Seaward Solutions Foreland Salt Marshes

Along the Wadden Sea man-made tidal marsh formation is a wide-spread practice. The system has been brought about by artificial drainage systems and brush wood groins. Originally these were managed to increase farming lands. Due to their height and width they also play an important role in breaking wave energy in front of the dikes. Natural values have decreased due to vertical accretion which enhances vegetation succession. During the last quarter of the 20th century maintenance of the drainage systems has largely ceased and many of the Foreland Salt Marshes are gradually developing towards a more natural situation.

A narrow belt of fertile marshland, stretching down from Denmark to the Netherlands dominates the mainland shores of the Wadden Sea. Based on the most recent data, salt marshes in the Wadden Sea extend over almost 40,000 ha (= 20% of European salt marshes). About half of the total are foreland salt marshes (Table 1). During the past century saltmarshes have grown in areal extent[1]. This growth has reduced the tidal water volumes, leading to the shallowing of tidal channels and gullies which originally used to drain these areas.

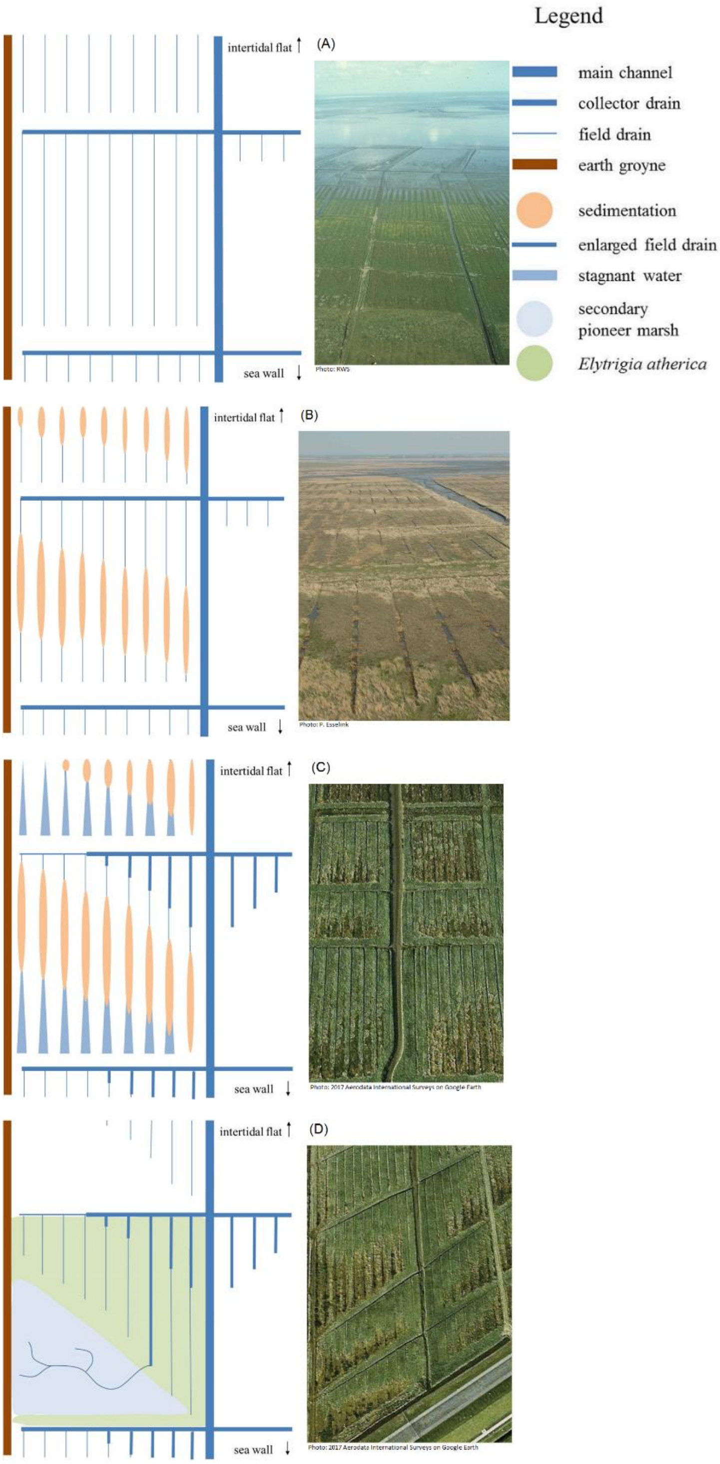
Despite the extension of salt marshes during the past century, pioneer and low-marsh vegetation types remained relatively constant and vegetation of late-succession stages increased. Along the Wadden Sea man-made tidal marsh formation finds its beginnings several centuries BC. From that time decimeters high mud ridges were formed by humans on the lower tidal marshes, apparently to further sedimentation. On the middle marsh summer dikes were built, restricting flooding to a few times per year, mainly during winter. Enhancement of salt marsh development can be shown from at least the late medieval times onwards. Maps and descriptions are available from halfway the 16th Century. Enhancing marsh development was mainly done by means of systems of ditches and earthen dams (so-called "*farmer's method*"). Since the 20th century upkeep of drainage and brushwood groins were combined (so-called "*Schleswig-Holstein method*") to establish foreland salt marshes.

