SEDIMENT DISTRIBUTION IN AN UNMAINTAINED COASTAL BRUSHWOOD GROYNE FIELD

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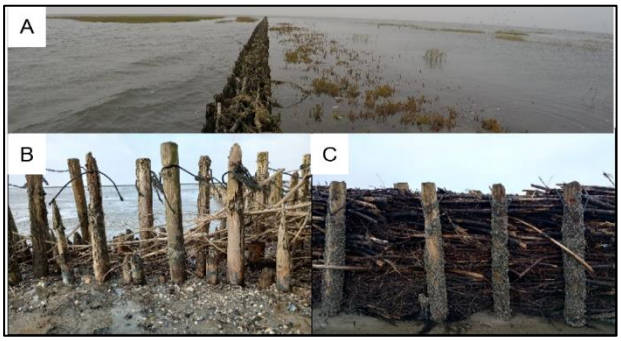

Figure 1 – Flooded brushwood groyne field with pioneer salt marsh vegetation on the island of Pellworm (A). Empty groynes at the field site (B) and refilled groynes with brushwood (C) after maintenance.

BACKGROUND

To adapt coastlines and their management to future sea level scenarios, resilient foreshores are a key element of coastal protection. A fully developed salt marsh foreshore acts as a buffer zone in front of a dike. There, the vegetation structure attenuates wave action and stabilizes the coastline (Vuik et al. 2016; Schoones et al. 2019). Marshes reduce erosion of the soil-surface depending on the presence of the existing vegetation and silty soil characteristics, providing important additional protection for the hinterland in case of a dike failure (Marin-Diaz et al. 2022). Consequently, the foreshore provides ecosystem services in terms of coastal protection, in addition to other valuable ecosystem services such as carbon sequestration. However, the dike foreshores in the German Wadden Sea are largely the result of anthropogenic interventions. Within the borders of constructed brushwood groynes (Figure 1A), calmed hydrodynamic conditions allow suspended sediments to settle (von Lieberman et al. 1998; Siemes et al. 2020). The resulting vertical land growth enables the establishment of different salt marsh succession stages. As a result, a semi-natural salt marsh ecosystem is formed that contributes to a spatial expansion of the foreshore: a nature-based solution for supporting coastal protection is constructed. However, little is known about the spatial distribution of sediments and vegetation and the interaction-based biogeomorphological processes operating in groyne fields, although this is crucial for the successful development of effective and future-oriented management strategies. Further, maintaining brushwood groynes is costly and time-consuming, although the effects have not yet been assessed. In order to successfully implement the aspects of economic efficiency and ecological enhancement in the planning and maintenance of groyne structures, it requires (i) an improved understanding of the impact of the interaction between hydro-, morpho-, and vegetation dynamics on the effectiveness of groyne fields, and (ii) an active involvement of local coastal protection authorities, enabling the transfer of knowledge between science and practice for the optimization of coastal protection.

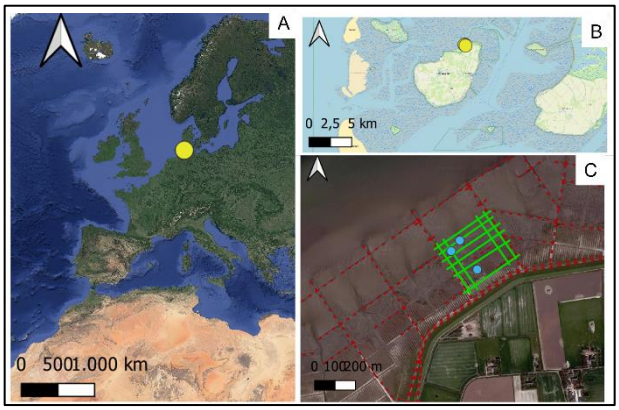

Figure 2 – (A) Location of research area in the German Wadden Sea (yellow). (B) Field site (yellow) on the island Pellworm. (C) Field setup with transects (green), hydrodynamic measurement (blue) and brushwood groynes (red dashed lines).

EXPERIMENTAL SETUP

At the groyne field on the island of Pellworm in the German Wadden Sea (Figure 2), the maintenance has not taken place since 2015 and the fences are thus no longer filled with brushwood (Figure 1B). This condition represents the scenario if brushwood fence maintenance were abandoned. After one year of monitoring, the previously empty fences will be filled with brushwood in summer 2024 (similar to that shown in Figure 1C). This procedure makes it possible to compare two different conservation states of groyne fields. To understand the spatial sediment distribution and deposition dynamics, the groyne field is equipped with a grid of measurement locations. The field study includes a variety of regular measurements in spring and autumn to compensate for seasonal fluctuations, and runs for three years. Sediment and vegetation characteristics are surveyed along four transects extending from the dike to the tidal flats (Figure 2C). Two of the four transects are equipped with ten measurement sites, including sedimentation-erosion-bars (SEB) to record seasonal sediment accretion rates, and cover different salt marsh successional stages in relation to their distance to the empty or brushwood-filled groyne. Potential sediment deposition during salt marsh flooding is measured with sediment traps. The grain size of the accumulated sediment is measured using surface samples collected semi-annually with a Laser Scattering Particle Size Analyzer. Further, the sediment

characteristics will be correlated with measured vegetation parameters like dry above ground biomass, density and vegetation height as well as species composition to identify biogeomorphologic relationships. Additional measurements of hydrodynamic conditions are recorded over multiple tidal cycles and semi-annually, providing insight into hydrodynamic boundary conditions (Figure 2C).

