Annex IV Environmental Research Webinar Series

Role of Biofouling in Marine Renewable Energy Development

Presenters

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- Raeanne Miller
  - Scottish Association for Marine Sciences (SAMS)
    - Biofouling and marine renewable energy: an emerging challenge
- Jennifer Loxton
  - Environmental Research Institute, University of Highlands and Islands
    - Biofouling and marine renewable energy: examples from industry

University of the Highlands and Islands
Oilthigh na Gàidhealtachd agus nan Eilean

SAMS

eri environmental research institute

Biofouling and marine renewable energy: an emerging challenge

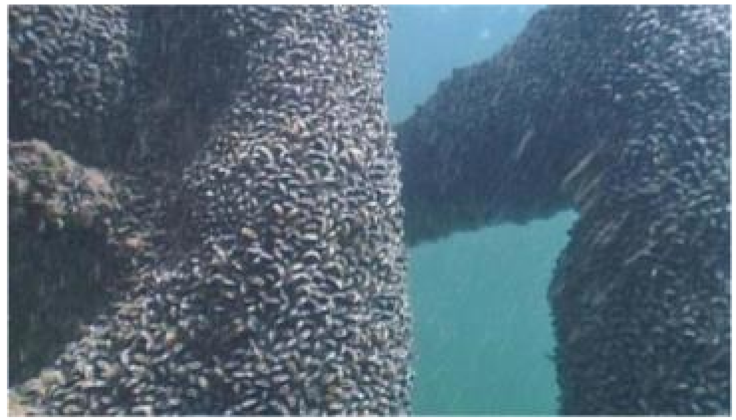
Raeanne Miller – Scottish Association for Marine Science

Jen Loxton – Environmental Research Institute

Contents

- What is biofouling?
- Legislation & guidelines
- Why is it an issue?
- Biology of biofouling – species of concern
- How can it be prevented?
- What can we learn from other industries?

What is biofouling?



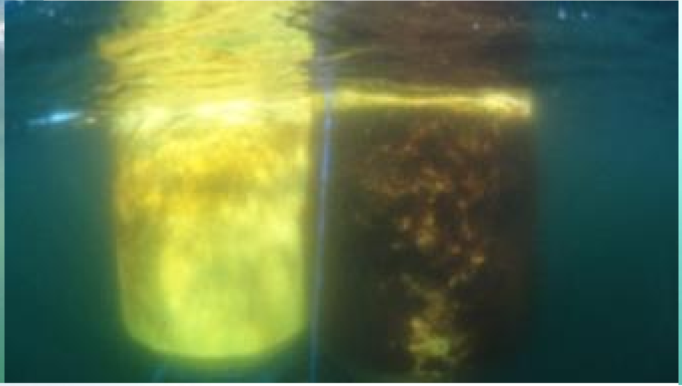
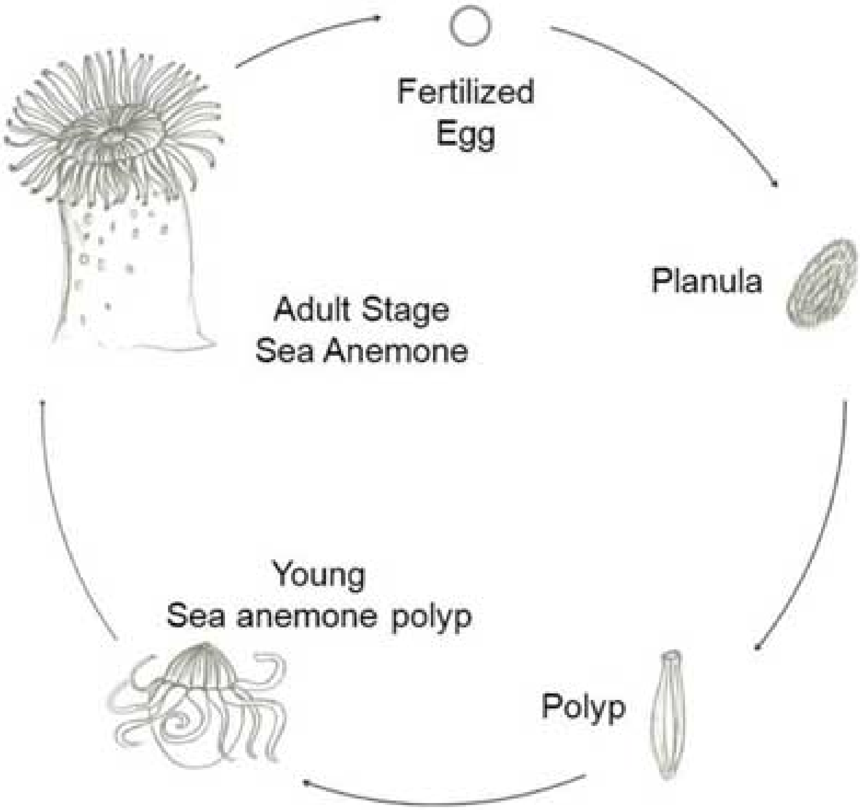
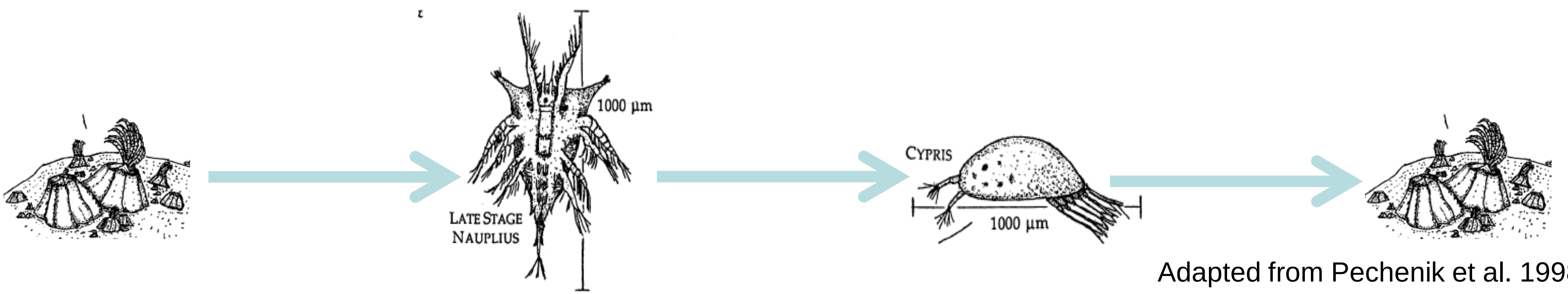



Photo credit: Udhayan Gunawardena
and Calum Kenny, AlbaTERN Ltd.

