

# Design and testing of novel antifouling strategies for turbine blades

## Combine lab-scale and Field testing Simulation Designs

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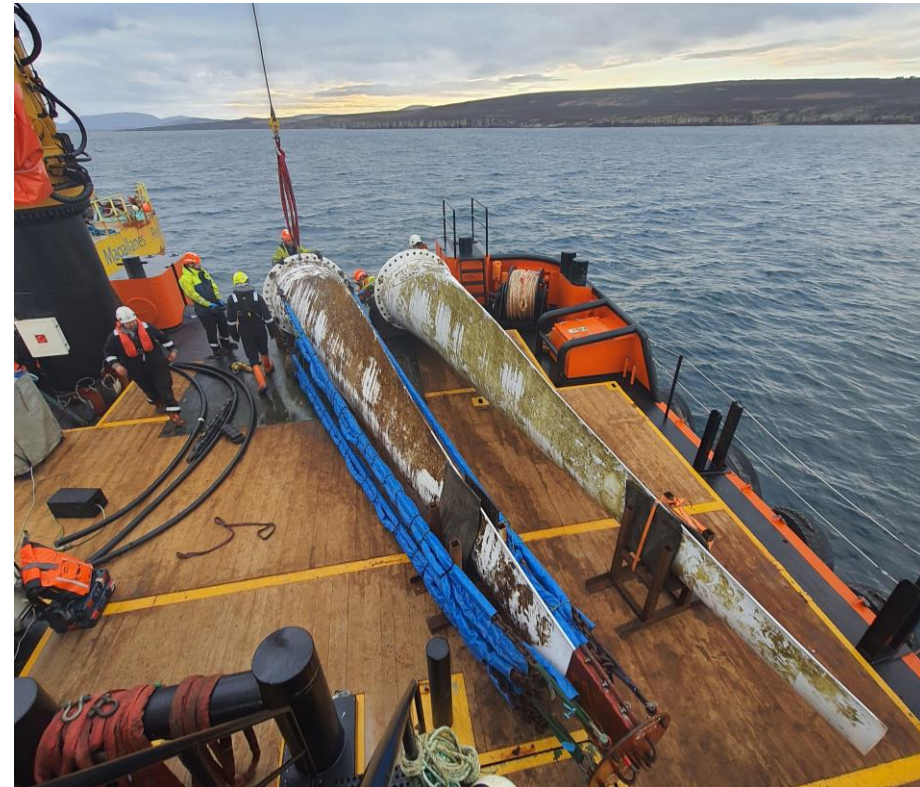


This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 815278.



# Antifouling strategies for turbine blades

- Novel solutions:
  - Coatings non toxic biocides
  - Biomimetics textures
- Testing
  - Static lab characterisation
  - Dynamic lab testing
  - Simulation predictions
  - Field testing



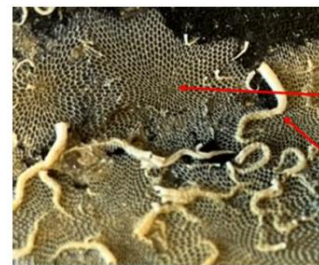
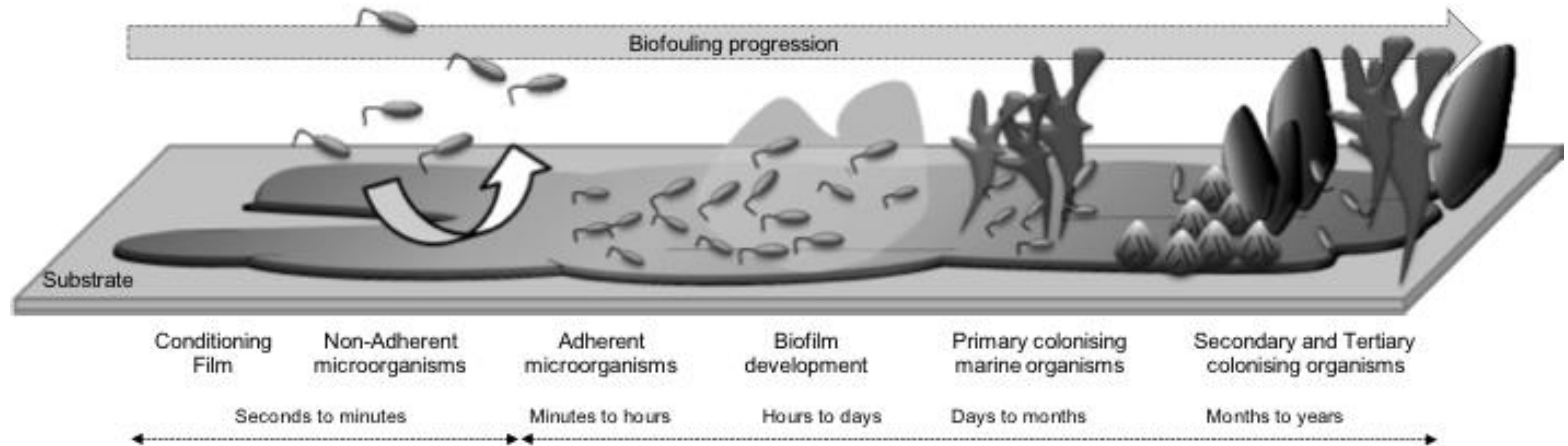
# Biofouling on tidal turbine blades





# Overview

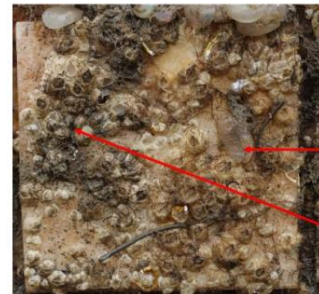
## Stages of Biofouling Formation



*Membranipora membranacea*  
(Membraniporidae)



*Spirobranchus triqueter*  
(Serpulidae)



*Austrominius modestus*  
(Elminidae)



