

# NUMERICAL MODELLING OF EUROPEAN BRUSHWOOD GROYNES

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## INTRODUCTION

The increasingly observable impact of climate change underscores the urgency for cost-effective and low-maintenance strategies in coastal protection, given the globally acknowledged increase in coastal erosion. The rise in sea levels elevates wave energy and facilitates the propagation of waves onto higher elevation coastal regions and defense structures (Oppenheimer et al. 2022). An increase in wave energy has the potential to intensify coastal erosion and increase the associated maintenance expenditure. Acknowledging this challenge, there is an increasing awareness of the significance of coastal ecosystems, such as salt marshes, in serving as natural coastal protection. Salt marshes not only provide essential ecosystem services and habitats with rich biodiversity but also diminish wave energy, thereby mitigating erosion (Dunlop et al. 2023). Furthermore, salt marshes have demonstrated the ability to adapt to rising sea levels by growing vertically. However, it is crucial to acknowledge that sea level rise is accelerating in specific areas, potentially surpassing the natural growth rates of salt marshes (Saintilan et al. 2022).

Brushwood groyne fields have been employed for over a century as a method to facilitate sediment accumulation in Northern Europe (Probst 1996). Brushwood groyne fields tend to reduce wave and current energy, increasing the settling of suspended sediment locally. The accumulating sediment is further protected from erosion as the brushwood groynes dissipate and reflect wave energy, also supporting the growth of soil-stabilizing vegetation. With their relatively low costs, low-tech material and, compared to other coastal protection measures, low environmental impact, brushwood groyne fields offer coastal engineers the potential to lower pressure on main line protection measures and adapt to a changing environment with rising sea levels more naturally.

Traditionally implemented along the Wadden Sea for land reclamation, the construction and composition of the brushwood groynes (cf. Figure 1) have primarily been guided by traditional knowledge and practitioners' experience (Probst 1996). The scientific optimization of brushwood groyne fields, encompassing considerations of field layout, alignment, and geometric dimensions, remains an emergent research area not currently addressed in the pertinent literature.

## OBJECTIVES & NOVELTY

This research aims to investigate the hydrodynamic characteristics of brushwood groynes through the application of a phase-resolving numerical toolbox. By evaluating current and wave interaction across comprehensive hydrodynamic scenarios and numerous construction specifications, a thorough understanding of

fluid-structure interaction (FSI) is attained. This knowledge contributes to an enhanced understanding of the protective efficacy of European brushwood groynes and their potential to foster the vertical growth of salt marshes.



Figure 1: A brushwood groyne constructed within a salt marsh in Northern Germany

## METHODS

Utilizing the data from Lieberman et al. (1998), a numerical modeling approach for a European brushwood groyne is employed using the volume-averaged Reynolds-averaged Navier-Stokes (VARANS) equations, incorporating a Darcy-Forchheimer sink term based on Sasikumar et al. (2020) within the open-source model REEF3D::CFD (Bihs et al. 2016). The calibration and validation of the numerical model are based on the observed pressure drop for current-structure interaction and the comparison of wave transmission coefficients for wave-structure interaction. To comprehensively replicate the structure through a porous media approach, a hybrid modeling approach is adapted that combines fully three-dimensional numerical simulations with data from physical experiments. Besides validation, the dataset from the original study is extended to cover additional hydrodynamic conditions, groyne dimensions, and distinctive design features such as ridges and impermeable wood panels that are frequently found in European brushwood groynes.

## RESULTS & DISCUSSION

The numerical model effectively replicates the pressure drop caused by current through a porous brushwood groyne, as depicted in Figure 2. The hybrid modeling approach demonstrates its applicability by reproducing the FSI across a wide range of headwater depths ( $d_{HW}$ ) and Darcy velocities. The wave transmission coefficients shown in Figure 3 for both physical experiments and numerical simulations also demonstrate a reproduction of the brushwood groyne-wave interaction.

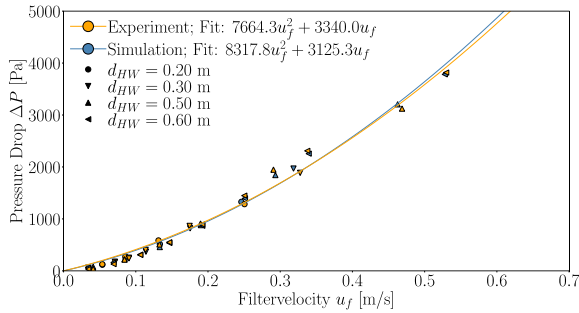


Figure 2: Pressure drop over Darcy velocities due to the brushwood groyne for different headwater depths for both the physical experiment of Lieberman et al. (1998) and the numerical simulation in orange and blue, respectively

Any underestimations observed in the simulated wave transmission coefficients may be attributed to unfiltered wave reflections inherent in the data of the physical experiment. Furthermore, additional hydrodynamic conditions are provided in Figure 3, highlighting an increase in wave transmission with an increase in water depth, nearly reaching a limit of one for some wave conditions.

