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Re-introduction of seagrass in the Netherlands Wadden Sea

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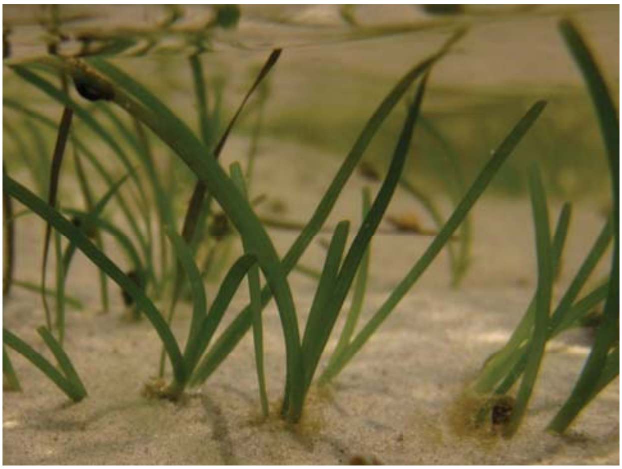
Introduction

Two seagrass species occur in the Netherlands Wadden Sea namely eelgrass (*Zostera marina*) and dwarf eelgrass (*Zostera noltii*). *Z. marina* occurs in two forms, a robust perennial submerged form and a flexible annual intertidal form. *Z. noltii* is a smaller, flexible perennial species found in the intertidal zone. Both species have declined in the Netherlands since the 1970s, and eelgrass has gone from being a widespread, commercially exploited species, to an uncommon species of conservation concern. Eelgrass and dwarf eelgrass are listed as 'least concern' by IUCN, but are reported as 'decreasing'. This trend is apparent world-wide for many seagrass species (Short *et al.,* 2011). *Zostera marina* is protected by Dutch law (Flora- en Faunawet, 2002), while seagrass beds of both species are protected by the EU Habitat Directive. Re-introductions were carried out on in the Netherlands part of the Wadden Sea, one of the world's largest international marine wetland reserves. It extends over 6,000 km² along the coasts of the Netherlands, Germany and Denmark. A 250,000 ha section of the Netherlands Wadden Sea has been declared a Ramsar wetland of international importance since 1984. In June 2009 the Wadden Sea was added to the UNESCO World Heritage List.



Dwarf eelgrass (*Zostera noltii*) with leaves only 6 - 22 cm long © Laura Govers, RU Nijmegen

Goals

- Overall goal: Restore nature values.
- Goal 1: Assessment of habitat requirements and site suitability for re-establishing seagrass populations.
- Goal 2: Experimental testing of donor populations for seagrass re-introduction.

- Goal 3: Field testing of various planting methods for the two seagrass species.
- Goal 4: Re-establishing viable seagrass beds at various locations in the Netherlands Wadden Sea.

Zostera marina **the leaves are 20 - 50 cm (can reach 1m) long © Arthur Bos, RU Nijmegen**

Success Indicators

- Indicator 1: Self-sustaining population (s) of seagrass permanently re-established in the Netherlands Wadden Sea.
- Indicator 2: Seagrass beds in the Netherlands Wadden Sea being a significant ecological feature, and playing a role once again as a habitat for fish (brood) and shellfish.

Project Summary

Feasibility: The Netherlands Wadden Sea once had extensive seagrass beds, with more than 150 km² remaining at the turn of the 20th century. Two species occur, namely *Zostera marina* (eelgrass) and *Zostera noltii* (dwarf eelgrass). *Z. noltii* has always been far less common than *Z. marina* in the Netherlands Wadden Sea. The robust form of eelgrass was of economic importance as insulation and filling material and was extensively harvested until the early 20th century. In the early 1930s, 'wasting disease' wiped out many robust, submerged eelgrass populations throughout Europe (den Hartog, 1987). Most populations recovered, but those in the Netherlands failed to do so and disappeared entirely. This was at least partly attributable to the closure of the dike separating the former Zuyder Sea from the Wadden Sea. As a result, permanent changes in hydrology and turbidity occurred. What remained in the Netherlands Wadden Sea were scattered remnant populations of dwarf eelgrass and of the flexible, annual form of eelgrass. These subsequently largely disappeared from the western Wadden Sea during the 1970s, due to a combination of eutrophication (and increase in turbidity), and the mechanical cockle and mussel fishing industries (Giesen *et al.*. 1990; van Katwijk *et al.*, 2009). However, both seagrass species are still abundant in the north-eastern parts of the Wadden Sea.