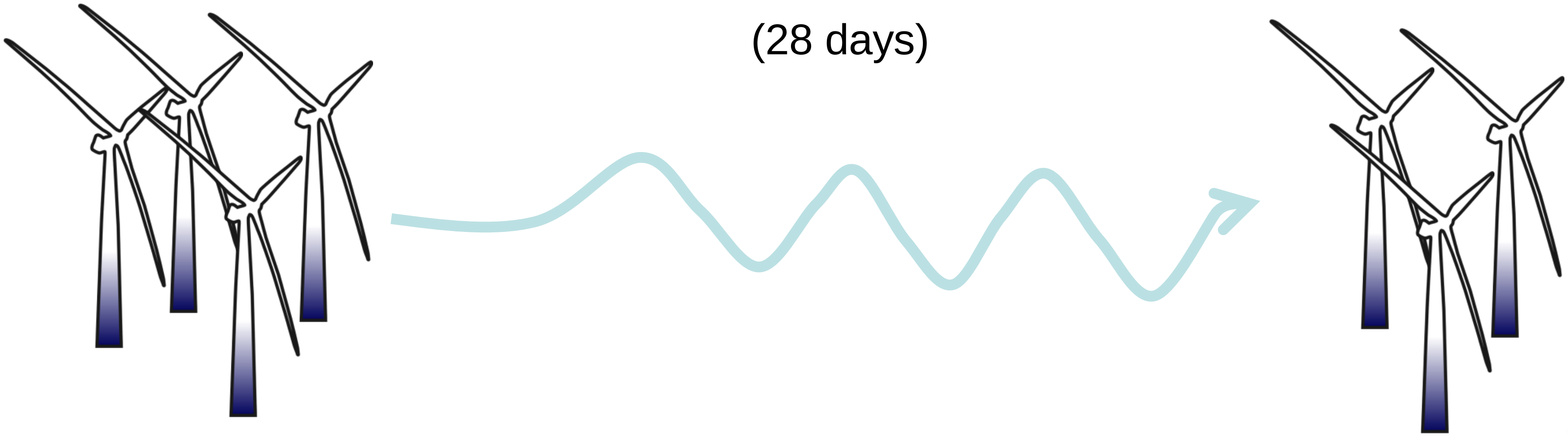
Life history traits of biofouling



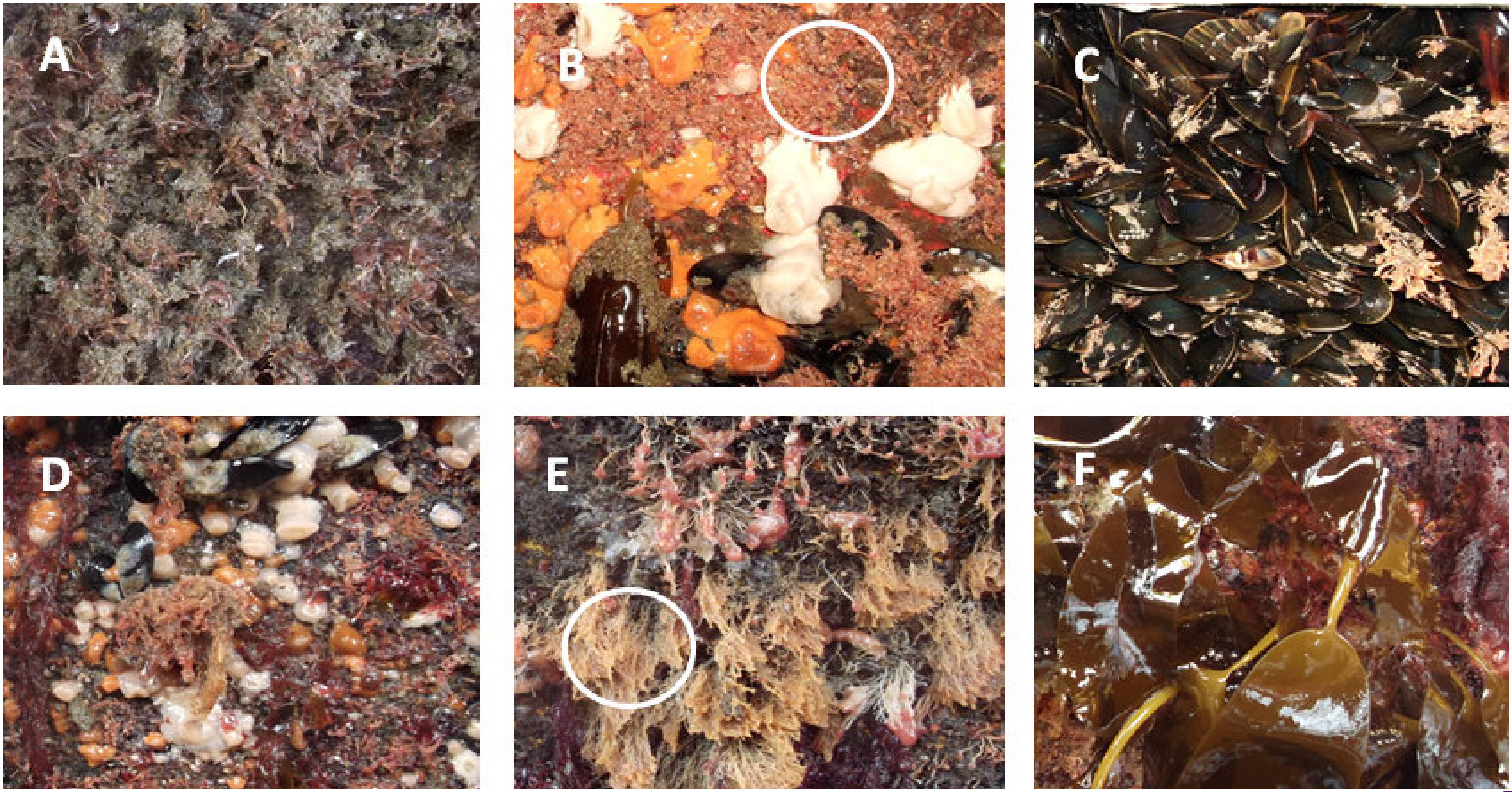
Life history traits of biofouling



Adapted from Pechenik et al. 1998



Types of biofouling communities



Macleod et al. (2016) Biofouling 32:3, 261-276

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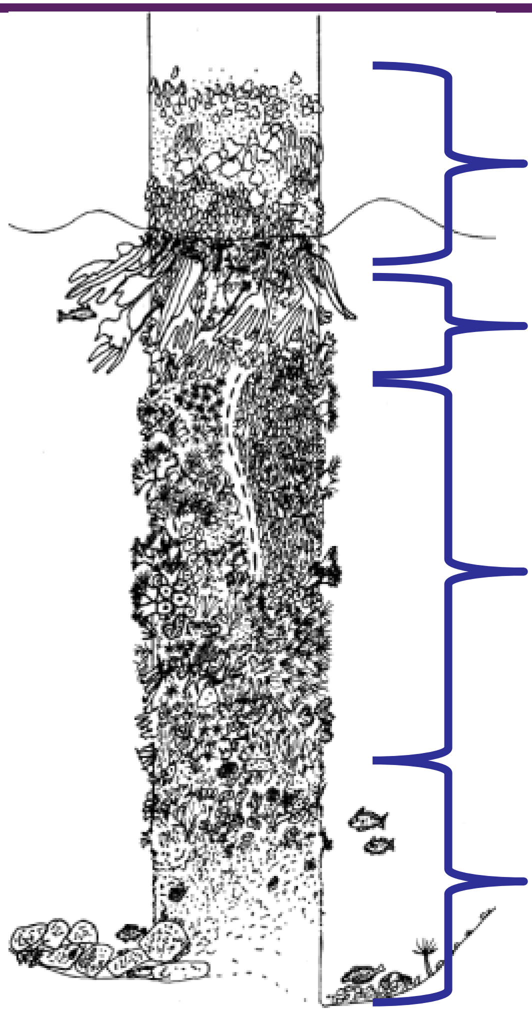


Intertidal – barnacles, algae

Kelp Zone – kelps, barnacles, foliose algae

Main column – mussels, anemones, soft corals, hydroids, tubeworms, barnacles

Base – varies depending on scour protection and seabed mobility

Hiscock, K., Tyler-Walters, H., Jones, H. (2002). AEA Technology, Environment Contract: W/35/00632/00/00.
Rees, J., Larcombe, P., Vivian, C., and Judd, A. (2006). Scroby Sands Offshore Wind Farm – Coastal Process Monitoring. Final Report. CEFAS

Legislation and regulations for biofouling

DNV·GL

STANDARD

DNVGL-ST-0164 Edition October 2015

Tidal turbines

Technical requirements

Wildlife and Natural Environment (Scotland) Act 2011 (asp 6)

NEMO ME IMPUNE LACESSIT

Wildlife and Natural Environment (Scotland) Act 2011

2011 asp 6

4.11.2014 EN Official Journal of the European Union L 317/35

REGULATION (EU) No 1143/2014 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 22 October 2014

on the prevention and management of the introduction and spread of invasive alien species