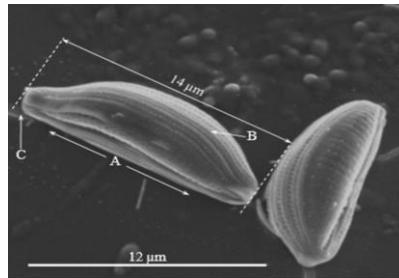
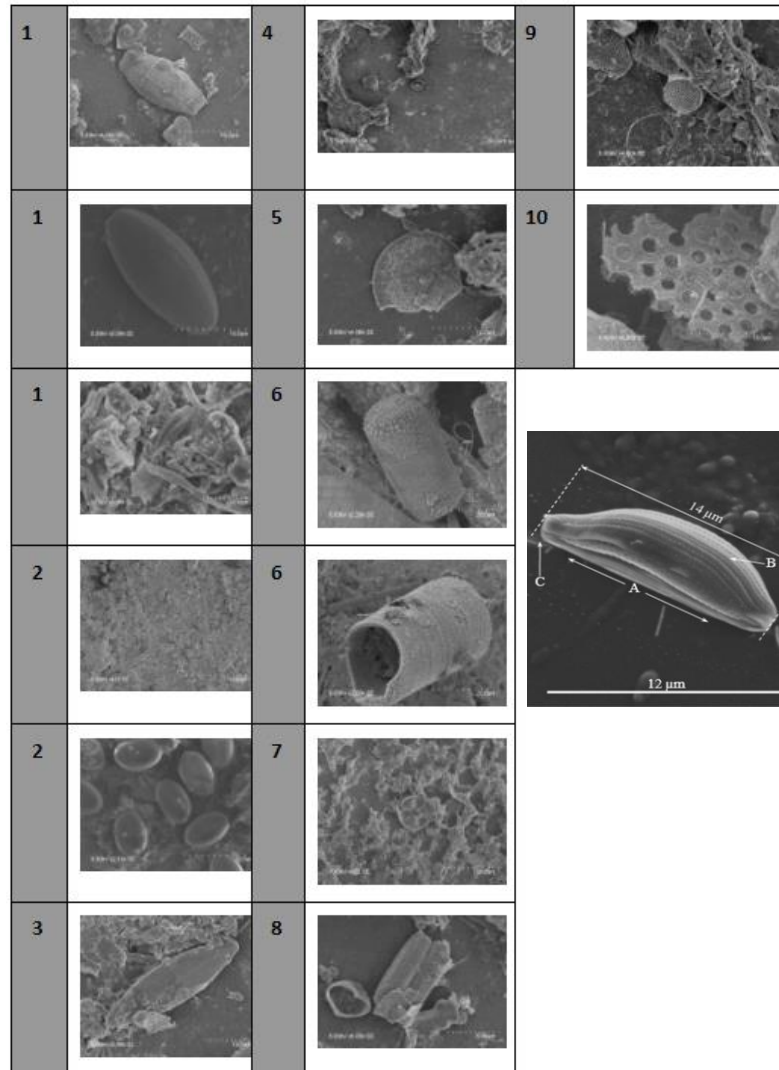
*Ascidia sp.*  
(Ascidacea)



Adrián Delgado, Seán Power, Chloe Richards, Philip Daly, Ciprian Briciu-Burghina, Yan Delauré, Fiona Regan, Establishment of an antifouling performance index derived from the assessment of biofouling on typical marine sensor materials, Science of The Total Environment, Volume 887, 2023, 164059.

# Identification of fouling organisms in Dublin Bay

**Legend:** SEM imagery of early fouling organisms identified in Dublin Bay. Amendments to this deliverable are still ongoing.



**Table 2. Summary of the key fouling organisms identified in Dublin Bay using scanning electron microscopy. \* = Due to COVID-19 restrictions, samples were not analyzed for M1. + = Genus present.**

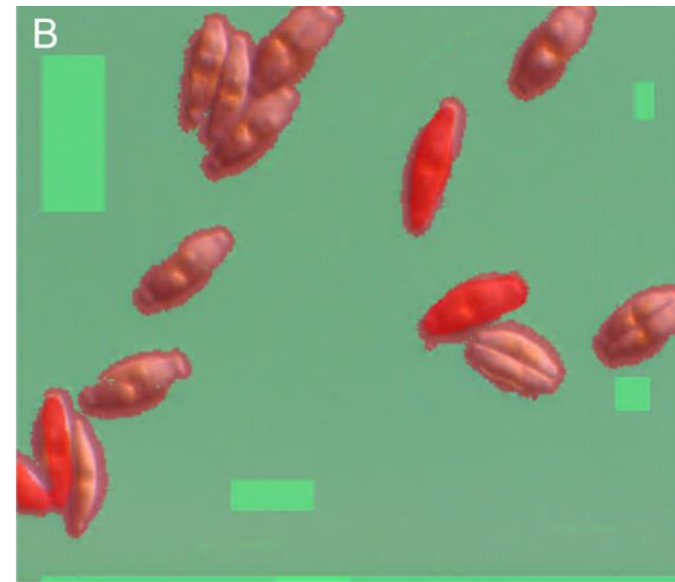
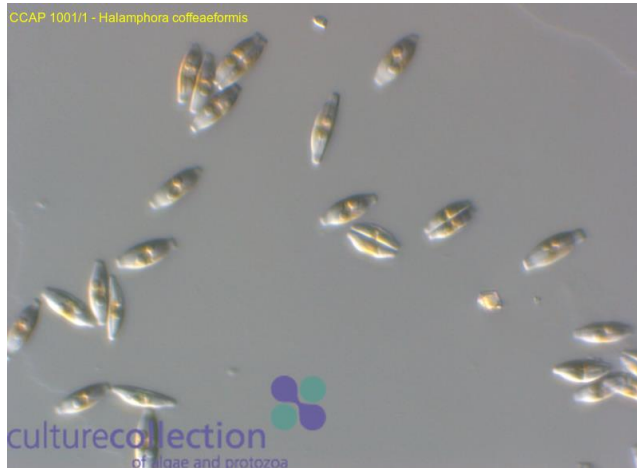
Genus	M1	M2	M3
1. Amphora	*	+	+
2. Cocconeis	*	+	+
3. Navicula	*	+	+
4. Emiliania	*	+	
5. Melosira	*	+	
6. Paralia	*		+
7. Asteromphalus	*	+	
8. Cantenula	*		+
9. Thalassiosira	*	+	+
10. Stephanopysis	*		+

# Fouling analysis from culture of fouling organisms

*Nitzschia ovalis* grown from the Culture Collection of Algae and Protozoa of the Scottish Marine Institute.



CCAP 1001/1 - *Halimnophora coffeaeformis*



Delgado A., Power S., Richards C., Daly P., Briciu-Burghina C., Delauré Y., Regan F. Establishment of an antifouling performance index derived from the assessment of biofouling on typical marine sensor materials (2023), *Science of the Total Environment*, 887, art. no. 164059 DOI: 10.1016/j.scitotenv.2023.164059

# Fouling analysis from culture of fouling organisms

## Coated Fiberglass Composite

- **Control:** 200  $\mu\text{m}$  thick coating made from Policor® GEL ISO NPG PA Ral 9003 gelcoat from Polynt with the Luperox® K12 G catalyst from Arkema (Paris, France)

## Water-based Polyurethane Coatings

- **PUD:** 1K resin
- **PUD +  $\text{SiO}_2$ :** 1K resin + 1% silica nanoparticles
- **PUD + Carbon NP:** 1K resin + 0,1% carbon nanoparticles

