Wave Damping by Flexible Aquatic Vegetation

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INTRODUCTION

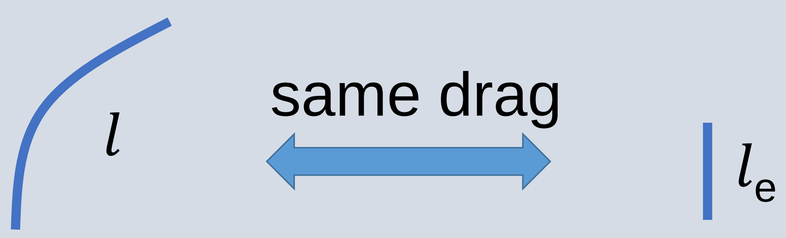
Aquatic vegetation provides a variety of ecosystem services, including the protection of shorelines from storms and erosion. Shoreline vegetation slows down wave motion and keeps sediments from being kicked up, such that the erosion due to wave impact can be reduced. However, the benefit of vegetation has not been incorporated into coastal management, because a universal physical model of wave damping over aquatic vegetation has not been developed.

The project will develop such a model to characterize the wave energy dissipation based on the flexibility and geometry of the vegetation. Using the model, costal engineers and scientists will be able to estimate how much the wave impact diminishes.

Figure 1. *Zostera marina* blades under current. Photo taken by Dr. Eduardo Infantes Oanes.

OBJECTIVES

The impact of reconfiguration of the blades is addressed through the effective blade length, l_e, which is the length of a rigid, vertical blade that generates the same drag as the flexible blade of length l.



- **Verify (modify) existing scaling laws for individual strap-like blades**

$$\frac{l_e}{l} \sim (Ca_w L)^{-1/4}$$

- **Extend the scaling laws to predict wave damping**
- **Consider wave-current conditions and vegetation of more complex morphology**

