The Impacts of Marine Growth on Dynamic Subsea Cables in the Offshore Renewable Energy Industry

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HERIOT WATT UNIVERSITY ORKNEY CAMPUS

Supergen Offshore Renewable Energy

UNIVERSITY OF EXETER

Floating Offshore Renewable Energy devices

-require dynamic subsea cables (dSPCs) to transfer electricity from device to the seabed

-dSPCs are vulnerable to structural fatigue from oscillating movements

-Maintenance/replacement costs: materials, vessels, ‘down-time’


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Image: A. Want


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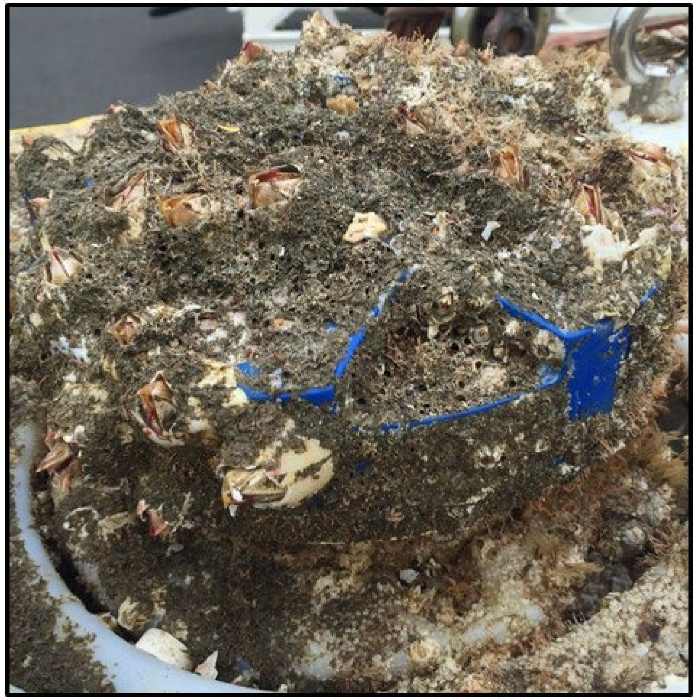
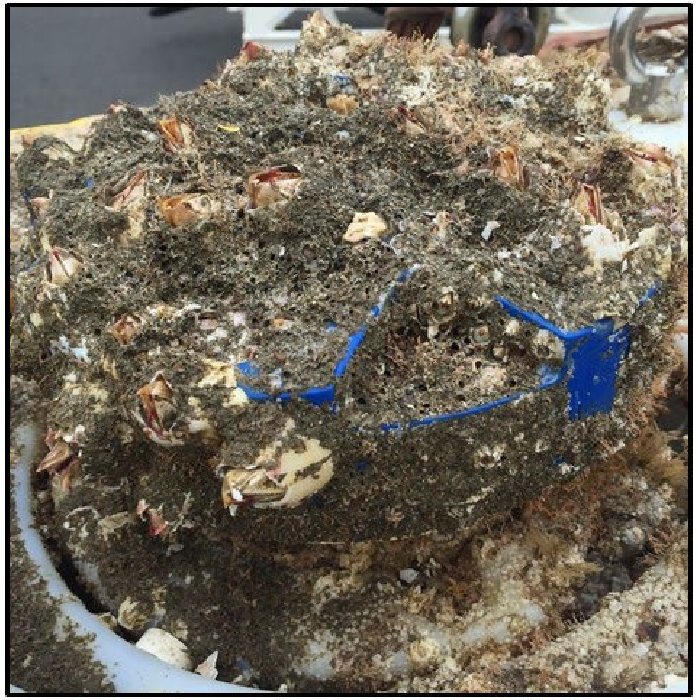
Biofouling

<u>The Technology Perspective</u>



Biofouling

The Technology Perspective



What is the problem?

- Increased roughness: ↑drag ↓performance/survivability
- Increased weight on cable systems: ↓survivability
- Accelerating corrosion of components: ↓survivability
- Antifouling strategies are expensive and require additional operational 'down-time': ↑costs

Is this a new problem?

Yes, there are several issues unique to the Offshore Renewable Energy (ORE) sector:

- Use of dynamic subsea power cables with floating technologies
- Devices are being placed in poorly understood habitats
- Novel components/materials used in the sector
- Hydrodynamic and mechanical consequences of biofouling on moving structures, e.g. static rotating turbines
- Sensor accuracy is compromised leading to inaccurate determination of device performance and resource assessment


Image: A. Want


Image: A. Want


Image: A. Want

EMEC WaveRider buoy

The Team:

A:
Heriot Watt University – Orkney Campus
European Marine Energy Centre
Orbital Marine Power

B:
The University of Exeter – Penryn Campus
and Dynamic Marine Component Test Facility
South West Mooring Test Facility

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Ultimately, the aim is to help lower Levilized Cost of Electricity,
allowing decarbonisation of energy generation in an environmentally responsible manner

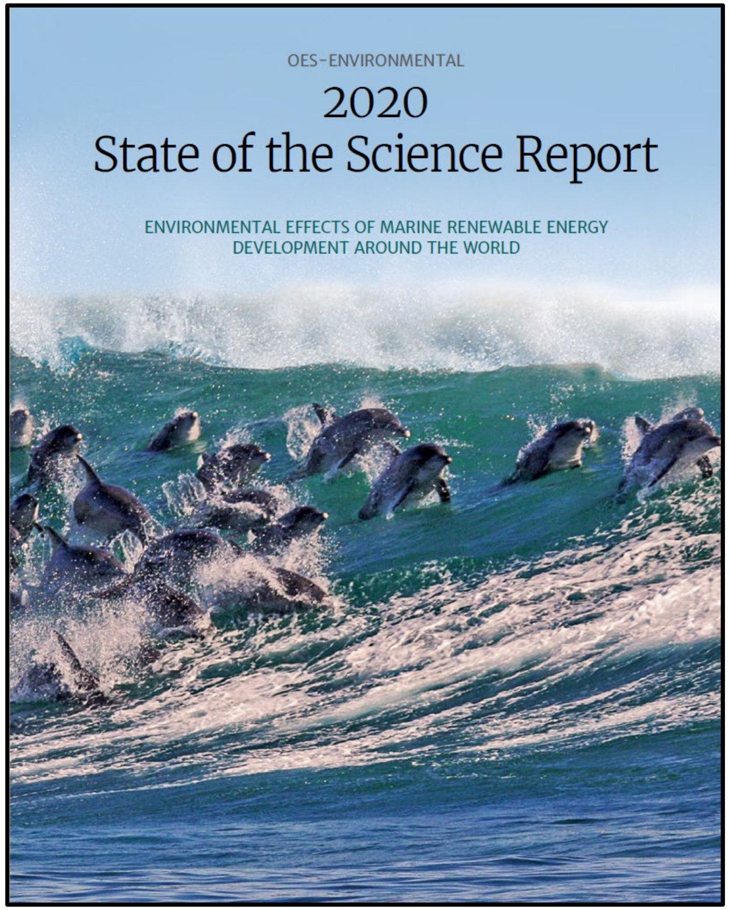
Key Project Objectives:

