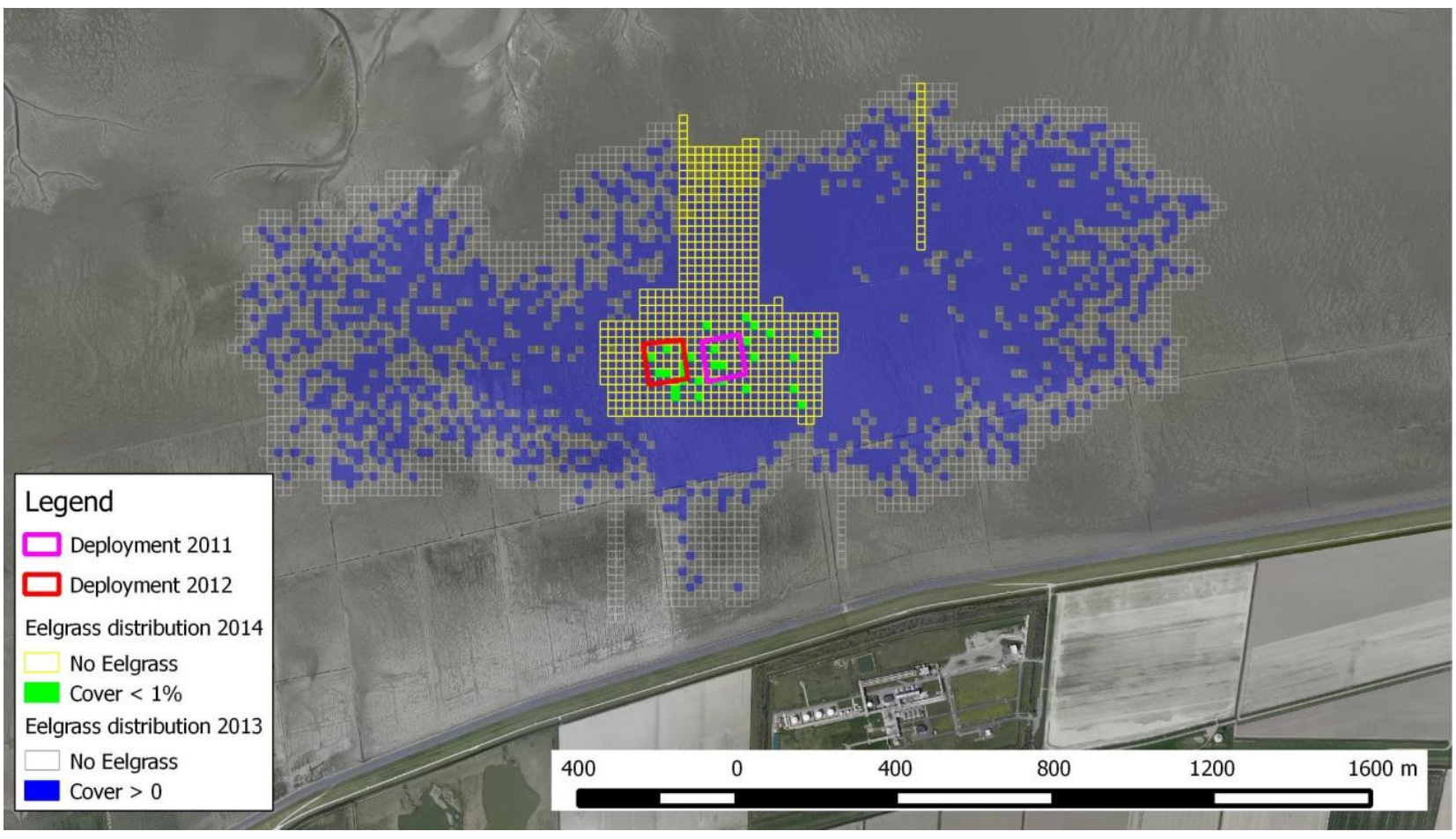


*Figure 4.1: Surveyed area at Uithuizen. Light green patches represent 0-1% cover. The blue squares indicate the extent of the eelgrass cover in 2013. The red box indicates the deployment locations of 2012, pink represents the 2011 deployment.*

The Uithuizen site is characterised by a significant population of dwarf eelgrass (*Z. noltii*). Dwarf eelgrass prefers a slightly higher elevation, but part of the meadow consists of a mix of *Z. marina* and *Z. noltii*. In 2013, Dwarf eelgrass had not been quantified, but in comparison to the distribution of 2012, also the cover of this species seems to have reduced, although nowhere near to the same extent as *Z. marina* (Figure 4.2).

