

Design and testing of novel antifouling strategies for turbine blades

Combine lab-scale and Field testing
Simulation Designs

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Adrián Delgado

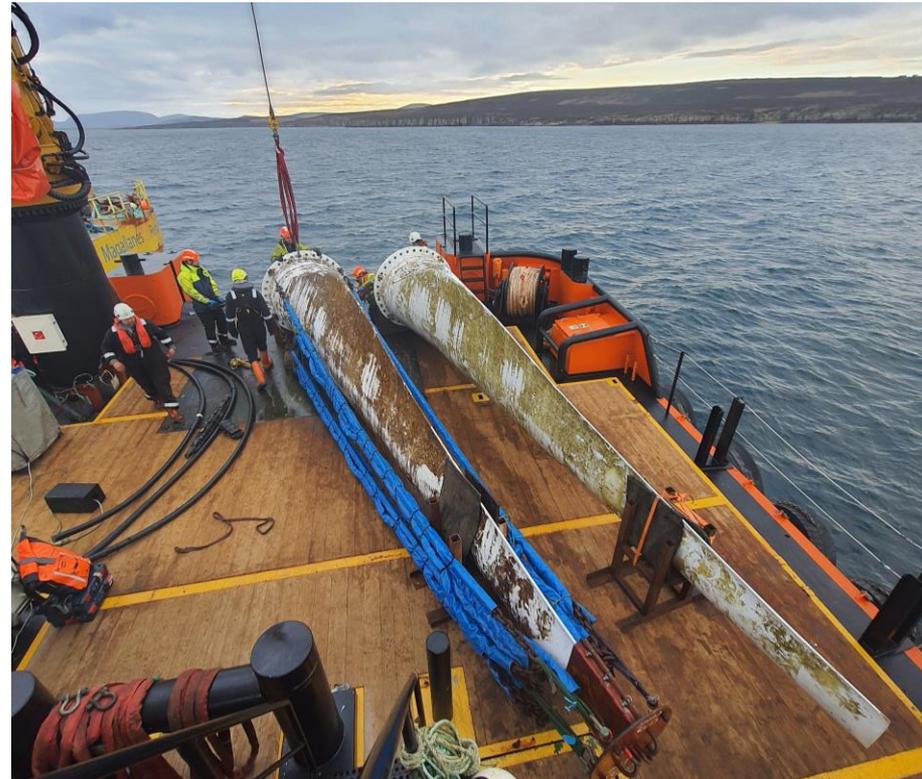


This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 815278.



Antifouling strategies for turbine blades

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

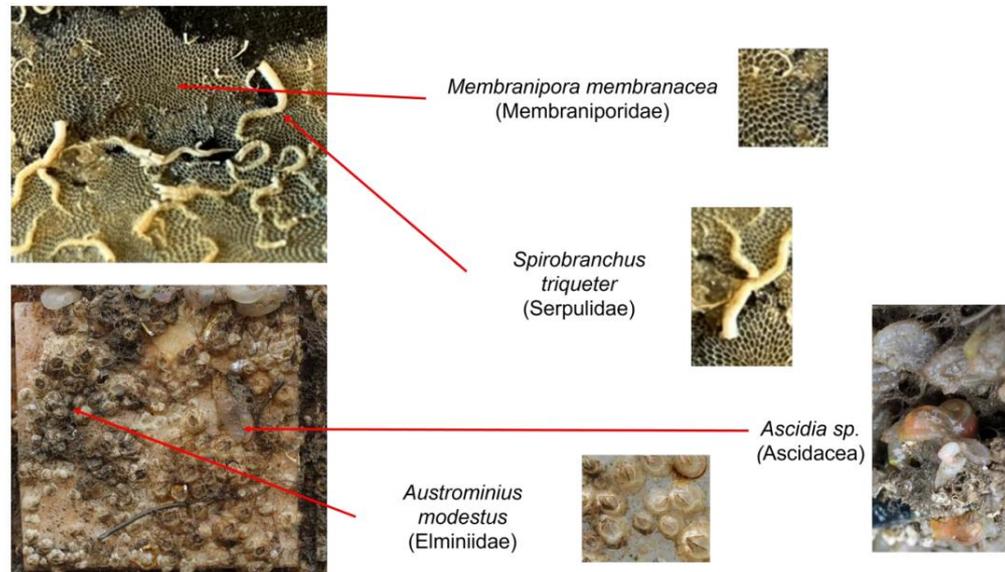
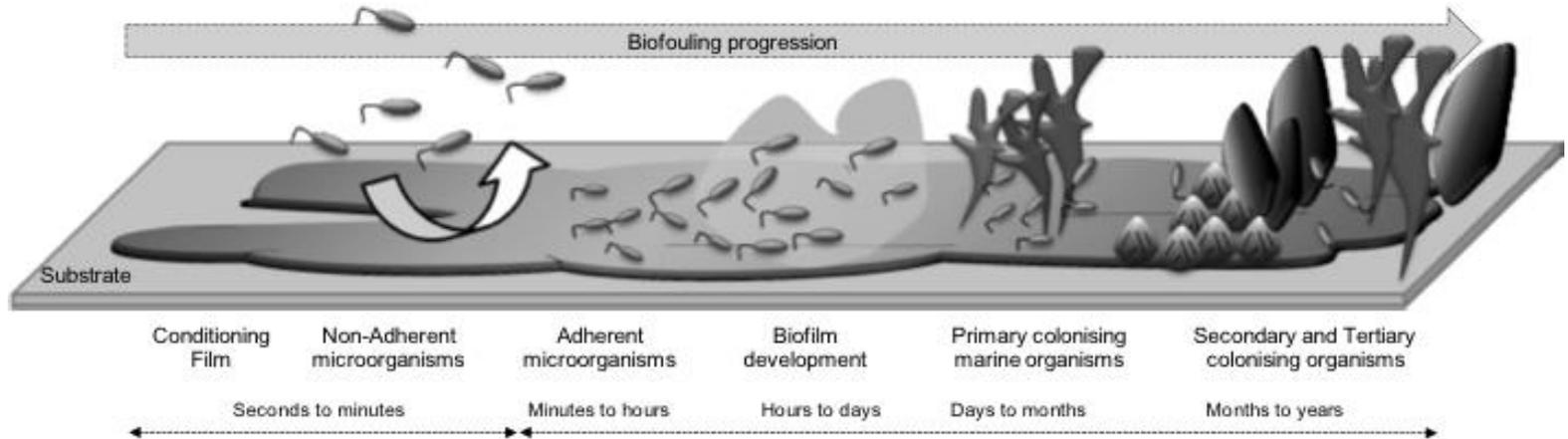


Biofouling on tidal turbine blades



Overview

Stages of Biofouling Formation



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.