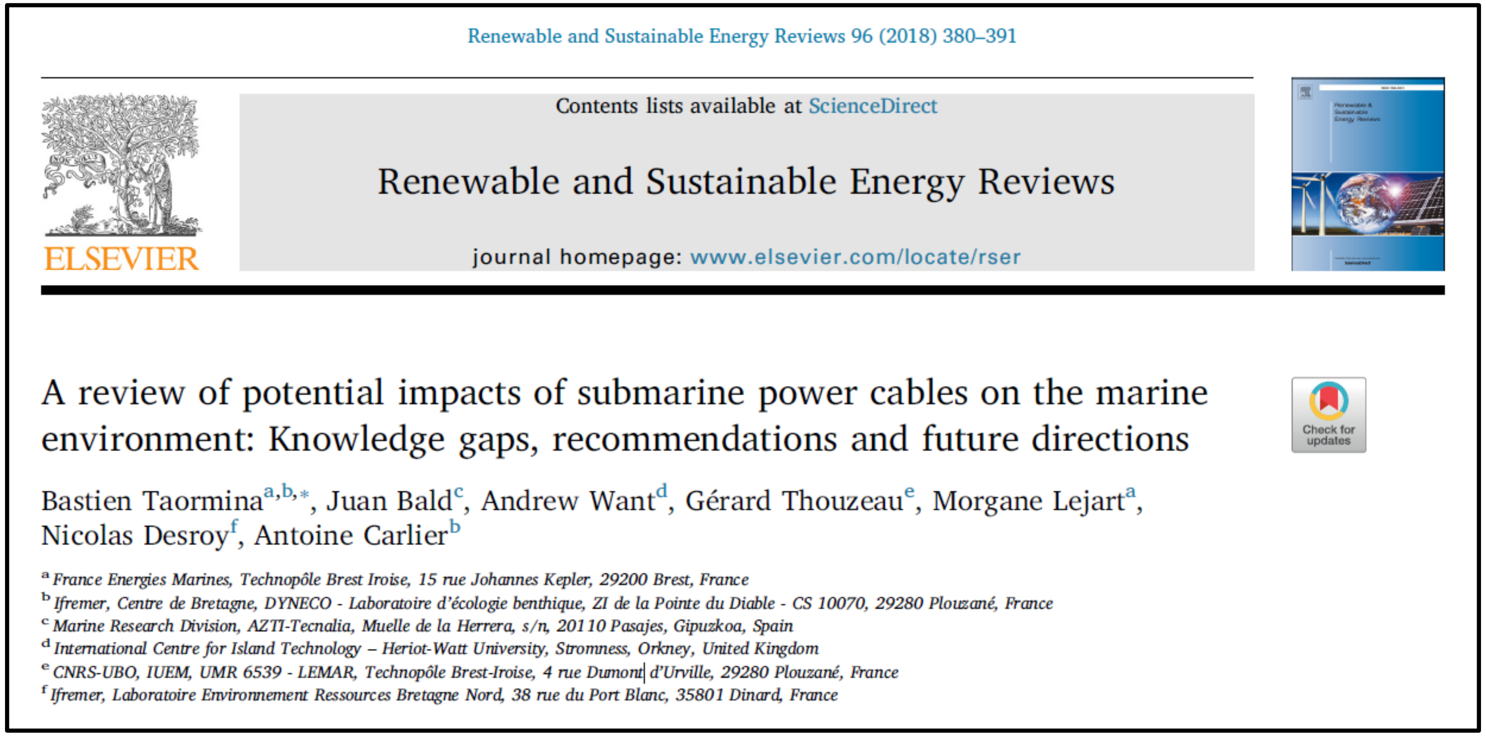
- Review of literature and data regarding marine growth on dSPCs
- Identifying and assessing potential mitigation strategies
- Preliminary modelling of impacts on hydrodynamic and structural responses of dSPCs to marine growth
- Preliminary assessment of economic impacts and risks
- Develop a large scale proposal to address gaps and test solutions

Review of literature and data regarding marine growth on dynamic subsea power cables

-Generally, there exists are paucity of published studies in the impacts of marine growth in the ORE sector, and especially regarding dSPCS

-Limited inferences can be made from existing studies in the Oil and Gas sector





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ELSEVIER

A review of potential impacts of submarine power cables on the marine environment: Knowledge gaps, recommendations and future directions

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Copping, A.E. and Hemery, L.G., editors. 2020. OES-Environmental 2020 State of the Science Report: Environmental effects of marine renewable energy development around the world. Report for Ocean Energy Systems (OES).

DNV·GL

STANDARD

DNVGL-ST-0437 Edition November 2016

Loads and site conditions for wind turbines

"Unless more accurate data are available, the density of the marine growth may be set equal to 1325 kg/m^3."