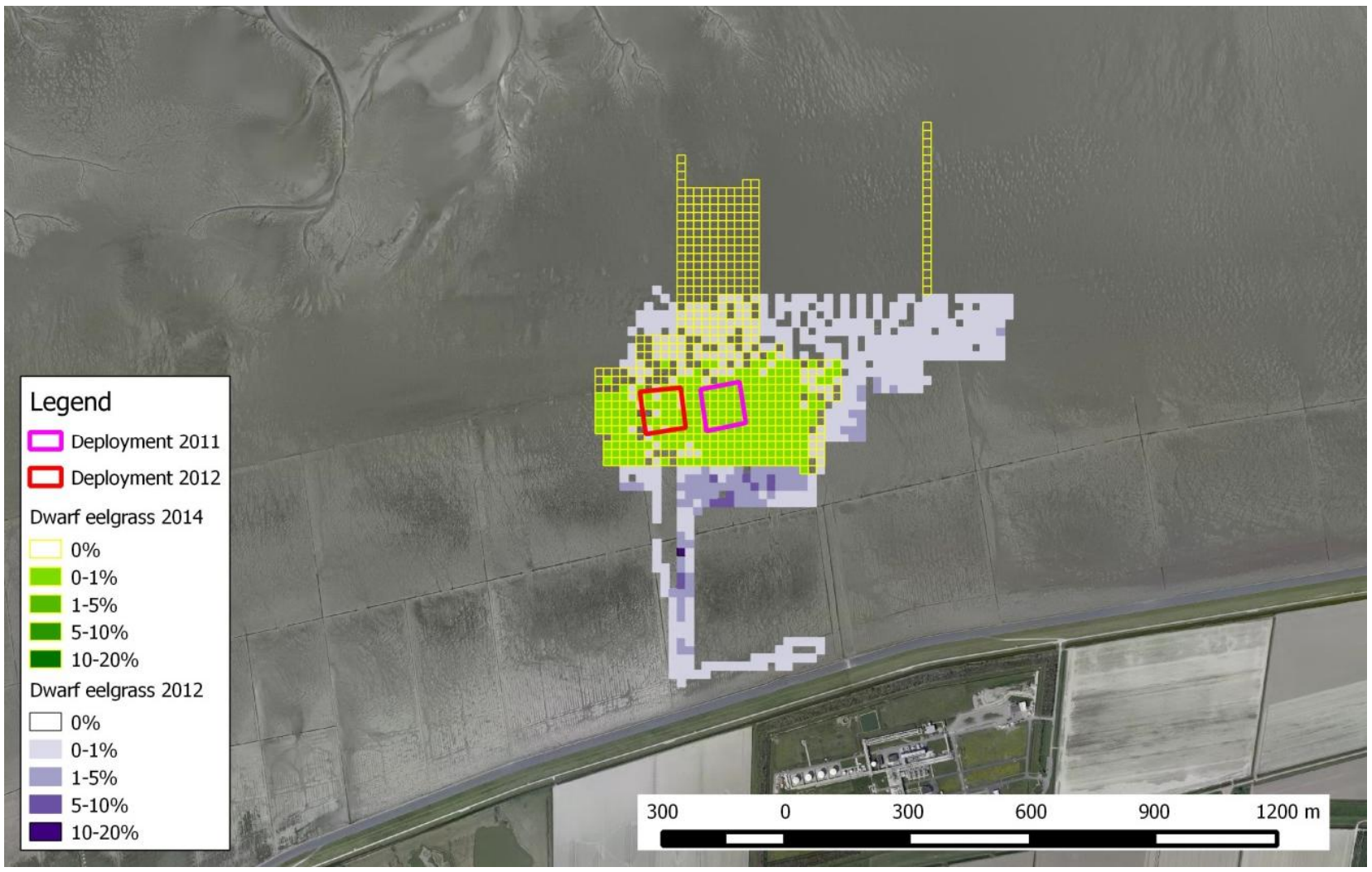


*Figure 4.2: Surveyed areas in 2014 at Uithuizen for Dwarf eelgrass (green), compared to the distribution in 2012 (purples)*

### 4.1.2 Vitality and seed development

All plants looked healthy, although relatively small, 15-40 cm in length (Figure 4.3). Most plants showed inflorescences with signs of seed development.

*Figure 4.3 A: Uithuizen, 2014, Plants looked healthy and vigorous, despite the relatively small size most showed healthy seed development. Photo: Tolman & Pranger*

## 4.2 Balgzand

This location was surveyed on 14, 15 and 23 August 2014. Similar to 2012 and 2013, 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** | **2014** |
| Number of surveyed cells | 256 | 981 | 482 |
| Number of cells containing *Z. marina* | 118 | 467 | 97 |
| Number of cells containing *Z. noltii* | 0 | 1 | 22 |
| Number of cells containing *R. maritima* | 1 | 4 | 6 |

The distribution of eelgrass on Balgzand is shown in Figure 4.4. There are clearly two centres with high distributions, corresponding to the deployment locations in 2012 and the one from 2011. Also in this location the amount of eelgrass is distinctly smaller than in 2013, although the decline is less extreme than in Uithuizen. The cover never exceeded more than 1%. The maximum number of (clumps of) plants per grid cell was 4, but in most cases was restricted to 1.