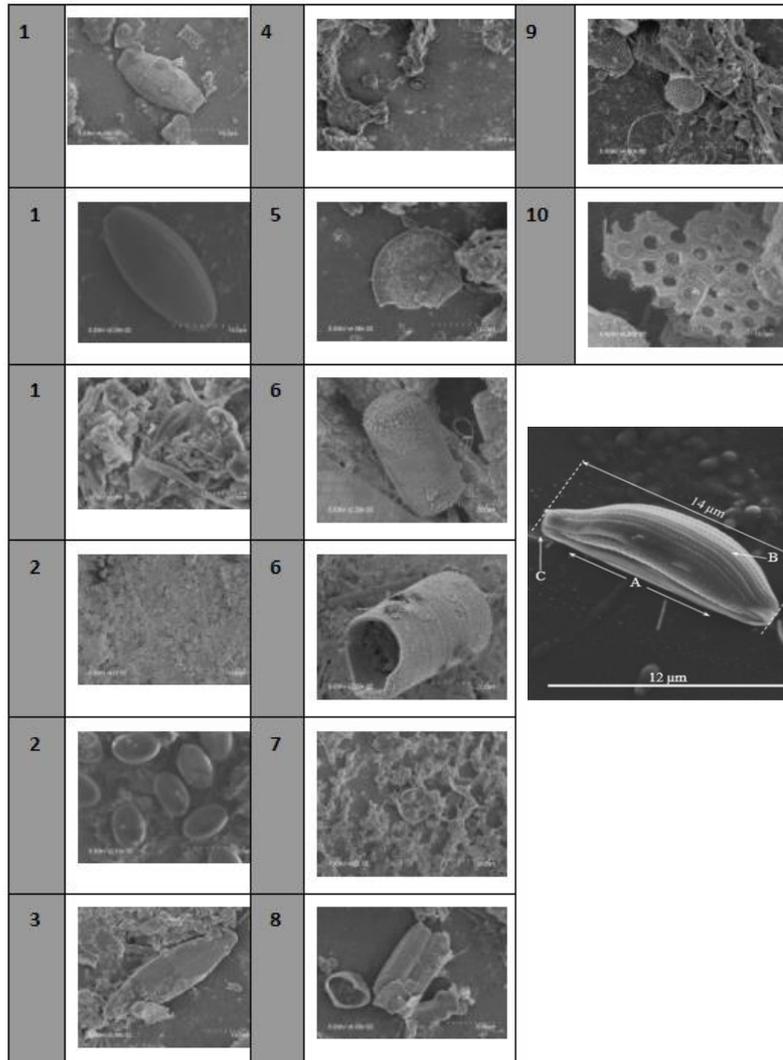


Table 2. Summary of the key fouling organisms identified in Dublin Bay using scanning electron microscopy. * = Due to COVID-19 restrictions, samples were not analyzed for M1. + = Genus present.

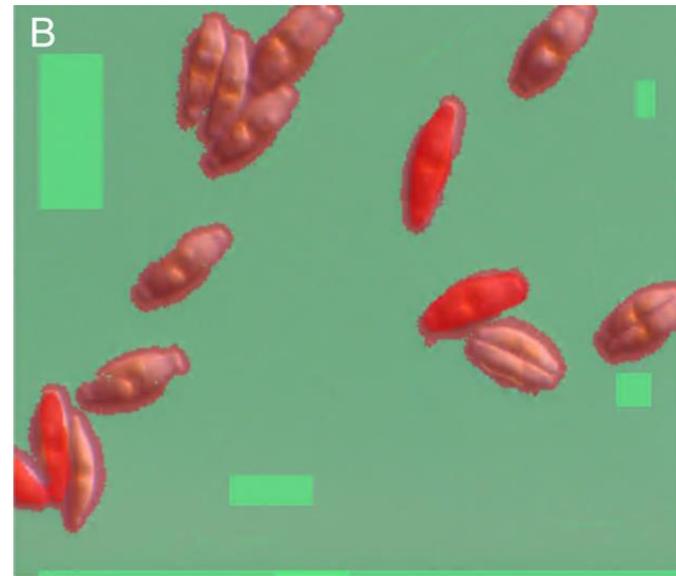
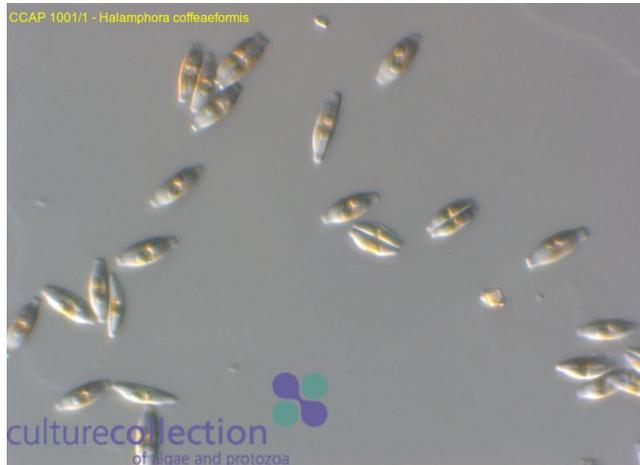
| Genus | M1 | M2 | M3 |
|------------------|----|----|----|
| 1. Amphora | * | + | + |
| 2. Cocconeis | * | + | + |
| 3. Navicula | * | + | + |
| 4. Emiliania | * | + | |
| 5. Melosira | * | + | |
| 6. Paralia | * | | + |
| 7. Asteromphalus | * | + | |
| 8. Cantenula | * | | + |
| 9. Thalassiosira |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

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 - *Halimphora 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 μm 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