Legislation for biofouling - engineering

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

Somewhat higher values, up to 150 mm between sea level and LAT −10 m, may be seen in the Southern North Sea.

The outer diameter of a structural member subject to marine growth should be increased by twice the recommended thickness at the location in question.

The type of marine growth may have an impact on the values of the hydrodynamic coefficients that are used in the calculations of hydrodynamic loads from waves and current.

Whenever possible, site-specific measurements should be used. This is particularly relevant for tidal turbine sites.

DNVGL-ST-0164 Tidal Turbines Section 4.8.5

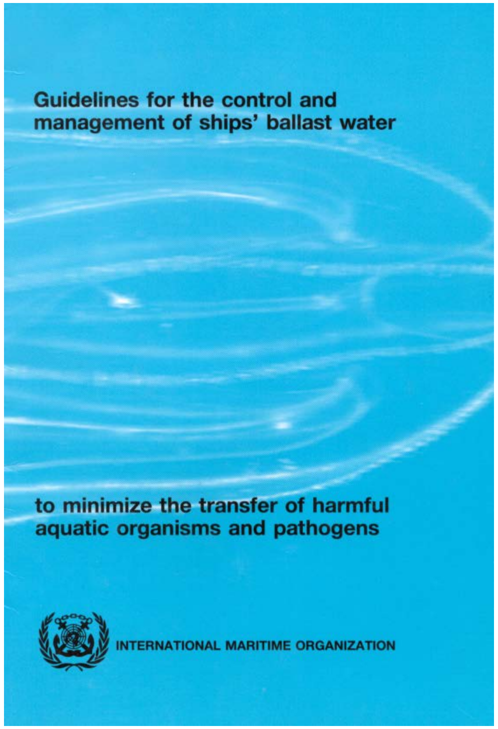
Legislation for biofouling – invasive species

Wildlife and Natural Environment (Scotland) Act 2011 (asp 6)

NEMO ME IMPUNE LACESSIT

Wildlife and Natural Environment (Scotland) Act 2011

2011 asp 6



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Biofouling as a consenting issue?

- Not at the moment
- BUT with changing invasive species legislation need to demonstrate ‘reasonable steps’ to prevent non-native species spread
- Biosecurity planning

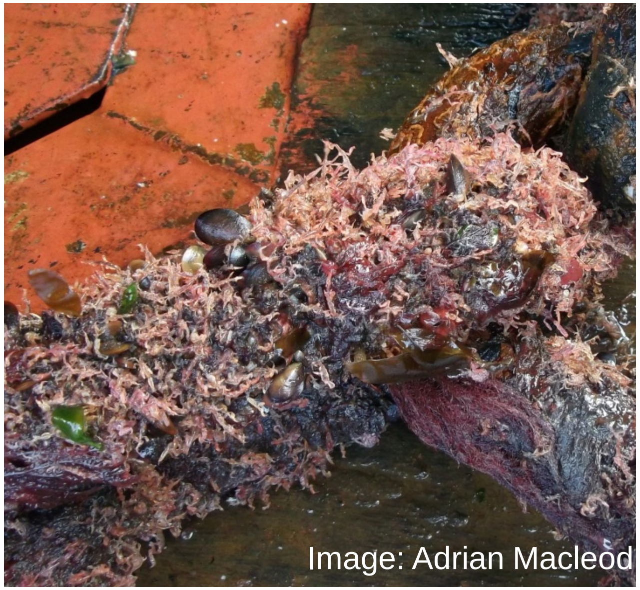
So why study biofouling?

Accelerated corrosion

Environmental loading and altered hydrodynamic properties

Why study biofouling?