Maintenance

Originally the maintenance was targeted to extension of foreland salt marshes to establish meadows for grazing animals. During the last quarter of the 20th century the aim is directed towards nature conservation. This led to changes in management that varied from minimal intervention to strategic upkeep of parts of the drainage and groin systems. One of the focus points is on slowing down succession and development of climax vegetation. The size of foreland salt marshes depends on the upkeep of the

[1] Over the period 1995/2001 to 2008/2014 mainland tidal marshes did not change much in areal extent in the Netherlands and Denmark, whereas expansion was observed in Schleswig-Holstein with ca 14% or 1,160 ha. For Lower Saxony available data show a decrease in area over the period 1995/2001 to 2002/2007.

brushwood groins at the seaward marsh edge. Natural expansion without human intervention of mainland marshes is mainly confined to the Leybucht and Jadebusen in Lower Saxony and the Schleswig Holstein region, N of the Elbe estuary.



Schematic overview of changes in the artificial drainage system after the traditional maintenance was discontinued. (A) Starting situation. (B) Central parts of the ditches or field drains have silted up. (C) As a consequence, drainage ceases upstream, whereas downstream the field drains deepen and decrease in width. The latter also occurs in the downstream part of the collector drains close to the main channel. (D) The increased soil-waterlogging causes local replacement of vegetation with Elytrigia atherica by secondary pioneer vegetation, and low-marsh vegetation. The photographs show examples from sites *in the Netherlands and Germany (text and figure from: Esselink et al., 2016; modified from van Wesenbeeck et al., 2014).*

To enhance development of man-made salt marshes, digging and a regular upkeep of the artificial drainage system were traditionally important management practices (figure). The function of artificial drainage was to (1) enhance vegetation on high intertidal flats; (2) increase the carrying capacity for livestock grazing; (3) prevent the formation of depressions and (4) prevent water logging of the dikes. Nowadays nature organizations are improving the drainage- and creek-quality to realize nature goals. For instance, to transport more mud in the direction of low areas near the dikes (Holwerd Oost), or for young or small fish which find shelter and food in those water courses (project Swimway).

