OYSTER REEF AND MUSSEL BED SURROGATES SUBJECTED TO WAVES

Jan Hitzegrad, Technische Universität Braunschweig, j.hitzegrad@tu-braunschweig.de
Lisa Rentsch, Technische Universität Braunschweig, l.rentsch@tu-braunschweig.de
Christian Windt, Technische Universität Braunschweig, c.windt@tu-braunschweig.de
Nils Goseberg, Technische Universität Braunschweig, n.goseberg@tu-braunschweig.de

INTRODUCTION

Benthic bivalve organisms are important eco-engineers for coastal ecosystems. They create habitats for many other species, attenuate waves and currents, enhance the water quality through filter-feeding, and stabilize seabed sediments. In shallow marine environments, they form bio-encrusted surfaces with large horizontal expanses. In the German Wadden Sea, these bio-encrusted surfaces account for roughly 6% of the tidal basins. A common feature of bio-encrusted surfaces by different species is the formation of a complex three-dimensional (3D) relief and increased hydraulic roughness compared to the surrounding sea floor. The potential for dissipating wave energy due to bed friction has been recognized in several studies (e.g., Donker et al. 2013; Manis et al. 2015) and applied as a nature-based solution (NbS) for coastal protection, e.g., on the East Coast of the USA (Morris et al. 2021). However, systematic studies on wave-biota interactions are still missing, which are needed to derive comprehensive recommendations for their use as NbS in costal protection.

MATERIAL AND METHODS

To quantify the wave-induced hydraulic roughness effects caused by bio-encrusted surfaces, an experimental study has been carried out in which surrogate models were subjected to waves. The surrogate models represent Pacific oyster reefs (*Magallana gigas*) and blue mussel beds (*Mytilus edulis*), the two most significant bio-encrusted surfaces in the German Wadden Sea. *M. edulis* beds are characterized by low-relief loose agglomerations of individuals, while *M. gigas* reefs are rigid, highly 3D, and consist of densely packed, sharp-edged individuals. For both species, parameterized surrogate models have been developed based on in-situ topographical roughness measurements (Hitzegrad et al. 2022) and 3D-printed at a scale of 1:3 using additive manufacturing with selective cement activation (Fig. 1; Lowke et al. 2018).

Figure 1 - Surrogate model tiles (0.50 x 0.25 m) of a Pacific oyster reef (left) and a blue mussel bed (right).

The surrogate models (total length of $x = 16$ m) were subjected to regular and irregular waves with varying water depths $d = 0.4 - 0.8$ m, wave periods $T = 1.0 - 3.0$ s, and wave heights $H = 0.05 - 0.20$ m, based on realistic sea state conditions in the German Wadden Sea.

RESULTS

The results show distinct wave height reductions for both bio-encrusted surface models (Fig. 2). The *M. gigas* reef model induced wave height reductions of $H_{s,oyster}/H_{s,ref} = 8 \pm 5\%$, compared to a smooth reference surface. The mussel bed model caused lower wave height reductions of $H_{s,mussel}/H_{s,ref} = 3 \pm 3\%$. Hence, the complexity of the bio-encrusted surfaces, defined by the predominant species, is decisive for the wave attenuation. Furthermore, explicit dependencies of the wave height reduction on the water depth d and the wave period T have been determined.

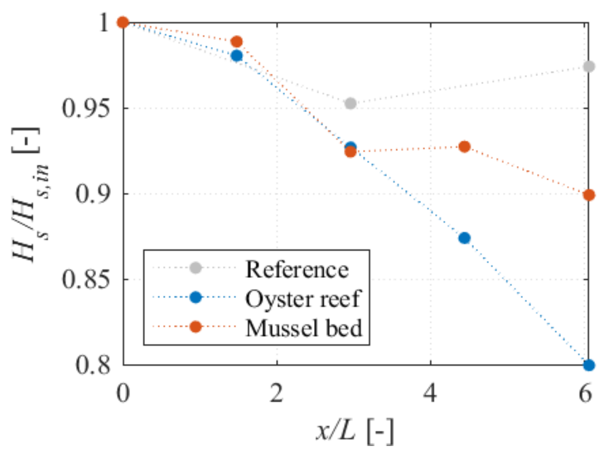

Figure 2 - Normalized wave heights $H_s/H_{s,in}$ over the length of the surrogate models x normalized by the wave length L.

Transformation processes of the shape of the regular waves and shifts in the wave energy density spectra of the irregular waves have been analyzed. In addition, wave friction factors f_w, bed shear stresses τ_b, and hydraulic roughness lengths k_s have been determined.

Thus, for the first time, this work covers wave attenuation effects for two distinct bio-encrusted surfaces over a wide range of hydraulic boundary conditions, typically found in estuarine contexts. It provides a systematic investigation of the wave-biota interactions and contributes to a better understanding of the ecohydraulic processes, which are the basis for the application as an NbS in coastal protection.

REFERENCES

Donker, J., van der Vegt, M., Hoekstra, P. (2013): Wave forcing over an intertidal mussel bed. *J. Sea Res.* 82, pp. 54–66. doi: 10.1016/j.seares.2012.08.010.

Hitzegrad, J., Brohmann, L., Pfennings, K., Hoffmann, T. K., Eilrich, A. K., Paul, M. et al. (2022): Oyster Reef Surfaces in the Central Wadden Sea: Intra-Reef Classification and Comprehensive Statistical Description. *Front. Mar. Sci.* 9. doi: 10.3389/fmars.2022.808018.

Lowke, D., Dini, E., Perrot, A., Weger, D., Gehlen, C., Dillenburger, B. (2018): Particle-bed 3D printing in concrete construction – Possibilities and challenges. *Cement and Concrete Research* 112, pp. 50–65. doi: 10.1016/j.cemconres.2018.05.018.

Manis, J. E., Garvis, S. K., Jachec, S. M., Walters, L. J. (2015): Wave attenuation experiments over living shorelines over time: a wave tank study to assess recreational boating pressures. *J. Coast. Conserv.* 19 (1), pp. 1–11. doi: 10.1007/s11852-014-0349-5.

Morris, R. L., La Peyre, M. K., Webb, B. M., Marshall, D. A., Bilkovic, D. M., Cebrian, J. et al. (2021): Large-scale variation in wave attenuation of oyster reef living shorelines and the influence of inundation duration. *Ecol. Appl.* 31 (6). doi: 10.1002/eap.2382.