Eelgrass did not spread much northward beyond the limits of the 2011 deployment location. The 2012 deployment location has a limited spread northward (±80m) and a 200m southward extension.

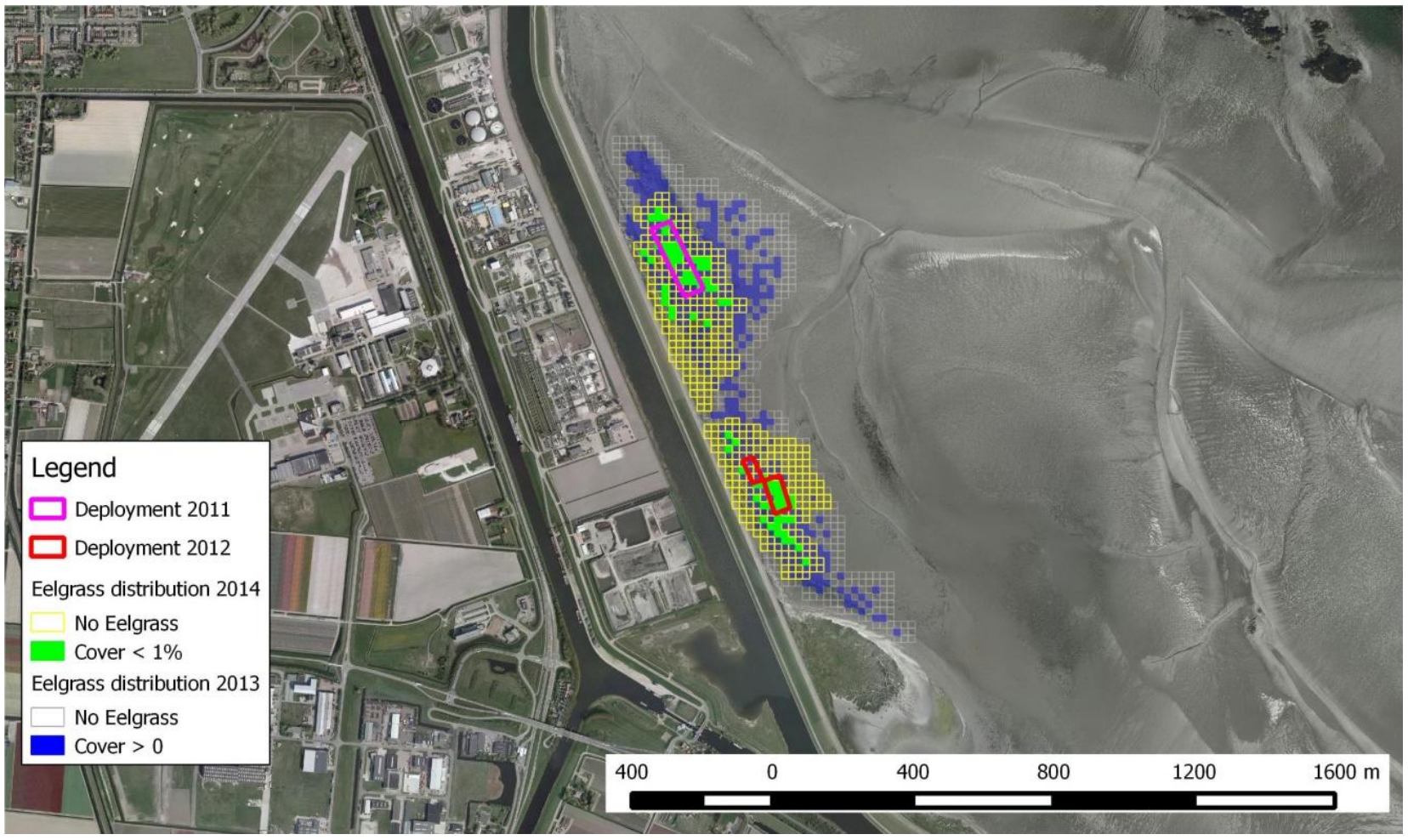


*Figure 4.4: Surveyed area on Balgzand. Light green patches represent 0-1% cover. The blue squares indicate the extent of the eelgrass cover in 2013. The red box indicates the deployment locations of 2012, pink represents the 2011 deployment.*

In previous years Dwarf eelgrass was seldom observed on this location. In the 2013 only one plant was observed. This year several plants of *Z. noltii* were observed, all within the vicinity of the 2012 deployment area. As in previous years a few isolated plants of *Ruppia maritima* were observed as well (Figure 4.5).