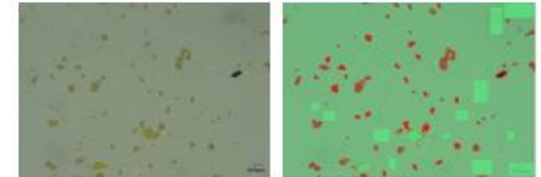
## Solvent-based Polyurethane Coatings

- **C13:** 2K resin
- **C15:** 2K resin
- **C15 +  $\text{SiO}_2$ :** 2K resin + 1% silica nanoparticles
- **PUD + Carbon NP:** 1K resin + 0,1% carbon nanoparticles

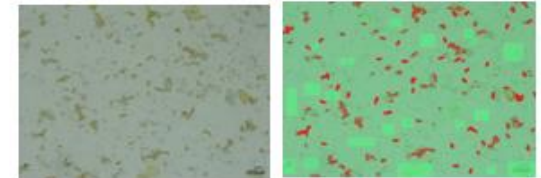
Microscope Image

Segmented Image

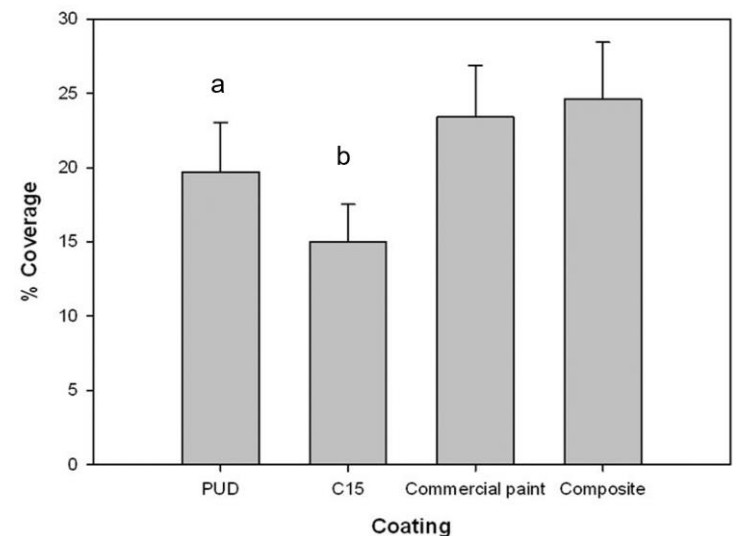
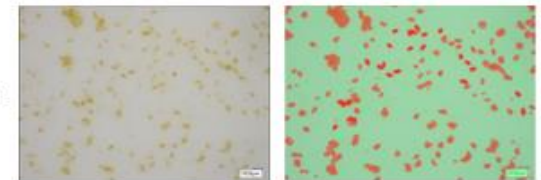
Coating PUD



Coating 15



Composite with no coating



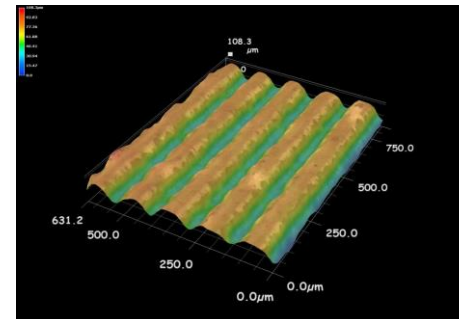


# Biomimetic surface micro-textures

- Identification biomimetic micro-textures
  - Inspired by the brill fish, a small oval and generally brownish flat fish with light and dark freckles and a creamy underside.
- Why was this candidate micro-texture chosen?



Micrographs of *S. rhombus* scale using scanning electron microscopy.

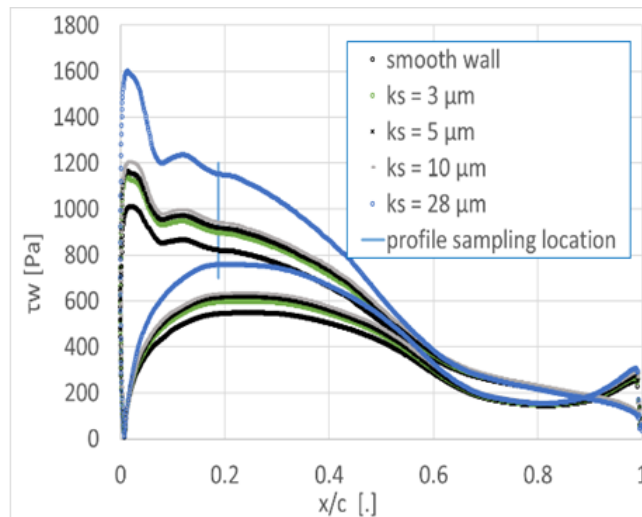
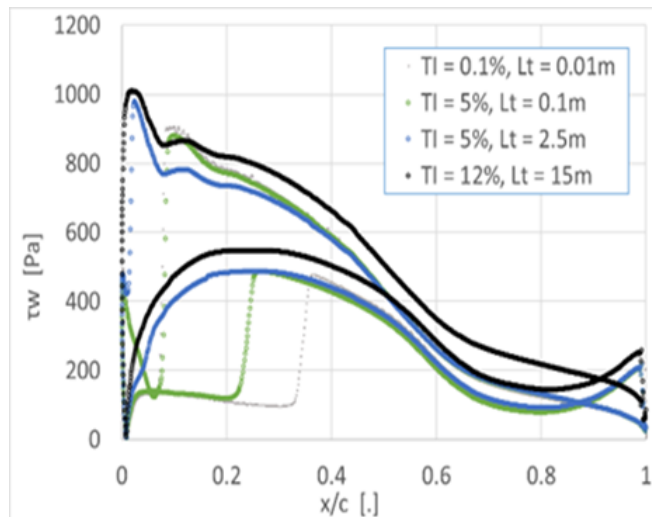




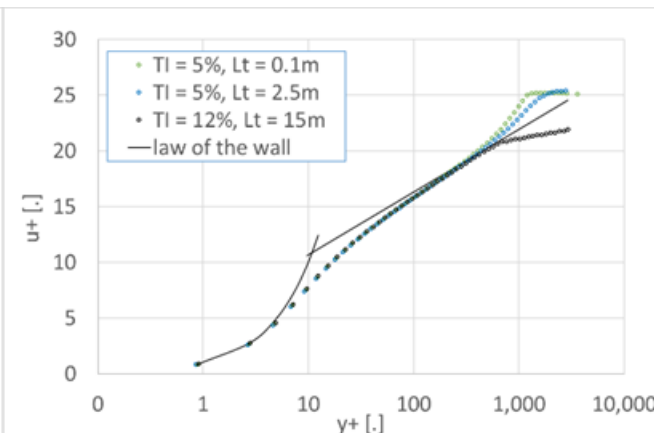
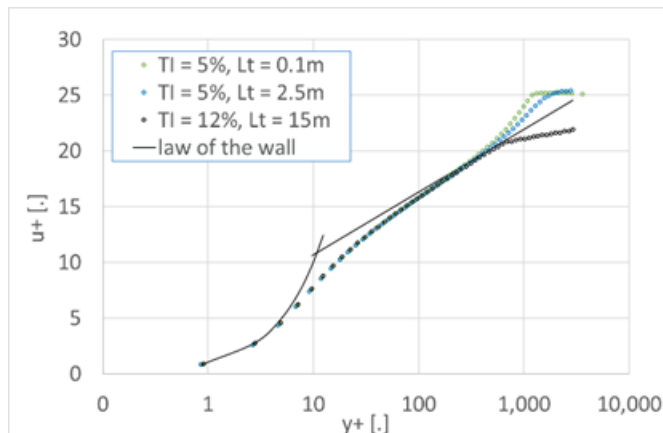
# Computational Assessment

