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FLOW STRUCTURE OF A HETEROGENEOUS SEAGRASS CANOPY

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1 INTRODUCTION

Seagrass canopies are widely recognized for their ecosystem services (Barbier et al., 2011) including flow and wave attenuation (Ondiviela et al., 2014), sediment stabilization (De Boer, 2007), carbon sequestration (Duarte & Krause-Jensen, 2017) and nutrient deposition (Gacia et al., 2002). Over the past decades, various studies have delved into the modifications imparted by a seagrass canopy under both unidirectional and oscillatory flow at various scales. However, until recently, the majority of studies have either reported on or modeled seagrass canopies without considering the heterogeneity of species within a single canopy. While simplified prototype models offer valuable insights into system dynamics, they can introduce biases, potentially leading to the reduction or amplification of relevant physical processes (Tinoco et al., 2020). For instance, the study by Weitzman et al. (2015) emphasized the significance of considering vertical heterogeneity in a canopy. They noted that the presence of an understory can modulate near-bed flow processes differently, with flow attenuation significantly increased due to the understory's presence. However, embedded physical mechanisms and quantitative limitations in ecosystem functioning and services are only little understood. Such a knowledge gap is pointed out in the recent review by Risandi et al. (2023) regarding field studies of seagrass meadows in Indonesia. Only few studies explore the interaction between such a heterogeneous canopy (Short et al., 2011) and hydrodynamics despite the abundance of seagrass species in the region (McKenzie et al., 2020). Through physical modeling of four different species of seagrass this study aims to improve the understanding of flow structure modulated by a heterogeneous canopy under unidirectional currents at full scale.

2 METHODOLOGY

All experiments were conducted in the closed-circuit flume at the Ludwig-Franzius-Institute for Hydraulic, Estuarine and Coastal Engineering which has a total length of 60 m, a width of 1 m, and offers a maximum flow depth of 0.8 m (Figure 1). 3D instantaneous velocity measurements were taken using a stereoscopic particle image velocimetry (PIV) system. Hollow glass spheres with a nominal median diameter of $d_{50} = 10\ \mu m$ and a bulk density of approximately $\rho_b = 1100\ \frac{kg}{m^3}$ were used to seed the flow. The seeded flow was illuminated in the center of the flume by a double pulsed Nd:YAG laser with 400 mJ pulsed energy at a wavelength of 532 nm. Two CCD Imager ProSX 5MP-resolution cameras were used to acquire 1500 double-frame images at a frequency of 7.2 Hz. The cameras were positioned to look into the flume through two water filled prisms at an angle of 30° to account for the image distortions arising from refraction.

In this study, vegetation canopies are modelled considering the seagrass species: a) *Enhalus acoroides* (Ea), b) *Thalassia hemprichii* (Th), c) *Halodule uninervis* (Hu) and d) *H. ovalis ssp. Bullosa* (Hb). To achieve dynamic similarity in the model the buoyancy to rigidity force ratio λ_1 (Ghisalberti & Nepf, 2002), was used as described in Equation (1):

$$\lambda_1 = (\rho_w - \rho_s)h^3/Et^2 \tag{1}$$

where ρ_w and ρ_s are the seawater and blade density, h is the height of the blade, E is the modulus of elasticity and t is the thickness of the blade. The values of λ_1 fall within the range of the field values of the target species, calculated from the mechanical and morphological properties reported by de los Santos et al. (2016). The canopy length used for this study was

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2 m. The model canopy was investigated at Reynolds number $Re = \frac{U_0 H_0}{\nu} \in [5.592 \times 10^4, 1.3656 \times 10^5]$, where U_0 is the incoming bulk velocity, H_0 (0.4 m) is the water depth in the flume and ν is the kinematic viscosity ($1\times 10^{-6}\ m^2/s$).

Figure 1. Canopy model in circulation-flume.

3 RESULTS

During the presentation, the current experimental data will be showcased. Qualitatively it is observed that at low velocities the model forms a distinct three-story canopy structure, where the constituent elements modulate the flow. This multi-story structure is, however, then gradually diminished by the increase in flow velocity; thus, resulting in a single-story canopy structure. Quantitative results will demonstrate the effects of element variability, characterized by differences in height, thickness, width, and stiffness of the constituent species, on the flow structure. Comparing this metric with published metrics from unispecific canopies will provide new insights into the fundamental differences in flow structures.

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