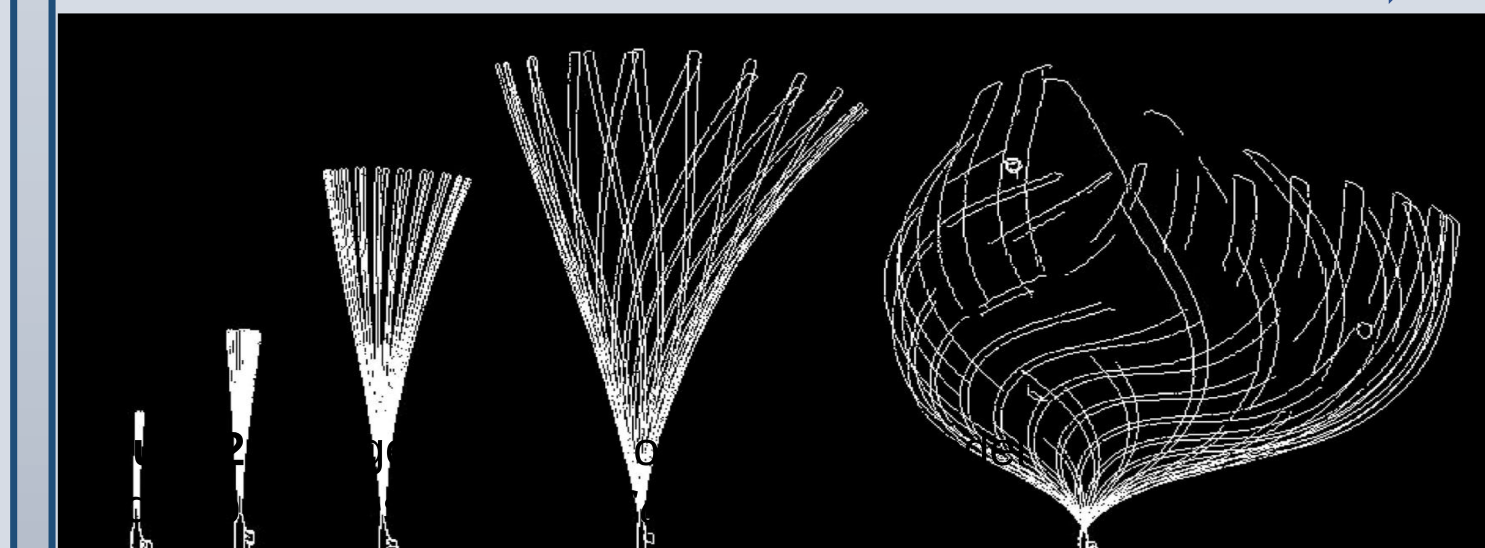
METHODS and MATERIALS

Two dimensionless parameters govern the blade motion in waves

$$Ca_w = \frac{hydrodynamic\ drag}{blade\ stiffness} = \frac{\rho b l^3 U_w^2}{EI}$$

$$L = \frac{blade\ length}{wave\ excursion} = \frac{2\pi l}{U_w T}$$

$Ca_w L$ increasing

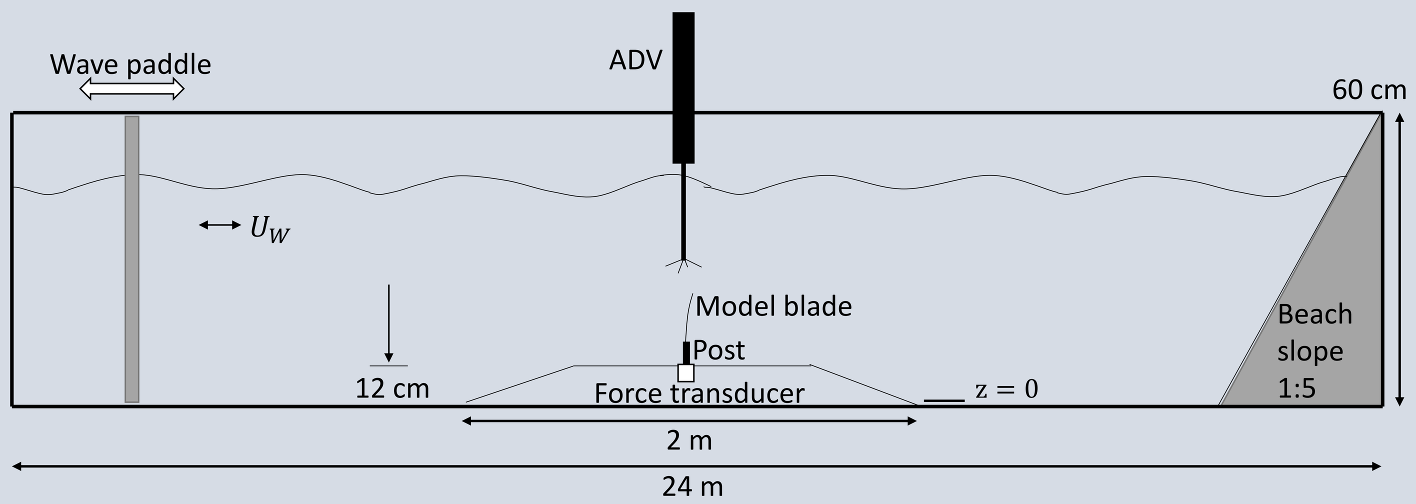


1. Materials and Wave Parameters

LDPE Blade
Wave period ***T* = 0.5 – 2s**
Wave amplitude ***A* = 0.5 – 5cm**
$Ca_w = 0.2\ to\ 1 \times 10^4$
$L = 0.5\ to\ 45$