Magallanes  
Section S9

Flow conditions	Quantity	notation	value
	Reynolds number	$Re_c = u_b c / \nu$	$8.9 \times 10^6$
	Friction Reynolds no	$Re_\tau = u_\tau x / \nu$	$< 2.5 \times 10^5$
	Viscous length scale	$\delta_\nu = \nu / u_\tau$	$< 1.5 \times 10^{-6} m$
	Boundary layer thickness	$\delta$	$< 10mm$



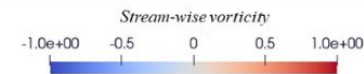
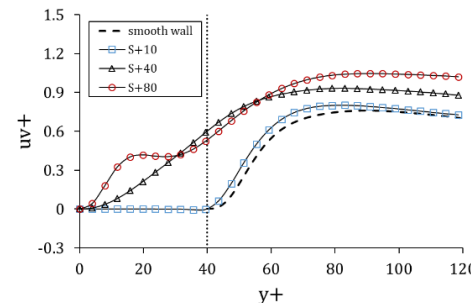
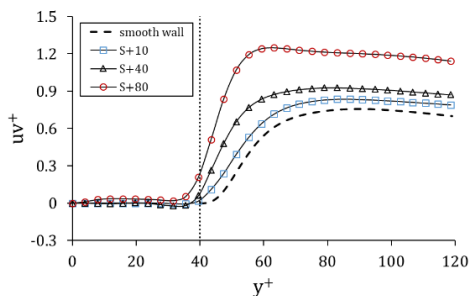
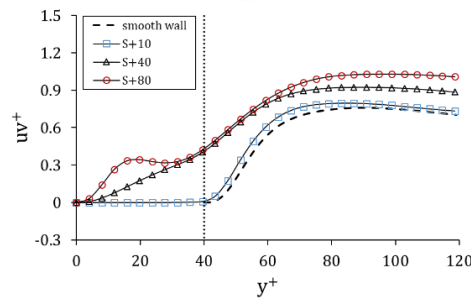
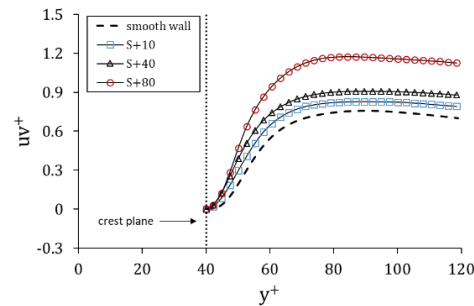
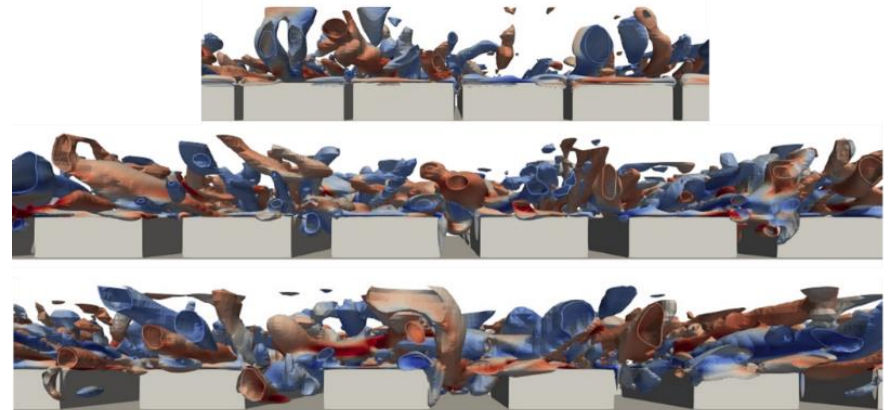
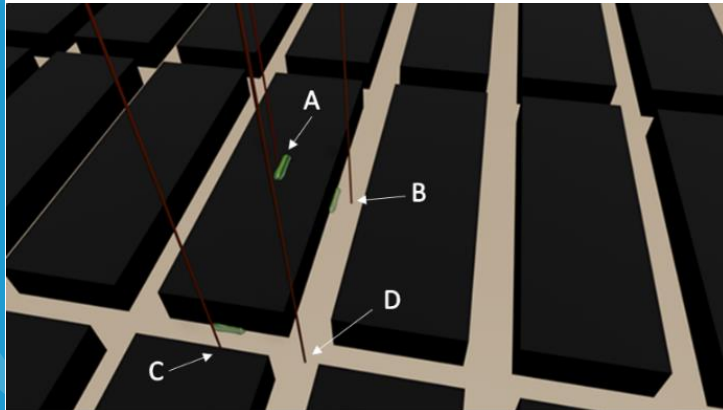
Stress  
distribution



velocity profiles  
on suction  
surface

# Computational Assessment

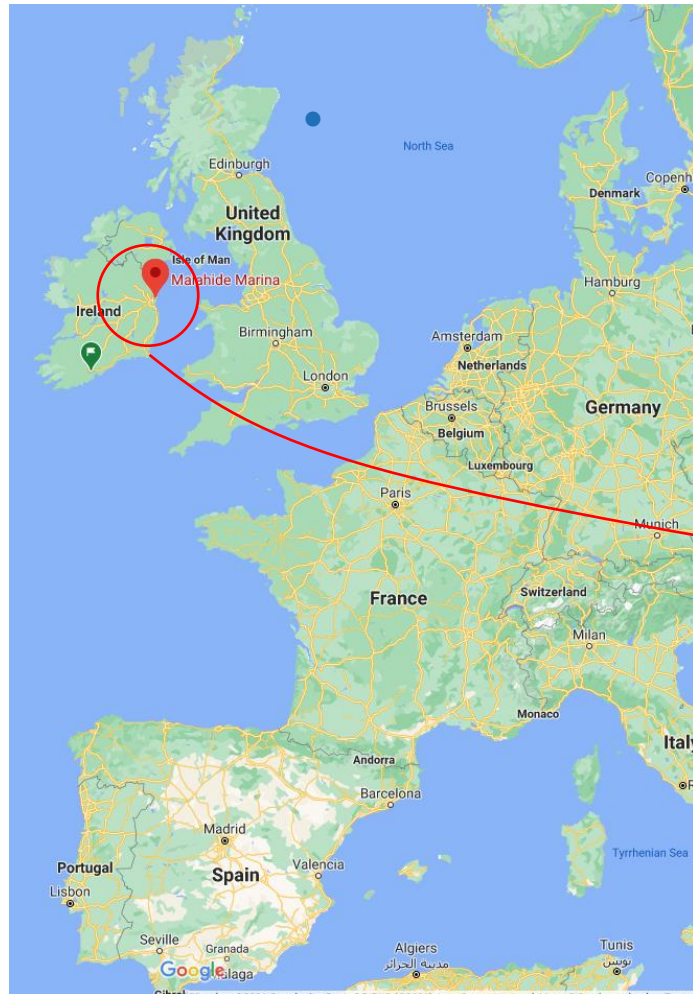
## LES high-fidelity simulation of flow around textures