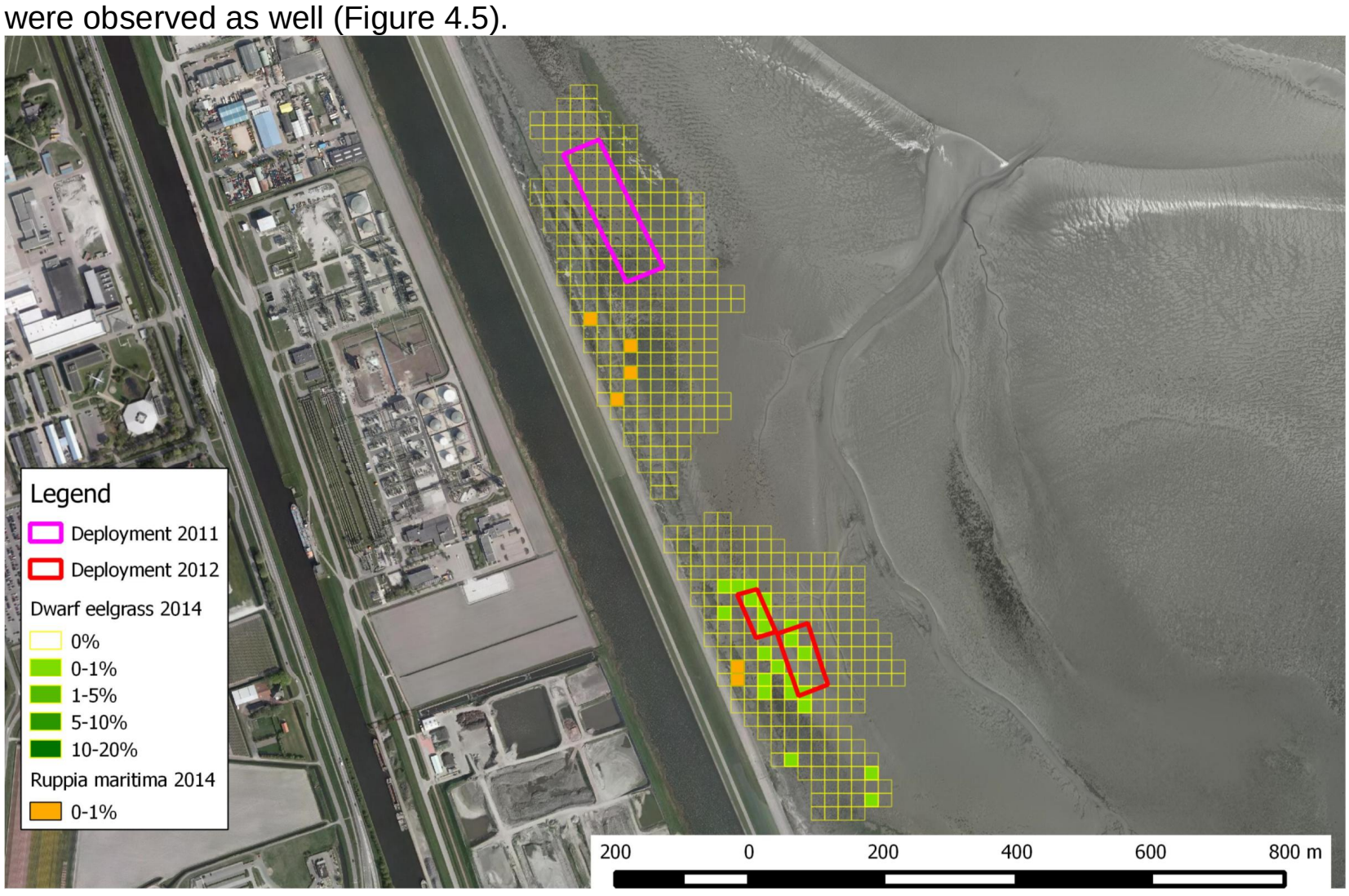


*Figure 4.5 Locations of Dwarf eelgrass (Z. noltii, in green) and Ruppia maritima (indicated in orange) around Balgzand*

4.2.2 Vitality and seed development

As in previous years, plant vitality varied considerably on this location. Generally plants were smaller than 40 cm in length. Mid-August many plants did show inflorescences and onset of seed development (Figure 4.6).

*Figure 4.6 On Balgzand Eelgrass often shows discoloured patches. This site is characterised by large amounts of algae that sometimes tend to smother the eelgrass plants. Photo: Tolman and Pranger.*

## 4.3 Schiermonnikoog

This location was surveyed on 20 and 22 August 2014.

