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BioFREE: an international collaboration to assess the impacts of biofouling on the marine renewable energy industry

Andrew Want and Joanne Porter – Heriot-Watt University

EIMR: 24 April 2018

What is the problem?

A major concern to industries working in the marine environment is biofouling - the settlement and growth of organisms on submerged structures.

- Increases to surface weight and roughness - impacting drag and efficiency
- Accelerating corrosion of materials
- Antifouling strategies are costly and require additional ‘down-time’
- Providing surfaces on artificial structures in the marine environment may create ‘stepping-stone’ habitats for the spread of fouling communities (including non-native species)

Is this a new problem?

Yes, there are several issues unique to the marine renewable energy (MRE) sector:

- Devices are being placed in poorly understood habitats
- Novel components used in the sector
- Sensor accuracy is compromised leading to inaccurate determination of device performance and resource assessment

FADCP camera lens

Schizoporella japonica (invasive non-native bryozoa) and *Balanus crenatus* (barnacle) on tidal device

… the hydrodynamic and mechanical consequences of marine growth on moving structures are of particular concern

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Scientists are working closely with MRE test site personnel, device developers and engineers to gather data, to share knowledge and to formulate expertise on specific aspects of biofouling that are relevant in assisting the development of the MRE industry

Objectives:

- Develop a quantifiable monitoring system designed for deployment at wave and tidal sites
- Testing of materials used by the MRE industry and anti-fouling strategies at suitable sites
- Gather critical benthic and environmental data from poorly-studied, high-energy habitat targeted by the MRE sector
- Dissemination: to industry, regulators, and the scientific community

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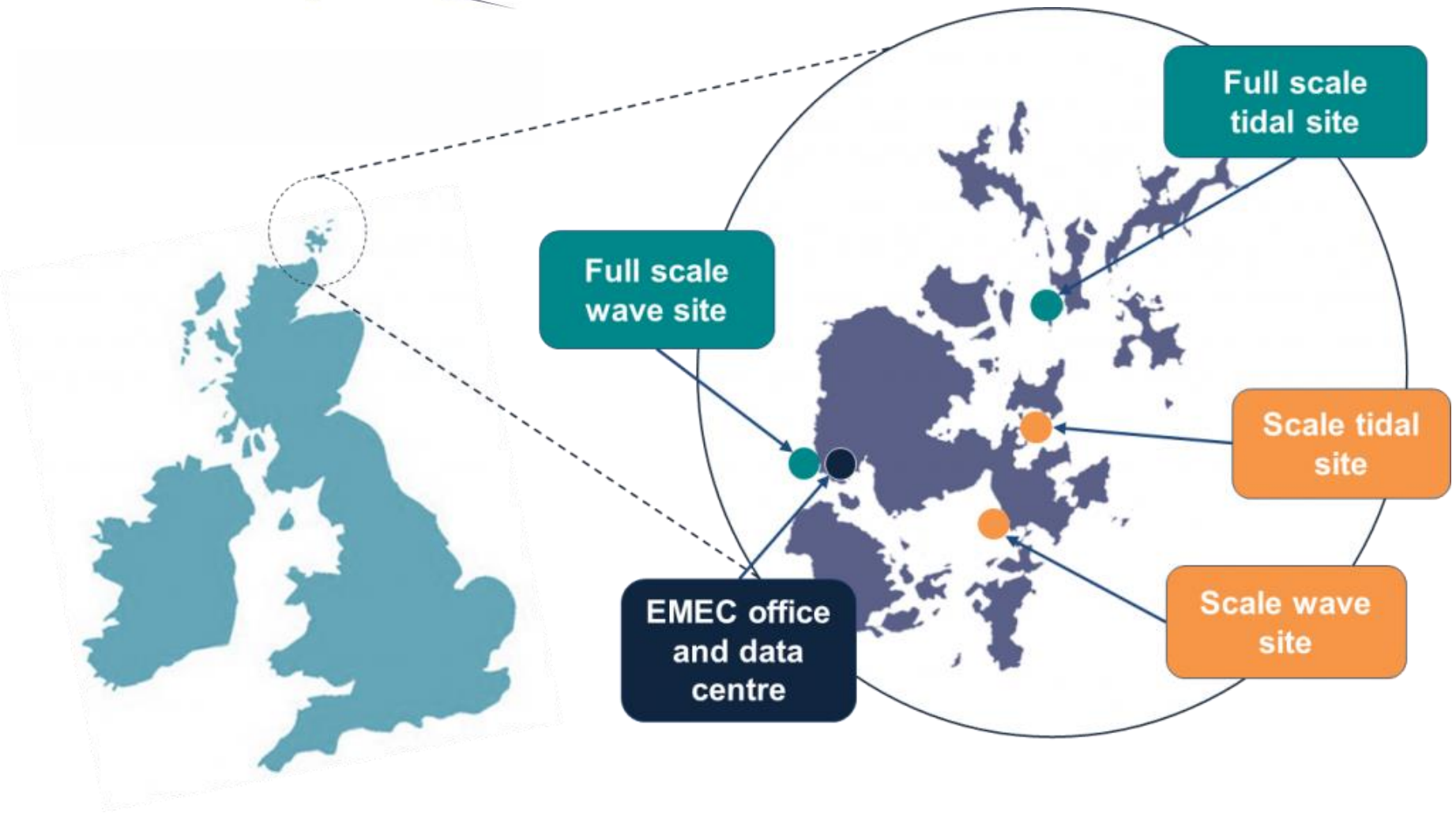