- Weight
- Density
- Thickness
- Roughness
- Heat transfer coefficients



Biofouling species of concern

- Taxa which have the greatest effect on biofouling thickness, roughness, mass, drag

Vance et al 2016 / ReDAPT

Kelps

- Europe: *Laminaria hyperborea,* ***Laminaria digitata****,* *Saccharina latissima*
- Grow in the photic zone
- Can be 2-4 m in length

Effects:

- Neutrally buoyant
- Abrasion
- Hydrodynamic properties

Mussels

- Frequently dominant in upper 30 m of water column
- Do well where high water flows (but not too high!)
- Calcareous shells – increase structural weight
- Increase thickness & roughness

Barnacles

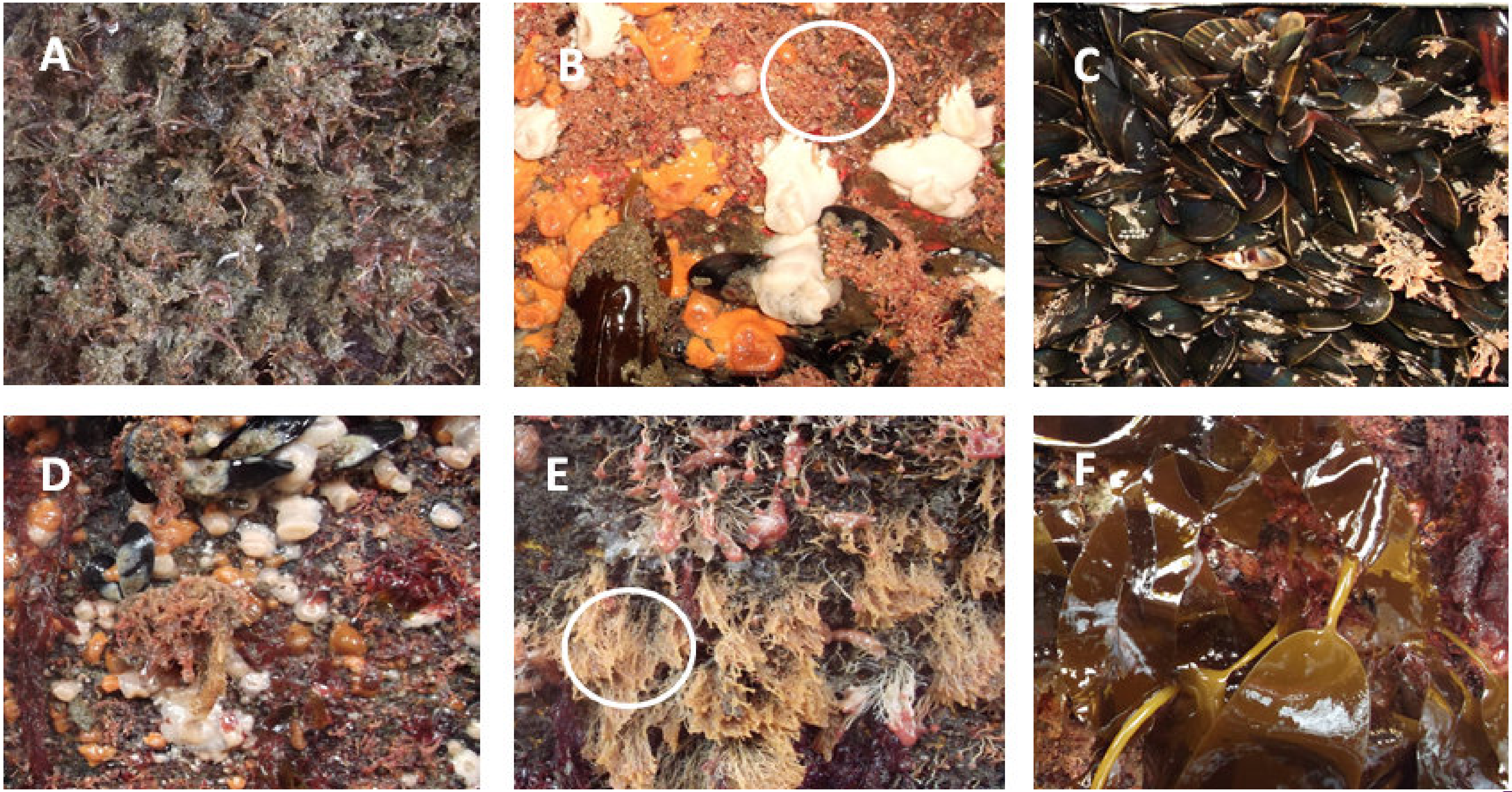
- Tolerate higher current speeds & wave exposure
- Likely dominant species?
- Large species, e.g. *Chirona hameri*, dominant in deep water & extreme flows (>7.5 cm height!)
- ‘Hard’ fouling – similar effects to mussels

Preventing biofouling

- Anti-fouling coatings
- Removal
- Cathodic protection

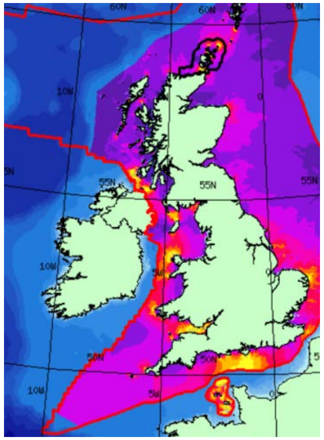
Vance et al 2016 / ReDAPT

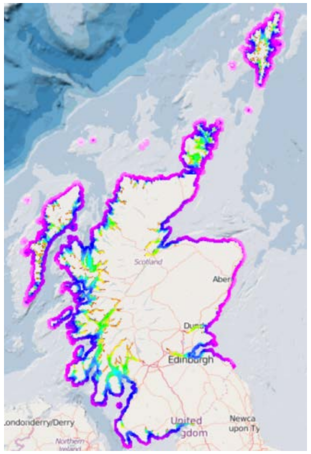
Can we predict biofouling communities?

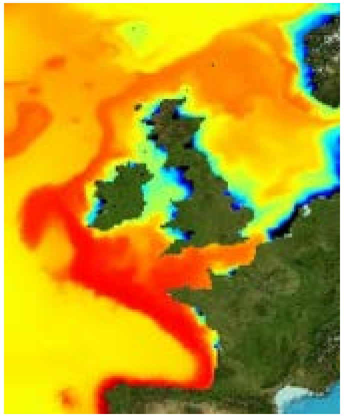


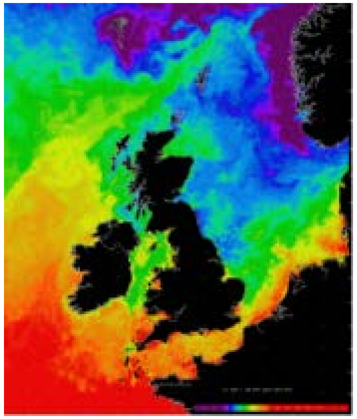
Environmental influences

- Current velocity
- Wave exposure
- Salinity
- Temperature
- Nutrient availability