A. Peyvastehnejad, F. Regan, C. Richards, A. Delgado, P. Daly, J. Grande, Y.M.C. Delauré,  
The impact of bio-inspired micro-textures on turbulence and implications for bio-fouling settlement, Ocean Engineering, Volume 285, Part 1, 2023, 115223

# Field testing

- Location: Lat. 53 27 101, Long. 06 06 811
- Tidal stream < 1m/s
- Max tidal amplitude: 0.5 m to 3.9 m
- Epifauna: macro-algae, ascidians, anthozoans, barnacles, gastropods, isopods, amphipods, nematodes, juvenile, and small crabs, and polychaetes

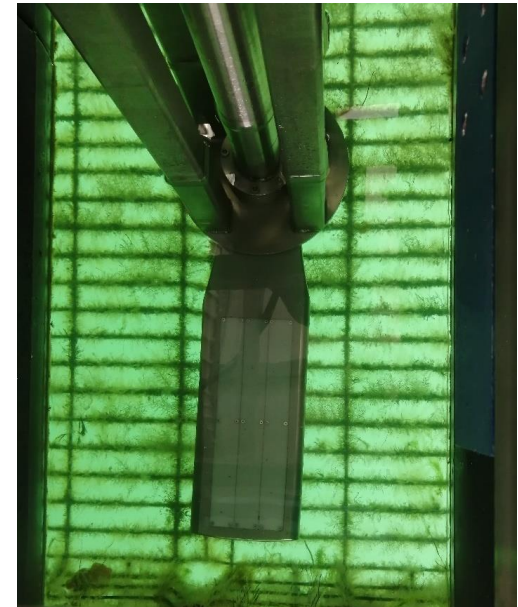




# Field testing

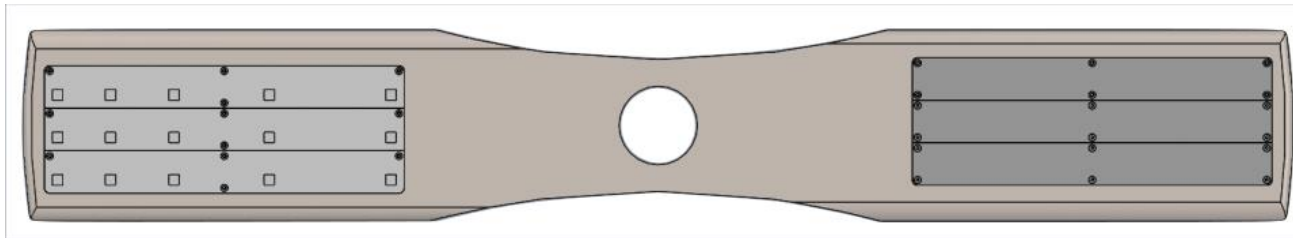


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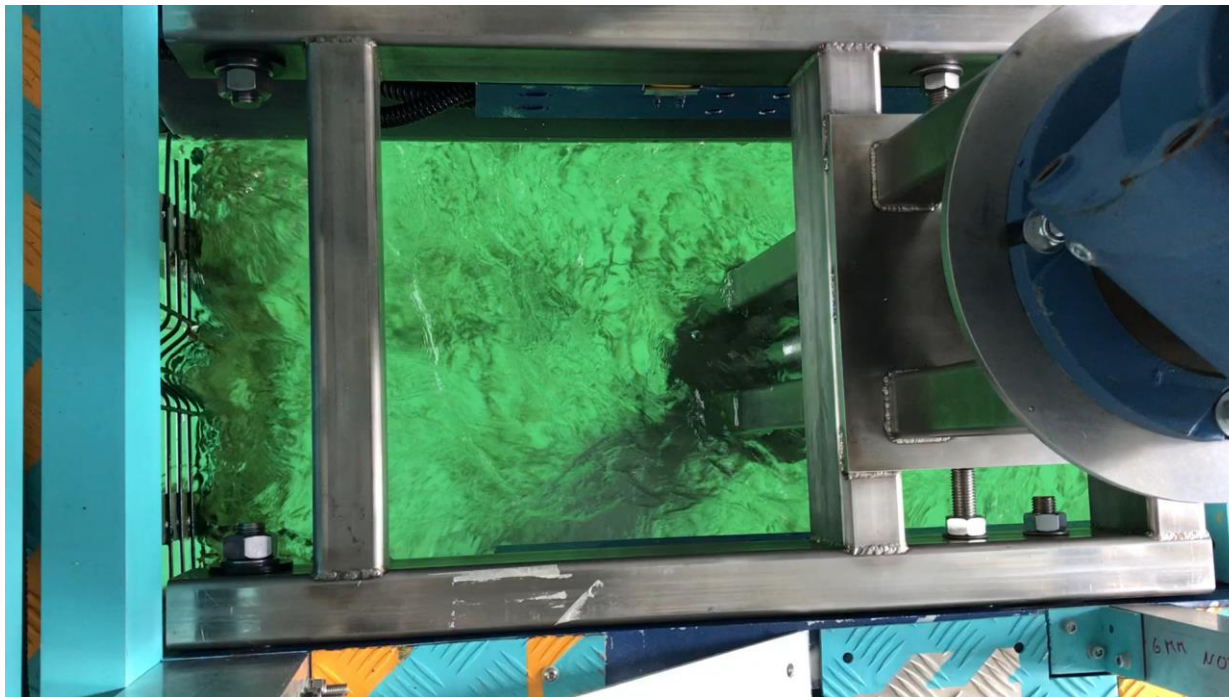