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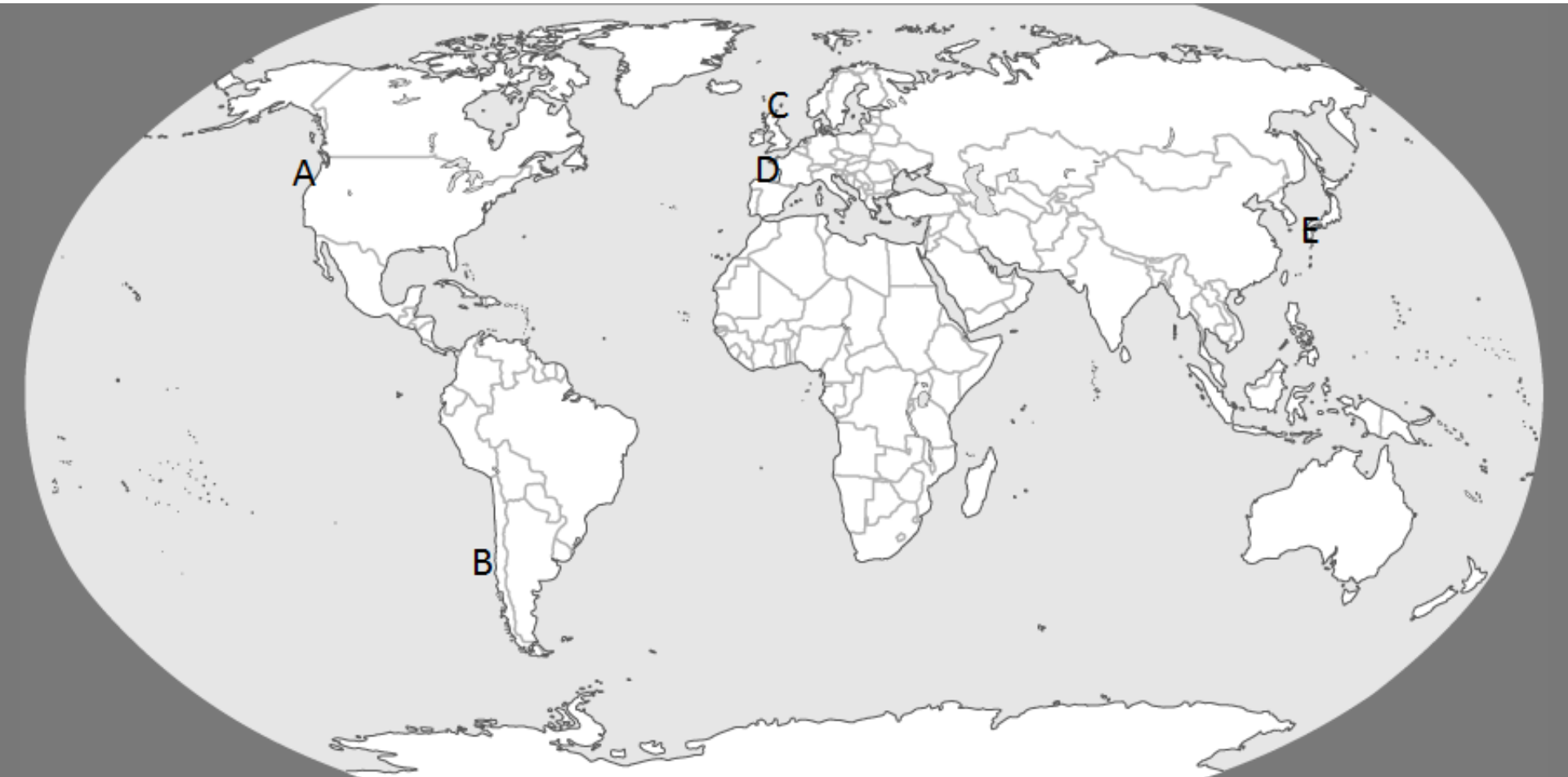
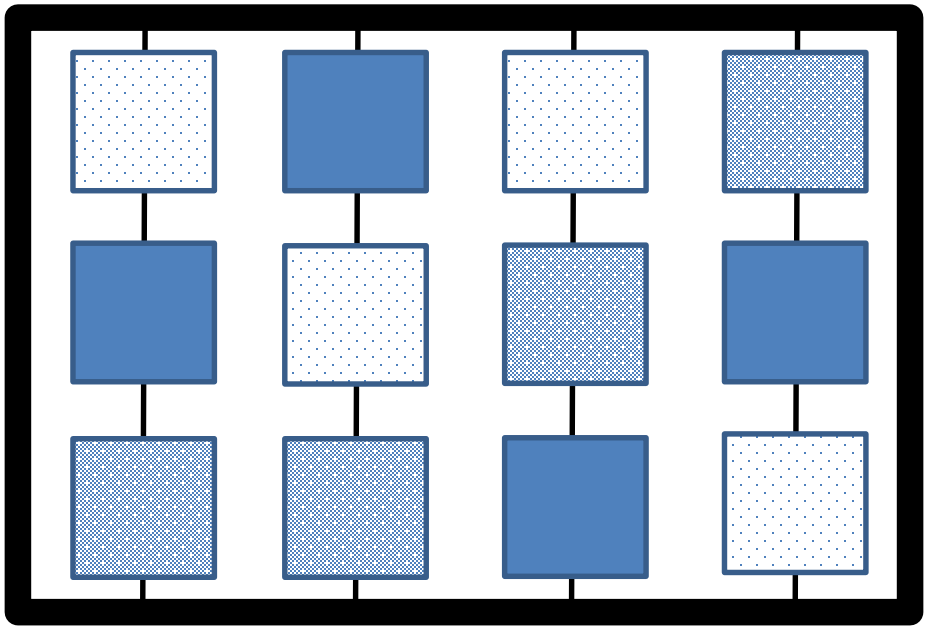
A: NNMREC – Oregon, USA
B: MERIC – Las Cruces, Chile
C: EMEC – Orkney, UK
D. FEM – Bretagne, France
E: OMST – Nagasaki, Japan





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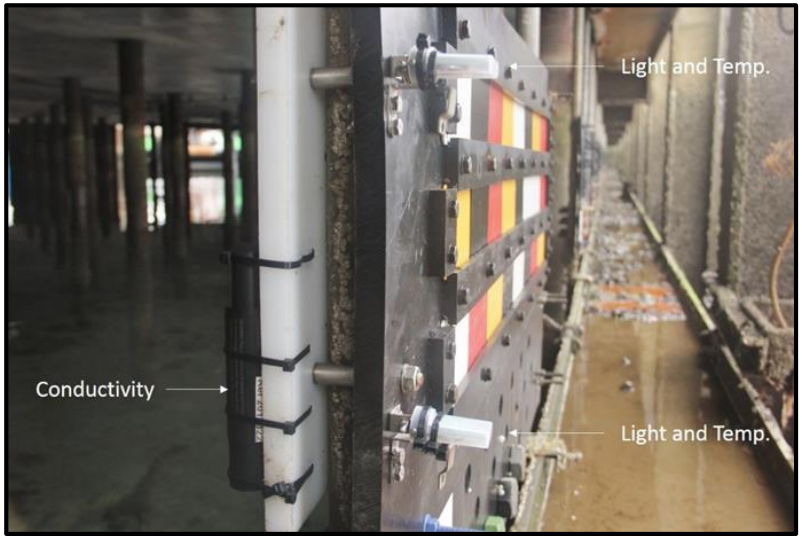
- Monitoring of fouling organisms at different depths and energy levels
- System allows testing of different materials and anti-fouling coatings
- Allows easy deployment and retrieval for regular access
- Physically and statistically robust