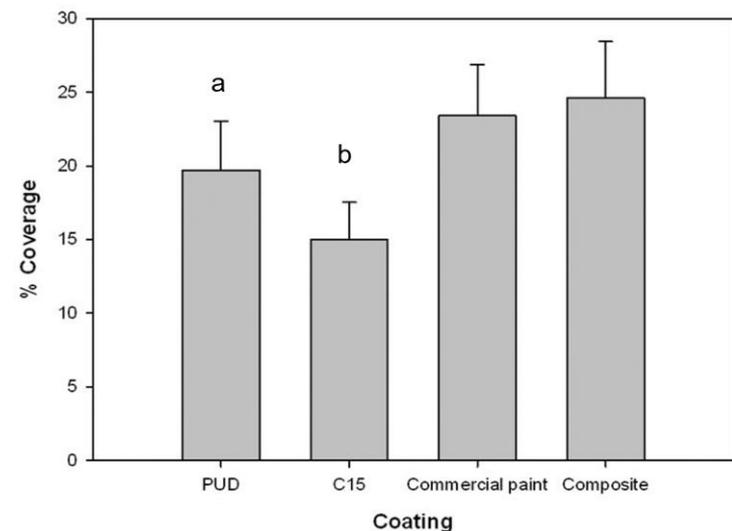
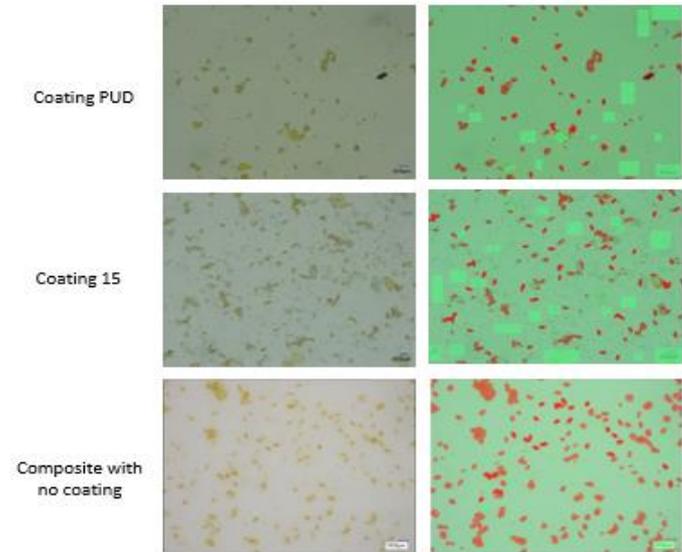
- **PUD:** 1K resin
- **PUD + SiO₂:** 1K resin + 1% silica nanoparticles
- **PUD + Carbon NP:** 1K resin + 0,1% carbon nanoparticles

Solvent-based
Polyurethane
Coatings

- **C13:** 2K resin
- **C15:** 2K resin
- **C15 + SiO₂:** 2K resin + 1% silica nanoparticles
- **PUD + Carbon NP:** 1K resin + 0,1% carbon nanoparticles

Microscope Image

Segmented Image

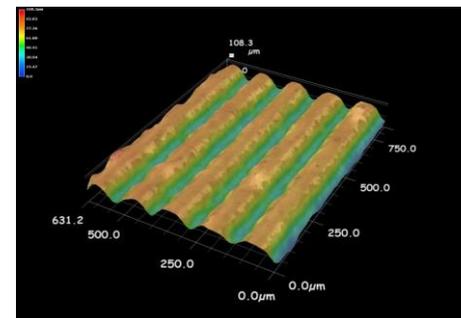


Biomimetic surface micro-textures

- 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?



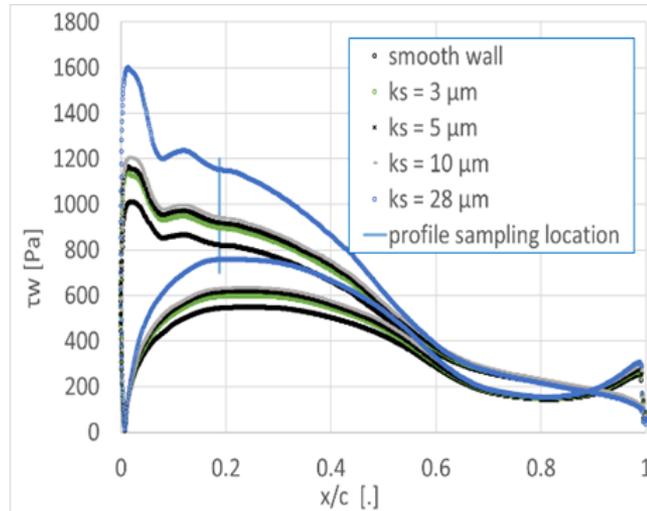
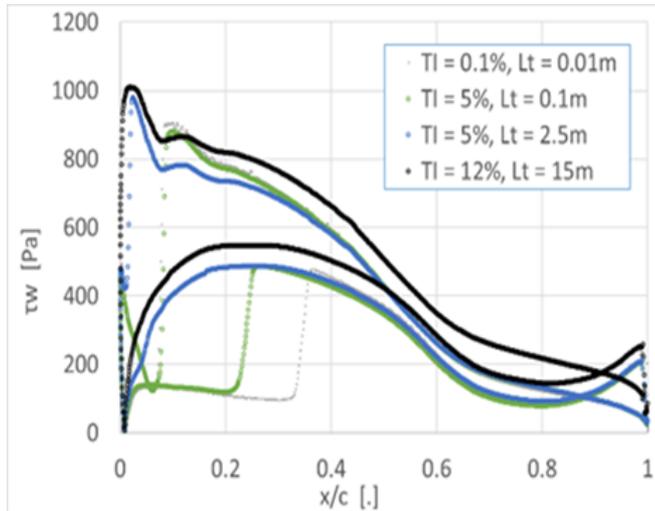
Micrographs of *S. rhombus* scale using scanning electron microscopy.



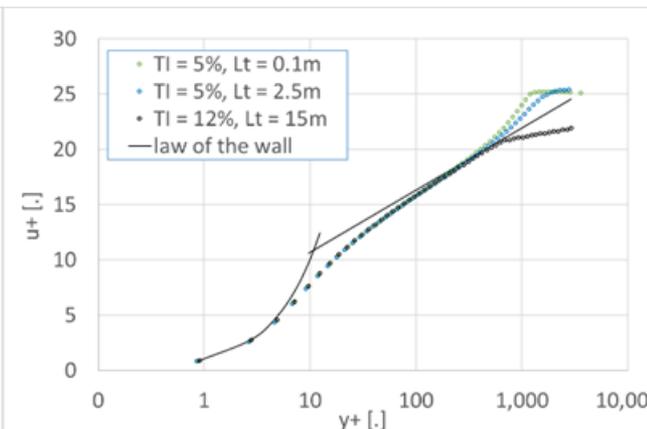
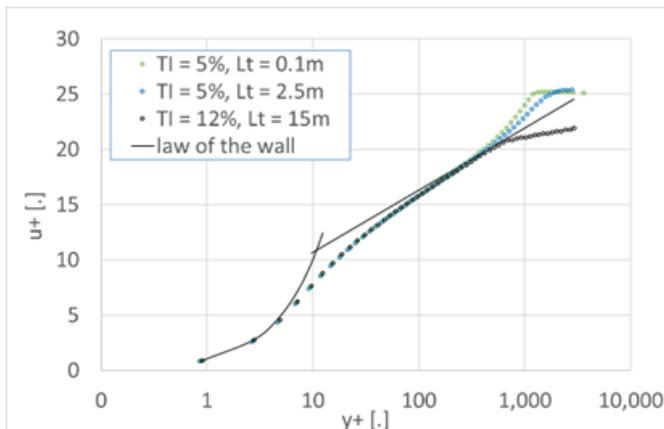
Computational Assessment