Since the 1980s, measures were undertaken to improve water quality and habitat conditions along the Dutch coast. By the 1990s turbidity and eutrophication had decreased, and shellfish industries were largely banned. In spite of these improvements, natural recovery of seagrass in the western Wadden Sea was considered unlikely to occur. Potential donor populations were located downwind of the western Wadden Sea (where westerly winds dominate), or were too distant (e.g. estuaries in south-western part of the Netherlands). Therefore, a seagrass restoration program was started in 1987 for *Z. noltii* and the flexible, annual form of *Z. marina.* It was decided not to focus on the robust, submerged form of eelgrass as this had already disappeared in the 1930s, and environmental changes were considered too great (van Katwijk *et al.,* 2009).

Implementation: Prior to the re-introduction program, mesocosm experiments were carried out on eelgrass from potential donor populations from France (Roscoff), Germany (Sylt), Denmark (Yderfjorden, in the Baltic), and the Netherlands (Grevelingen and Terschelling). Aim was to assess survival rates, and if plant reproductive strategies were suited to local conditions. As a result of these experiments, eelgrass from Yderfjorden and Roscoff were deemed unsuitable (low survival rates) and re-introduction focused on donor sites in the Netherlands and Germany (van Katwijk *et al*., 1998). From 1991 - 2004, 39 seagrass transplantations were carried out at 14 locations in the Netherlands Wadden Sea: Balgzand (3 sites), Texel (3 sites), Vlieland, Terschelling (4 sites), Schiermonnikoog, Ems Estuary, Friesland coast (van Katwijk *et al*., 2009). At four sites seagrass had disappeared in the 1970s, while at 6 sites disappearance had occurred before 1970. Three sites had remnant seagrass populations and functioned as donor and control sites, as did the donor population in Sylt, Germany. One transplantation site was not known to previously have a seagrass population.

Altogether 10,000 *Z. noltii* shoots and 23,000 *Z. marina* shoots were used in these transplants. On average about 800 seagrass shoots were transplanted per site. Sylt (Germany), Ems Estuary and Terschelling (both located in the Netherlands Wadden Sea), Goese Sas and Grevelingen (both south-western part of the Netherlands) were donor locations for *Z. marina*, and Sylt and Terschelling for *Z. noltii.* All *Z. noltii* transplants used the ‘bare root’ method, whereby sediment is removed from rhizomes before transport and replanting. With *Z. marina* transplants, the bare root method was also most commonly used, but sods and seed-bearing shoots were also utilised. Time between harvesting and replanting was kept to a minimum and was always less than 48 hours, during which plants were kept cool and moist (to reduce stress and desiccation).

Post-planting monitoring: *Z. marina* transplants had a highly variable performance, witnessing years of significant expansion and massive contraction. Eventually they all disappeared, the longest period of survival being eight years. Problems were due to premature die-off before seed formation at muddy sites (prone to high macro algae cover) or a low seedling survival in sandy areas. Also, seagrass patches were thinly spread, and lack of pollination may also have affected these annual plants (van Katwijk *et al.,* 2009). *Z. noltii* transplants were more successful, with a population on Balgzand still surviving after 13 years (i.e. the last time this was monitored). The difference is noteworthy, especially as fewer transplants of dwarf eelgrass were carried out and the re-introduction program was more focused on *Z. marina.* The main reason for this difference is probably because dwarf eelgrass is a perennial, and not dependent on seed production, germination and survival as is the annual form of eelgrass (van Katwijk *et al.,* 2009).

Eelgrass planting using bare root method
© Marieke van Katwijk, RU Nijmegen

Major difficulties faced

- Formidable logistic hurdles were faced in order to keep the time between harvesting and replanting within acceptable limits (e.g. many volunteers, long hours, muddy habitats).
- Optimal transplantation techniques were not well understood when the program began, and had to be learned during the process. This included understanding the self -facilitation processes of seagrass beds, and the effects of mussel beds, shell armouring, anchoring techniques, etcetera on seagrass growth.
- Results were highly variable, with successful and total loss plots next to each other. Also year-to-year variation was large. This stochasticity made results more difficult to interpret.
- Disappearance of the plants after the adverse season (winter).
- High macroalgae cover preventing seed production (due to early die-off) at muddy sites, and a lack of recruitment at sandy sites.