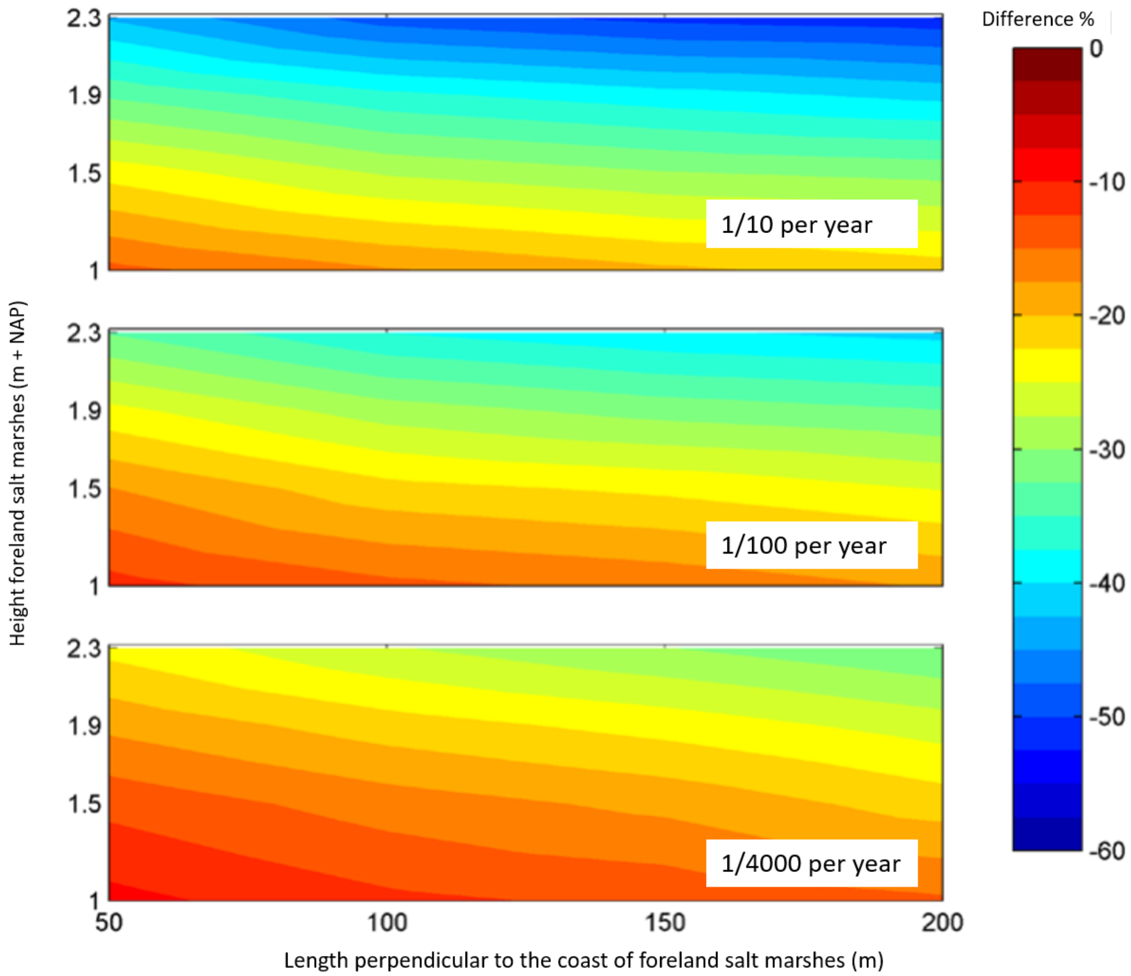
Foreland salt marshes show an average elevation increase of almost 10 mm/yr, i.e. well above the increase rate of MHT (2.0–3.0 mm/yr). The high accretion rates lead to a relatively quick vegetation succession and can eventually lead to a species-poor climax vegetation dominated by sea couch. Although grazing delays the succession, a more dynamic system helps to create a more natural marsh in which accretion and erosion are kept in balance by cyclic succession. To that end, upkeep of brushwood groins has been reduced by 40% in the Dutch Wadden Sea. Also, maintenance of artificial drainage systems has been stopped over extensive areas in Germany and the Dollard area (70- and 80-ies), and along the Frisian and Groningen coast (from the 1980s onward, stopped completely by 2001). Furthermore, in some restoration projects parts of the drainage system were filled up or the top soil was removed. In Lower Saxony clay mining projects are used to establish a more natural development of the creek systems (See Factsheet clay pits). In managed retreat projects in the Netherlands and in Germany more natural creeks are built to start a landscape which will function and develop in more natural way (See Factsheet managed retreat). In the Netherlands, ditching is only continued locally by farmers in order to facilitate livestock grazing. As a result of stopping artificial drainage systems, many foreland salt marshes are slowly shifting towards a state with increased naturalness. However, it should be realized that, given their artificial origins, such semi-natural areas cannot be restored to completely natural salt marshes.