Magallanes
Section S9

| | Quantity | notation | value |
|-----------------|--------------------------|-----------------------------|--------------------------|
| Flow conditions | Reynolds number | $Re_c = u_b c / \nu$ | 8.9×10^6 |
| | 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 | δ | $< 10mm$ |



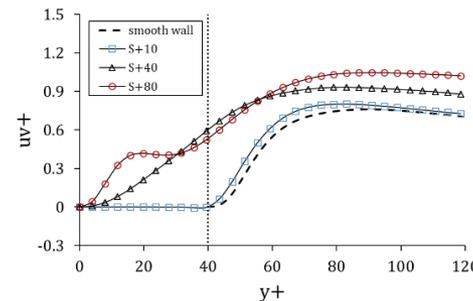
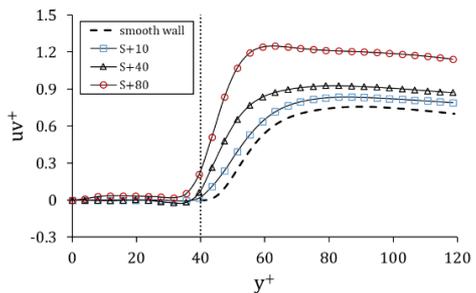
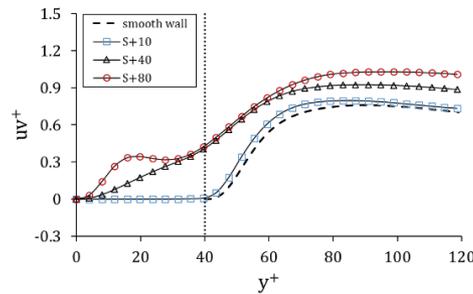
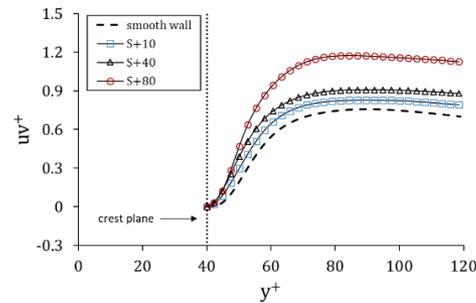
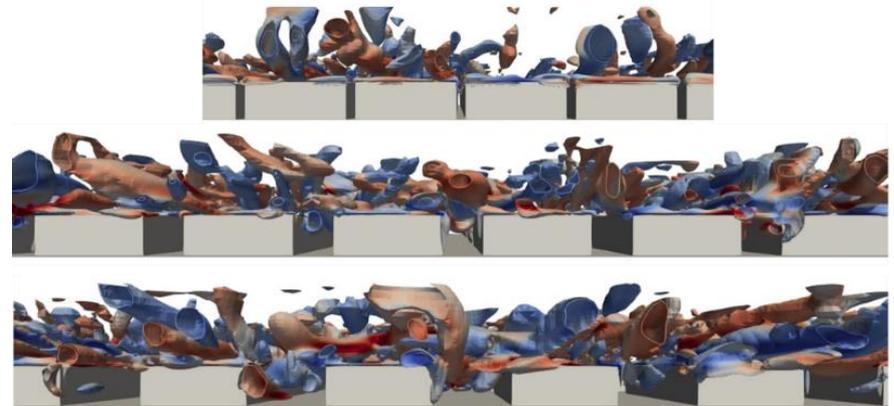
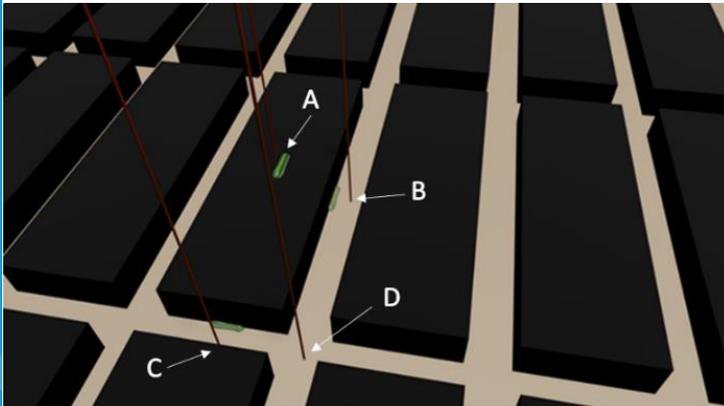
Stress
distribution



velocity profiles
on suction
surface

Computational Assessment

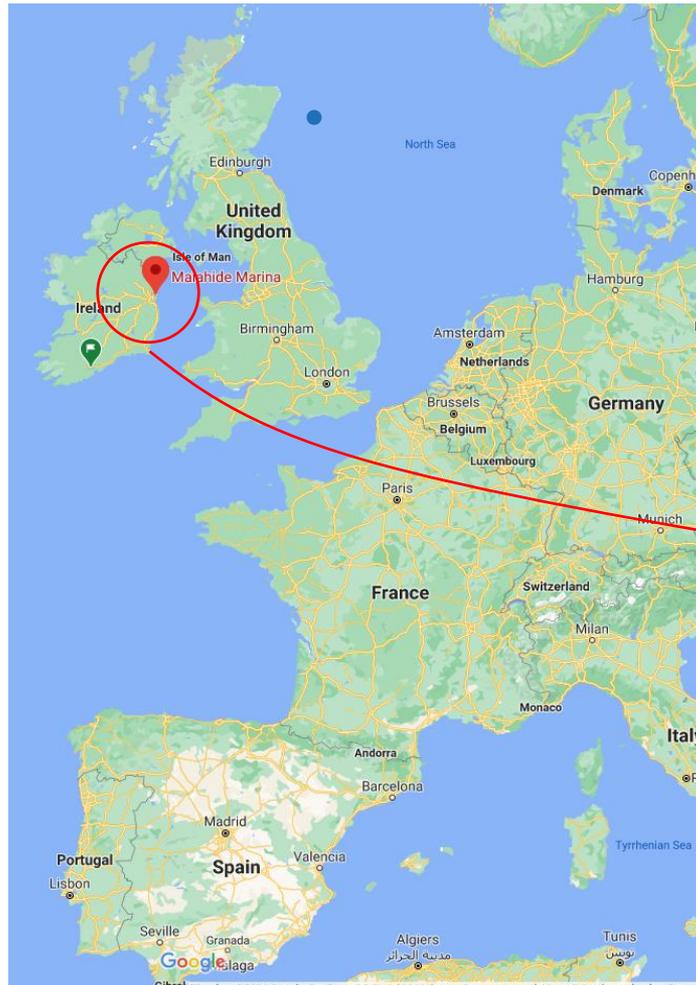
LES high-fidelity simulation of flow around textures



