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Not all Laminaria digitata are the same! Phenotypic plasticity and the selection of appropriate surrogate macroalgae for ecohydraulic experimentation

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Whilst early physical modelling and theoretical studies of the interactions between vegetation and flowing water employed rigid structures such as wooden dowels, recent studies have progressed to flexible surrogate plants. However, even appropriately-scaled flexible surrogates fail to capture the variability in thallus morphology, flexibility and strength, both within and between individuals, and frontal or planform area over space and time. Furthermore, although there have been a number of field studies, measurements of hydraulic variables have generally been limited to time-averaged at-a-point measurements that aim to approximate the depth-mean velocity. This is problematic because in spatially heterogeneous flows, point measurements are dependent upon the sampling location. Herein, we describe research carried out by the participants in the PISCES work package of the HYDRALAB IV project that sought to address these limitations and assess the level of complexity needed to adequately reproduce the hydrodynamics of the natural system in physical models.

We selected an 11 m long $\times$ 6 m wide region of a tidal inlet, the Hopavågen Bay, Sør-Trøndelag, Norway, that contained 19 Laminaria digitata thalli and 101 other macroalgae thalli. Two L. digitata specimens $\sim$0.50 m apart were selected for detailed study and a 2 m long $\times$ 8 m wide frame was oriented around them by enforcing zero cross-stream discharge at its upstream edge. We then quantified: 1. the mean and turbulent flow field of the undisturbed condition (Case A); 2. the positions, geometrical and biomechanical properties of the macroalgae; and 3. the mean and turbulent flow field after the macroalgae were completely removed (Case B). Later, Case A was replicated in the same location ($\pm$0.025 m) before the 19 L. digitata thalli were replaced with 19 "optimized" surrogates (Case C). These three cases were then repeated in the Total Environment Simulator at the University of Hull, UK. Live macroalgae thalli could not be transported from Norway to the UK, so we used the same species of live macroalgae harvested from a wave-dominated coast in the UK. These algae exhibited longer, narrower and more flexible blades. The same surrogate plants were used in both the field and flume experiments. In all cases, a profiling ADV was used to collect 45 velocity profiles composed of up to seven 35 mm-high profiles collected for 240 s at 100 Hz, at a streamwise spacing of 0.25 m and cross-stream spacing of 0.20 m.

The results show that the live macroalgae in the flume simulation exerted less influence on the flow field than the live macroalgae at the field site. In contrast, the "optimized" surrogate macroalgae behaved similarly to the live algae at the field site and yielded similar mean and turbulent velocity fields as our prototype live macroalgae. This emphasizes both the importance of phenotypic plasticity and the importance of selecting surrogates that adequately represent the mean characteristics of the species of interest.