Guidance note:
Unless data indicate otherwise, the following marine growth profile may be used for design in Norwegian and UK waters:

Depth below MWL (m)	Marine growth thickness (mm)	
	Central and Northern North Sea (56° to 59° N)	Norwegian Sea (59° to 72° N)
−2 to 40	100	60
>40	50	30

Forensic Decommissioning for Tidal Energy Converters

FoDTEC

Interreg North-West Europe FORESEA

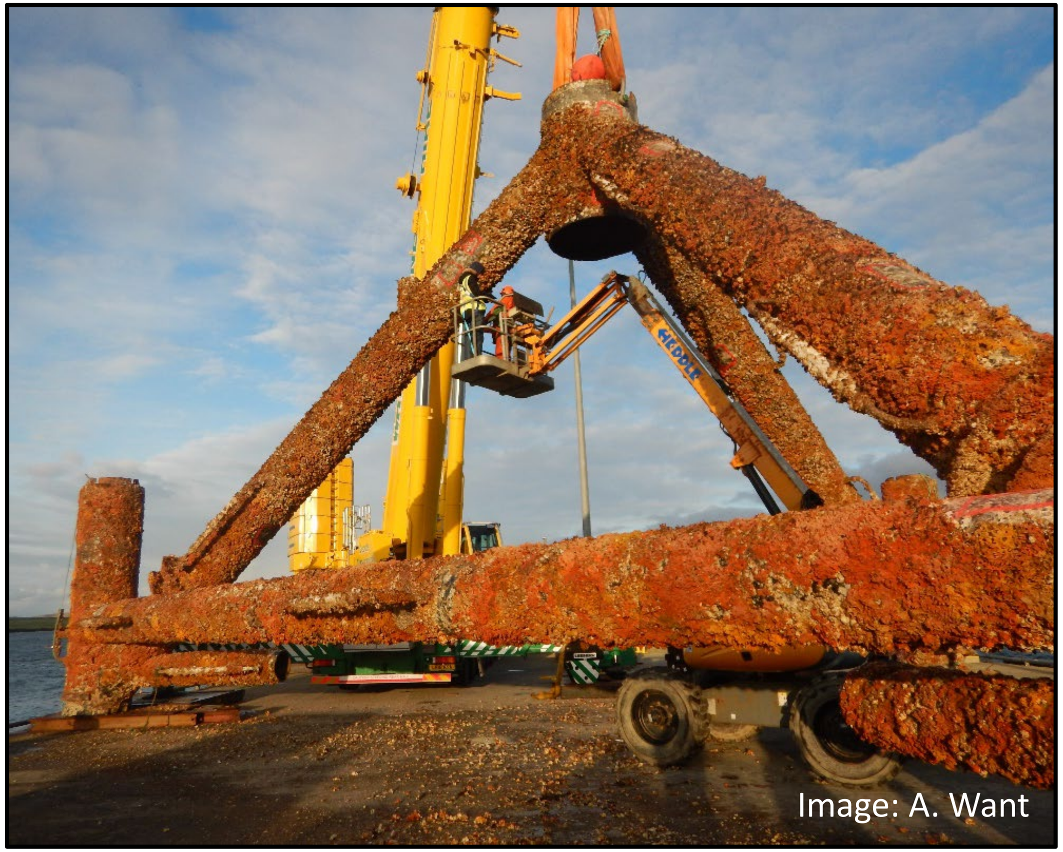
Image: A. Want

Amphilectus fucorum	*Chirona hameri*	*Majidae* spp.
Amphisbetia operculata	*Didemnum maculosa*	*Metridium dianthus*
Anomia ephippium	*Diplosoma* spp	*Mytilus edulis*
Aphroditinae spp.	*Echinus esculentus*	*Nematoda* spp.
Archidoris pseudoargus	*Electra pilosa*	*Nemertea* spp.
Asterias rubens	*Filograna implexa*	*Nereidae* spp.
Balanus balanus	*Gibbula cineraria*	*Ophiothrix fragilis*
Botryllus schlosseri	*Grantia compressa*	*Platyhelminthes* spp.
Bugulina flabellata	*Haplopoma graniforum*	*Polychaetae* spp.
Calliostoma ziziphynum	*Henricia oculata*	*Sarsia extinia*
Cancer pagarus	*Hiatella arctica*	*Spirobranchus triqueter*
Caprella spp.	*Jassa falcata*	*Sycon ciliatum*
Cellaporina hassallii	*Leuconia nivia*	*Trivia arctica*
Cellepora lineata	*Leucosolenia* spp.	*Verruca stroemia*
Cellopora pumicosa	*Macropodia* spp.	

Zone	Wet weight (g)	Dry weight (g)
Upper	1413.99	913.84
Mid	1381.82	946.15
Lower	1365.32	820.22

Zone	*Chirona*	*Porifera* spp.	*Mytilus*	*Hydroidea* spp.	*Ophiothrix*
Upper	52	15	31	2	0
Middle	54	37	6	3	0
Lower	34	52	7	5	2

Want, A. Harris, R.E. and Porter, J.S. (2020). Forensic Decommissioning for Tidal Energy Converters – Biofouling report. Heriot-Watt University Report: FT-010.