Overview of tidal marsh types in the trilateral Wadden Sea (After: Esselink et al., 2016).

Landvorm	Netherlands	Lower Saxony	Hamburg	Schleswig-Holstein	Denmark	Total
Year of survey	2008/2012	2004	2009/2014	2011/2012	2010/2012	
Island salt marsh						
Barrier connected (foreland incl.)	4.640	3.670	310	1.700	3.280	**13.600**
De-embanked (summer) polder	90	150	40			**280**
Mainland salt marsh						
Barrier connected				780	1.340	**2.120**
Foreland type	4.000	5.460		8.580	2.520	**20.560**
De-embanked summer polder	360	380				**740**
Hallig salt marsh						
	50			2.180		**2.230**
Total	**9.140**	**9.660**	**350**	**13.240**	**7.140**	**39.530**

To slow down succession grazing with livestock or mowing is used at many locations. Grazing creates a short turf. Although the number of plant species is, on the larger scale, somewhat higher in grazed than in ungrazed areas, different plant communities tend to converge to become a community dominated by *Elytrigia atherica,* unless sediment input is small and wet conditions prevail. Mowing results in lower plant species richness. Short term cessation of grazing is beneficial for plant species richness and invertebrates. Long term cessation results in tall vegetation. This is not good for geese and waders but good for songbirds. Resuming grazing can remove the tall vegetation and litter and increase plant species richness, especially on the high marsh. Grazing leads to higher compaction of the soil than no grazing, thus reducing the net accretion rate. Furthermore, it reduces the large soil fauna and leads to anoxic soil conditions.

Furthermore, it should be noted that foreland tidal marshes play an important role in dampening the waves which are directed towards the mainland dikes. Last figure shows that primarily the height and, secondarily, the length of a foreland salt marsh leads to a significant dampening of the waves which impact the dike. Wave conditions are given for 1/10 year, 1/100 year and 1/4000 year storm surge. Recent studies for the Dutch Wadden coast revealed that there are locally possibilities to generate new foreland salt marshes. Furthermore, experiments are being carried out to generate new foreland marshes (see local examples).



Dampening effect of height and width of foreland salt marshes on waves, given as difference percentage (Van Loon-Steensma et al., 2012)

Research

Monitoring is in place in several areas to study accretion, vegetation, biodiversity, maintenance of brushwood groins and drainage systems and Natura 2000-habitats on annual basis which is reported to the managers. It is an instrument to steer the abiotic and biotic maintenance of the Foreland Salt Marshes.

Results

At present many of the Foreland Salt Marsh areas are developing in the direction of a more natural system. Foreland Salt Marshes are increasing in height faster than MHW rise. On the longer run succession will lead to a larger area with climax-vegetation. Also, it decreases the space for the pioneer zone, which is wedged between the seaward extension of the tidal marshes and the tidal flats. Although grazing delays the succession to the climax vegetation, a more dynamic system could help to create a more natural marsh in which accretion and erosion are kept in balance by cyclic succession.

Lessons learned

Although ceasing maintenance has furthered the naturalness of the Foreland Salt Marshes, sedimentation-driven succession will lead to climax vegetation and squeeze of the pioneer zone. A new management course may be needed, but succession is not the only problem (see discussion points). A clear definition of means and targets will help to identify the best management and will enable evaluation of the management practices.