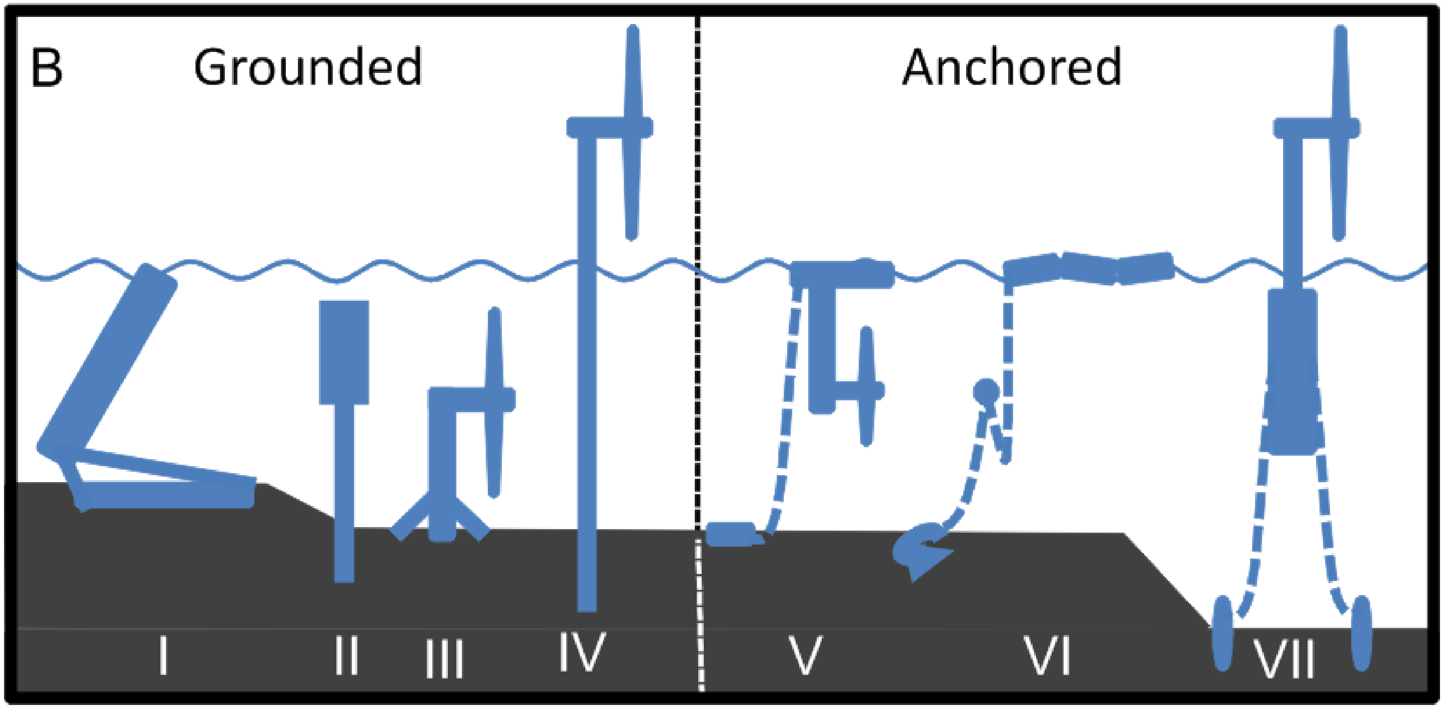






Structural influences

- Free moving or static?
- Floating or fixed?
- Splash zone or intertidal zone?

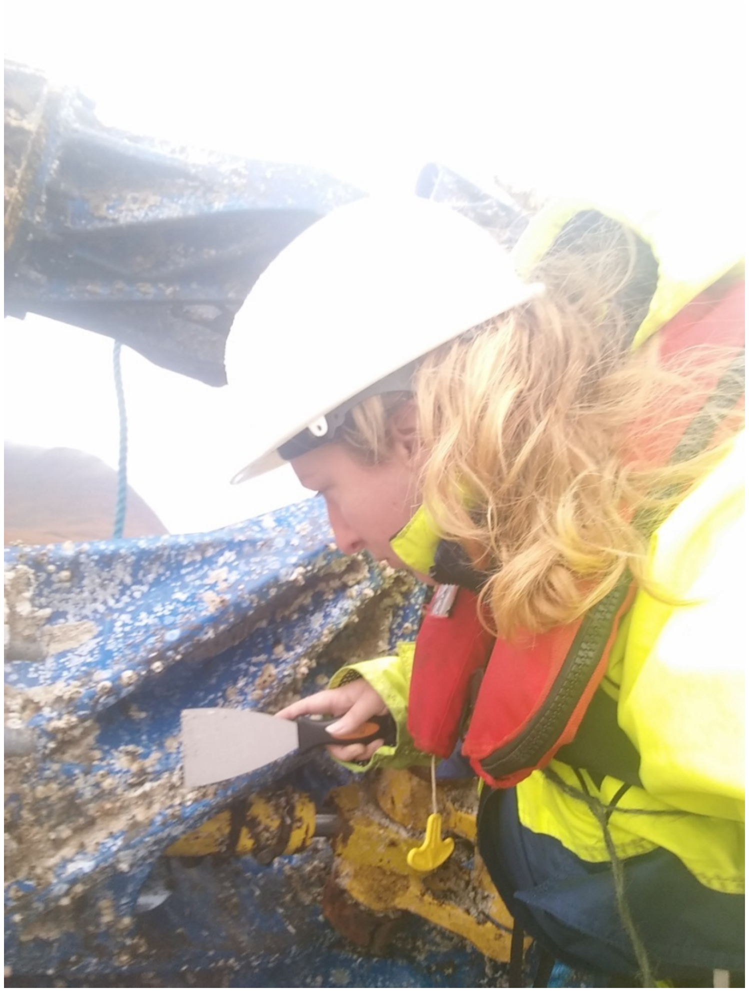


Miller et al. (2013). Frontiers in Ecology and the Environment 11:8, 433-440

Comparisons across industries

- Biofouling happens in all industries
- Particularly relevant in this one – devices are highly tuned to extract optimum energy

Biofouling in practise - over to Jen



Biofouling and marine renewable energy: examples from industry

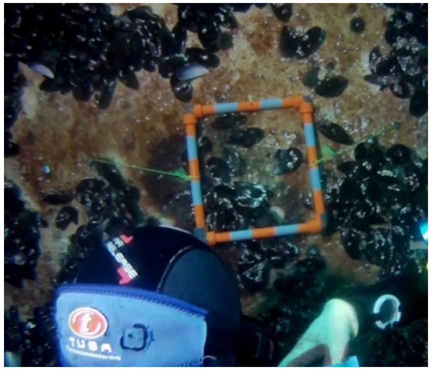
Jen Loxton – Environmental Research Institute, UK
Chris Nall – Environmental Research Institute, UK
Ines Machado – WavEC, Portugal