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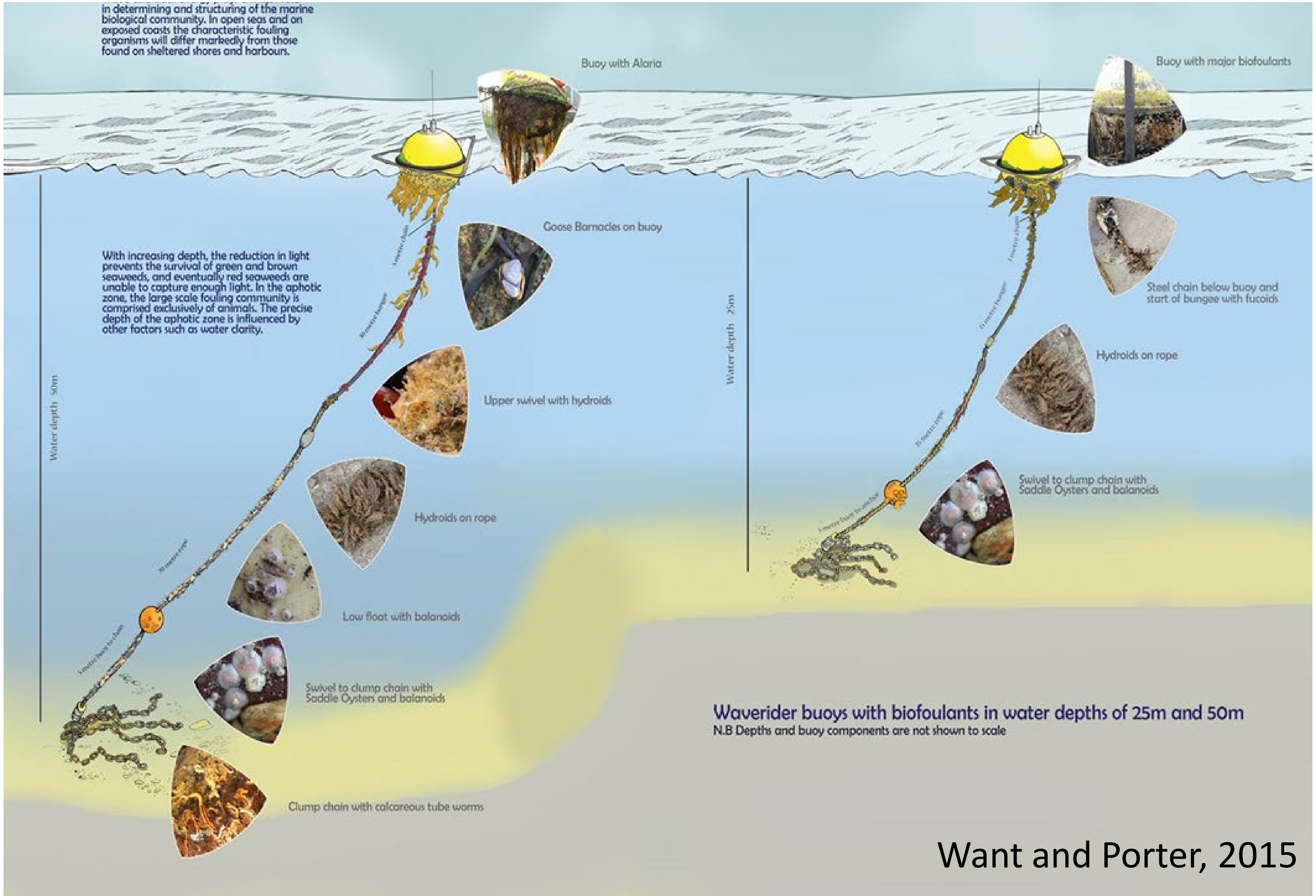
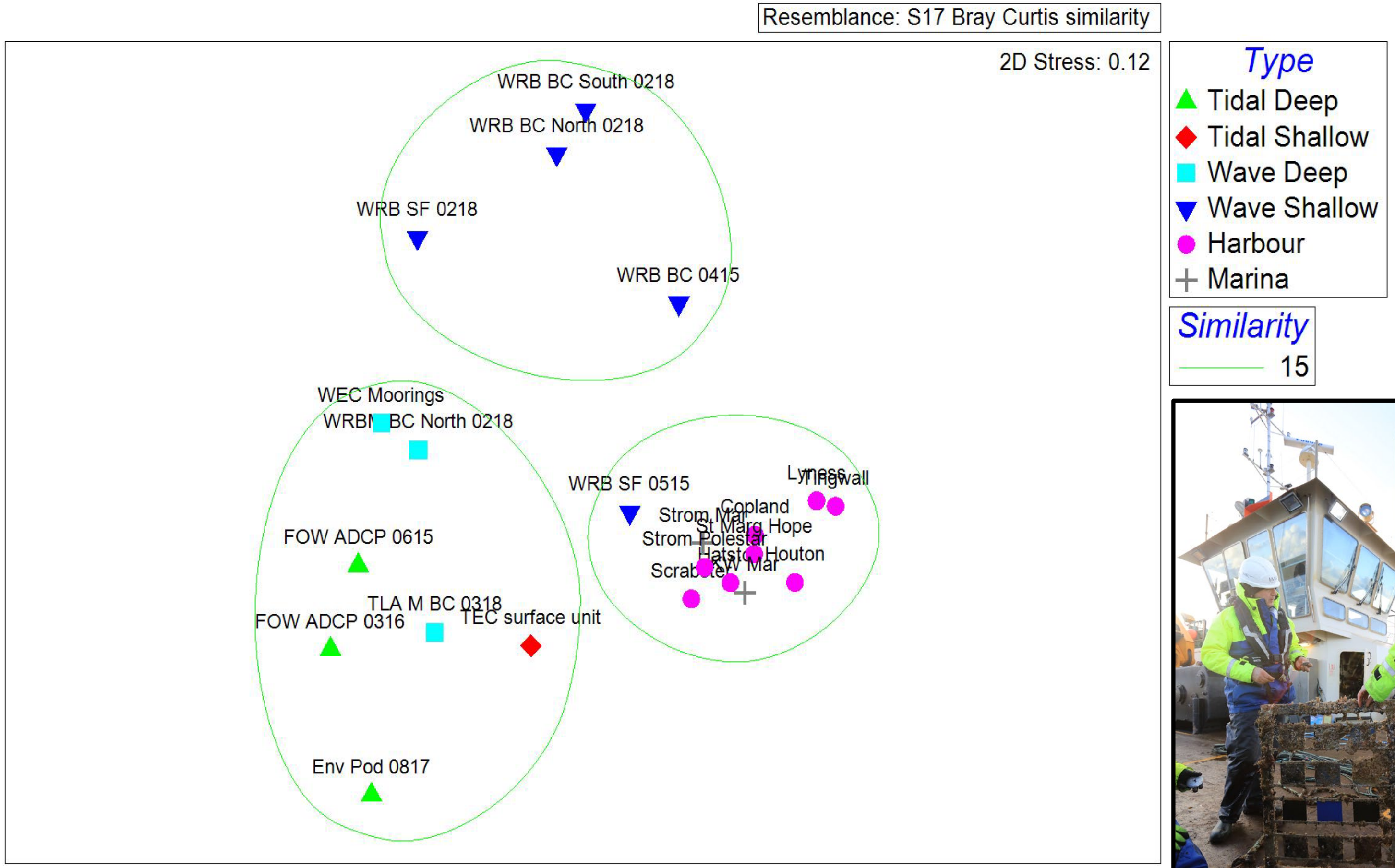
Biofouling at different depths and hydrodynamic conditions:



Want and Porter, 2015

- 200+ species recorded
- 7 INNS (in harbours/marinas)
- MDS plot to show differences visually in species suites, between locations

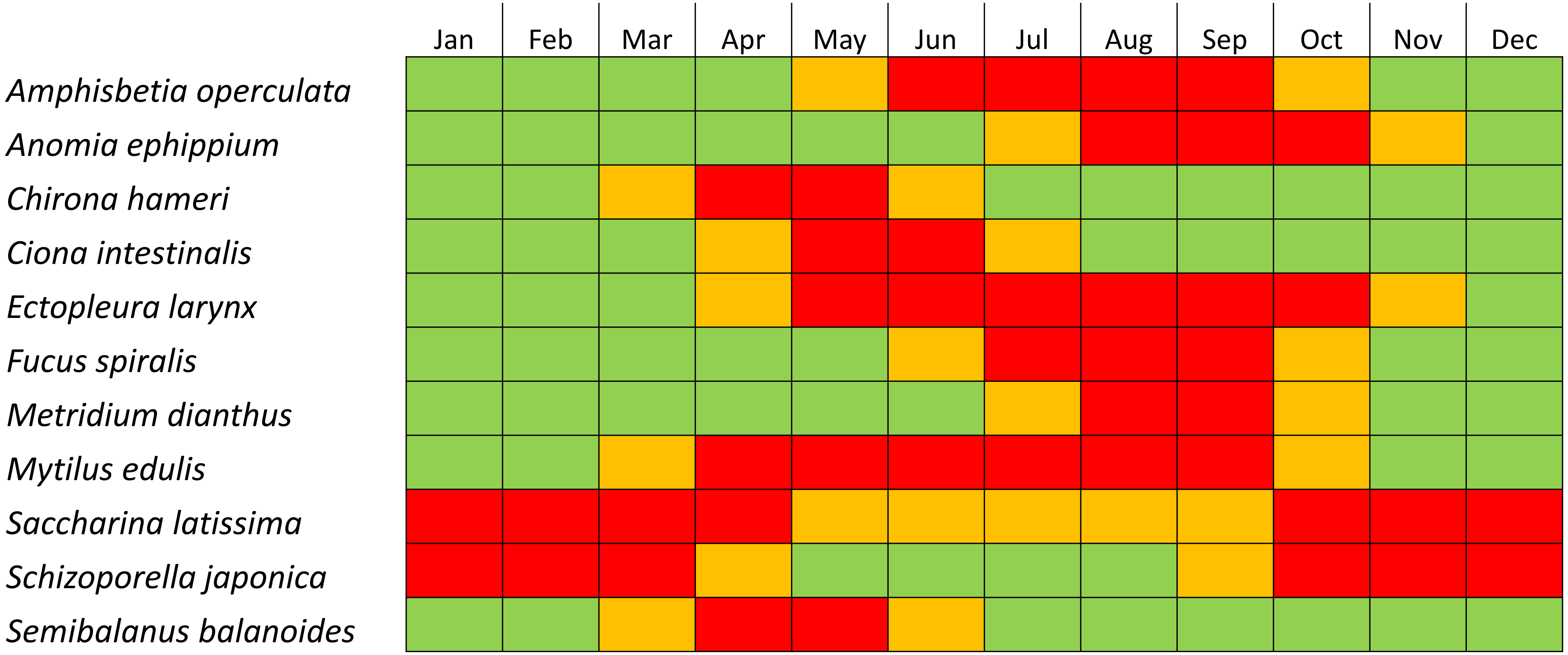


Want, A., Bell, M.C., Harris, R.E., Hull, M.Q., Long, C.R. and Porter, J.S. (2021). Sea-trial verification of a novel system for monitoring biofouling and testing anti-fouling coatings in highly energetic environments targeted by the marine renewable energy industry. *Biofouling*.
DOI: 10.1080/08927014.2021.1928091

Seasonality and Succession:

- Evidence gathered has provided examples of profound levels of fouling occurring over a relatively short period of time, depending on seasonality and succession
- Marked seasonality of fouling suggest that scheduling deployment and maintenance operations in a targeted manner may be an effective means to minimise fouling impacts and mitigate risk of invasive species

Waverider buoy deployed for >8 mths; fouling dominated by the barnacle *Semibalanus balanoides.*