Stakeholder processes

The stakeholder processes mainly consist of interactions between responsible ministries, tidal marsh owners and users (partly private parties) and nature organizations. All salt marshes in the Wadden Sea area are part of Natura 2000. Next to the national legislation and nature protection regulations in the three Wadden Sea countries, the trilateral 2010 Wadden Sea Plan (WSP) provides the framework for the management of the entire area (CWSS, 2010). In the WSP, the following five targets have been formulated for salt marshes:

1. To maintain the full range of variety of salt marshes typical for the Wadden Sea landscape;
2. To maintain a salt marsh vegetation diversity reflecting the geomorphological conditions of the habitat with variation in vegetation structure;
3. To maintain or to achieve favorable conditions for all typical species;
4. To achieve an increased area of salt marshes with natural dynamics;
5. To achieve an increased natural morphology and dynamics, including natural drainage of mainland salt marshes, under the condition that the present surface area is not reduced.

Targets 1 to 3 pertain to all types of salt marshes. Target 4 is only relevant for salt marshes which formed without any interference of humans and are mainly related to islands. As such they are hardly relevant for Foreland Salt Marshes. Target 5 is relevant for Foreland Salt Marshes as nowadays parts of the Foreland Salt Marshes are dug out to enhance a more natural development (for instance: Noorderleech; Holwerd Oost in the Netherlands; Neuwapeler Außengroden in the Jadebusen; Elisabeth Außengroden in Germany).

Discussion points

- Especially in the pioneer zone upkeep of brushwood groynes might be focused on the development of the pioneer zone. Succession reversal and nature and policy goals could be combined with an increase in dynamics and naturalness in the process. It would imply a new big shift in maintenance practices, which should be more focused on tailor-made solutions addressing the local peculiarities of the Foreland Salt Marsh in question.
- However, already now growth season changes and changes in precipitation patterns are marked. On the long run sea-level rise will yet be another effect of climate change. All these changes can be expected to influence the development of the Foreland Salt Marshes. How should we react on the current and future climate-related changes?
- Should squeeze of the pioneer zone be the focus of future Foreland Salt Marsh management or should be focused more on climate change and sea-level rise? Or a combination? And how?

Literature

Abrahamse J., Joenje W. & Van Leeuwen-Seelt N. (eds), 1976: Wadden Sea – Nature area of the Netherlands, Germany and Denmark. Landelijke Vereniging tot Behoud van de Waddenzee, Harlingen and Vereniging tot Behoud van Natuurmonumenten, 's-Graveland.

Anonymous: https://swimway.nl/wat-betekenen-de-randen-van-het-wad-voor-vis/

Arens S. & Götting E., 2008: Untersuchungen zur ökologischen Entwicklung naturnaher Lahnungsfelder und ihre Stellung im Naturhaushalt. - Gutachten, gefördert von der Niedersächsischen Wattenmeerstiftung und der Niedersächsischen Lottostiftung. 81 pp.

Bakker J.P., 2014: Ecology of salt marshes; 40 years of reseach in the Wadden Sea. Waddenacademie publ. ISBN 9789490289324, 99 pp.

Bakker J.P., Bos D., Stahl J., De Vries Y. & Jensen A., 2003: Biodiversität und Landnutzung in Salzwiesen. Nova Acta Leopoldina 87: 163-194.

Bartholdy J., Pedersen J.B.T. & Bartholdy A.T., 2010: Autocompaction in shallow silty salt marsh clay. Sedimentary Geology 223: 310–319.

Dijkema K.S., 1987: Changes in salt-marsh area in the Netherlands Wadden Sea after 1600. In: Huiskes, A.H.L., Blom, C.W.P.M. & Rozema, J. (eds). Vegetation between land and sea, pp. 42-49. Junk Publishers, Dordrecht.

Dijkema K.S., Nicolai A., de Vlas J., Smit C.J., Jongerius H. & Nauta H., 2001: Van landaanwinning naar kwelderwerken. Rijkswaterstaat Directie Noord-Nederland¸ Leeuwarden, Alterra, Texel. 68 pp.