2. Experimental setup for drag force measurement

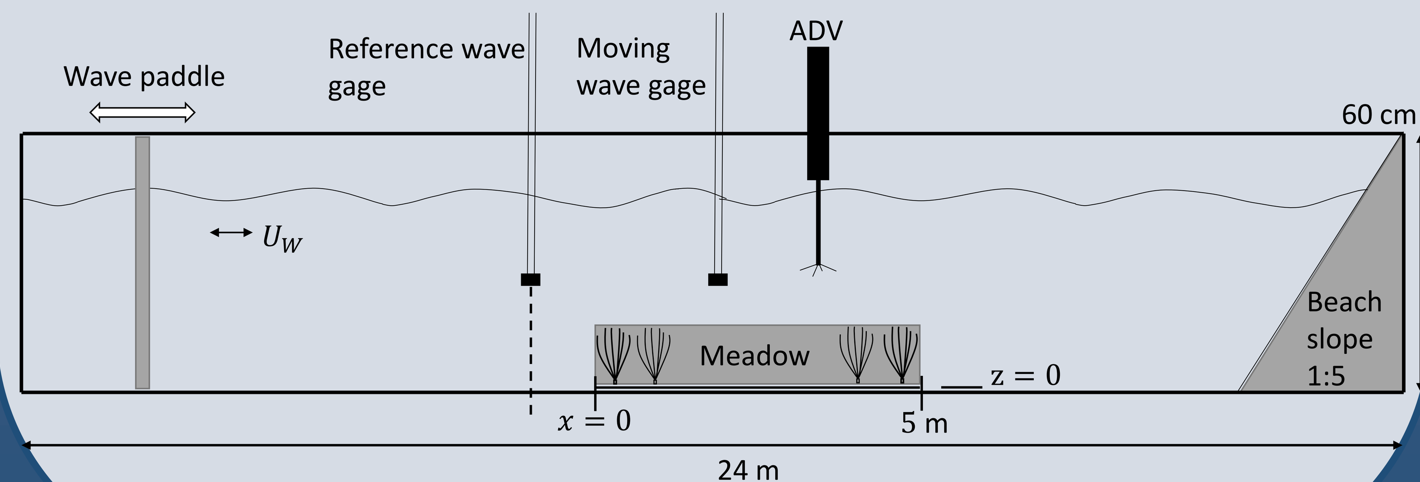
$$\frac{le}{l}(rms) = \frac{measured\ rms\ F}{expected\ rms\ F\ for\ rigid\ blade (= \int_0^l \frac{1}{2}\rho C_D b |u_w| u_w)}$$