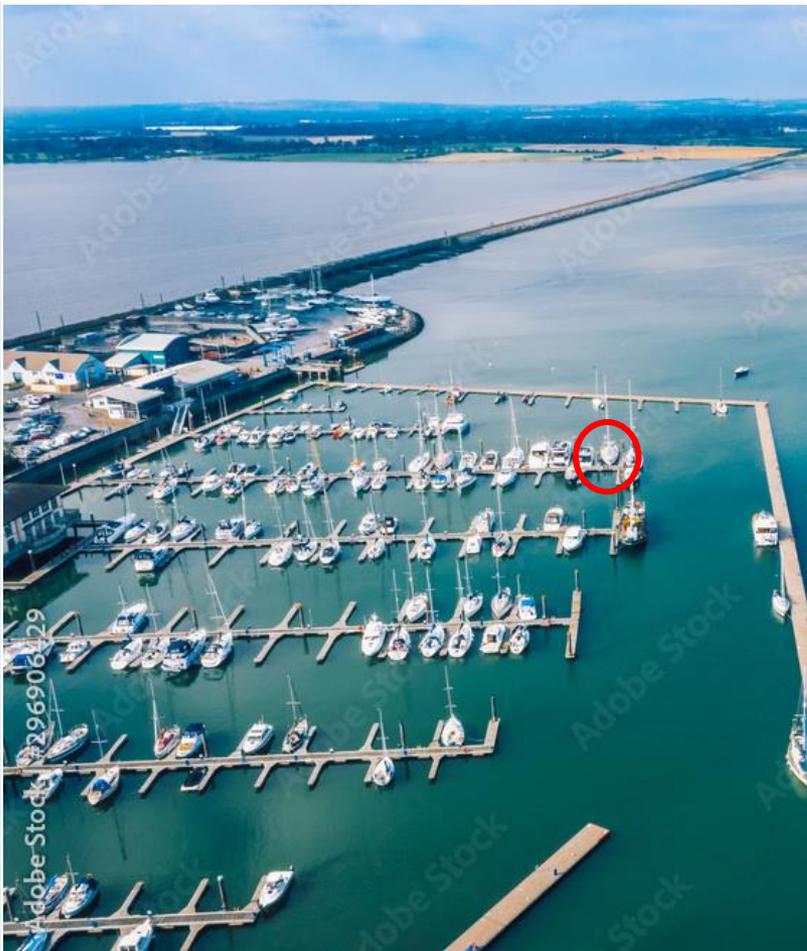
A. Peyvastehnejad, F. Regan, C. Richards, A. Delgado, P. Daly, J. Grande, Y.M.C. Delauré,
The impact of bio-inspired micro-textures on turbulence and implications for bio-fouling settlement, Ocean Engineering, Volume 285, Part 1, 2023, 115223

Field testing

- Location: Lat. 53 27 101, Long. 06 06 811
- Tidal stream <math>< 1\text{ m/s}</math>
- 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