4.3.1 Cover

| **Schiermonnikoog** | | | |
|---|---|---|---|
| | **2012** | **2013** | **2014** |
| Number of surveyed cells | 271 | 1620 | 1095 |
| Number of cells containing *Z. marina* | 140 | 1077 | 360 |
| Number of cells containing *Z. noltii* | 0 | 29 | 25 |
| Number of cells containing *R. maritima* | 0 | 0 | 0 |

The cover of eelgrass appears to have diminished in this location, but to a somewhat lesser extent than Uithuizen and Balgzand. During the 2013 survey, a substantial amount of plants

was observed relatively close to the dyke, an area that was not surveyed in 2012. Also in 2014 eelgrass cover extends all the way to the dyke. The extension eastward is distinctly less than it was in 2013. South of the deployment the spread was limited.
Densities were also marginally higher here than at the other two sites. Maximum number of plants observed per grid cell was 13, although in most locations it was just one or two plants.

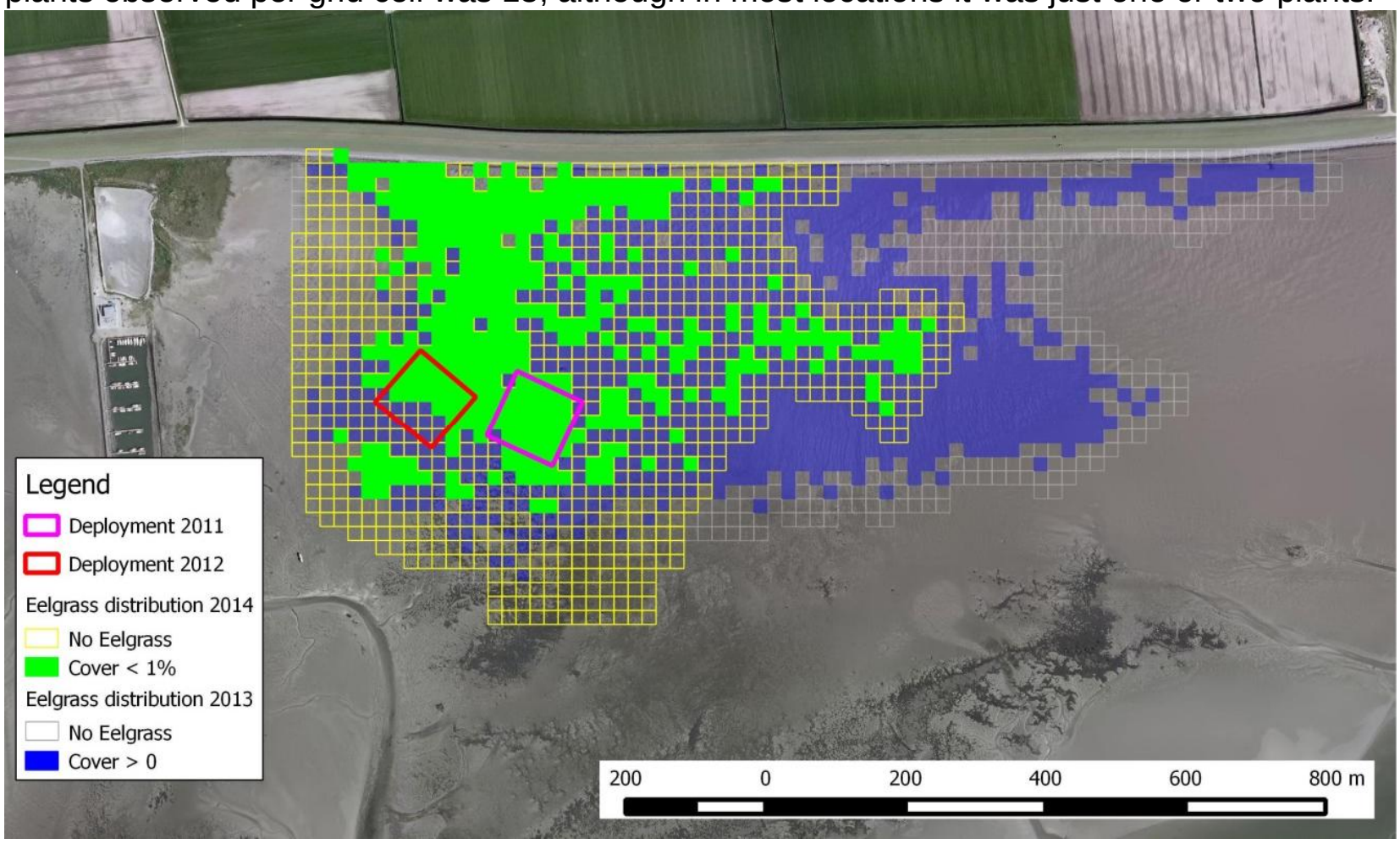


*Figure 4.7: Surveyed area on Schiermonnikoog. Light green patches represent 0-1% cover. The blue squares indicate the extent of the eelgrass cover in 2013. The red box indicates the deployment locations of 2012, pink represents the 2011 deployment.*

In 2013 29 cells were observed to contain *Z. noltii*, 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.
Also in 2014 this species was observed, partly in the same location as in 2013, but curiously this year also within the perimeter of the 2011 deployment, where no dwarf eelgrass was observed previously (Figure 4.8).