3. Experimental setup for wave damping measurement

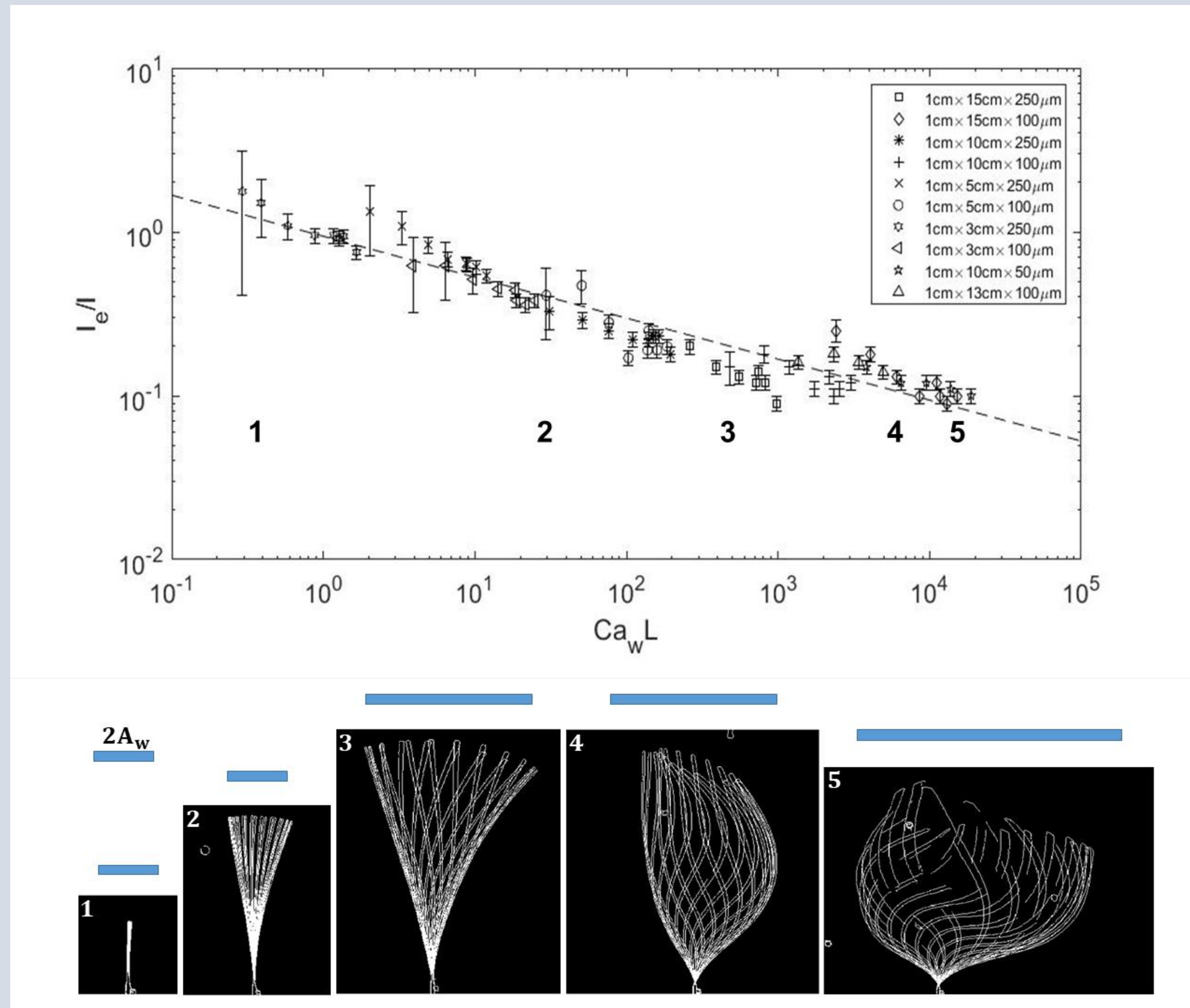
$$\frac{a_w(x)}{a_{w0}} = \frac{1}{1+K_D a_{w0} x}$$