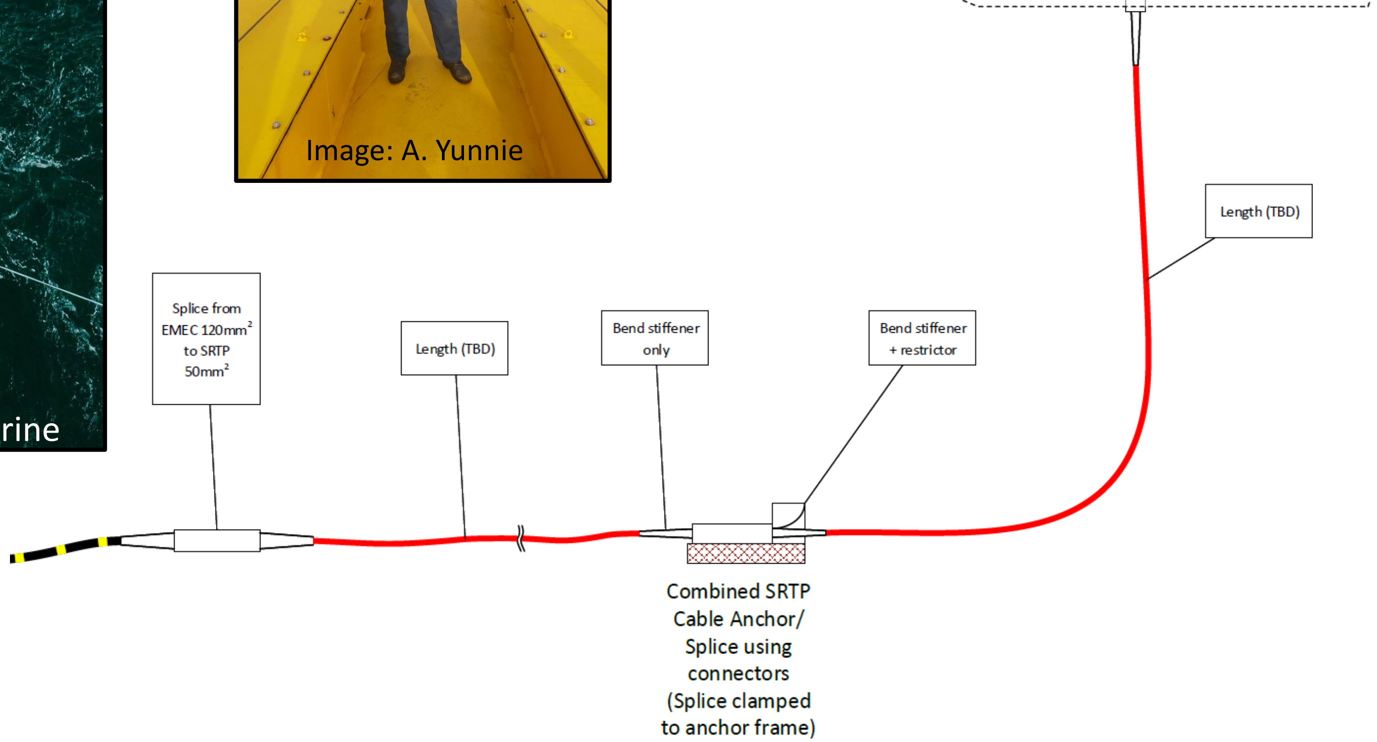


Periods of settlement associated with major fouling organisms at MRE test sites in Orkney. Months in red indicate the highest recognised settlement season, orange months are of intermediate concern, and green months are of least concern. Table updated from **Want *et al.*, 2017**.

ORBITAL

MARINE POWER

- Founded in 2002
- O2 device is the world's most powerful tidal turbine
- Grid connected 2 MW device
- Operating at Fall of Warness, Orkney



EMEC

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ROV Biofouling Surveys

ORBITAL
MARINE POWER

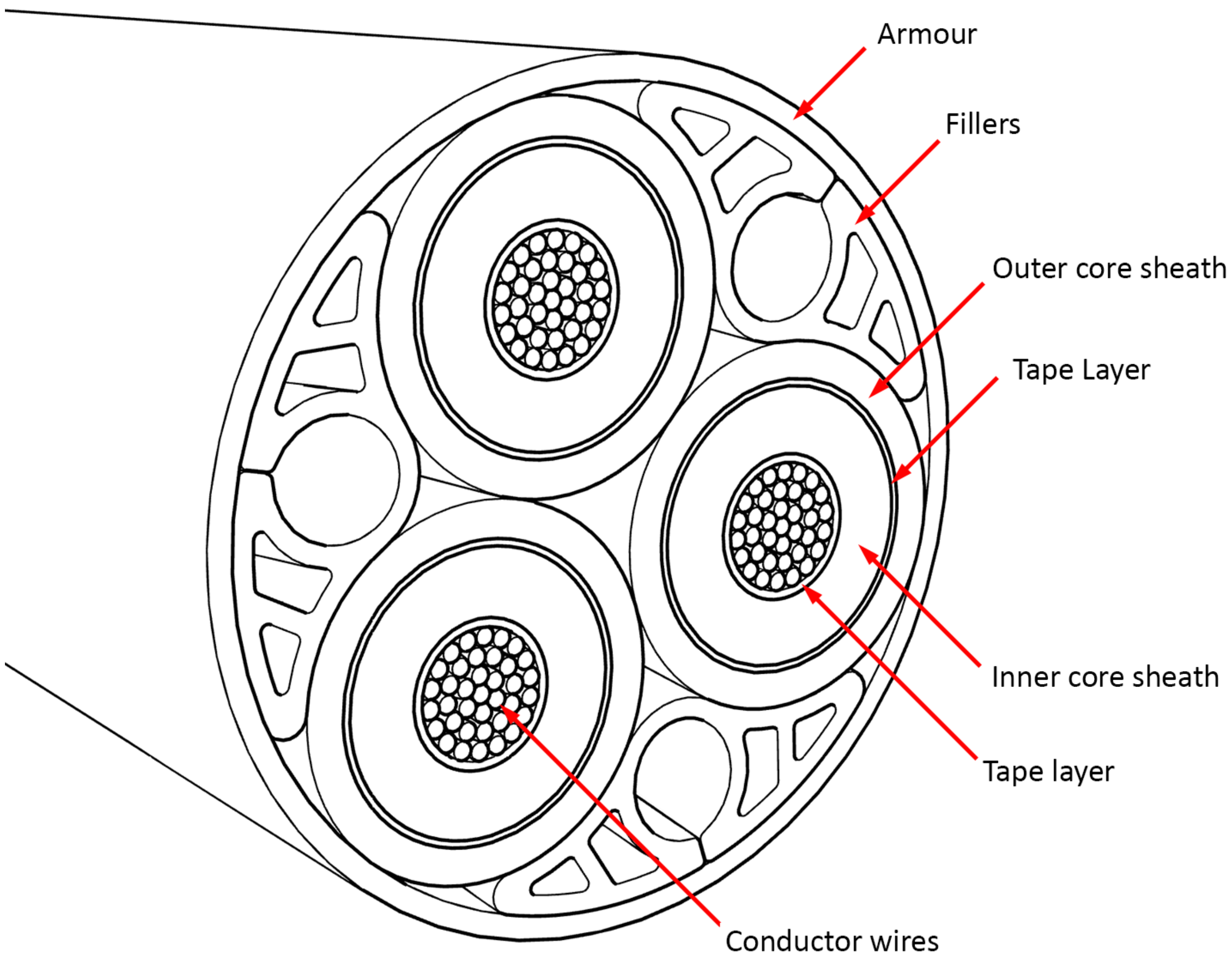
ROV Biofouling Surveys

Preliminary modelling of impacts on hydrodynamic and structural responses of dSPCs to marine growth