Data Collecting Opportunities:

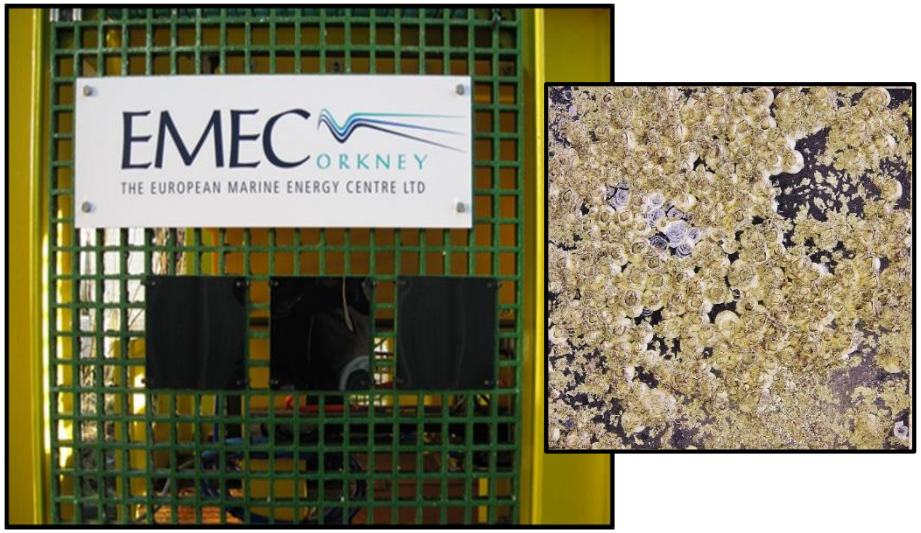
-Biofouling on device mooring system: 31 March 2018

-Waverider buoy mooring survey: 27 Feb 2018

-Test panels (Whitford Ltd.): Stromness Harbour



-Settlement panels: EMEC infrastructure



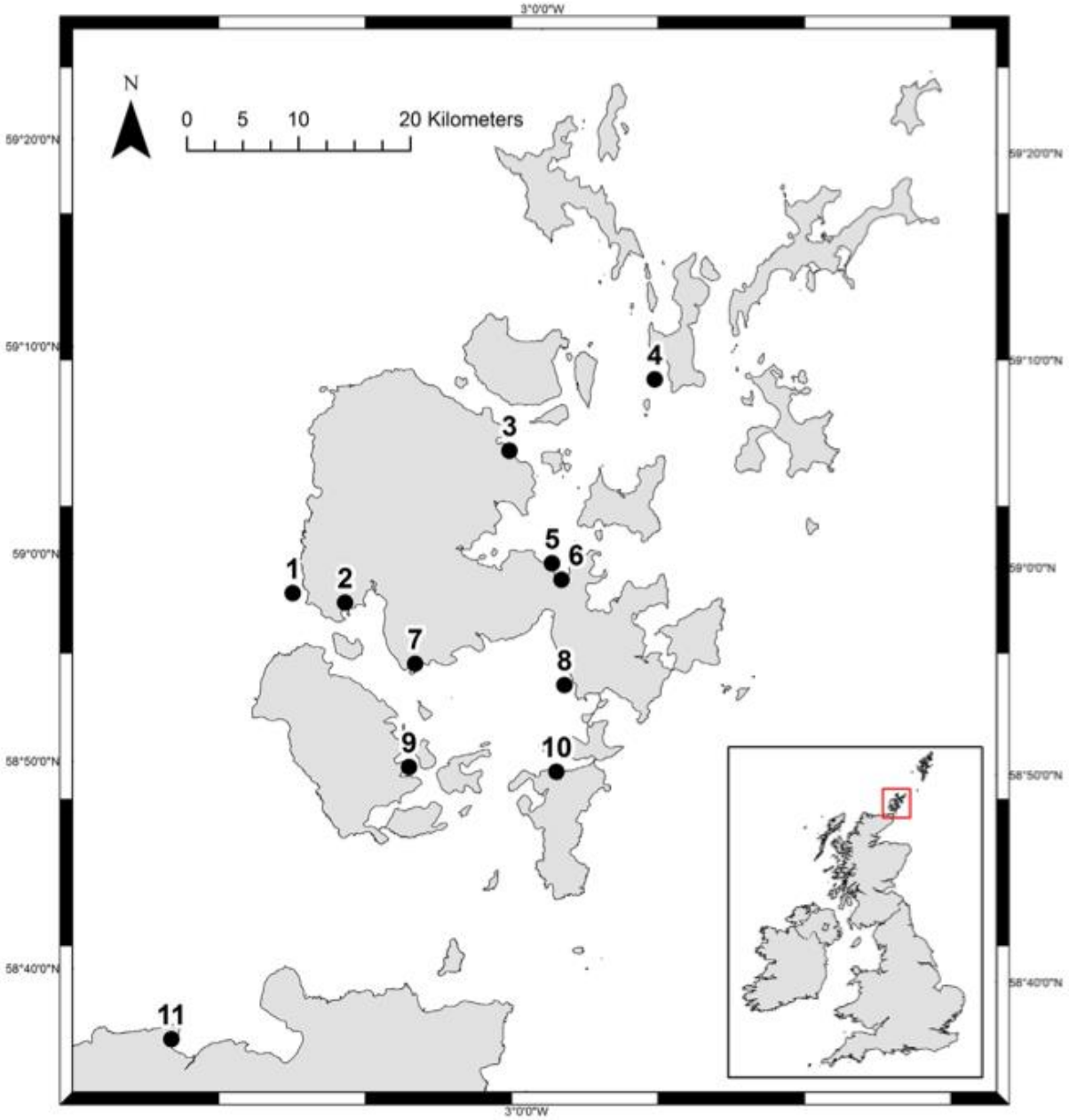
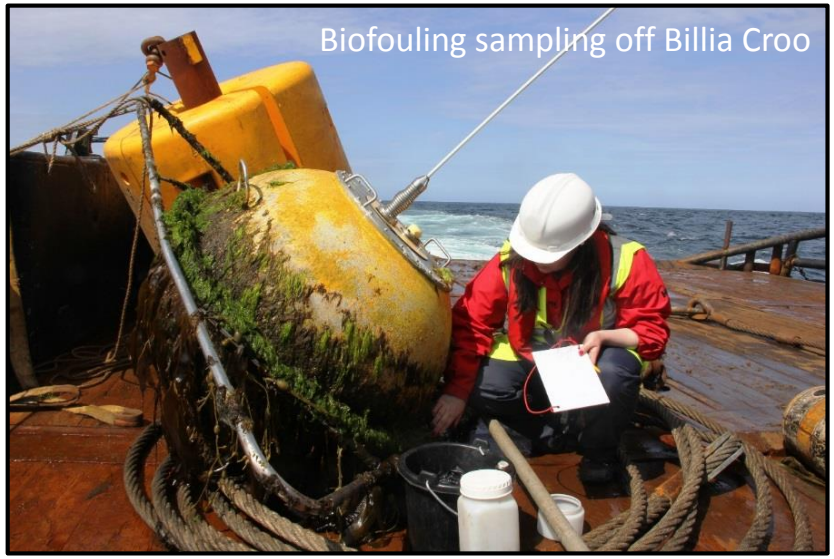


