

EXPERIMENTAL AND NUMERICAL APPROACH TO THE FOILAR BEHAVIOUR OF SEAGRASSES

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INTRODUCTION

Coastal health relies on the delicate equilibrium between the biotic and abiotic factors. Flora and fauna offer dynamics, connectivity, and productivity, while the physical environment provides habitat, energy flow, and substrate. Regrettably, coastal ecosystems remain vulnerable to various types and sources of pressure which are inescapable or demanding to alleviate without considerable socio-economic modifications. Consequently, the dynamic balance governing the physical, biological, and chemical processes fundamental to the functioning of the ecosystem is compromised. In numerous locations, there is clear evidence of degradation, resulting in a reduction in connectivity, biodiversity, and species population and consequently, a notable decline in both the quality and quantity of environmental services these ecosystems offer. The relationship between the quantity, quality and circulation patterns of water and the functioning, survival, and connectivity of ecosystems, especially coastal ecosystems, is now widely acknowledged.

Biological research encompassing hydrodynamics has bolstered the fundamentals and theories of aquatic ecology (Statzner et al. 1988). This has resulted in the creation of sustainable management strategies and interventions that align with the bio-chemical cycles and procedures of the ecosystems involved (Nikora 2010). Simultaneously, hydraulic engineering has benefited from the incorporation of ecological concepts. Since this approach acknowledges that water is the primary medium for inter- and intra-ecosystem transport, the analysis can be conducted by examining exchanges between boundaries or interfaces that occur at various scales (Marion et al. 2014). Interfaces are narrow regions where exchange happens between two or more phases or domains of the same flow. The interfaces of greatest importance to the current research are the interactions between water and organisms or water with itself. However, additional interactions, including those between water and sediment or water and chemical processes, as well as possible combinations between them, may require analysis. It is necessary to analyse these factors thoroughly. Water-water interfaces are influenced by changes in regime (turbulent, viscous), forcing (wave, tidal, river), flow type (two- or three-dimensional), or quality (saline, brackish, polluted). Conversely, water-organism interfaces interact at varying scales - from smaller to larger. These interactions consist of flow interactions with periphyton, hyporheic zones, individual organisms, meadows, a mosaic of meadows, and the entire wetland as a whole. Each phase has its unique analysis and modelling approach, alongside its sustainable and healthy flow attributes.

The current investigation focuses on examining the interaction between water and seagrass organisms on an individual level, hereafter referred to as foliar interaction.

Past research has predominantly explored the role of seagrass as a friction supplier and identified the relevant coefficients primarily for integrating into numerical models (Shaefer et al. 2022; Dinu et al. 2023). The aim of this study is to investigate foliar interaction and gather data for seagrass restoration and conservation, as well as for upscaling investigations involving seagrass patch-water interaction. To achieve this goal, we selected an experimental methodology that utilises an idealized model of a single seagrass leaf along with its complementary CFD model validation.

EXPERIMENTAL SETUP

The experimental work was conducted in the wave flume of the Institute of Engineering of the National University of Mexico. This is a 22 m long, 0.4 m wide facility which features a piston type wavemaker with a dynamic absorption system attached.

The idealized seagrass leaf model is a 20 cm long foam with a 1 cm wide squared cross section. The foam density is lower than the water to ensure floatability. Fig. 1 displays the seagrass leaf within the wave flume.

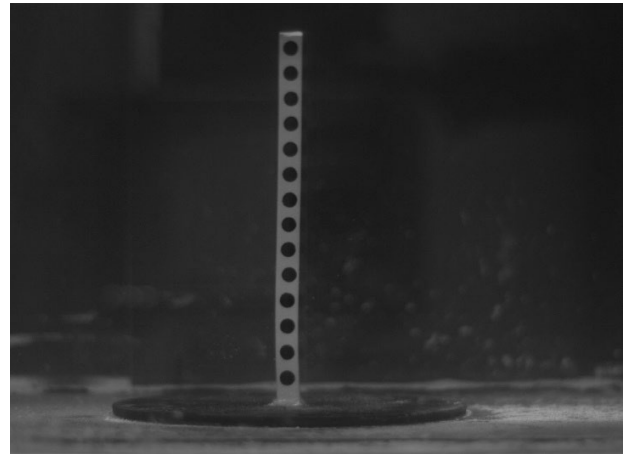


Figure 1 - Idealized seagrass leaf for water-organism interaction studies.