a) Wave Energy Converter
b) Floating Offshore Wind Platform

<u>Dynamic Subsea Cable Data</u>

- Rated Power - 72.5kV
- Aluminium conductors
- XLPE insulation
- Novel, lightweight composite armour
- Outer diameter = 122mm
- Wet weight = 5.5kg/m
- Bending Stiffness = 6.24 kNm^2
- Axial Stiffness = 42.1 MN
- Torsional Stiffness = 4.62kNm^2

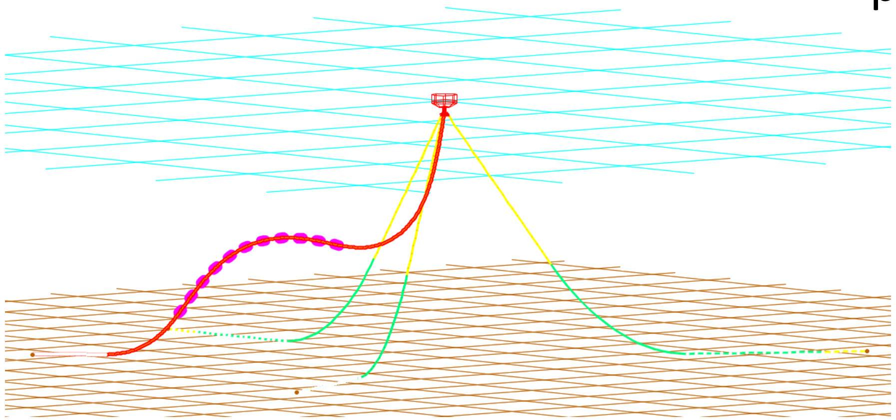


WEC Data

- South West Moorings Test Facility (SWMTF) buoy – point absorber

V. Harnois, et al, "Numerical model validation for mooring systems: Method and application for wave energy converters", *Renewable Energy*, vol. 75, pp. 869-887, 2015

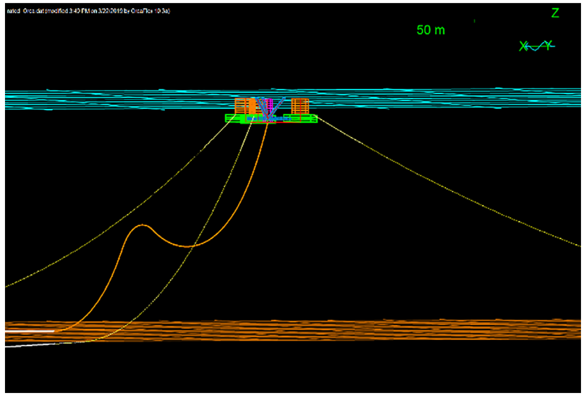
Particular	Value	Unit
BUOY		
Diameter	2.9	m
Depth (to base)	1.42	m
Depth (to keel)	2.45	m
Centre of Gravity (from keel)	1.13	m
Draught	1.66	m
Displacement	3250	kg
MOORINGS		
Anchor (drag embedment)	1100	kg
Ground Chain (32 mm stud link)	5	m
Riser Chain (24 mm stud link)	36	m
Rope Tail (44 mm Jacketed parallel lay nylon)	20	m



Parameter	Value	Unit
Water Depth	30	m
Significant wave height (Hs)	3.5	m
Wave Period (Tp)	8	s
Wave Spectrum	JONSWAP	
Current	0.662 m/s	

- OrcaFlex Model
- Cable float buoyancy distributed over central section
- Current and waves applied perpendicular to cable

FOWT Data

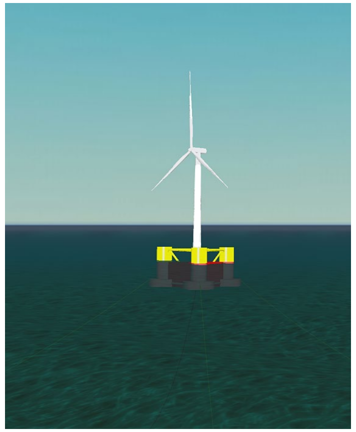


Turbine - NREL 5MW baseline turbine

Platform - DeepCWind OC4 semi-submersible

Sea state - Representative floating offshore wind farm:

- JONSWAP
- Hs=2.7m, Tz=7.1s
- Water depth = 200m



Key parameters of the components of the National Renewable Energy Laboratory (NREL) 5 MW wind turbine.

Rating 5 MW, 3 Blades
Hub height = 90.0 m
Blade length = 61.5 m
Rotor mass = 109,390 kg
Nacelle mass = 240,000 kg
Tower mass = 349,390 kg

Platform Parameters:

Beam = 74m
Platform mass, including ballast = 13,473 te
Number of mooring lines = 3
Platform draft = 20.0 m
Displaced volume = 13,917 m3