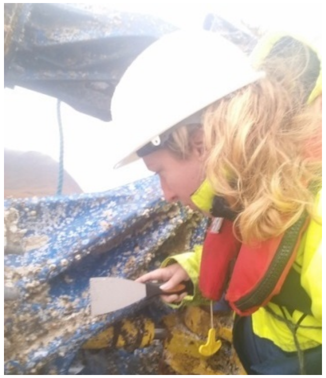
Contents

- Methods for analysing biofouling
- Establishing baselines of biofouling species on MRE devices.
- Comparing MRE biofouling to other manmade structures
- Introducing settlement panels

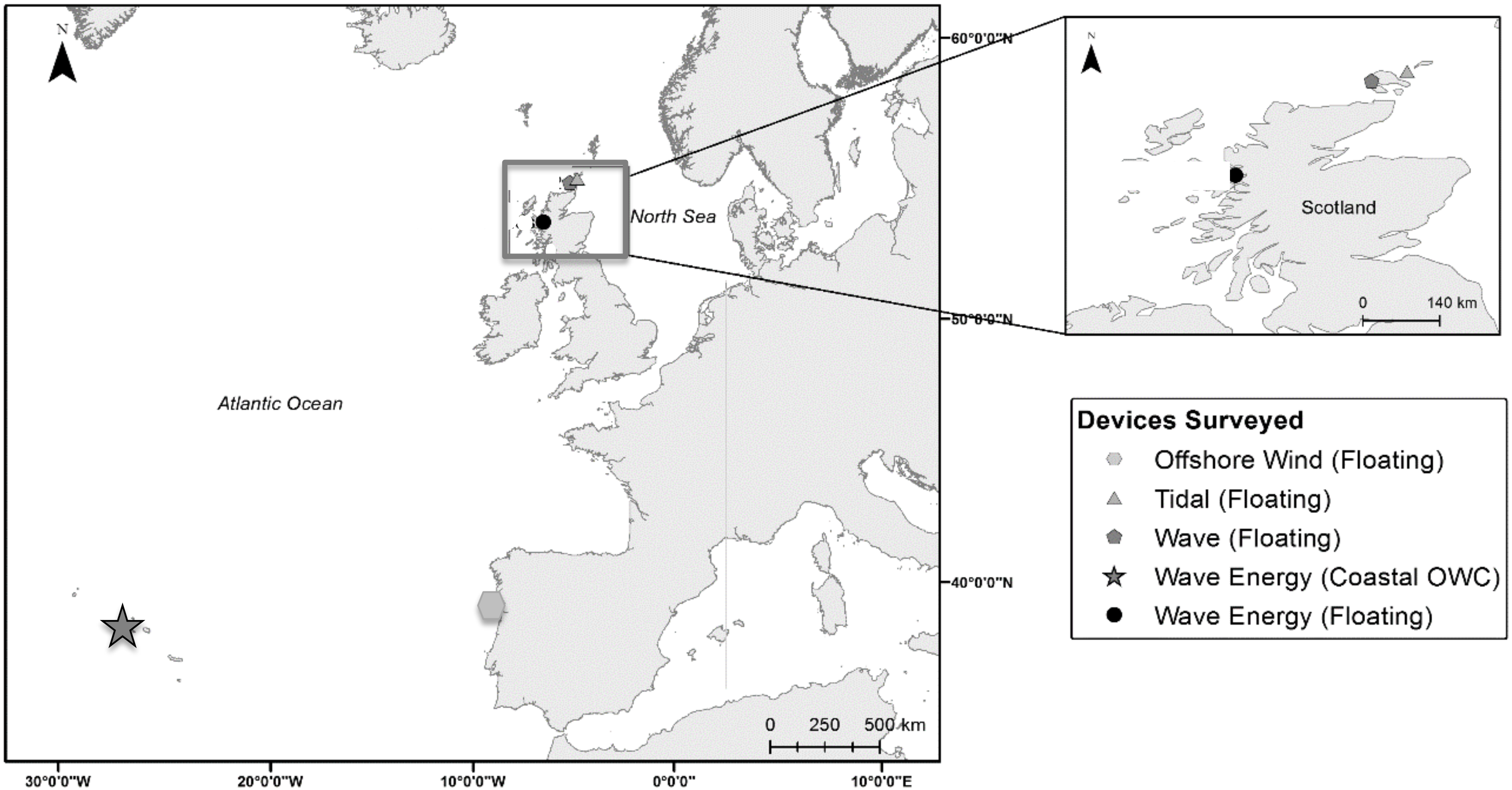
How to analyse biofouling

- Quadrat samples to quantify biomass, thickness etc.
- Use Remote Operated Vehicle and video footage
- Take scrapes of biofouling and identify species in a laboratory.
- Settlement panels