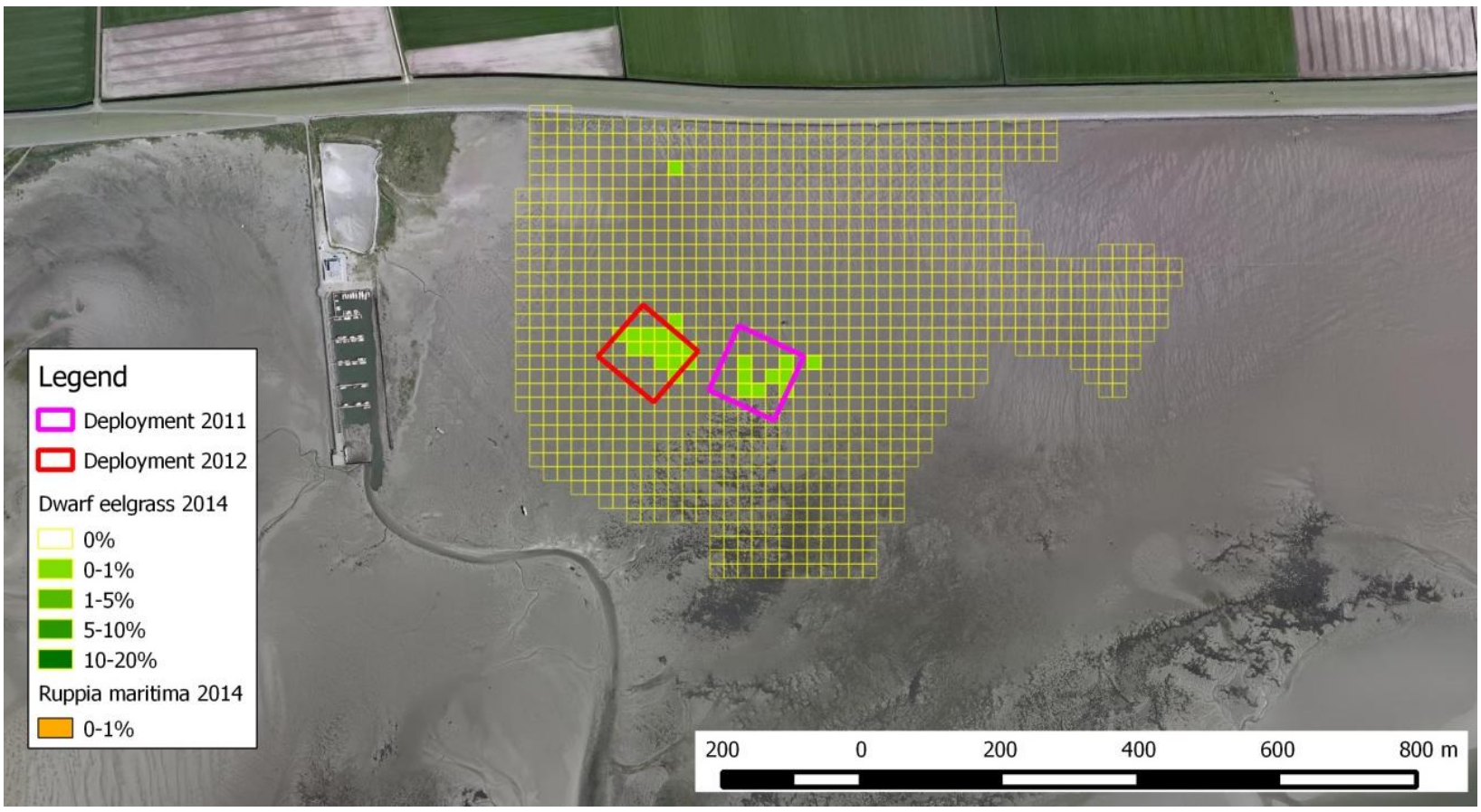


*Figure 4.8 Distribution of dwarf eelgrass on Schiermonnikoog in 2014*

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 60 cm. Although not quantified it appears that plants are slightly smaller than in previous years, when maximum sizes of up to 80 cm in length were reported. Nearly all plants showed development of seed in inflorescences.

## 4.4 Comparison with 2012 and 2013

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 in 2013, in all three locations eelgrass cover extended, while in 2014 the populations retreated. A comparison has been made between the cells that were surveyed in all three years (Figure 4.9).