# Field testing with non uniform stress distribution



Name	P5	P4	P3	P2	P1
Radial position	0.569m	0.519m	0.459m	0.369m	0.255m

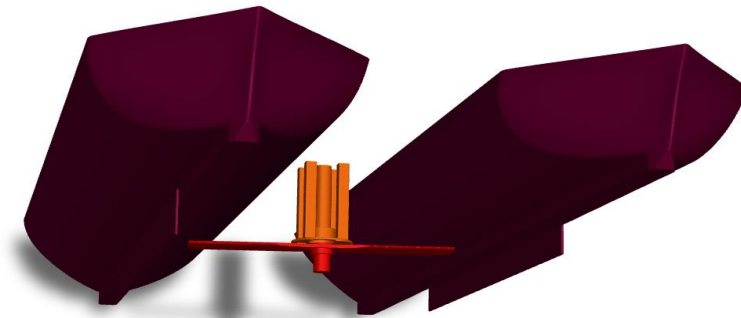
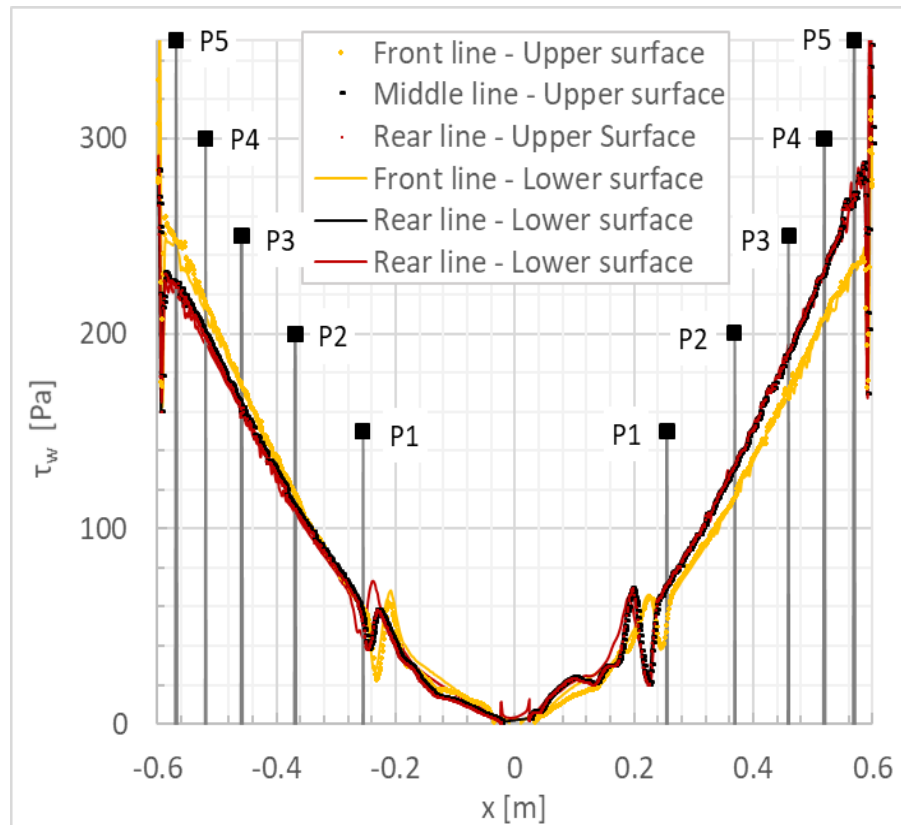




# Field testing with non uniform stress distribution

## CFD simulation of transitional flow:

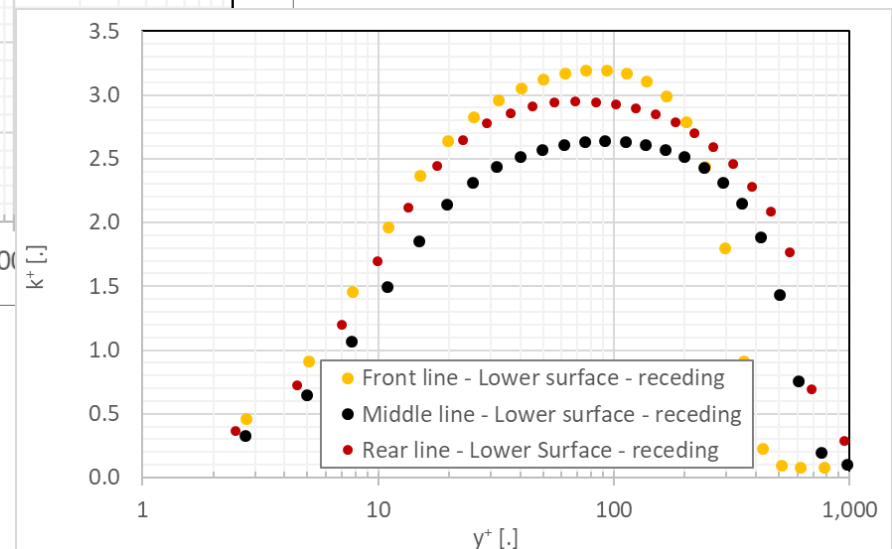
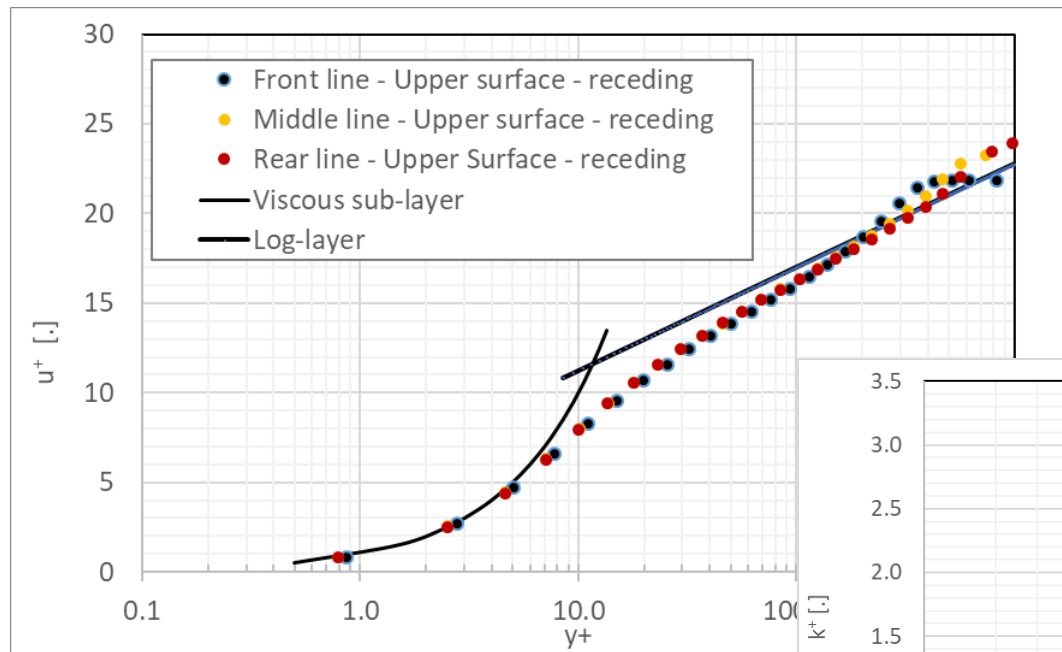
- Daily shearing for 30mins at 196.5rpm/40hz set point or 11.5m/s tip velocity.
- 2min ramp up and down.