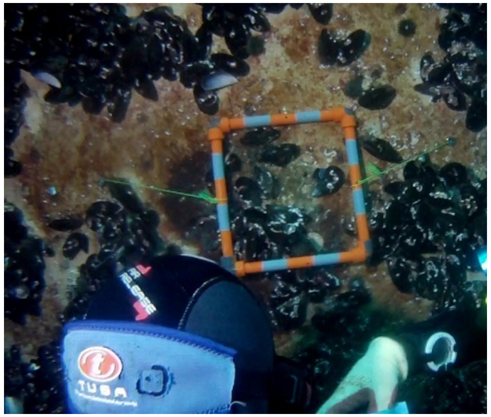


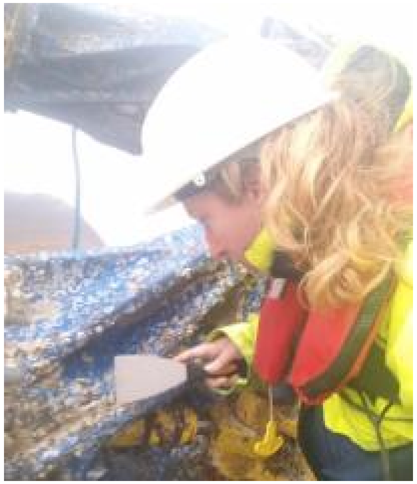
Compiling species lists - method



Compiling species lists - method

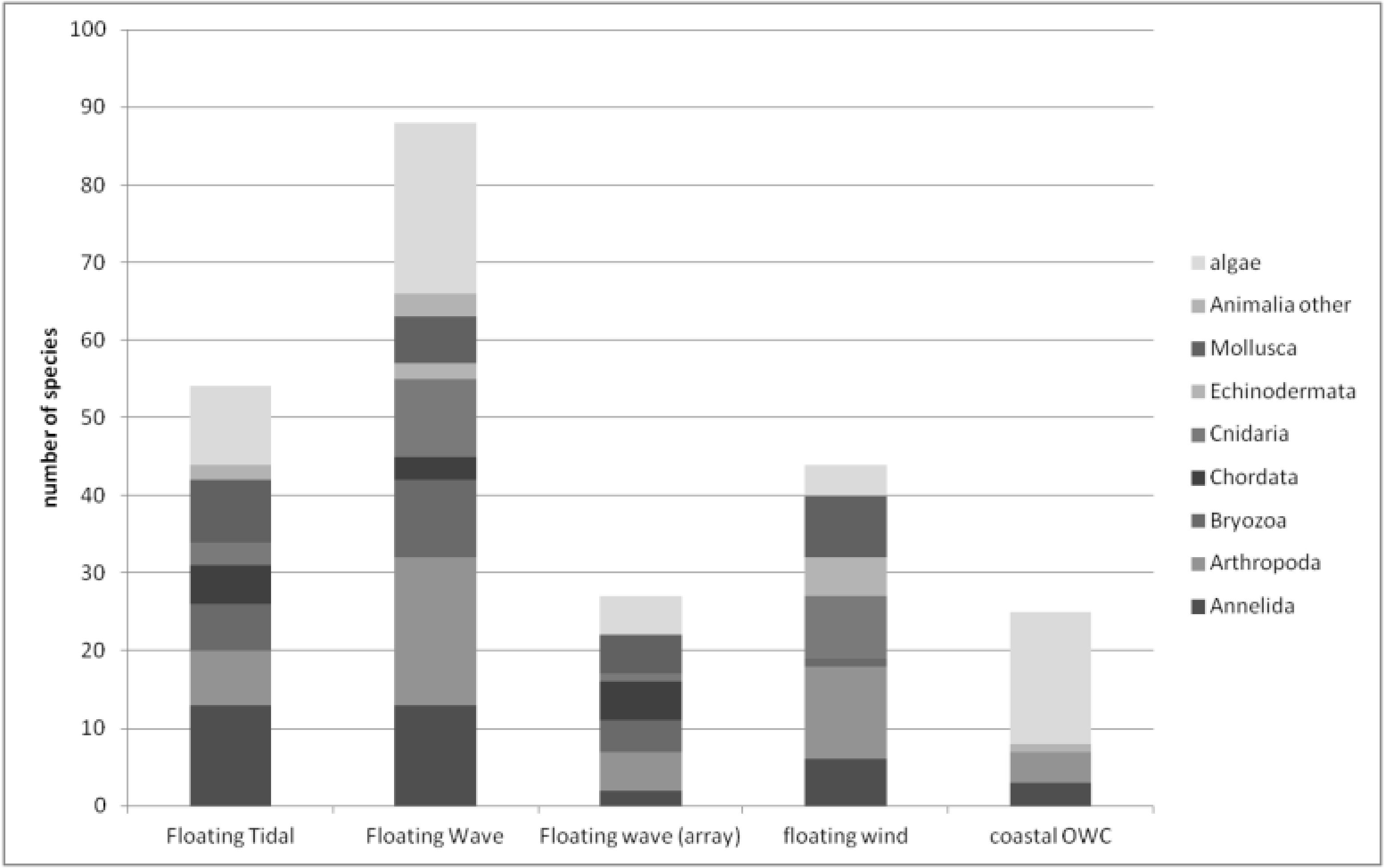
- Scraping samples from devices and preserving them for subsequent analysis.
- Identifying to species level under a microscope
- Statistical analysis