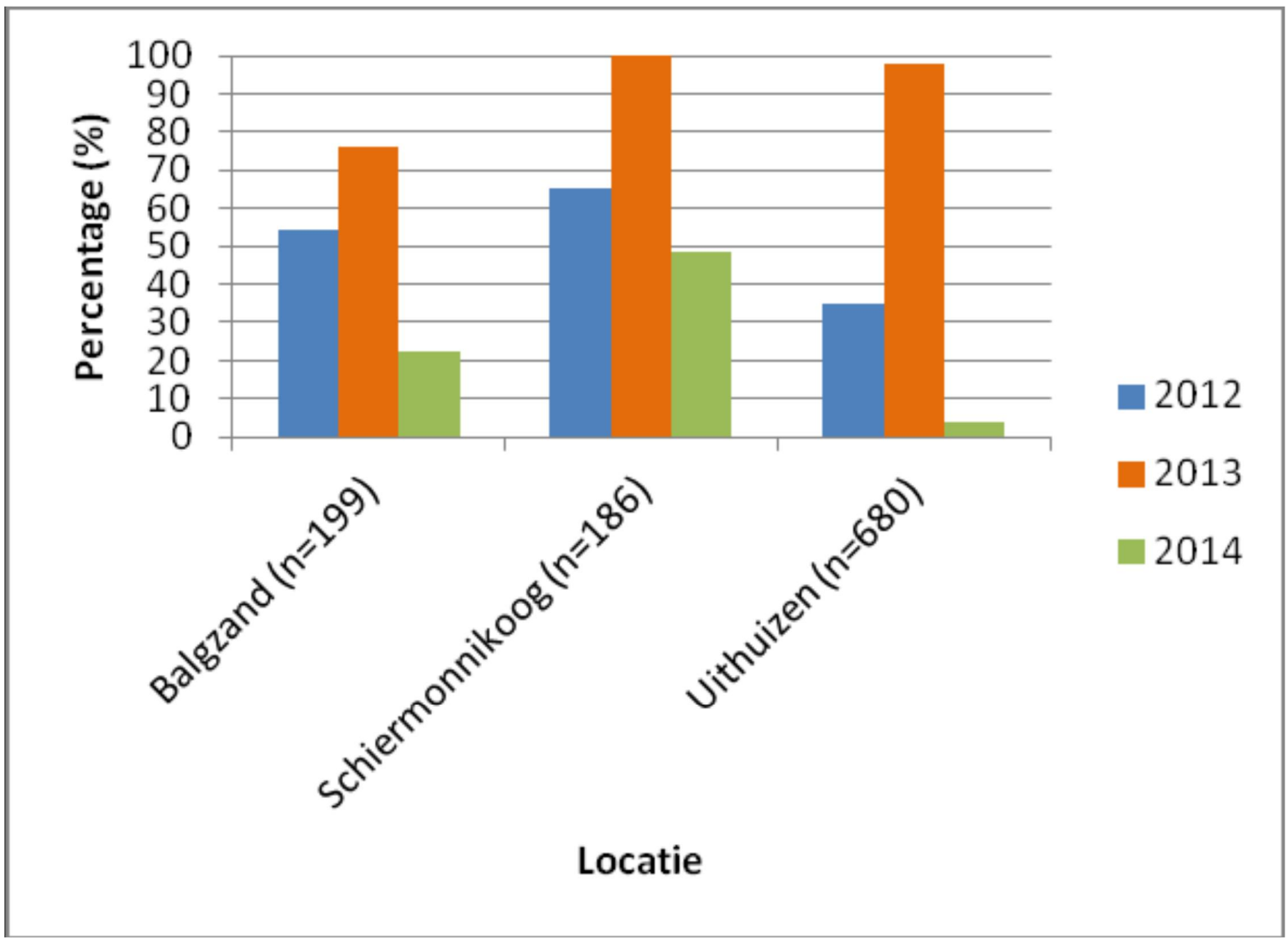


*Figure 4.9: Comparison between 2012, 2013 and 2014 in terms of proportion of cells containing eelgrass; 100% being the total number of cells surveyed in 2012, 2013 and 2014, n = the number of cells surveyed in all three years.*

Figure 4.9 shows the development over the 3 years, indicating that the cover in 2013 was less patchy than in 2012 and 2014. The decline at the Uithuizen site is the most extreme. In previous years, this site showed the largest extension of eelgrass. At all three sites the vegetation appeared to be also more patchy than it was after the first deployment in 2012, although slightly less distinct at Schiermonnikoog.

### 4.4.2 Vitality and seed development

In all three 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 differed between years, although plant sizes appear to be smaller in 2014 compared to previous years.
Although seed development was never 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. In 2014, despite the relatively small size of the plants seed development was (on the face of it) similar to 2012.