Figure 1. Map of the sampling sites in Orkney waters and the Pentland Firth. (1) Billia Croo; (2) Stromness (including Polestar and Copland's piers, and the marina); (3) Tingwall; (4) Fall of Warness; (5) Hatston; (6) Kirkwall Marina; (7) Houton; (8) Bay of Sandoyne; (9) Lyness, Hoy; (10) St Margaret's Hope, South Ronaldsay; and (11) Scrabster Marina, Caithness.

Example Species List - Waverider Buoy – extreme wave environment

Buoy

Amphisbetia operculata
Laminaria sacharina
Mytilus edulis
Balanus balanus
Semibalanus balanoides
Fucus spiralis
Patella vulgata
Caprella tuberculata
Pomatoceros triqueter
Palmeria palmata
Hiatella arctica
Lomentaria articulata
Celleporina hassallii
Electra pilosa
Idotea neglecta


Biofouling sampling off Billia Croo

Line

Fucus seratus
Mytilus edulis
Laminaria sacharina
Laminaria digitata
Balanus cretanus
Nereis pelagica
Ceramium rubrum
Ulva lactuca
Metridium senile
Electra pilosa

Antispin triangle

Porphyra umbilicalis

Smaller buoy

Alcyonium digitatum
Balanus cretanus
Caprella tuberculata
Ciona intestinalis
Anomia ephippium

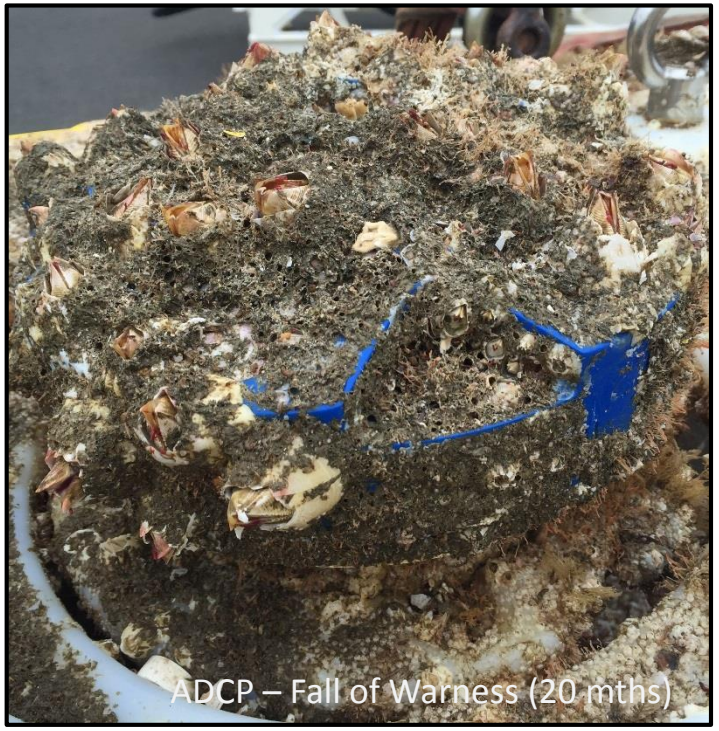
Rope

Scrupocellaria scruposa
Ascidia mentula
Sabella pavonina
Amphipholis squamata

Sampled in the lab

Fenestrulina malusii
Nereis pelagica
Amphisbetia operculata
Hiatella arctica
Caprella tuberculata
Scrupocellaria scruposa
Anomia ephippium
Idotea neglecta
Cauloramphus spiniferum
Callapora lineata
Hydroides norvegica
Ceramium rubrum
Jassa falcata
Anomia ephippium

Site	Date (2015)	Dominant species
Tingwall	May 05	• *Semibalanus balanoides* • *Fucus spiralis*
Stromness marina	May 07	• *Mytilus edulis* • *Saccarhina latissimi* • *Semibalanus balanoides*
Kirkwall marina	May 11	• *Ciona intestinalis* • *Metridium senile* • *Laminaria digitata*
Wave Rider Buoy	May 15	• *Amphisbetia operculata* • *Mytilus edulis* • *Semibalanus balanoides*
Houton	May 17	• *Semibalanus balandoides* • *Ulva intestinalis*
Stromness Polestar	May 19	• *Mytilus edulis* • *Semibalanus balnoides* • *Palmaria palmata*
St. Margaret's Hope	June 3	• *Semibalanus balanoides* • *Fucus spiralis*
Waverider Buoy– Billia Croo	June 4	• *Alaria esculenta* • *Ectopleura larynx* • *Lepas anatifera*
Lyness, Hoy	June 5	• *Semibalanus balanoides* • *Patella vulgata* • *Fucus spiralis*
Copland's Dock, Stromness	June 16	• *Semibalanus balanoides* • *Porphyra umbilicalis* • *Fucus spiralis*
Scrabster, Caithness	June 16	• *Saccarhina latissimi* • *Ciona intestinalis*
Hatston	June 22	• *Ciona intestinalis* • *Schizoporella japonica* • *Obelia geniculata*
ADCP – Fall of Warness	June 23	• *Chirona hameri* • *Ectopleura larynx* • *Botryllus schlosseri*