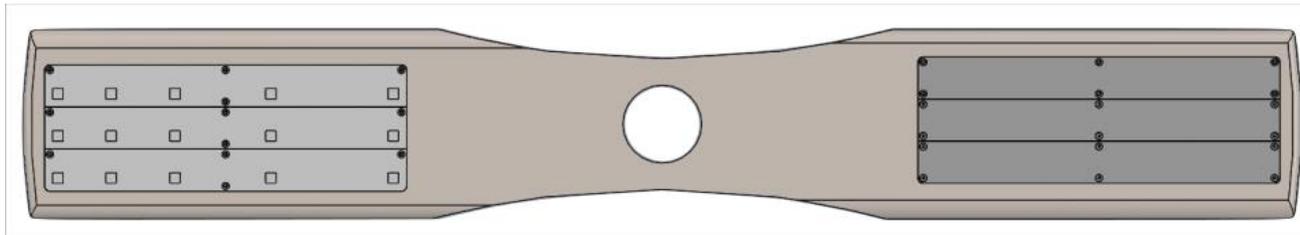
Field testing



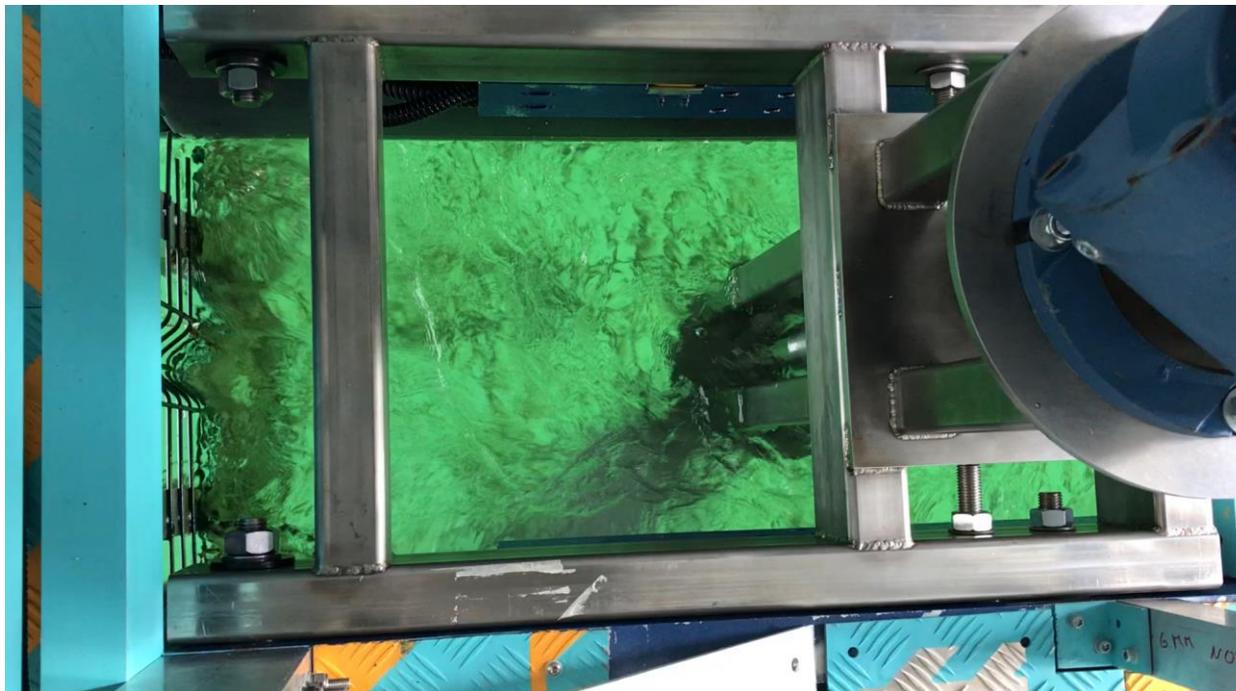
Field testing



Field testing with non uniform stress distribution



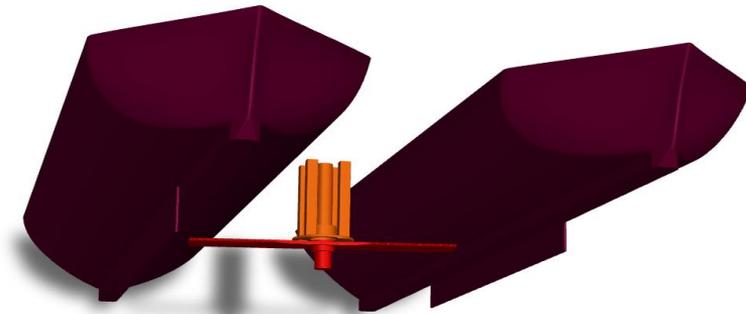
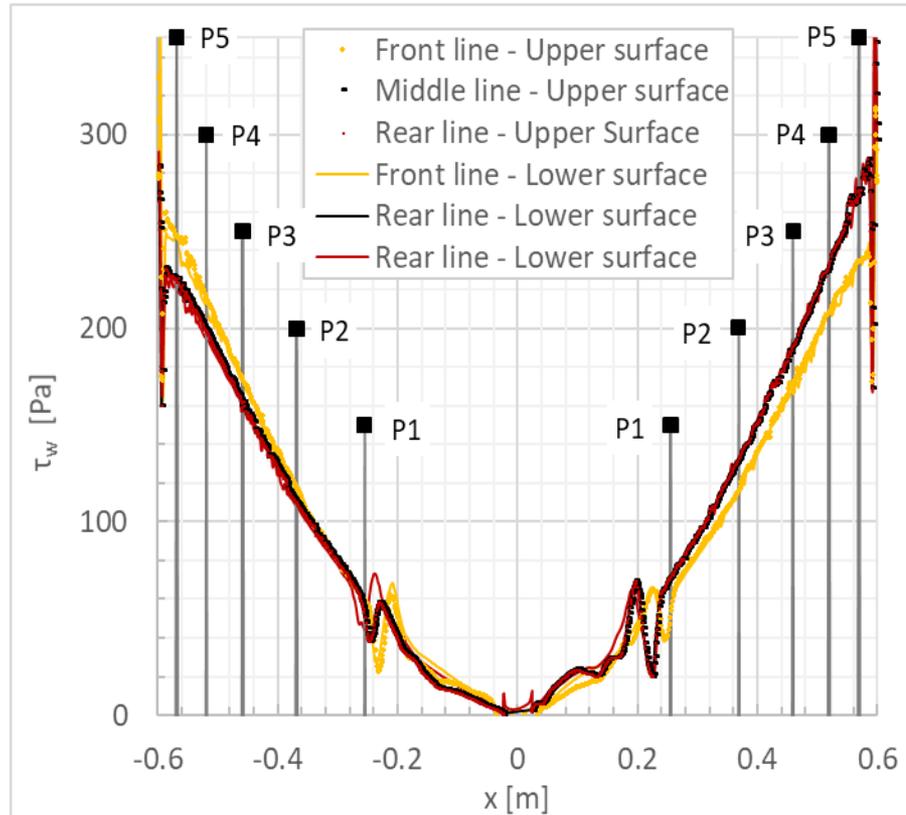
| Name | P5 | P4 | P3 | P2 | P1 |
|-----------------|--------|--------|--------|--------|--------|
| Radial position | 0.569m | 0.519m | 0.459m | 0.369m | 0.255m |



Field testing with non uniform stress distribution

CFD simulation of transitional flow:

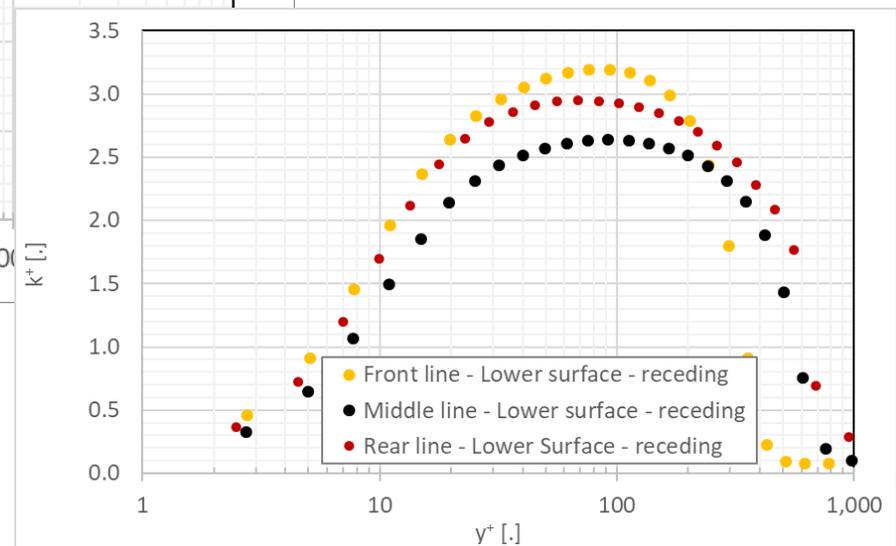
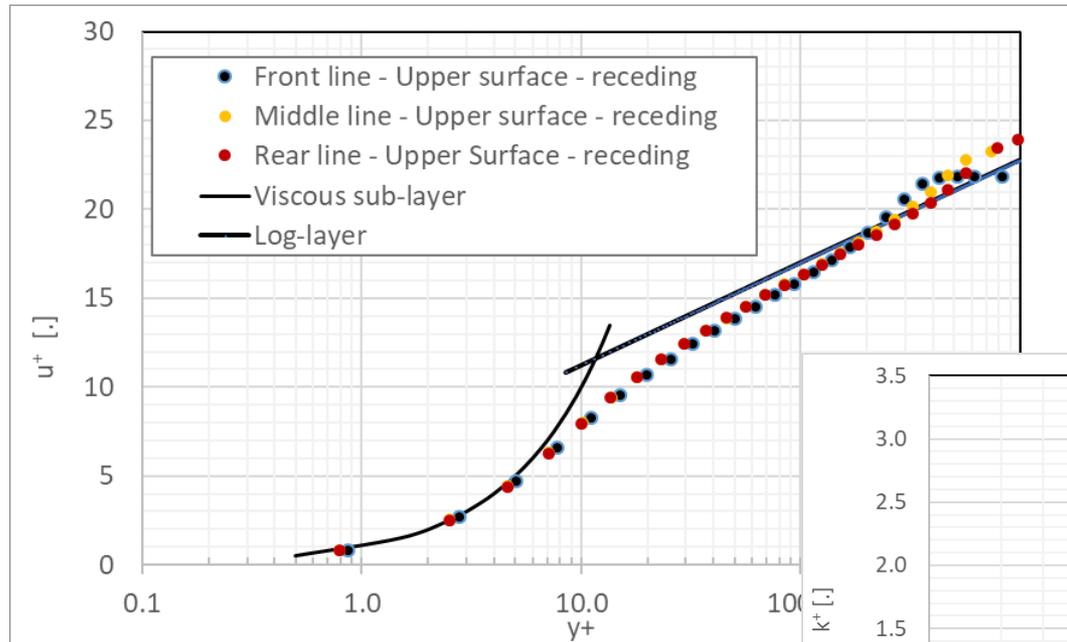
- Daily shearing for 30mins at 196.5rpm/40hz set point or 11.5m/s tip velocity.
- 2min ramp up and down.