Esselink P., 2000: Nature management of coastal salt marshes – Interactions between anthropogenic influences and natural dynamics. PhD-Dissertation, University of Groningen.

Esselink P., van Duin W.E., Bunje J., Cremer J., Folmer E.O., Frikke J., Glahn M., de Groot A.V., Hecker N., Hellwig U., Jensen K., Körber P., Petersen J. & Stock M., 2017: Salt marshes. In: Wadden Sea Quality Status Report 2017: Eds.: Kloepper S. et al., Common Wadden Sea Secretariat, Wilhelmshaven, Germany. Last updated 21.12.2017. https://qsr.waddensea-worldheritage.org/reports/salt-marshes.

Fischer L., (ed), 1997: Kulturlandschaft Nordseemarschen, Bredstedt/Westerhever, Nordfriisk Instituut/Hever.

Michaelis H., 2008: Langzeitstudie zur Entwicklung von Höhenlage, Sediment, Vegetation und Bodenfauna in Landgewinnungsfeldern. Untersuchungsbericht 02/08 (internal report). Niedersächsischer Landesbetrieb für Wasserwirtschaft, Küsten- und Naturschutz, Forschungsstelle Küste, Norderney. 60 pp.

Nolte S., 2014: Grazing as a nature management tool. The effect of different livestock species and stocking densities on saltmarsh vegetation and accretion. PhD-Dissertation, University of Groningen, Groningen. 245 pp.

Rupprecht F., Wanner A., Stock M. & Jensen K., 2015: Succession in salt marshes – large-scale and long-term patterns after abandonment of grazing and drainage. Applied Vegetation Science: 18: 86–98.

Suchrow S., Pohlman M., Stock M. & Jensen K., 2012: Long-term surface elevation change in German North Sea salt marshes. Estuarine, Coastal and Shelf Science 98: 75-83.

Stock M., 1997: Salt marsh management in the National Park "Schleswig-Holsteinisches Wattenmeer". Wadden Sea Newsletter 1997(1): 11–15.

Tacke B. & Lehmann, B., 1924: Die Nordseemarschen, Bielefeld/Leipzig, Velhagen & Klasing.

Van Geer P., 2013: Invloed van afplaggen op benodigde kruinhoogte in de Westerschelde en Waddenzee. Deltares memo 1207459-003-ZKS-0001, 10 pp.

Van Loon-Steensma J.M., de Groot A.V., van Duin W.E., van Wesenbeeck B.K., Smale A.J., Meeuwsen H.A.M., Wegman R.M.A., 2012: Zoekkaart kwelders en waterveiligheid Waddengebied: een verkenning naar locaties in het Waddengebied waar bestaande kwelders of kwelderontwikkeling mogelijk kunnen bijdragen aan waterveiligheid. Alterra-rapport 2391. Alterra Wageningen UR, Wageningen. http://edepot.wur.nl/244770

van Wesenbeeck B.K., Esselink P., Oost A.P., van Duin W.E., de Groot A.V., Veeneklaas R.M., Balke T., van Geer P., Calderon A.C. & Smale A., 2014: Verjonging van half-natuurlijke kwelders en schorren. Rapport nr. 2014/OBN196-DK. VBNE, Vereniging van Bos- en Natuurterreineigenaren, Driebergen. 73 pp.

Vollmer, M., et al. (eds), 2001: Landscapes and Cultural Heritage in the Wadden Sea Region, Wilhelmshaven, Common Wadden Sea Secretariat.

Wanner A., Suchrow S., Kiehl K., Meyer W., Pohlmann N., Stock M. & Jensen K., 2014: Scale matters: Impact of management regime on plant species richness and vegetation type diversity in Wadden Sea salt marshes. Agriculture, Ecosystems and Environment 182: 69–79.

Wolters M., Garbutt A. & Bakker J.P., 2005: Salt-marsh restoration: evaluating the success of de-embankments in north-west Europe. Biological Conservation 123: 249–268.