Analysis of Biofouling Data:

- 143 species recorded
- PRIMER software
- Bray Curtis similarity to explore differences in species between locations/types of substrate
- ANOSIM algorithm to see which species responsible for the differences
- MDS plot to show differences visually in species suites, between locations

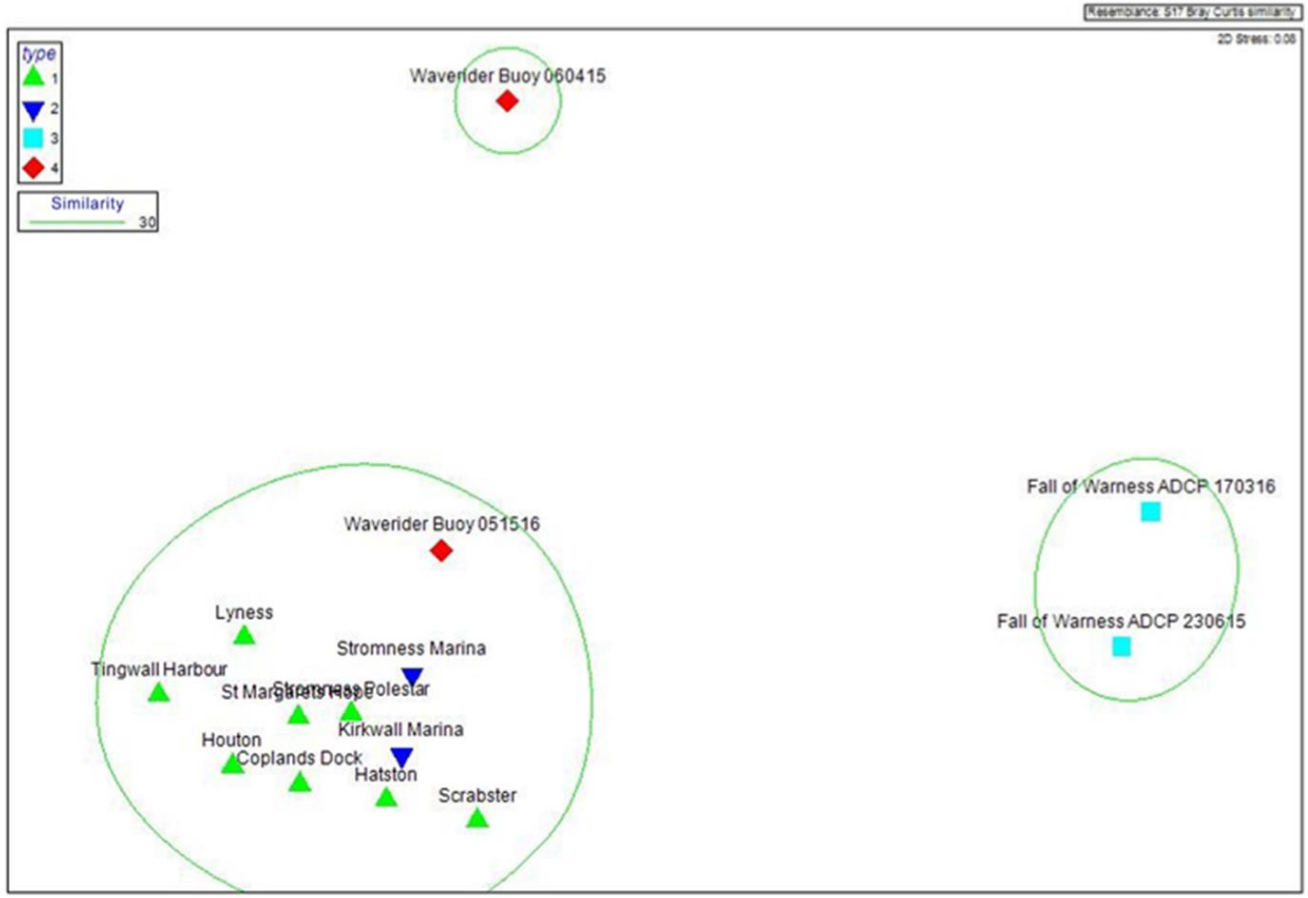


Figure 4. MDS plot using biofouling community data associated with various types of substratum: (1) harbour walls; (2) marina pontoons; (3) fixed ADCP outer surface and frame; and (4) Waverider buoys and moorings. Ellipses represent groups identified by average-linkage cluster analysis based on Bray–Curtis similarities.

Want *et al*. 2017

Table 3. Periods of settlement associated with the major fouling organisms.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Amphisbetia operculata												
Chirona hameri												
Ciona intestinalis												
Ectopleura larynx												
Fucus spiralis												
Mytilus edulis												
Saccharina latissima												
Schizoporella japonica												
Semibalanus balanoides												

Months in red indicate the highest recognised settlement season; orange months are of intermediate concern, and green months are of least concern.

Want *et al*. 2017

Hydroid colonies/mussels: on Waverider Buoy

Modelling Buoy Response to Biofouling:

- Using Waverider buoy data generated at the EMEC wave testing site (Billia Croo)
- Modelling responses (OrcaFlex) including light, medium, and heavy fouling parameters
- Output: analysis of Spectral Moments (curve profile of the wave encountered)

Modelling Buoy Response to Biofouling:

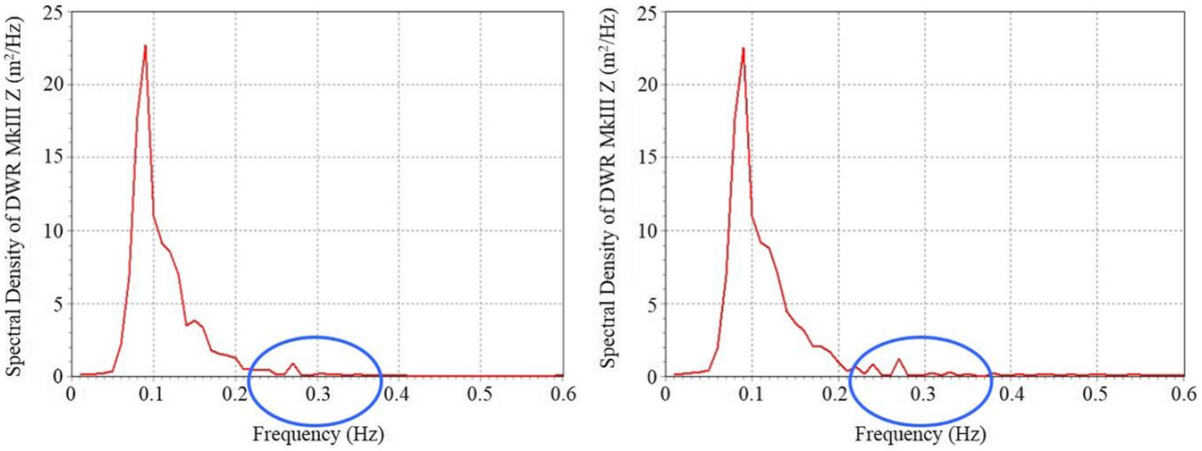


Figure 6. ISSC spectral density of buoy heave response (H_s 4 m, T_p 8 s). (Left) no fouling; (right) heavy fouling. Higher frequency spectral components are identified in the circles.