Field testing with non uniform stress distribution

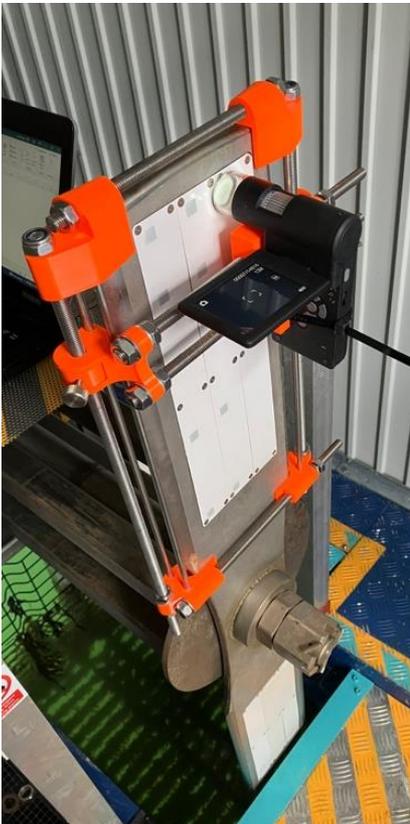
CFD simulation Results

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



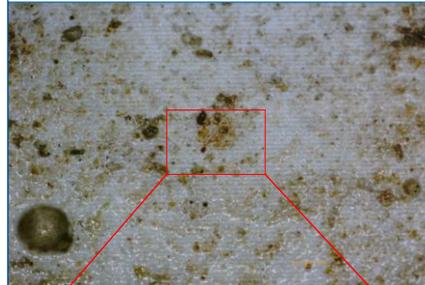
Field testing with non uniform stress distribution

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

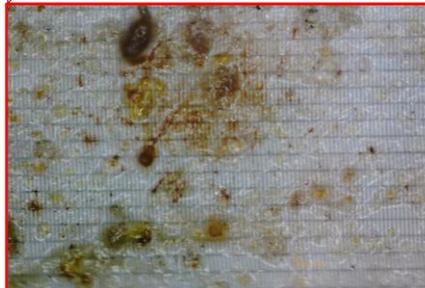


B1 texture middle M1
week 17

30X: 6.2mm x 8.3mm

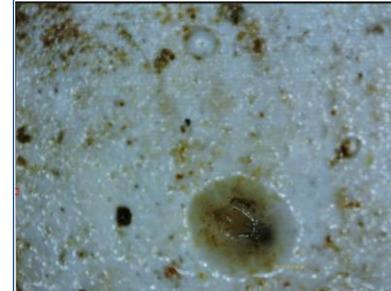


190X: 1.6mm x 2.14mm

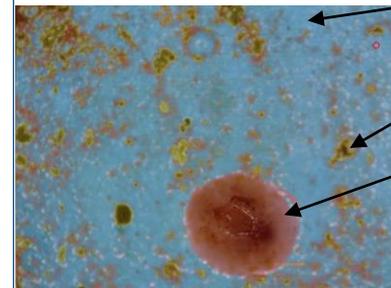


B1 texture rear M1
30x week 17

Raw 30x image



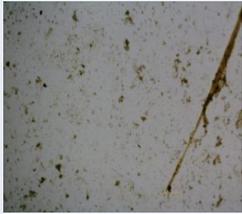
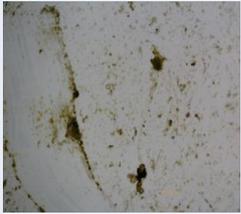
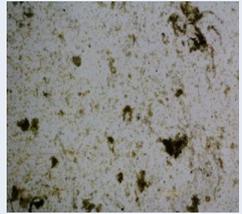
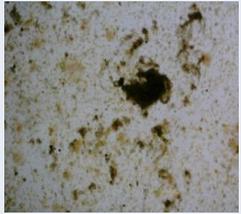
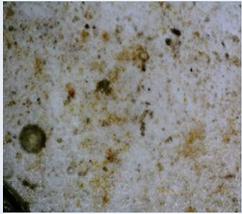
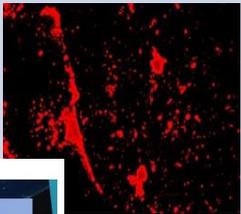
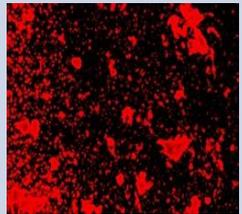
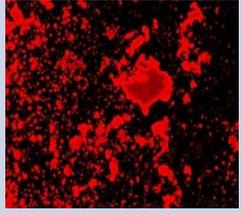
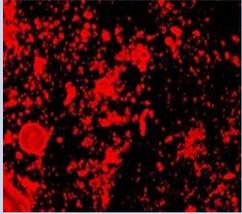
Classification



