Spectral wave energy dissipation by a seagrass meadow: integrating analytical and empirical models

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INTRODUCTION

Waves propagating across partially emerged and submerged vegetation (such as a seagrass meadow) gradually lose energy due dissipation generated by the drag forces exerted by the vegetation elements (e.g., stems, blades, etc.) (Mendez & Losada, 2004). How vegetation characteristics influence wave dissipation is important to quantify how a canopy affects the physical processes that ultimate lead to the attenuation of waves. However, field studies on wave dissipation in seagrass meadows have often not considered the impact of plant flexibility on both in-canopy flows and wave attenuation. In this study we aim to (1) understand how wave interactions with flexible seagrass canopies affect wave dissipation, (2) assess the role of flow modifications by canopies to explain frequency-dependent wave dissipation, and (3) evaluate the role of flexibility on wave attenuations relative to assuming rigid canopy flow theory.

METHODOLOGY

We deployed an array of 10 RBR pressure sensors over 1 km of a dense seagrass meadow at an exposed beach at Rottnest Island, Western Australia. The observed wave energy flux between each station was used as an input to calculate the bulk drag coefficient $(\widetilde{C_D})$ and the frequency-dependent wave energy factor $(f_{e,j}$, with j being the frequency) as in the classic empirical models by Dalrymple et al. (1984) and Mendez & Losada (2004). As we also wanted to account for how frequency-dependent flow attenuation influenced wave dissipation, we compared these results with canopy wave dissipation formulations proposed by Lowe et al. (2007) using the effective blade length (Luhar & Nepf, 2016). To measure the vertical attenuation of the currents and waves by the meadow, we deployed a Nortek Aquapro HR that sampledat 1 Hz in continuous mode from 10 to 200 cm above the bed (cmab), a Nortek Vector measuring at 8 Hz and a Nortek Vectrino measuring at 25 Hz that could be freely moved vertically with a rod. The Vectrino has a small probe, which allowed us to obtain detailed flow measurements inside the canopy from 1 to 40 cmab. Time-averaged velocity and root mean squred (rms) velocities were divided by their free-stream equivalents (~200 cmab) to calculate flow attenuation coefficients.

RESULTS AND DISCUSSION

During the experiment, measured wave heights varied between 0.15 to 0.5 m, with wave direction being fairly constant in all frequencies. Mean currents inside the canopy were 5% of the free stream and rms wave velocities were 47%, on average. The attenuation of wave velocities were frequency-dependent, with higher attenuation found for lower frequencies (Figure 1).

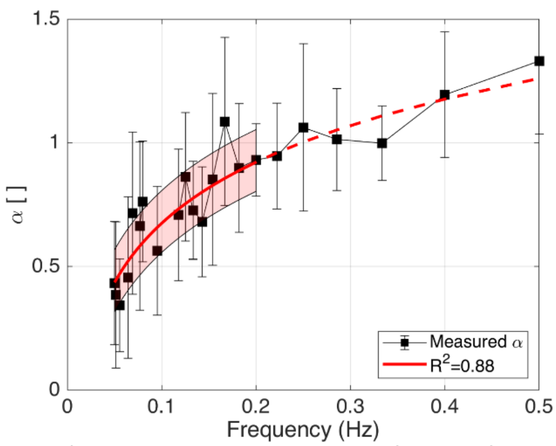

Figure 1: Wave velocities attenuation for each frequency

Wave dissipation calculated with leaves considered in full upright position and no vertical flow attenuation by the seagrass meadow is much higher than the equivalent drag coefficient considering vertical attenuation and the effective blade length.

CONCLUSION

The results highlight the significant role that seagrass meadows play in dissipating wave energy. However, the effective blade length and vertical attenuation need to be taken into account so the dissipation and, consequently, coastal protection are not overestimated.

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