Table 4. Values of heave spectral moments using simulated biofouling (>0.3 Hz, H_s 4 m, T_p 8 s).

Simulation	M_0 (m²)	M_1 (m² s⁻¹)	M_2 (m² s⁻²)	M_3 (m² s⁻³)	M_4 (m² s⁻⁴)
No fouling	1.0886	0.1317	0.0276	0.0261	0.1121
Light	1.0857	0.1321	0.0294	0.0305	0.1145
Medium	1.0793	0.1345	0.0317	0.0364	0.1124
Heavy	1.0653	0.1359	0.0323	0.0383	0.1202

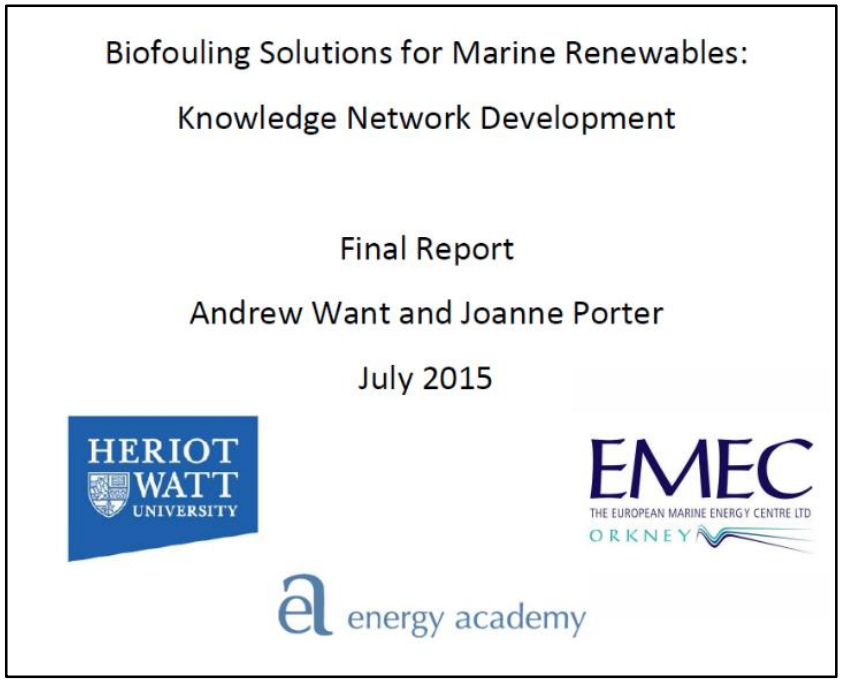
M_0, zeroth moment is the area under the spectrum; M_1, 1st moment is the mean; M_2, 2nd moment is the SD; M_3, 3rd moment is the skewness; M_4, 4th moment is the kurtosis (Sokal & Rohlf 1995).

Want *et al*. 2017

- Analysis of heave data identified small changes to the overall spectral response
- Most of the changes were observed as a dampened high frequency response
- This high frequency response could be used as a tool to further compare biofouling influence, and suggests a means of identifying when a buoy is fouled and by which organism
- More data needed…

Outputs (so far) from Biofouling Studies:

- Database of species from different locations and substrates
- Improved knowledge of key fouling species and their settlement timing
- Image catalogue of biofouling organisms to aid developers with identification
- Development of hydrodynamic modelling tools to study impacts of biofouling
- Outreach poster providing guidance to stakeholders (right)
- Flowchart for MRE sector (next slide)


Biofouling Solutions for Marine Renewables:

Knowledge Network Development

Final Report

Andrew Want and Joanne Porter

July 2015

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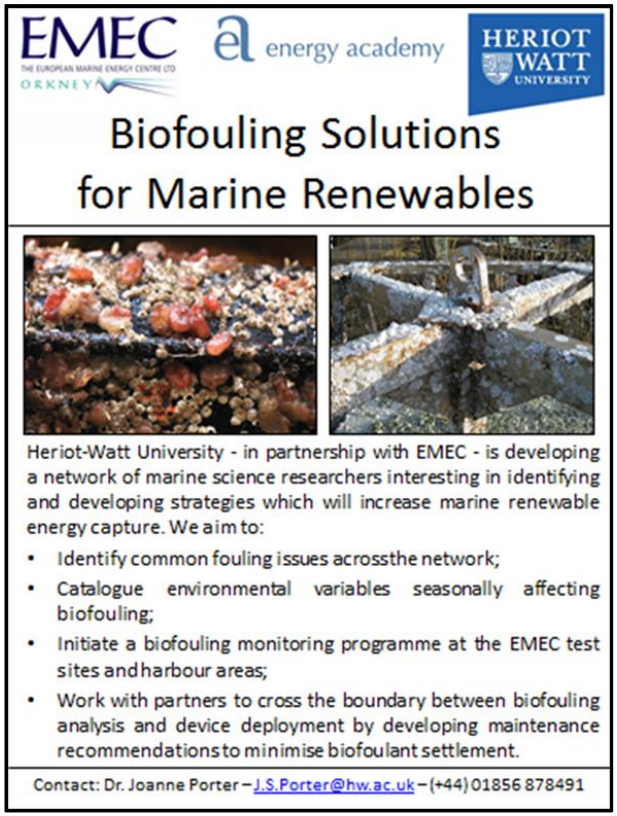
energy academy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Biofouling Solutions for Marine Renewables

Heriot-Watt University - in partnership with EMEC - is developing a network of marine science researchers interesting in identifying and developing strategies which will increase marine renewable energy capture. We aim to:

- Identify common fouling issues acrossthe network;
- Catalogue environmental variables seasonally affecting biofouling;
- Initiate a biofouling monitoring programme at the EMEC test sites and harbour areas;
- Work with partners to cross the boundary between biofouling analysis and device deployment by developing maintenance recommendations to minimise biofoulant settlement.