Background
Slime
barnacle

Field testing with non uniform stress distribution

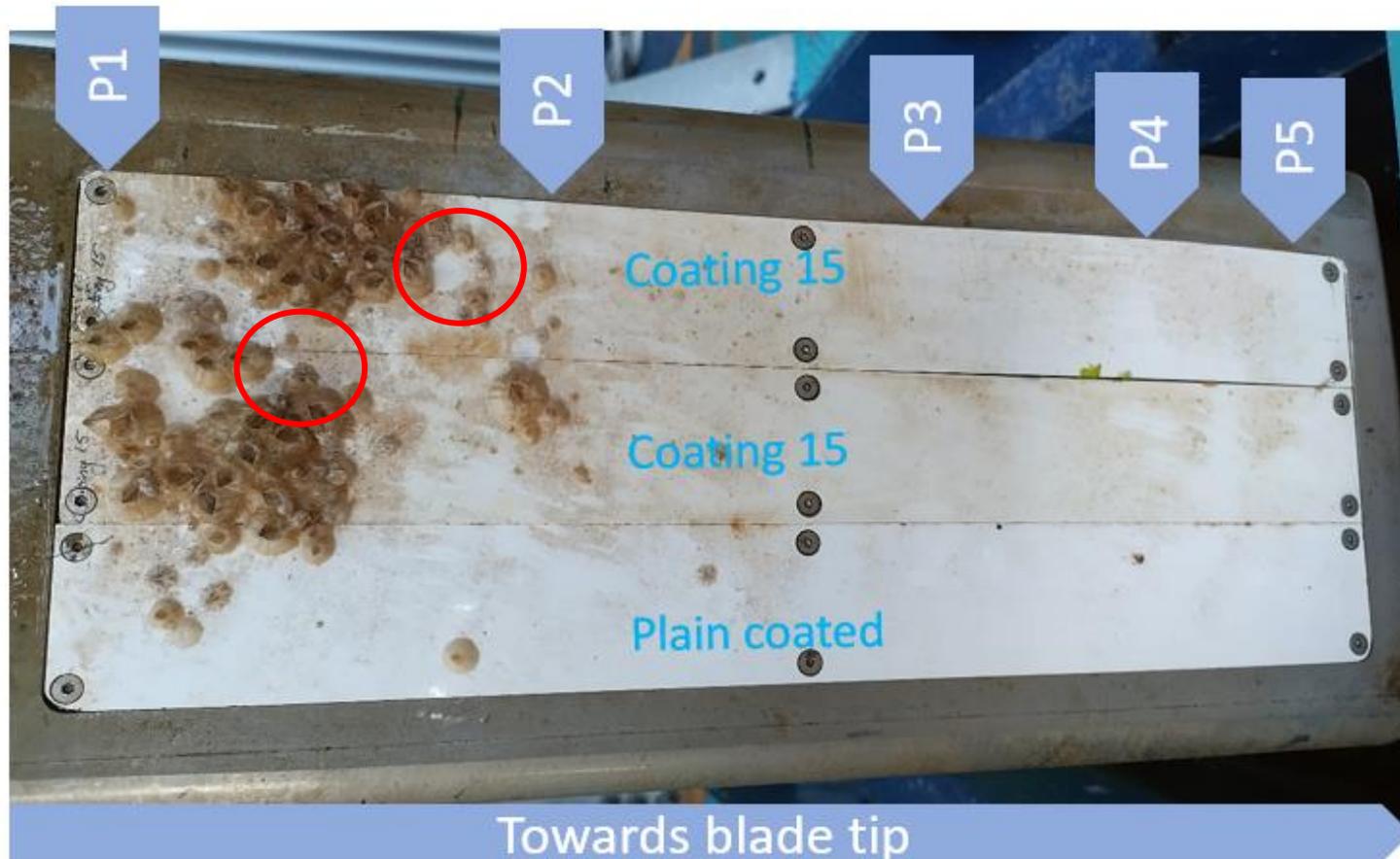
Evolution of biofouling over 17 week period on control material

| 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 |



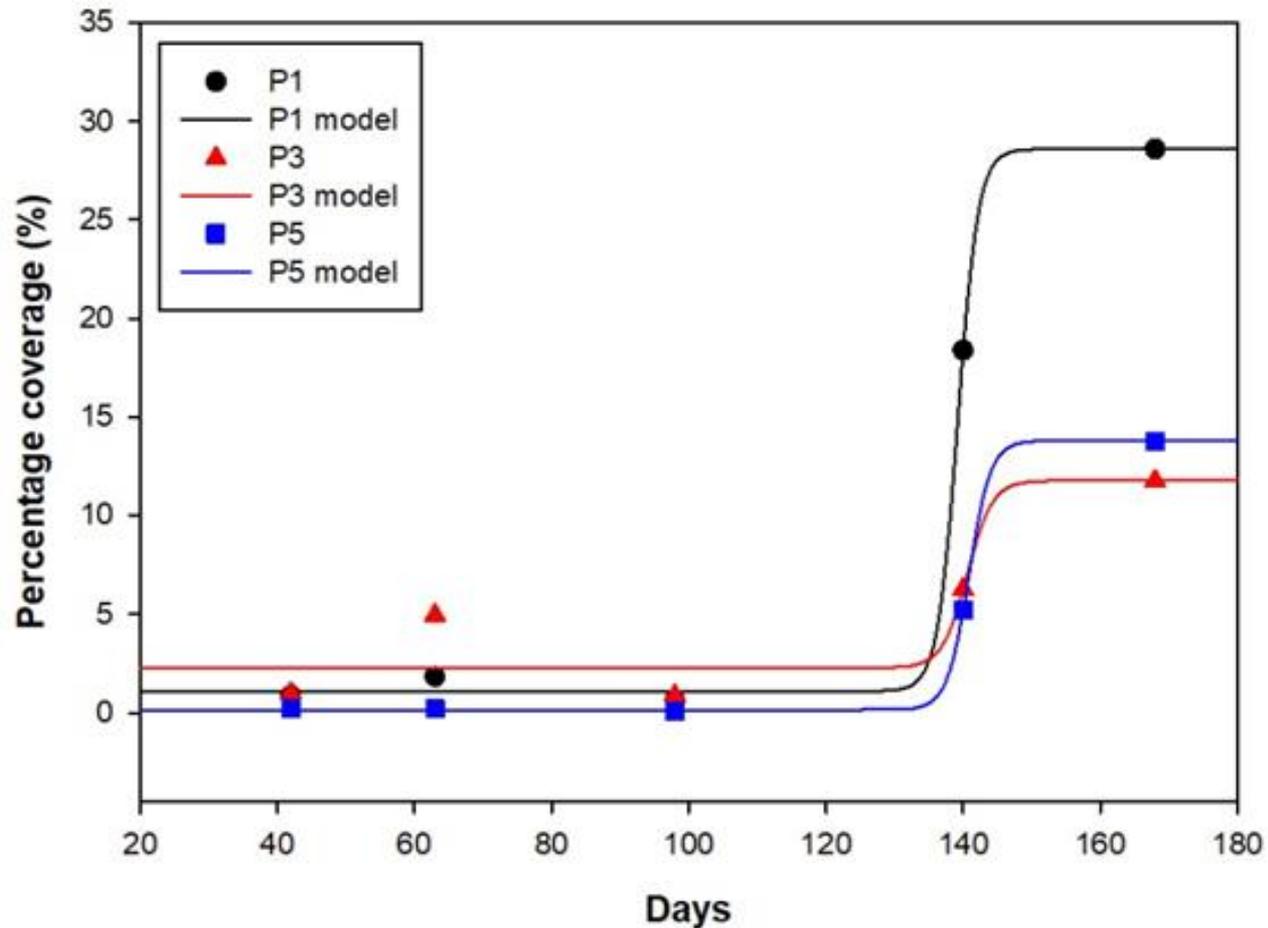
Field testing with non uniform stress distribution

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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