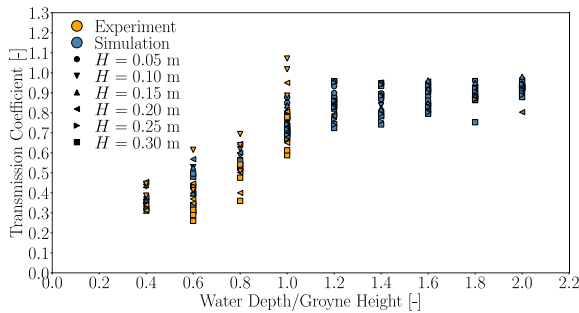


Figure 3: Wave transmission coefficient for numerous relative water depths and wave heights for both the physical experiment of Lieberman et al. (1998) and the numerical simulation in orange and blue, respectively

The influence of design specifications on the brushwood groyne is depicted in Figure 4, which features mathematical fits for the wave transmission coefficient for various relative water depths. The plot includes data for a plain brushwood groyne, a wide brushwood groyne, a brushwood groyne obstructed by an impermeable wooden panel, and a brushwood groyne with a ridge. It is evident that impermeable blocking, introduced through ridges and wooden panels, reduces wave transformation at lower relative water depths, whereas its impact becomes negligible at higher water depths. Conversely, enlarging the width of the brushwood groyne has only a negligible effect on wave transmission. Increasing the width of the brushwood groyne might prove less effective in reducing wave transmission, as impermeable blocking results in wave reflection at lower water depths. Moreover, adjustments to the brushwood groyne design aimed at reducing wave transmission may conflict with sought sediment dynamics within the groyne field, potentially

causing a decrease in landward sediment transport.

## CONCLUSION AND OUTLOOK

The study demonstrates that the FSI of European brushwood groynes can be reproduced under various current and wave conditions using a VARANS approach. The numerical model allows the investigation of both the dimensions of the groyne and the unique design features frequently observed for European brushwood groynes. The findings highlight the influence of design specifications on wave damping and, consequently, the potential for sediment mobilization within the brushwood groyne field. Future research endeavors should consider the three-dimensional aspects of the structure, addressing both its parameterization and spatial extent.

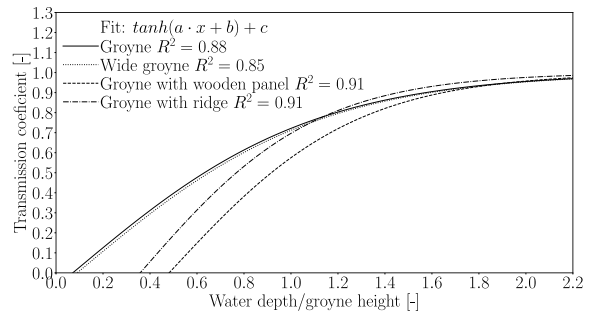


Figure 4: Mathematical fits for the wave transmission coefficient for numerous relative water depths, a plain brushwood groyne, a wide brushwood groyne, a brushwood groyne blocked by a wooden panel, and a brushwood groyne with a ridge

## REFERENCES

- Bihs, et al. (2016): A New Level Set Numerical Wave Tank with Improved Density Interpolation for Complex Wave Hydrodynamics. In *Computers & Fluids* 140, DOI: 10.1016/j.compfluid.2016.09.012.
- Dunlop, Thomas et al. (2023): Restoring Estuarine Ecosystems Using Nature-Based Solutions: Towards an Integrated Eco-Engineering Design Guideline. In *Science of The Total Environment* 873, . DOI: 10.1016/j.scitotenv.2023.162362.
- Lieberman, Nicole von et al. (1998): Ausführung und Wirkungsweise von Lahnungen. (in German). In *Die Küste*, 60 Die Küste (60).
- Oppenheimer et al. (2022): Sea Level Rise and Implications for Low-Lying Islands, Coasts and Communities. In *Intergovernmental Panel on Climate Change (Ed.): The Ocean and Cryosphere in a Changing Climate: Cambridge University Press.*
- Probst, Bernd (1996): Deichvorlandbewirtschaftung im Wandel der Zeit. (in German). In *Die Küste* 58.
- Saintilan et al. (2022): Constraints on the Adjustment of Tidal Marshes to Accelerating Sea Level Rise. In *Science* 377 (6605). DOI: 10.1126/science.abo7872.
- Sasikumar et al. (2020): Modeling Porous Coastal Structures Using a Level Set Method Based VRANS-solver on Staggered Grids. In *Coastal Engineering Journal* 62 (2). DOI: 10.1080/21664250.2020.1734412.