AN ASSESSMENT OF WAVE ATTENUATION BY MANGROVE ROOT SYSTEMS

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INTRODUCTION

Tidal wetland ecosystems, such as mangrove forests, can act as a natural coastal defence against flooding by attenuating storm-driven waves and surges (McIvor, A., et al., 2012b) and contributing to increasing the resilience of coastal regions (Saenger, 2003). Additionally, mangroves provide a wide range of other ecosystem services, such as sediment trapping, to mitigate coastal erosion.

The complex structure of mangrove trees, comprising roots, trunk, and canopy, exerts drag on wave-driven flows, which can lead to considerable wave attenuation. Previous studies have found that the rate of wave decay is dependent on the tree morphology and density of mangrove trees, as well as wave conditions. However, most of the studies have only considered measurements of wave attenuation, and there is limited understanding of how drag itself varies across different tree morphologies and wave conditions. This lack of understanding limits the development of generic formulations that can be implemented in widely used wave models.

The capacity to quantify wave attenuation in mangroves will help assess their effectiveness in protecting coastal communities and ecosystems, promoting sustainable and cost-effective strategies for coastal management.

In this study, we employ detailed experimental observations, including measurements of drag forces, for a wide range of mangrove forest models and wave conditions. We combine these observations with a phase-resolving, non-hydrostatic wave model to enhance our understanding of wave-mangrove interactions.

METHODOLOGY

Physical experiments were conducted in a large-scale wave flume (54m long, 1.5m wide, and 1.1m deep) located at the Coastal and Offshore Research Laboratory (CORLab) at the University of Western Australia (UWA).

The mangrove forest was built using 30 mangrove tree models of Rhizophora species on a 1:8 scale. The tree models follow the model described in Ohira et al. (2012). In our experiments, the roots consist of bend wires attached to PVC pipes as trunks (see Figure 1). At this stage, the canopy is not considered in the experiments. Both regular and irregular wave conditions with wave heights ranging from 0.1 to 0.3 m and wave periods from 1 to 5 s were tested for three different water depths covering a typical Mean Sea Level, High Tide, and High Tide + Storm Surge level.

A total of 15 wave gauges were deployed to measure the free surface elevation, wave height, and wave setup. Additionally, three load cells were placed in a 10-cm-high false bed attached to the bottom of a mangrove tree model to quantify the drag and inertial forces. An Acoustic Doppler Velocimeter (ADV) was used to measure velocity profiles at selected locations.

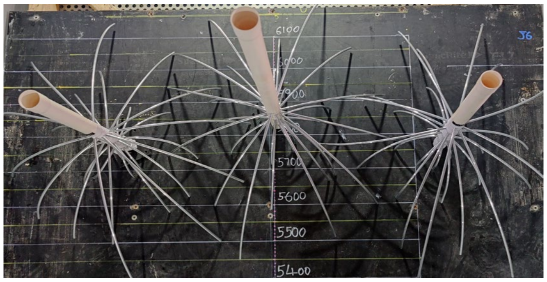

Figure 1 - Frontal view of the mangrove model.

All experimental runs were first simulated with the SWASH wave model (Zijlema et al., 2011) to estimate the wave attenuation a priori. Subsequently, the model is contrasted with the experimental observations of the wave flume.

KEY FINDINGS

A preliminary experiment representative of the low-mangrove density case shows a good agreement between the measurements and SWASH simulations (see Figures 2a and 2b).

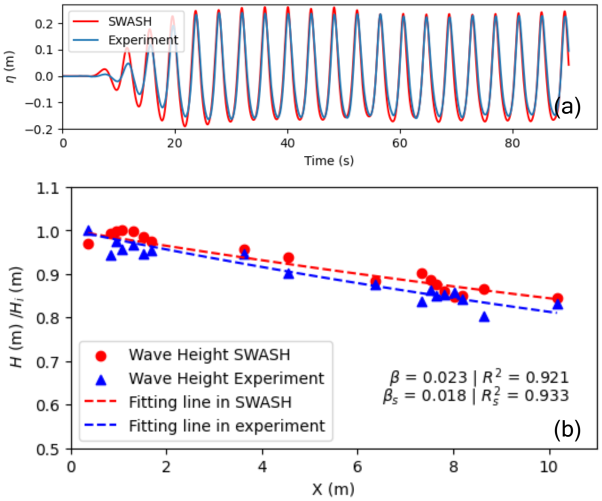

Figure 2 - (a) Free surface elevation of the low-mangrove density (b) Dimensionless wave height along the wave flume from the experiments and the SWASH simulation.

The preliminary results of experiments with mangrove forests showed three main concepts: 1) a high correlation between the damp coefficient β when the Ursell number increases; 2) a high correlation between the damp coefficient and the wave steepness parameter; and 3) there is not a clear relation between the wave period and the wave attenuation. There is debate regarding point 3. Some literature suggests that increasing the wave periods leads to reduced wave attenuation, while others propose the opposite effect: an increase in wave attenuation with longer wave periods. Further research is required to draw definitive conclusions or provide an explanation for the relationship between wave attenuation and wave period. The use of SWASH simulations is anticipated to provide valuable insights into this relationship.

NEXT STEPS

Besides elucidating the relation between the wave period and the wave attenuation, the upcoming research will investigate the impact of two factors: the frontal area (A) and the velocity of reference (U_{ref}) to estimate the drag coefficient (C_d) in dense mangrove forests, considering Reynolds (Re) and Keulegan-Carpenter (KC) numbers across different submersion conditions.

REFERENCES

Maza, M., Lara, J., & Losada, I. (2019): Experimental analysis of wave attenuation and drag forces in a realistic fringe Rhizophora mangrove forest. Advances in Water Resources. Vol. 131.

McIvor, A., Spencer, T., Möller, I., & Spalding, M. (2012b): Storm surge reduction by mangroves. In Natural Coastal Protection Series: Report 2. The Nature Conservancy and Wetlands International: Cambridge, UK.

Kelty, K., Tomiczek, T., Cox, D., Lomonaco, P., & Mitchell, W. (2022): Prototype-Scale Physical Model of Wave Attenuation Through a Mangrove Forest of Moderate Cross-Shore Thickness: LiDAR-Based Characterization and Reynolds Scaling for Engineering with Nature. Frontiers in Marine Science. Vol. 8.

Saenger, Peter. (2003): Mangrove Ecology Silviculture and Conservation, Springer Dordrecht, pp.1-360.

van Rooijen, A, Lowe R., Ghisalberti, M., McCall R., Hansen J., (2022): Modelling wave attenuation through submerged vegetation canopies using a subgrid canopy flow model, Coastal Engineering, Volume 176., pp. 1-14.

Zijlema, M., Stelling, G., Smit, P., (2011): SWASH: An operational public domain code for simulating wave fields and rapidly varied flows in coastal waters. Coastal Engineering, Volume 58., pp. 992-1012.