Major lessons learned

Adapted from van Katwijk *et al.* (2009):

- **Reverse habitat degradation:** Prior to any restoration or re-introduction effort, the causes of the decline should be known and alleviated or reversed. Most seagrass recoveries have been reported following habitat improvements such as reduced eutrophication and restored hydrology. Reduction of eutrophication and turbidity and a ban on mechanical shellfish harvesting had taken place in the Netherlands Wadden Sea by the time the reintroduction program began in 1991.
- **Select the appropriate location:** Transplantation locations should: i) have a past history of seagrass occurrence; ii) depth should be similar to that of nearby natural seagrass beds; and iii) meet other habitat requirements (e.g. micro-topography, hydrodynamics, sediment, nutrients, competition). Note that a past history of seagrass occurrence is no guarantee for plant survival, as conditions may have changed at a site.
- **Select an appropriate donor population:** General criteria for selecting a donor population is that it should i) be large enough not to be impacted by the donation; ii) survive the transplantation to the new environment; iii) be able to

expand, either sexually or vegetatively; and iv) have the traits to be able to survive in the long-term.

- **Spreading of risks:** In a dynamic coastal and estuarine environment, the spreading of the risk of plant losses (e.g. due to storms, ice scouring, salinity fluctuations, temperature fluctuations, desiccation, foraging by geese, disease) in time and space is important. Natural seagrass populations survive the vagaries of nature by maintaining genetic variation, phenotypic plasticity, and multiple reproductive or growth strategies. Spreading risks can be carried out by: i) transplanting to areas with different hydrodynamic exposure and habitat differences; ii) planting replicates at intervals (e.g. of tens of metres) at each site; iii) transplanting at different dates and in different years; and iv) transplanting genetically diverse material. Larger transplants over a large number of sites will result in a spreading of the risks, and is likely to result in a more permanent seagrass population.
- **Hydrodynamics:** Optimise techniques and account for ecosystem engineering effects. The distribution of most seagrass species is often governed by the presence of shelter. Accordingly, the results of most transplants are shaped by hydrodynamic stress or disturbances. Transplantation of plants with intact sediments (e.g. using sods) generally yields the highest rate of success, but is more costly and labour intensive. Various enhancing techniques tested during the transplants revealed that in the Wadden Sea i) anchoring techniques had no positive effect on seagrass growth; ii) shell armouring benefited seagrass at exposed sites only; and iii) mussel beds had a positive impact on seagrass survival.

Success of project

Highly Successful	Successful	**Partially Successful**	Failure
		√	

Reason(s) for success/failure:

- Due to permanent habitat changes, only the intertidal annual form of *Z. marina* can survive in the Netherlands Wadden Sea. However, this form also faces problems for re-establishment. Premature die-off at muddy sites (with high macroalgae cover) stifles seed production, while low recruitment rates affect hydrodynamic sandy areas. Also, thinly spread eelgrass patches face a lack of pollination (and low seed production), and higher risk of plant loss due to fluctuations in environmental conditions (e.g. storms, ice scouring, and so on). Planting larger numbers at (many) more sites will spread the risks and should lead to overall survival of the species.
- *Zostera noltii* dwarf eelgrass transplants survived for up to 13 years (i.e. when monitoring ended) and appear successful. Dwarf eelgrass is a perennial that survives the winter period underground, and unlike the annual form of eelgrass it does not depend on the vagaries of seed production, germination and survival.
- Eutrophication is likely related to the low seagrass transplantation survival via the stimulation of macro-algae, which was also shown to be related to the

extinction of the most western located donor population of *Z. marina*. The flourishing seagrass populations in the Northern Wadden Sea support the relationship with nutrient loads, as these are twice as high in the Dutch Wadden Sea. Also the decline in the Eastern Wadden Sea coinciding with increased agriculture points to a relationship with eutrophication.

- The success at the Balgzand area, with a 8-year survival of the *Z. marina* population and the 13 year survival of the *Z. noltii* populations, notwithstanding the very low numbers that they had to start with in such a dynamic environment– a strong support that this site is still very suitable for seagrass colonisation and shows that seagrass transplantations in the Wadden Sea have been successful; upscaling can be recommended.

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