8th IAHR
EUROPE
CONGRESS
LISBON - PORTUGAL
4-7 JUNE 2024

Innovative Nature-Based Solutions for Coastal Resilience

Raylton BENDÔ[1], Bárbara Proença[1], Andreia GOMES[1], Ivana BOSNIC[1]; Lénia RATO[1;]; Diogo MENDES[2],
Diogo FONSECA[1],

[1]HAEDES Portugal, Portugal
raylton.bendo@haedes.eu; barbara.proenca@haedes.eu; andreia.gomes@haedes.eu;
ivana.bosnic@haedes.eu; lenia.rato@haedes.eu; diogo.fonseca@haedes.eu
[2] CERIS, Instituto Superior Técnico, Portugal
diogo.silva.mendes@tecnico.ulisboa.pt

ABSTRACT

This work aims to address the feasibility of using nature-based solutions (NBS) by taking advantage of systems of biological organisms integrated in coastal activities to simultaneously promote coastal resilience. Precisely, the solution here presented consists in combining offshore seaweed aquaculture with wave attenuation purposes (AQUABREAK). Several studies on similar solutions have addressed the effectiveness of submerged canopies in reducing wave energy. However, the feasibility of such implementations under storm conditions remains uncertain.

With this study we aim at bridging the gap between the use of submerged canopies and coastal resilience by assessing the performance of a floating seaweed field exposed to high energy conditions. This assessment is accomplished through physical and numerical modelling.

The findings support inferences on relevant design considerations and parameters for adapting NBSs to specific local needs and enable the evaluation of the effectiveness of such systems for coastal resilience.

1. Introduction

Coastal protection measures against natural hazards are usually achieved through seawalls and breakwaters, which are rigid structures that require ongoing and expensive maintenance. In addition, these have high initial costs that do not always represent an effective measure, such as the case in Furadouro (Ovar) (Tavares et al. 2021).

Several studies have previously addressed the effectiveness of submerged aquatic canopies in mitigating wave energy. For instance, Mork (1996) documented a wave energy reduction ranging from 70% to 85% across 258-meter-long kelp natural kelp forests. Thus, a seaweed aquaculture field appears as a viable alternative or complement to coastal protection, both in economic and ecological perspectives. However, the documented wave conditions under testing do not allow to understand the effectiveness of such biologically based floating structures to apply them as coastal resilience solutions. Here we aim to discuss this subject and contribute to filling this apparent research gap.

2. Methods

This study involved assessing the accuracy of a numerical model in simulating wave dissipation caused by suspended seaweed. The SWASH model was employed to emulate and replicate an experiment conducted in a wave flume to assess the wave reduction capacity of a suspended algae field (Miranda et al., 2024). With this purpose, a one-dimensional wave propagation model was executed in order to replicate the progression of the wave height along the flume. The non-hydrostatic SWASH model, that solves the nonlinear shallow water equation, was used to propagate irregular waves considering their interaction with the floating seaweed patch to simulate the transmission and attenuation of the wave energy. The geometry of the mimicked algae field considered by SWASH is represented by the following parameters: element height (hv = 0.075 m), element equivalent diameter (dv = 0.007 m), and density (Nv = 1600 stems/m^2) of the canopy field. The drag coefficient

(C_d), a numerical input parameter, was calibrated by comparing the numerical results of the wave decay with the physical experiments using a statistical method.

In the numerical model, a 34.0 m long flume was considered, including a 4.0 m sponge layer at the opposite side of the incoming wave generation. A wavemaker boundary was defined in accordance with the target wave conditions varying between 0.04 m and 0.14 m for Hm0 and 1.3 s and 2.6 for peak period. The time step was automatically adjusted according to a Courant number ranging between 0.6 and 0.2. All cases were simulated during 5 min, where only the last 4 min were considered valid for post-processing.