Use wave gages to measure wave amplitude $a_w(x)$



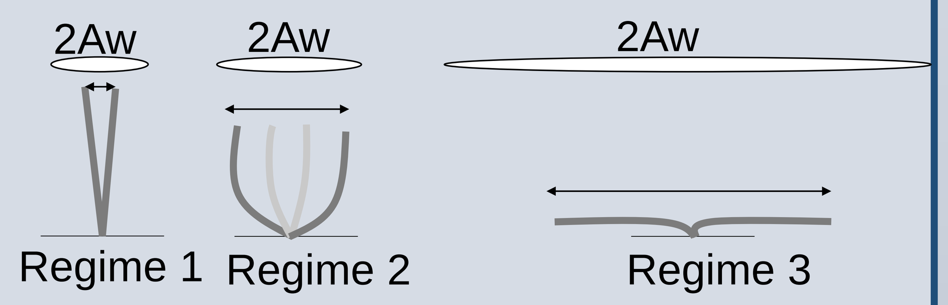
RESULTS and DISCUSSION

1. Drag force on individual blades



- **Verify (modify) existing scaling laws for individual strap-like blades**

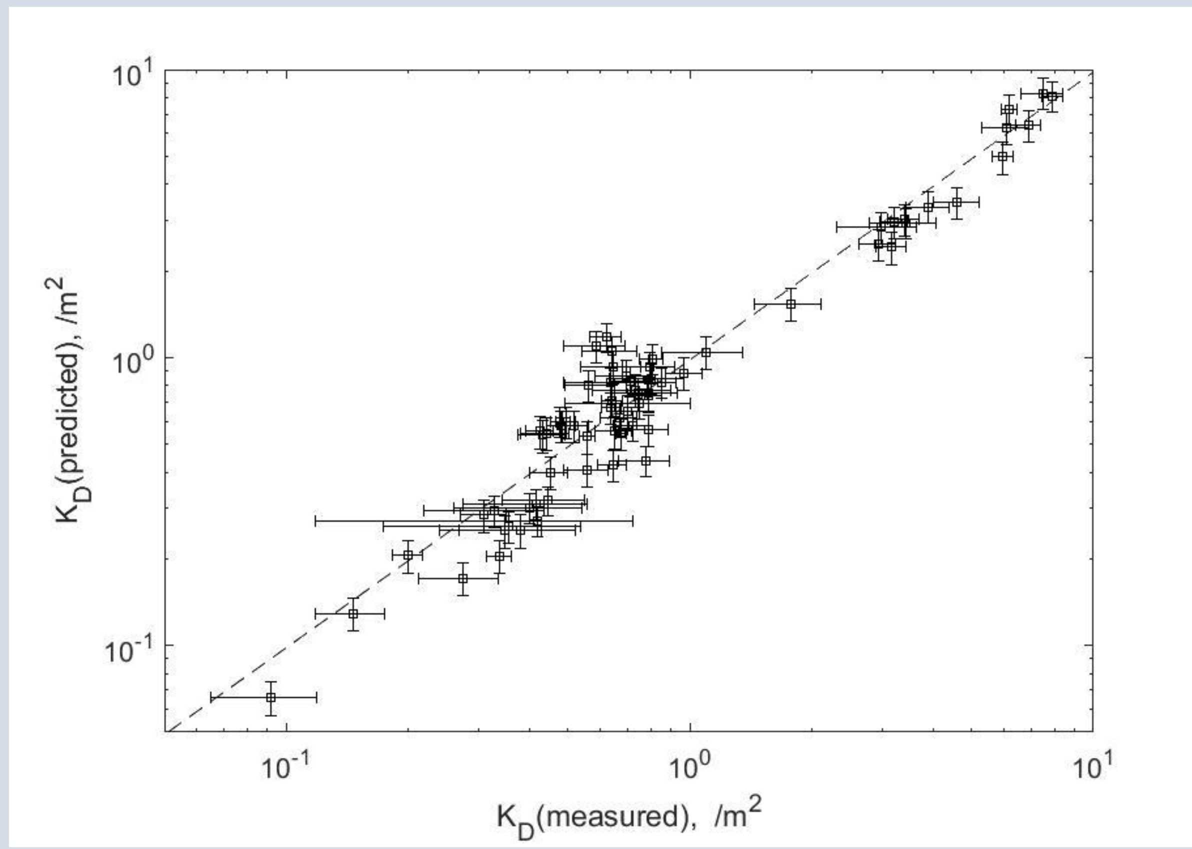
$$\frac{l_e}{l} = 0.94(Ca_w L)^{-0.25}$$



There are three regimes of the wave-vegetation interaction.
Regime 1: Stiff blade, $Ca_w < 1$, $\frac{l_e}{l} \approx 1$
Regime 2: Short waves, flexible blade, $Ca_w > 1, L \sim 1$
Regime 3: Long waves, flexible blade, $Ca_w > 1, L < 1$ (not included in experiments)

2. Extend the scaling laws to predict wave decay coefficient, K_D

Predict K_D using l_e: $K_D = \frac{2}{9\pi} C_D a_v k \left(\frac{9 \sinh(k\,l_e) + \sinh(3\,k\,l_e)}{\sinh kh\,(\sinh(2kh) + 2kh)} \right)$



Linear-fit of $K_D(predicted)$ versus $K_D(measured)$ yields

$K_D(predicted) = 0.83 \pm 0.04 K_D(measured)$ with a correlation coefficient of $r^2 = 0.97$

Overall, the predicted K_D has good agreement with the measurement (error < 20%).

3. Other findings

- **Wave-induced current makes blades in meadow more pronated than blades in isolate; however, it does not play an important role in wave damping.**
- **Wave damping is similar for regular and random shoot arrangement in meadow.**

4. Future work

Extend the proposed model to combined wave-current conditions and to vegetation of more complex morphology.