Fouling Data*

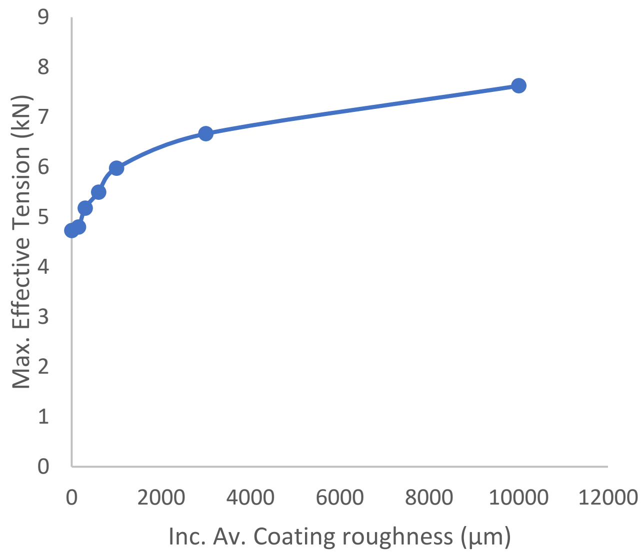
	Equivalent sand roughness height	Increased average coating roughness	Resistance Increase	Drag Coefficient
Description of condition	*(μm)*	*(μm)*	*(%)*	
Hydraulically smooth surface	0	0	0	1.16
Typical as applied AF coating	30	150	2	1.18
Deteriorated coating or light slime	100	300	11	1.29
Heavy slime	300	600	20	1.39
Small calcareous fouling or weed	1000	1000	34	1.55
Medium calcareous fouling	3000	3000	52	1.76
Heavy calcareous fouling	10000	10000	80	2.09

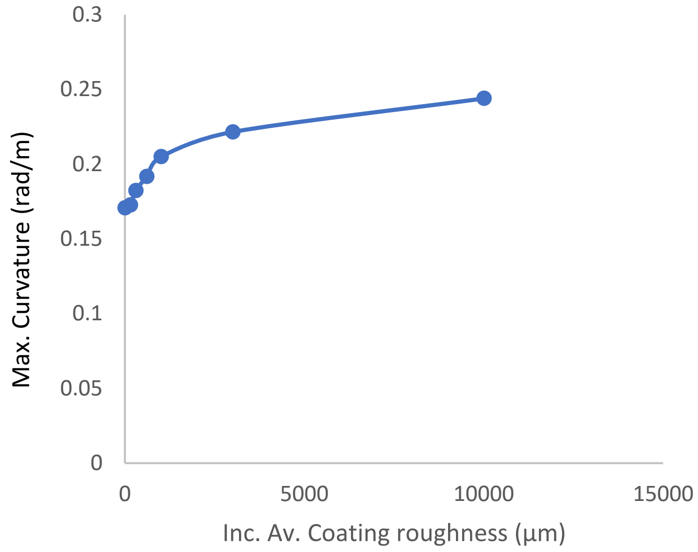
*Schultz (2007) Effects of coating roughness and biofouling on ship resistance and powering, *Biofouling*, 23:5, 331-341

*Fouling assumed to be neutrally buoyant; applied evenly along cable

WEC Results:

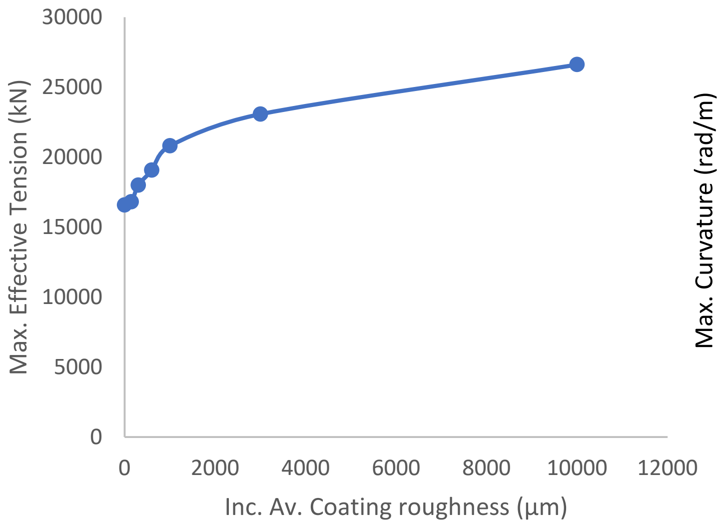
- Increase in surface roughness from heavy calcareous fouling:
  - 61% increase in max tension
  - 43% increase in max curvature

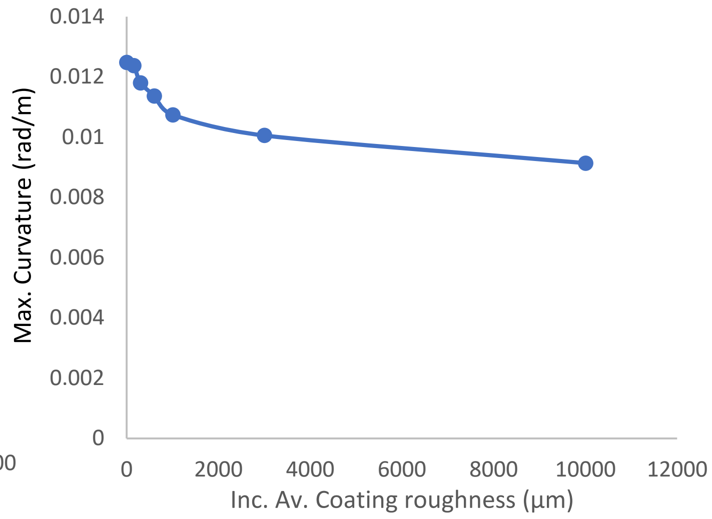




FOWT Results:

- Increase in surface roughness from heavy calcareous fouling:
  - 60% increase in max tension
  - 27% decrease in max curvature





Conclusions/next steps

- Early stage – initial study
- Existing estimates of biofouling tend to be broad with limited application to dSPCs
- ↑ understanding of the specifics of marine growth may improve management
- Biofouling increases cable roughness and the drag coefficient
- Max tension ↑>60% in both preliminary test cases
- Max curvature ↓27% for the FOWT but ↑43% for the WEC
- Future work:
  - Collate relevant fouling data and identify knowledge gaps
  - Consider antifouling strategies in this sector
  - Use data from *in situ* floating wind installations and MRE technologies for fouling, including mass
  - Consider CFD modelling of fouling to obtain improved drag value inputs into OrcaFlex global model; consider effect of fouling on cable stiffness
  - Model economic impacts of expected dSPC failure rates
  - Develop larger proposal to address knowledge gaps and mitigate economic impacts

Thank you

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