Particle Image Velocimetry (PIV) was implemented to analyse the velocity field around the leaf. The flow was seeded glass spheres coated with silver. A high-speed camera was set to 200 fps and a continuous blue laser sheet was used. Exposure time was set such that the dots in Fig. 1 were visible and the motion of the seeded particles wasn't blurred. Images of the area surrounding the leaf were processed with PIVLab and the displacements of the dots were measured with ImageJ software.

The experimental programme included regular waves with periods of 0.8-1.2 s and wave heights of 5 and 8 cm. The still water level was set to 0.3 m. Wave gauges were placed before and after the leaf as a reference.

NUMERICAL MODELLING

Flow3D model was used to numerically compute the water-organism interaction. This CFD tool is capable to calculate the deformation of a leaf with the same physical properties of the one tested during the experiments. The model can use different cell sizes along the domain to improve the computation in the leaf's near field.

RESULTS

As stated before, the main results are the displacements of the idealized leaf and the velocity field on its surroundings. Fig 2. Shows a couple of images of the leaf being deformed by waves during the experiments. It can be seen that the leaf moves back and forth in a similar way as some seagrass species.

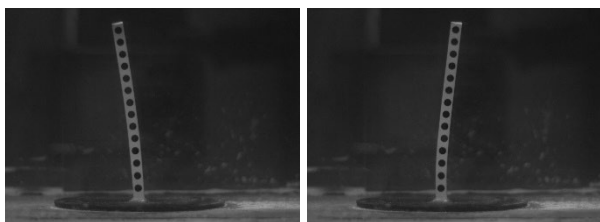


Figure 2 - Examples of the idealized leaf deformed by waves.

The analysis of the images gave the time series of the displacements (black dots) which have been plotted in Fig. 3. As expected, the displacements of the leaf along the vertical column showed linear and sinusoidal behaviour, and its amplitude is inversely proportional to the water depth. It is noticeable that the displacements are slightly larger in the wave direction, i.e. the wave crest is able to deform the leaf more than the trough is able to bring it back.

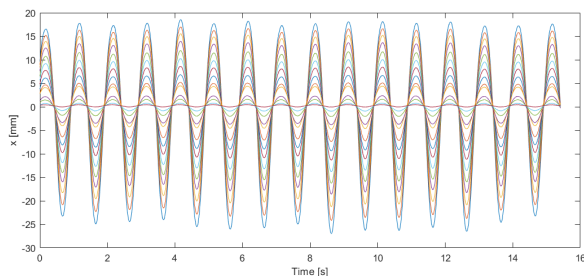


Figure 3 - Leaf displacements along the water column; larger amplitudes are closer the water surface.

The velocity of displacement of the leaf is proportional to the wave orbital velocity. Evidently, the shape of this velocity is ellipsoidal and tends to circular with water depth. This can be seen in Fig. 4 where the velocity of each black dot has been plotted versus its position along the wave propagation axis.

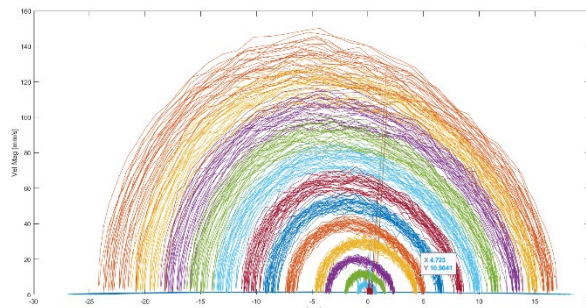


Figure 4 - Leaf displacement velocities along the vertical column.

In the final paper, the experimental results will include the PIV-recorded velocity fields in the leaf vicinity.

The water-organism interaction has also been numerically modelled as shown in Fig. 5 where the computed velocity field for two any given instants are presented.

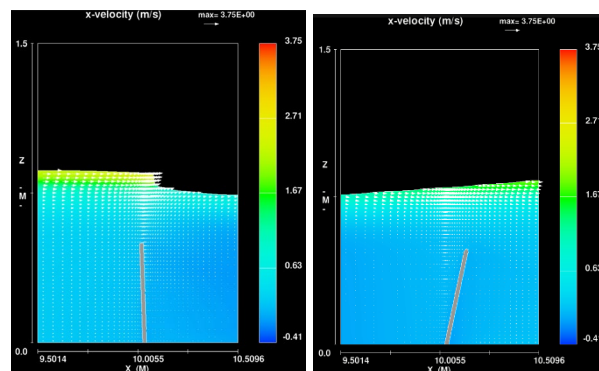


Figure 5 - Computed velocity field on the vicinity of the seagrass leaf.

The full validation and numerical results will be presented in the complete version of this work.

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