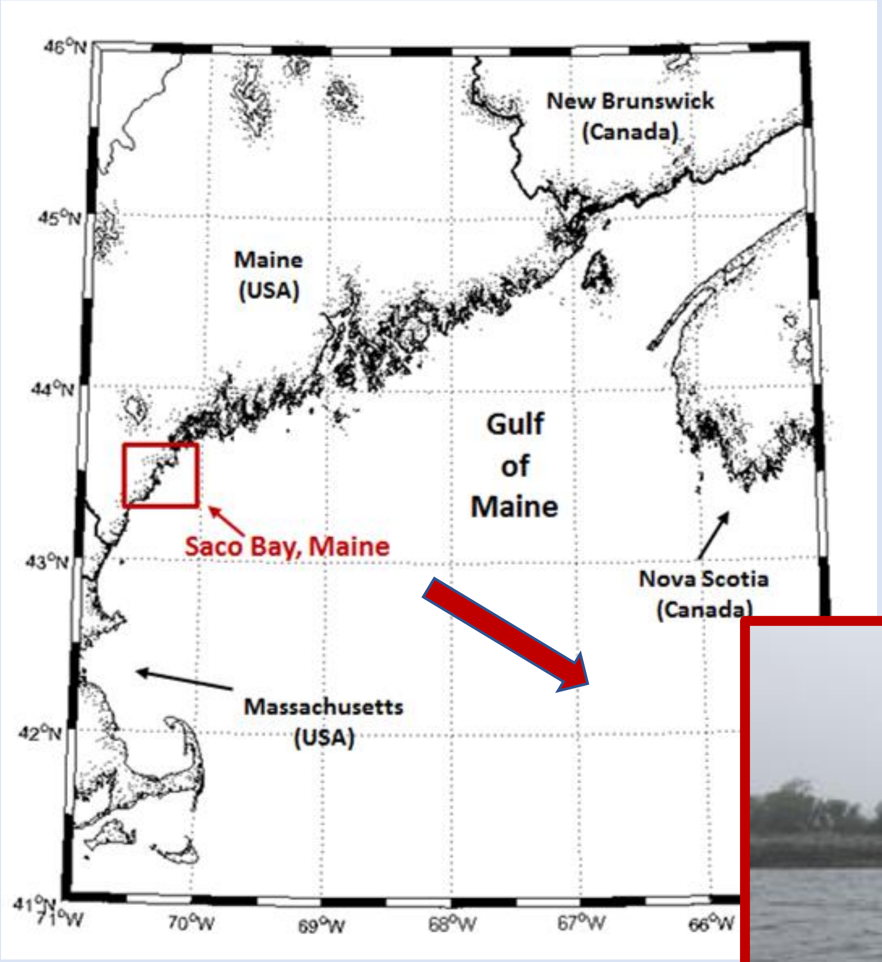
Hydrodynamic characteristics of a full-scale kelp model



1. Build a full-scale model representing *Saccharina latissimi (Sugar Kelp)* densely grown in Saco Bay Maine.
2. Match the exposed length, flexural rigidity, the number of blades, the mass/length of biomass, and mass density.
3. Tow model in the 116m x 7.9m x 4.9m with the model at aligned and perpendicular orientations
4. Resolve the normal and tangential drag area characteristics.
5. Use results in numerical model validation

Fredriksson, D.W., Dewhurst, T., Drach, A., Beaver, W.M., St. Gelais, A.T., Johndrow, K., and B.A. Costa-Pierce. (2020). Hydrodynamic characteristics of a full-scale kelp model for aquaculture applications. *Aquacult. Eng*. 90: https://doi.org/10.1016/j.aquaeng.2020.102086.