# 5 Eilanderbalg location

After receiving a notification of several *Z. marina* plants near buoy EB7 at Eilanderbalg in 2013, 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. In 2014 this site was revisited on 2 days (4 and 5 August). The first day a similar route to

2013 was covered, although the small isolated patch that was found in 2013 was not revisited. On day 2 the site was approached from the Schiermonnikoog direction and an area was surveyed that was not visited the previous year.

*Figure 5.1: Detail of the surveyed area in 2014 with the cyan coloured points indicating the presence of eelgrass plants. Red circles indicate the location of eelgrass in 2013.*

In total 3689 cells were surveyed, of which 25 contained eelgrass plants. The distance between the plants in this area was large and this site does not constitute a coherent meadow, like it appeared to be in 2013.

The plants appeared healthy, with dense leaves, and nearly all plants showed seed development (Figure 5.2). Most plants ranged around 20-30 cm, while the largest ones reached up to 60 cm. This appeared to be smaller than the plants that were observed in 2013. Some seed development was observed.

*Figure 5.2 Plants with inflorescences at EB7 buoy, photo RWS-CIV*

# 6 Discussion

## 6.1 Habitat suitability

From results of the previous years it was already clear that the “Habitatkansenkaart” is a valuable instrument in selecting suitable areas and that there is indeed a reasonable amount of suitable habitat available in the Wadden Sea. At the very small scale accurate prediction of maximum suitability is slightly more difficult. The Wadden Sea is a dynamic area and exact locations with the right elevation, the right wave exposure etc. will shift from year to year. In Uithuizen and Balgzand most of the spread of the eelgrass is parallel to the coast, indicating that elevation is restrictive for the distribution of this species, very likely due to limitations in light availability. On Schiermonnikoog, the first year the location of the deployment area was selected on the basis of detailed local elevation maps. The subsequent years showed a distinct spread towards the dyke, with seagrass growing right to the “toe” of the dyke. At this location a small mussel bed on the seaward side of the deployment area disappeared after an autumn storm in 2011. Whether small scale elevation subsequently changed was not checked.

## 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. In 2013 all (qualitative) observations indicated that seed development that year was severely inhibited. Although the plants appeared healthy and large, seed developed very late, there appeared to be a distinctly skewed male-female ratio (very few male flowers were observed) and very few plants appeared to have produced viable seeds in late summer (Van Duren and Van Katwijk 2013). The poor development of eelgrass in 2014 after a year with very poor seed development is a very strong indication that seed limitation is indeed the most likely cause of the limited level of recovery of eelgrass in the Wadden Sea at present.

## 6.3 Dispersal

### 6.3.1 Around the deployment locations

The fact that the original Balgzand deployment locations of 2011 are still recognisable in the field, separated from the 2012 location, indicates that a substantial proportion of the produced seeds germinates very locally and hardly disperses at all. This was also observed in 2013.
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 “new” sites.

Based on the original dispersal models the most likely origin for the Eilanderbalg site was deemed to be Uithuizen, although it is theoretically possible that seeds originated from the Schiermonnikoog location, which is as the crow flies closer, but is on the other side of the tidal divide. Recent fine sediment models have indicated that the transport of very fine sediment across tidal divides is more substantial than previously thought, however whether the relatively large inflorescences are easily transported over the shallow intertidal areas remains to be seen. Bed-load transport of the heavy and large seeds over so many kilometres (i.e. transport of seeds that are buried within the sediment) seems unlikely.
In 2014 no observations were made at Rottum and no other distinctive sites were reported.

## 6.4 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 has caused limited recruitment in 2014. Certainly at Uithuizen the left-over population does not appear to be viable.

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. In 2014 a consortium of NGOs has received a grant from the “Waddenfonds” for additional restoration efforts in the vicinity of the current deployments. Their 2014 deployments coincided with the 2012 deployment sites for Balgzand and Uithuizen, while on Schiermonnikoog the location is in the 2011 deployment site (Figure 6.1).


The results of 2012 indicate that even after one year there can be a fair bit of dispersal of seed around deployment areas (on Schiermonnikoog eelgrass was observed at a distance of up to 600 m from the deployment site). Next year it will therefore be not be possible to differentiate between plants originating from the 2011 and 2012 deployments and the 2014 deployment, at least at the Schiermonnikoog site. At the Uithuizen site the number of plants left is so low that the contribution of the previous deployments will be minimal. Only at Balgzand the 2011 site may remain distinguishable from the 2014 site, as these sites have been spatially separated.

*Figure 6.1 Locations of the 2014 deployments of the Waddenfonds project in relation to the 2011 and 2012 deployment sites and the 2014 distribution of eelgrass. Note that the boundaries of the 2012 and 2014 deployments at Uithuizen overlap virtually completely, leaving the 2014 marking obscured.*

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