3. Results

The evolution of the wave height along the flume is illustrated in **Fig. 1**. The results suggest a good capacity of the numerical model to reproduce the wave propagation and dissipation along the wave flume. Furthermore, the statistical metrics show small errors and a strong correlation coefficient. Namely, the Root Mean Square Percentage Error (RMSPE) is approximately 3.97%, the relative Bias is 0.023, and the correlation coefficient is close to 1. These results indicate that the model can accurately reproduce the wave attenuation phenomenon and that the considered seaweed field is effective in reducing wave heights for 14 simulated conditions.

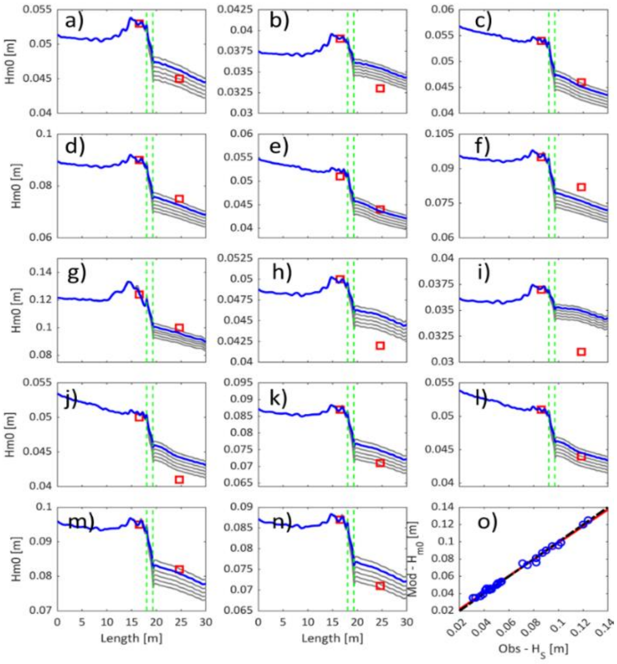

Fig 1. (a-n) Comparison between measured (red square) and modelled (continuous line) wave heights (H_{m0}), where the offshore wave height H_0 was propagated across the flume, including the leading edge of the AQUABREAK, is illustrated for the grey lines for the various Cd combinations. Note that the blue line represents Cd = 1.2, and the green lines signify the presence of AQUABREAK (length = 1.25 m) in the flume; (o) correlation between the modelled (Hm0) and measured significant wave height (Hs).

4. Conclusions

NBSs represent innovative approaches to coastal protection using submerged canopies. This study showed that for 14 conditions a seaweed field can be effective in inducing wave attenuation. These results are relevant to support the design features such as the field length and its relative positioning to the coast. These parameters are essential for an optimized wave energy dissipation system and consequent coastal inundation reduction in coastal implementations. In addition, NBSs represent a step toward achieving the EU's CO_2 emissions targets.

Aknowledgements

This work was performed in the scope of the AQUABREAK - Aquaculture Living Breakwater for Coastal Protection and Sea Decarbonization project, Grant code PT-INNOVATION-0093, funded by the “Blue Growth” Program of the EEA Grants Portugal 2014-2021.

References

Miranda, F., Proença, B., Fonseca, D., Haerens, P., Bento, A.M., Siriwardane, S., Pavlou, D., Rosa Santos, P., Taveira Pinto, F. and Fazeres Ferradosa, T. (2024). AquaBreak Project: A Nature-Based Solution Towards Food Demand and Coastal Protection. In Analytical and Experimental Methods in Mechanical and Civil Engineering. DOI: 10.1007/978-3-031-49723-0_7

Mork, M. (1996). The effect of kelp in wave damping. Sarsia, 80(4), 323–327. https://doi.org/10.1080/00364827.1996.10413607

Tavares, A. O., Barros, J. L., Freire, P., Santos, P. P., Perdiz, L. and Fortunato A. B. (2021) A coastal flooding database from 1980 to 2018 for the continental Portuguese coastal zone. Applied Geography, 135, 102534