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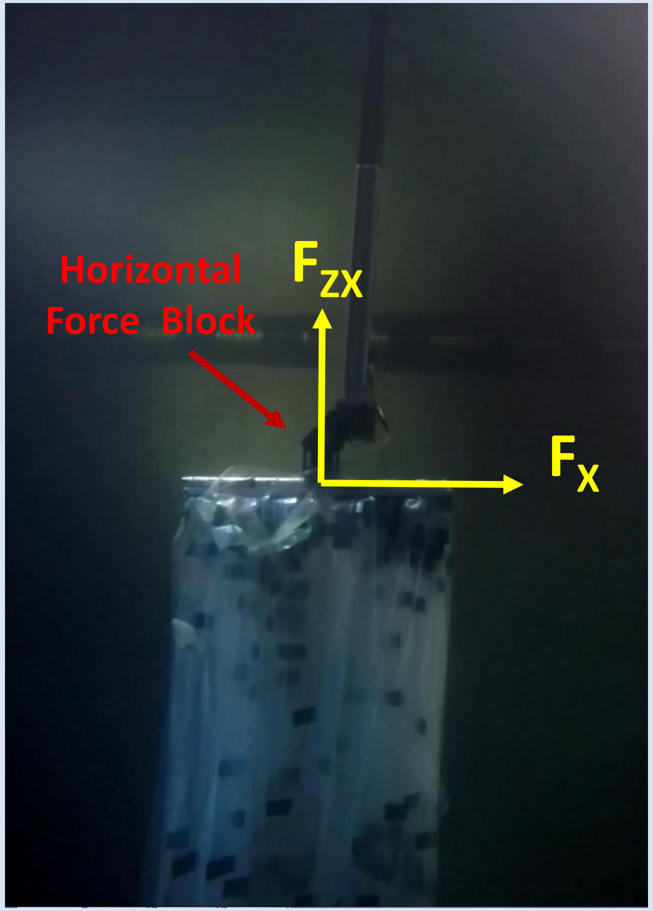
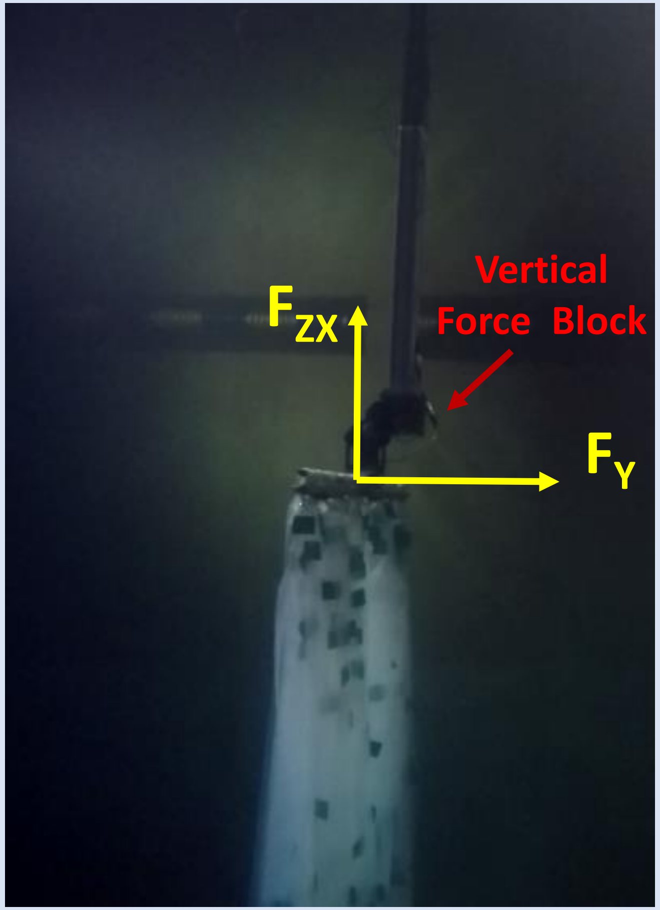
Kelp Model

- Length: 3m, Width: 1m, flexural rigidity
- 178 strips of LDPE (534 m)
- Actual 300-400 blades/m
- ≈ 16 kg/m

Aligned Orientation



Perpendicular Orientation



- Forces measured with two force blocks
- Tangential forces obtained with coordinate transformation
- Normal forces resolved as a balance from weight and buoyancy
- Tows done at 5 speeds from 0.25 to 1.25 m/s