# Field testing with non uniform stress distribution

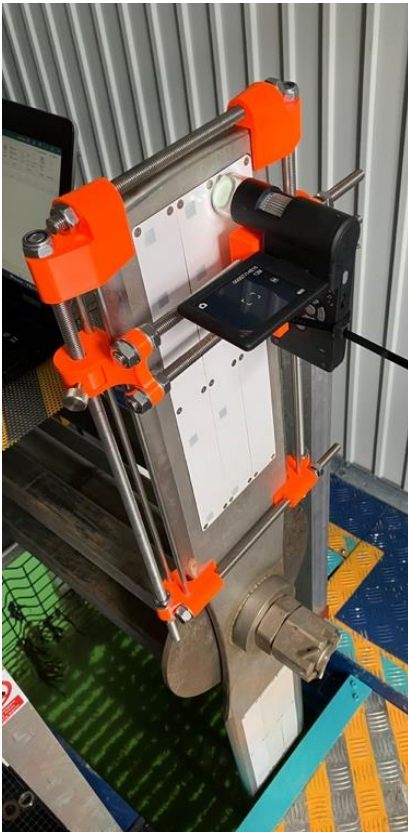
## CFD simulation Results

- Flow similarity along sampling lines.
- Flow similar to **turbulent flow over flat surfaces**



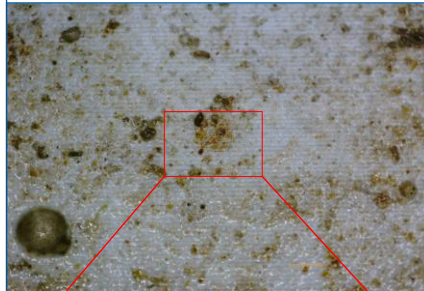
# Field testing with non uniform stress distribution

Sample materials have been immersed for **8 months**

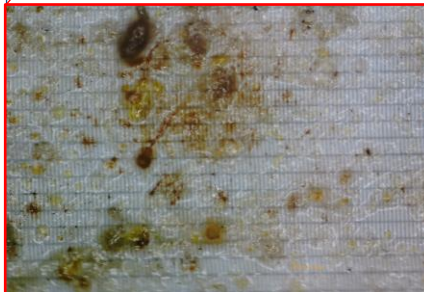


B1 texture middle M1  
week 17

30X: 6.2mm x 8.3mm

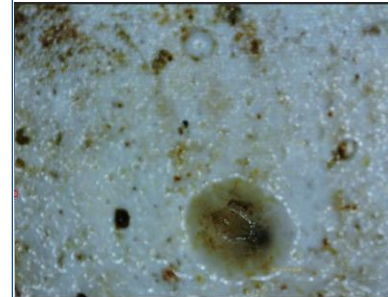


190X: 1.6mm x 2.14mm

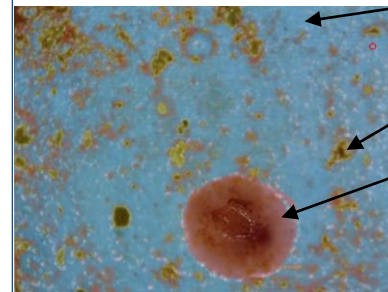


B1 texture rear M1  
30x week 17

Raw 30x image



Classification



Background

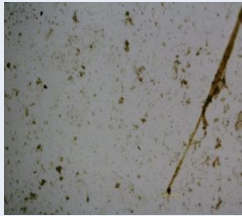
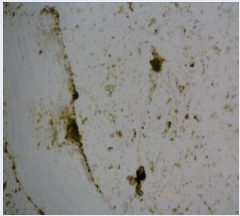
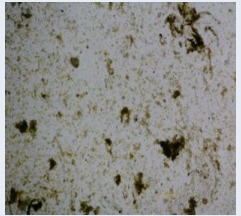
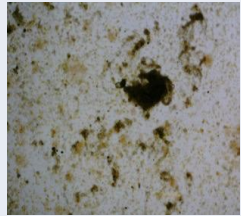
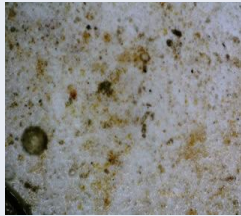
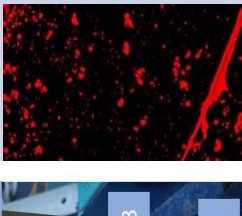
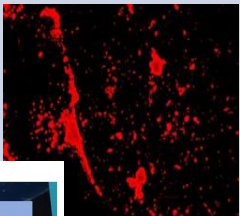
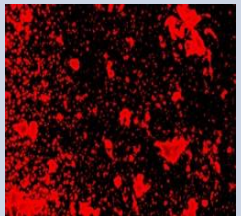
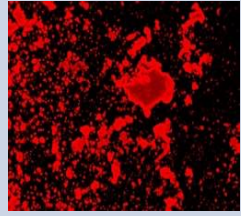
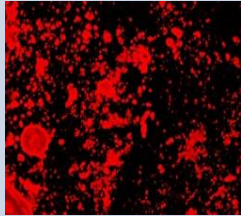
Slime