Contact: Dr. Joanne Porter – J.S.Porter@hw.ac.uk – (+44) 01856 878491

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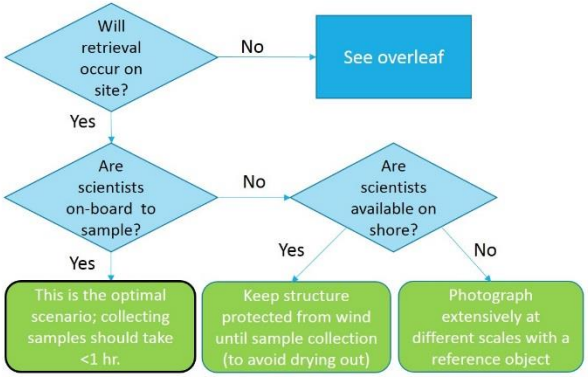
Guidelines for collecting data from MREDs

Biofouling data collected from devices and infrastructure is of highest quality when obtained as soon as the structure is removed from its deployed location and with minimal removal or drying out of biological material. Fresh material is easier to identify and quantify; lost material is a loss of mutually beneficial data.

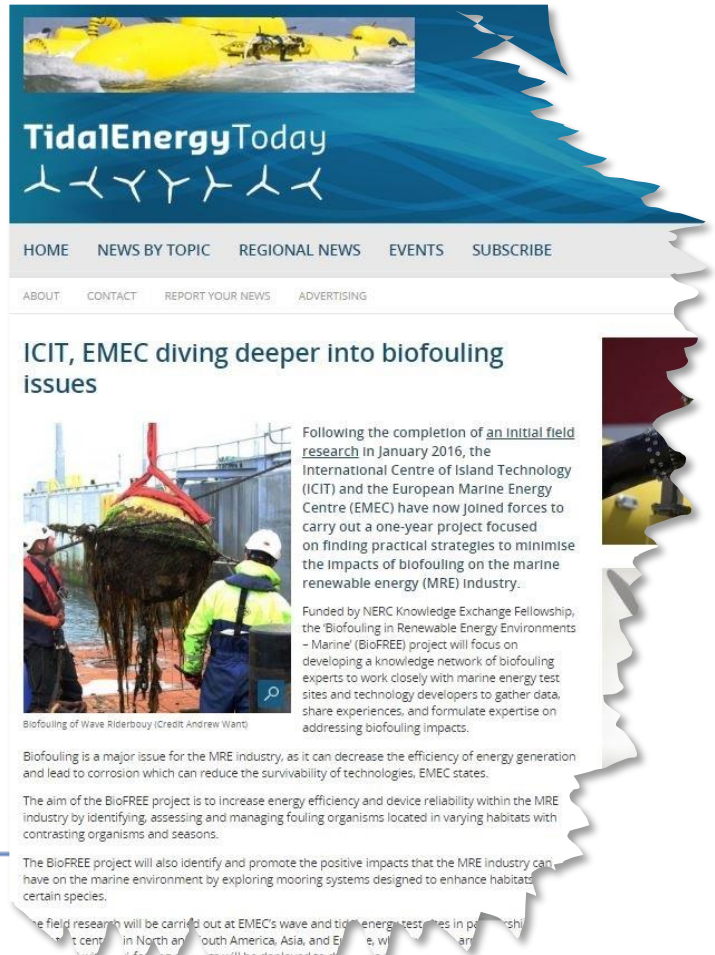
Keep in mind: it is useful for biofouling scientists to know the deployment history of the structure, i.e. duration time, dates, and all locations, as well as any associated environmental sensor data, i.e. temperature, salinity, light.



Tips for taking photographs of Biofouling:

- Try to include detailed close-ups, as well as wider shots
- There cannot be too many photos or too much information
- A 20p coin makes an ideal reference object

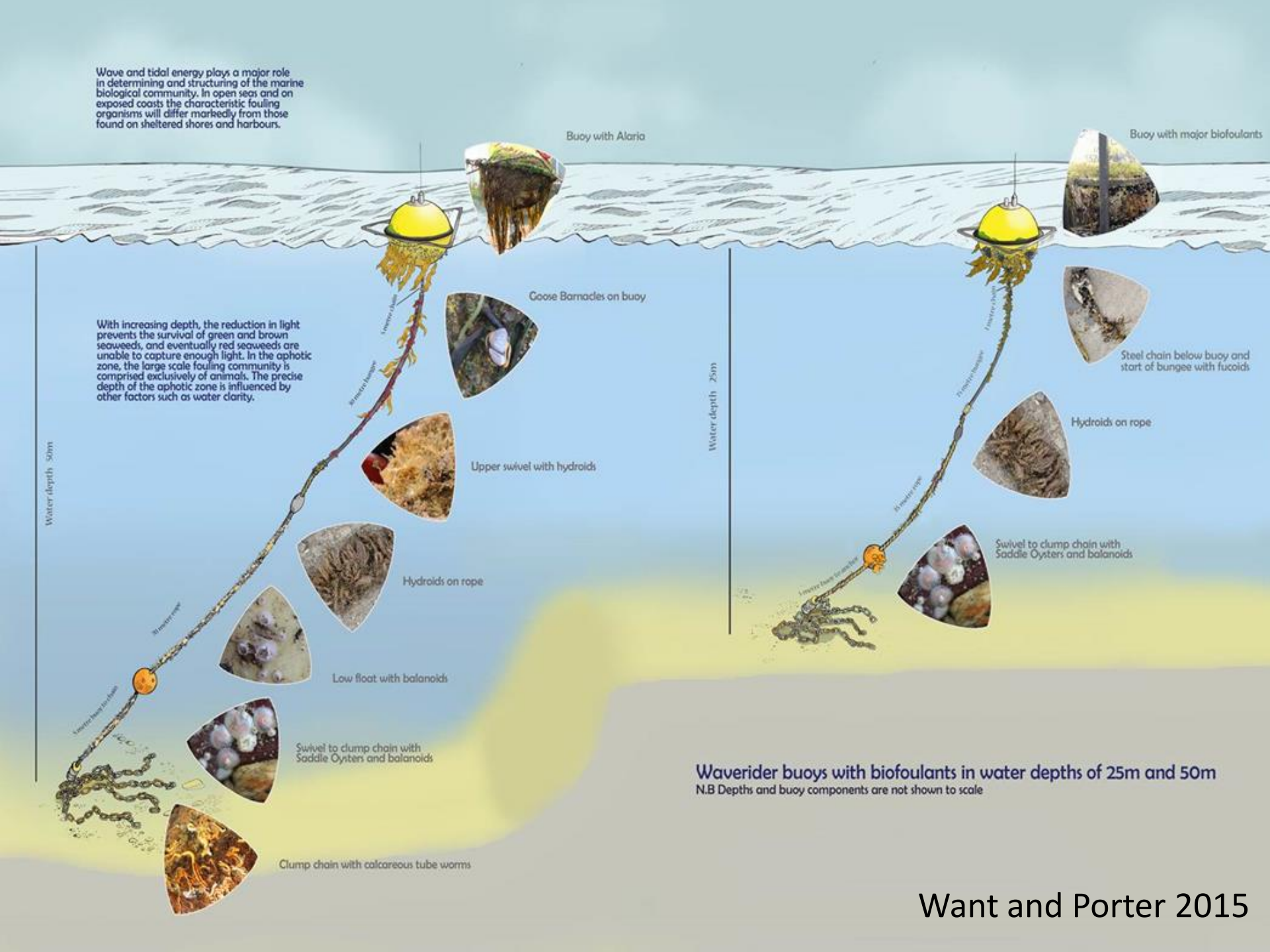
BIOFOULING, 2017
https://doi.org/10.1080/08927014.2017.1336229