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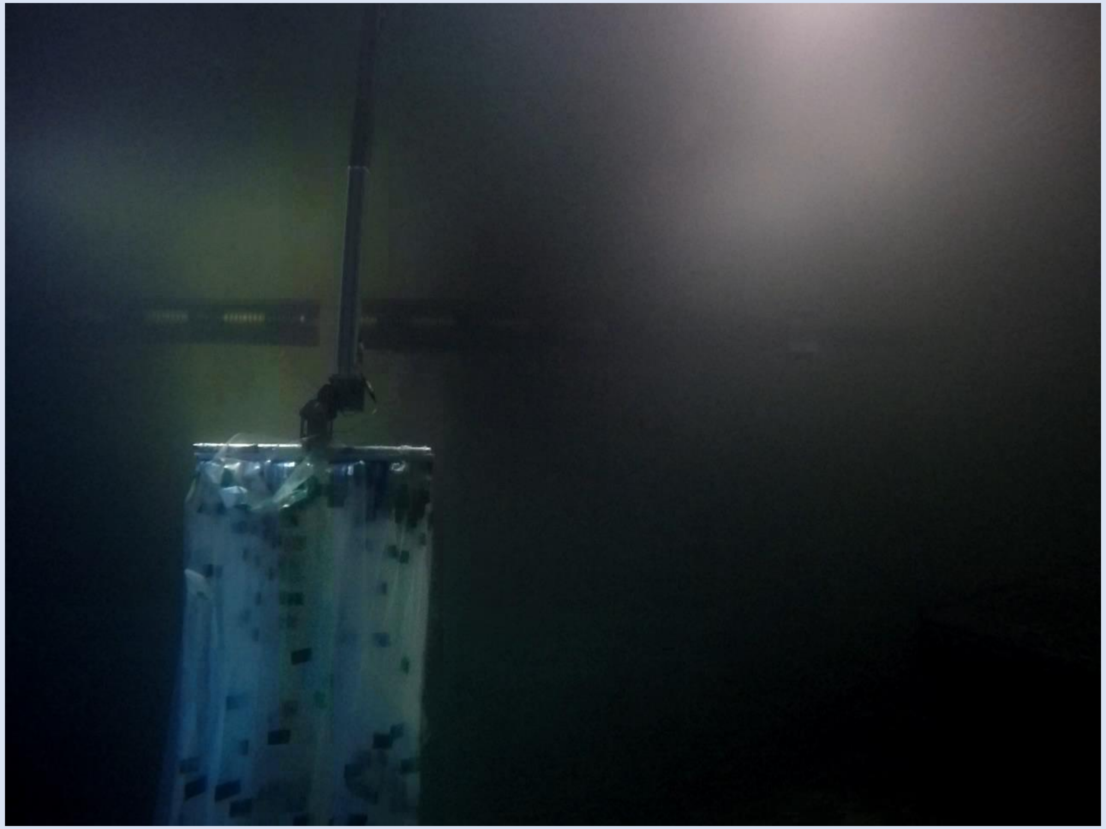
Aligned Orientation



Normal

$$s_{Dx} = \frac{(f_{Dx})}{\frac{1}{2}\rho_w {U_x}^2} \rightarrow \boldsymbol{D_n C_n}$$

Tangential

$$s_{Dz_a} = \frac{(f_{Dz_a})}{\frac{1}{2}\rho_w {U_{z_a}}^2} \rightarrow \boldsymbol{D_t C_t}$$

Perpendicular Orientation

Normal

$$s_{Dy} = \frac{(f_{Dy})}{\frac{1}{2}\rho_w {U_y}^2} \rightarrow \boldsymbol{D_n C_n}$$

Tangential

$$s_{Dz_p} = \frac{(f_{Dp})}{\frac{1}{2}\rho_w {U_{z_p}}^2} \rightarrow \boldsymbol{D_t C_t}$$

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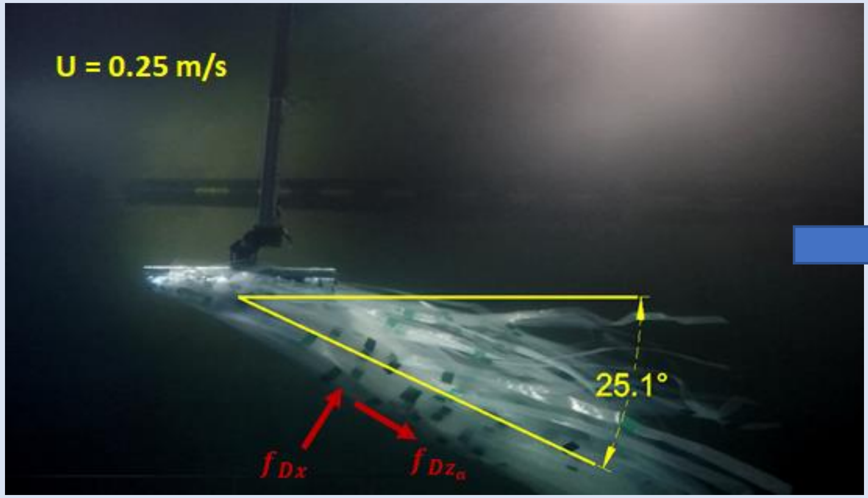
Results