barnacle



# Field testing with non uniform stress distribution

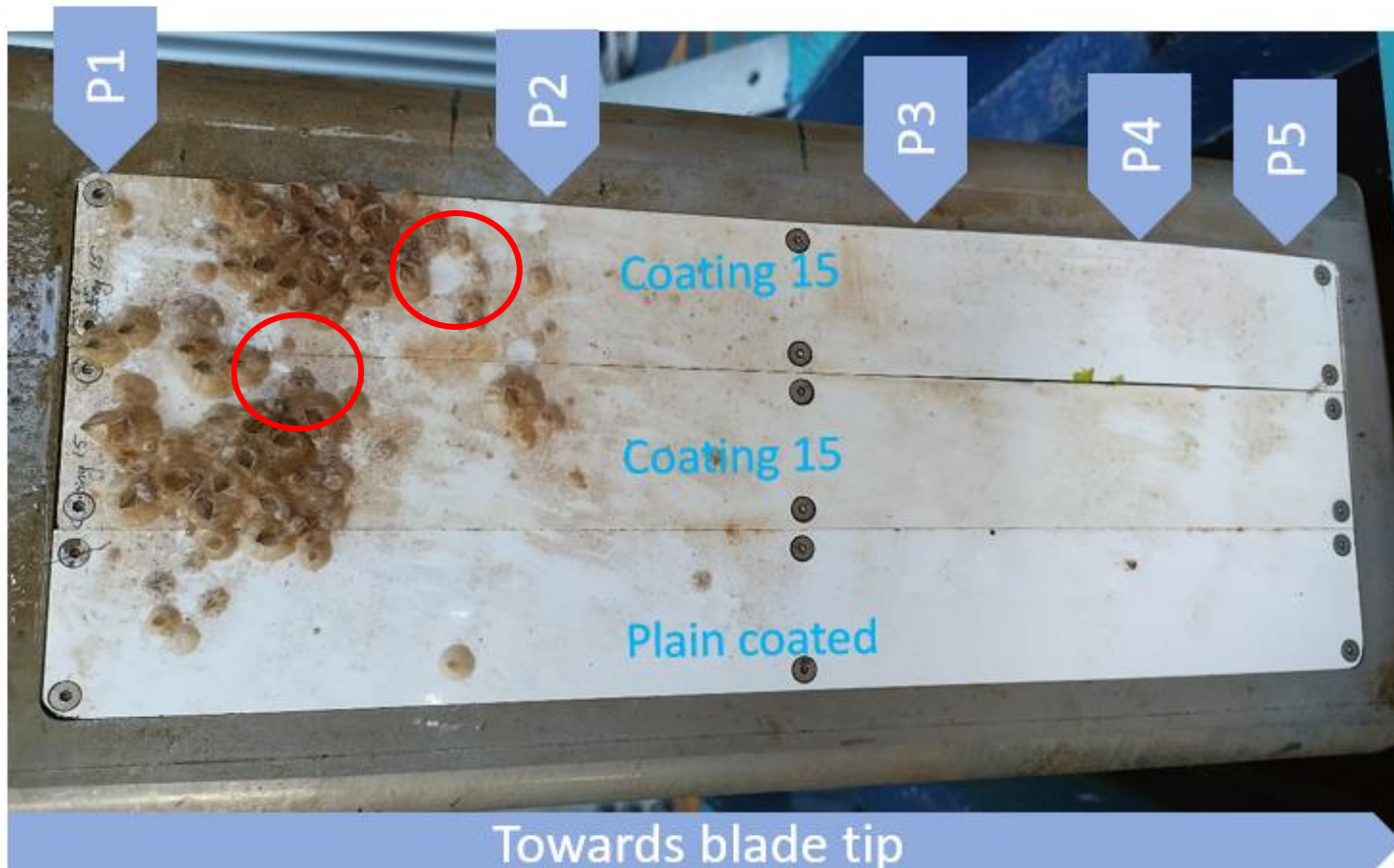
Evolution of biofouling over 17 week period on control material

Image/ Position	P5	P4	P3	P2	P1
Control Sample					
Original Image					
Segmentation Image					
		16 % biofouling cover	20.83 % biofouling cover	24.69 % biofouling cover	26.98 % biofouling cover



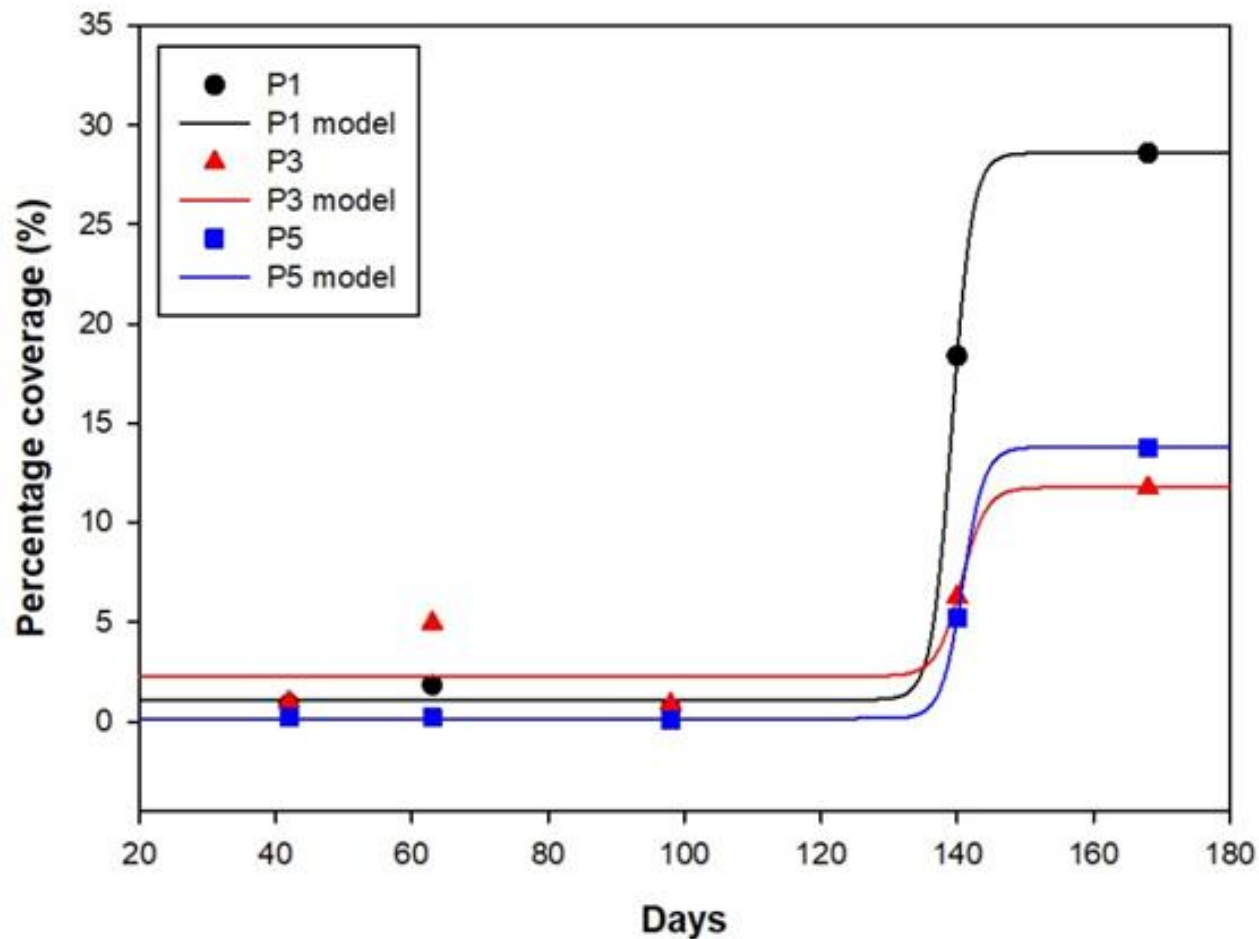
# Field testing with non uniform stress distribution

Sample image at week 17 from control material



# Field testing with non uniform stress distribution

Behavioural model from control material





# Field testing with non uniform stress distribution



# Thank you for your attention!

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