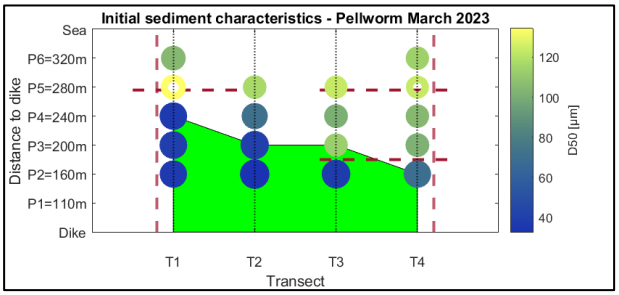

Figure 3 - Spatial distribution of particle sizes (D50) measured at fixed locations along four transects T1 - T4 (grey dashed lines) within the boundaries of the brushwood groynes (red dashed lines) at the initial conditions of the field study in March 2023. Unfilled markers represent a negative skewness (coarse-grained sediments). Smaller marker sizes represent better sorting. Green background represent areas with salt marsh vegetation.

PRELIMINARY RESULTS

The initial state at the field site, measured during three field studies in March 2023, October 2023 and March 2024, will be presented. Preliminary results from March 2023 show a gradient for the median sediment particle size (D50) distribution perpendicular to the dike within the groyne field (Figure 3). That means, smaller D50 values were measured closer to the dike as well as in the vegetated areas (Figure 3). The minimum recorded D50 was 32.6 µm. By contrast, coarser sediments were measured in the seaward field (Figure 3), reachingmaximum D50 values of 134.33 µm. A slightly decreasing trend is found in the D50 values from south-west to north-east. Based on the SEB measurements in March 2023 and October 2023 a wider range in erosion and sedimentation were measured on the bare tidal flat without vegetation in the outer groyne field than in the sheltered dikewards partly vegetated field (Figure 4). In the exposed seawards field sedimentation with a median value of 3.5 cm (site T1 P6) on one side and erosion with a median of 2.6 cm (site T4 P6) on the opposite side of the field is recorded during a period of six months (Figure 4). A contrary surface elevation change was measured in the dikeward area. Increasing erosion was measured there for transect 1 between site P2 (1_2) to P4 (1_4) in the south-west area of the field. While minor sedimentation rates were documented for transect 4 between site 2 (4_2) and site 3 (4_3) with stagnation at site 4 (4_4).

OUTLOOK

The recent sediment conditions in the groyne field show that there are gradients in spatial grain size distribution in established but unmaintained groyne fields. Alongside the familiar sea-to-dike decreasing gradients in sediment grain size driven by hydrodynamic sediment transport, we also identified alongshore gradients within the field. This suggests that the unmaintained groynes affect these gradients. This might be indirectly driven by the vegetation and surface elevation conditions developed by the groynes and will be studied during this project. The contrasting erosion and sedimentation patterns along the transects 1 and 4 reinforce this observation. The provided knowledge extends beyond the specific project, also addressing other coastal management efforts that focus on sediment management to create supportive conditions for salt marshes. The results contribute to discussions about nature-based solutions and can guide future projects involving brushwood groynes for sediment management, while analyzing the impact of advanced structural conditions on sediment characteristics and sedimentation behavior in different distances to the groyne after establishment. Later in the project, the impact of groyne maintenance on the sediment distribution will be measured. Finally, this study will help to give recommendations for the maintenance and sustainable design of brushwood groynes, taking into account the ecological enhancement of the vegetated sites.

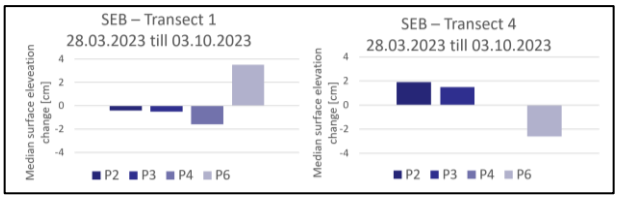

Figure 4 - SEB-derived sedimentation rates showing surface elevation change from March to October 2023 at transect 1 and transect 4 at four different sites per transect.

ACKNOWLEDGEMENTS

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