	Aligned Orientation			Perpendicular Orientation		
Tow Speed (m/s)	s_{Dx} (m^2/m)	s_{Dz_a} (m^2/m)	θ_x (deg)	s_{D_y} (m^2/m)	s_{Dz_p} (m^2/m)	θ_y (deg)
0.25	2.35	0.225	25.1	2.49	0.195	24.4
0.50	1.95	0.0803	14.1	2.03	0.0693	13.8
0.75	1.66	0.0478	10.1	2.46	0.0476	8.3
1.00	1.39	0.0401	8.3	1.57	0.0401	7.8
1.25	1.45	0.0326	6.5	1.88	0.0394	5.7
	Normal	Tangential		Normal	Tangential	

1. Normal and tangential drag-area values per 3m length of model obtained for a 1m aggregate.

2. Small difference between tow orientations.

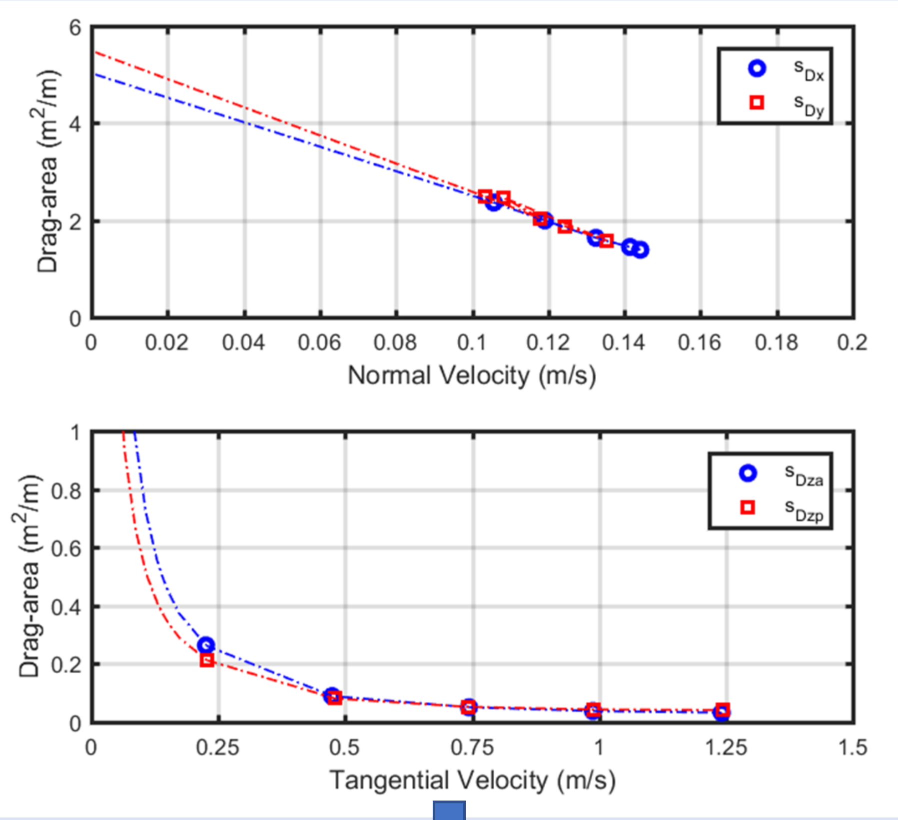
3. Defines the hydrodynamic scale for FEM approach as a 1 meter section on the grow line

4. Consistent with “Morison equation” approach using relative velocity components

5. Discretized beam elements (sub-meter) – will want to reproduce the angles

Hydrodynamic characteristics of a full-scale kelp model

Characterization of the transition from normal to tangential drag



$$0 = f_{Dx_i} - [\rho_{aggregate} A_c g - f_B] cos(\theta_{x_i})$$

$$0 = f_{Dy_j} - [\rho_{aggregate} A_c g - f_B] cos(\theta_j)$$