Biodiversity characterisation and hydrodynamic consequences of marine fouling communities on marine renewable energy infrastructure in the Orkney Islands Archipelago, Scotland, UK

Andrew Want[a], Rebecca Crawford[a], Jenni Kakkonen[a,b], Greg Kiddie[a], Susan Miller[a], Robert E. Harris[a] and Joanne S. Porter[a]

[a]International Centre for Island Technology, Heriot Watt University, Orkney Campus, Old Academy, Stromness, UK; [b]Marine Services, Orkney Islands Council, Kirkwall, UK



Want and Porter 2015

Findings:

- Community varies between deployment habitats
  - Depth
  - Substrate
  - Hydrodynamic conditions
- Key foulants exhibit contrasting species-specific seasonality of settlement
- From a developer/energy provider viewpoint, accurate assessment of biofouling impacts on deployed devices and structures is essential for maximising energy capture and lowering electricity generating costs
- Determining biofouling contribution to wave data buoy sensor accuracy is critical as wave resource assessment and device capture may be underestimated as organisms affect movement of buoys and devices

Semibalanus balanoides, Stromness Harbour

Non-native Species (NNS): Orkney

Corella eumyota – Kirkwall Marina

Schizoporella japonica – Hatston Pier

Caprella mutica – Stromness Marina

Note: no NNS have been recorded at MRE sites

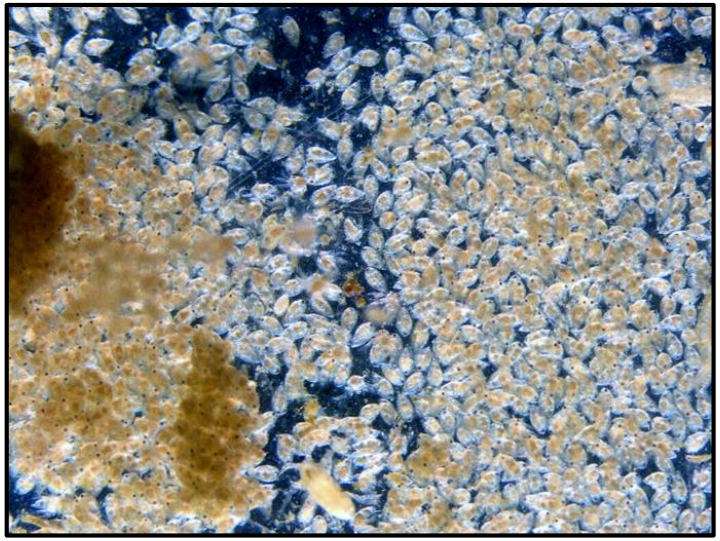
Recommendations:

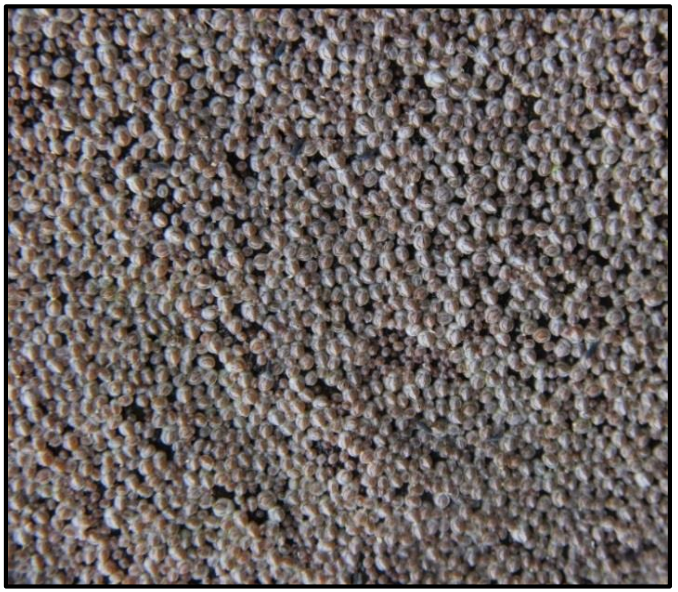
- Biofouling data can inform device operations and maintenance scheduling
- Quantification of biofouling monitoring
- Testing different materials and antifouling solutions
- Close knowledge gaps in habitats used by MRE featuring poorly understood species
- Increased communication and access will reduce losses in critical data collection - together we can improve energy efficiency and capture… *so, please talk to us*!

Billia Croo wave test site:
27 Feb. 2018

Outputs planned for 2018:

- MRE stakeholder engagement:
  - Gathering data and preventing lost opportunities
  - Dissemination of findings
- Stakeholder webinar through established networks, i.e. IEA–OES Annex IV, ORJIP, International WaTERS, etc
- User resource to ID foulants/flowchart to capture data
- Additional scientific papers
- Additional press releases





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