NB/ variations in sampling methodology

High level results

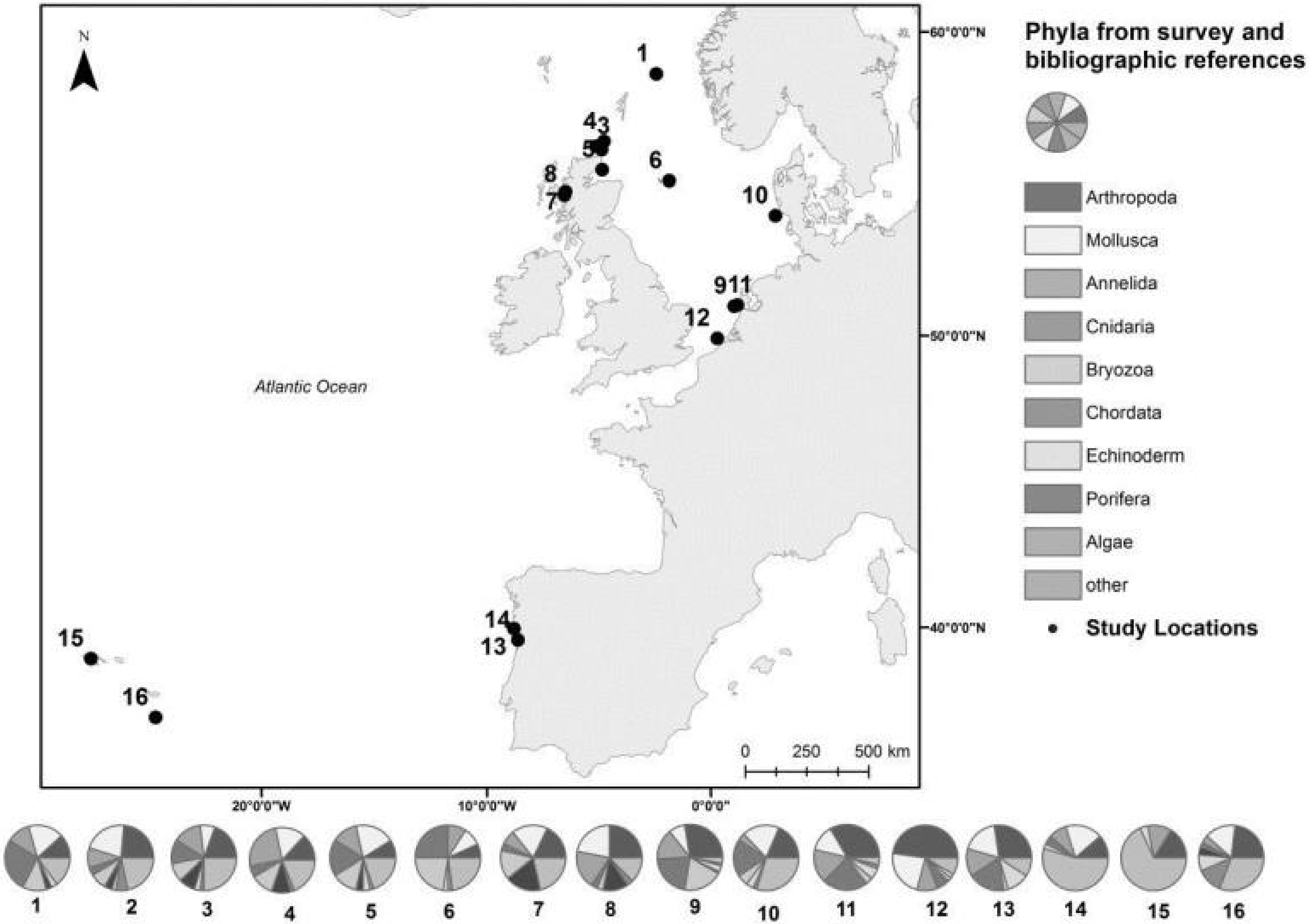


Comparing to other man made structures

- Species split amongst phyla was extracted from scientific literature for other marine structures.

	Site	Location	Type	latitude	longitude	reference
1	Heather A	Shetland	Offshore fixed oil platform	61.36304	1.579761	Picken (1986)
2	Orkney buoys	Orkney	Nearshore floating buoy	58.84953	-3.01148	A Macleod PhD (2013)
3	Floating Wave	Orkney				
4	Floating Tidal	Orkney				
5	Beatrice	N. Scotland	Offshore fixed oil platform	58.11667	-3.08333	Picken (1986)
6	Montrose Alpha oil	N.E Scotland	Offshore fixed oil platform	57.45065	1.388264	Forteath et al. (1982)
7	Floating wave array	W Scotland				
8	Skye buoys	W Scotland	Nearshore floating buoy	57.27505	-5.71501	A Macleod PhD (2013)
9	Princess Amalia wind	Netherlands	offshore fixed wind	52.59	4.22	Vanagt et al. (2013)
10	Horns Rev windfarm	Denmark	offshore fixed wind	55.50001	7.820015	Leonhard & Pederson (2006)
11	OWEZ	Netherlands	offshore fixed wind	52.606	4.419	Bouma Lengkeek (2012)
12	Thornton Bank wind (2009)	Belgium	offshore fixed wind	51.54548	2.92978	Kerckhof et al (2010)
13	Floating wind	N. Portugal				
14	Aguda sea wall	N. Portugal	Inshore fixed seawall	41.04815	-8.65674	Santos J (2008)
15	coastal OWC	Azores				
16	Azores	Azores	natural shoreline	36.97	-25.1	Botehlo + (2009)

Comparing to other manmade structures



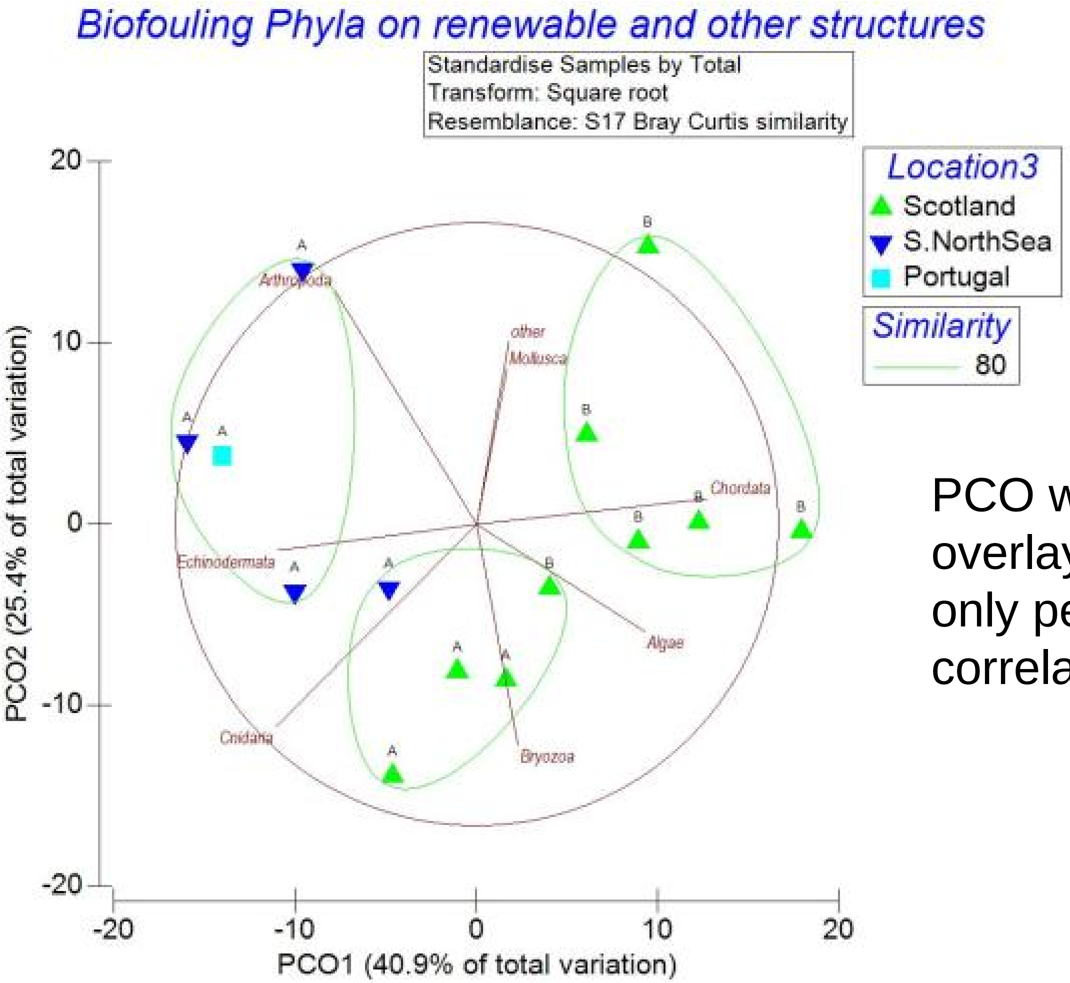
Comparing to other manmade structures –does location matter?

- Cluster analysis showed the Aguda sea wall, Azores shoreline and the Pico Plant coastal OWC to be significantly different to other sites. They were excluded from further analysis.

- Why?
  – Portugal/Azores flora and fauna
  - All in shoreline.

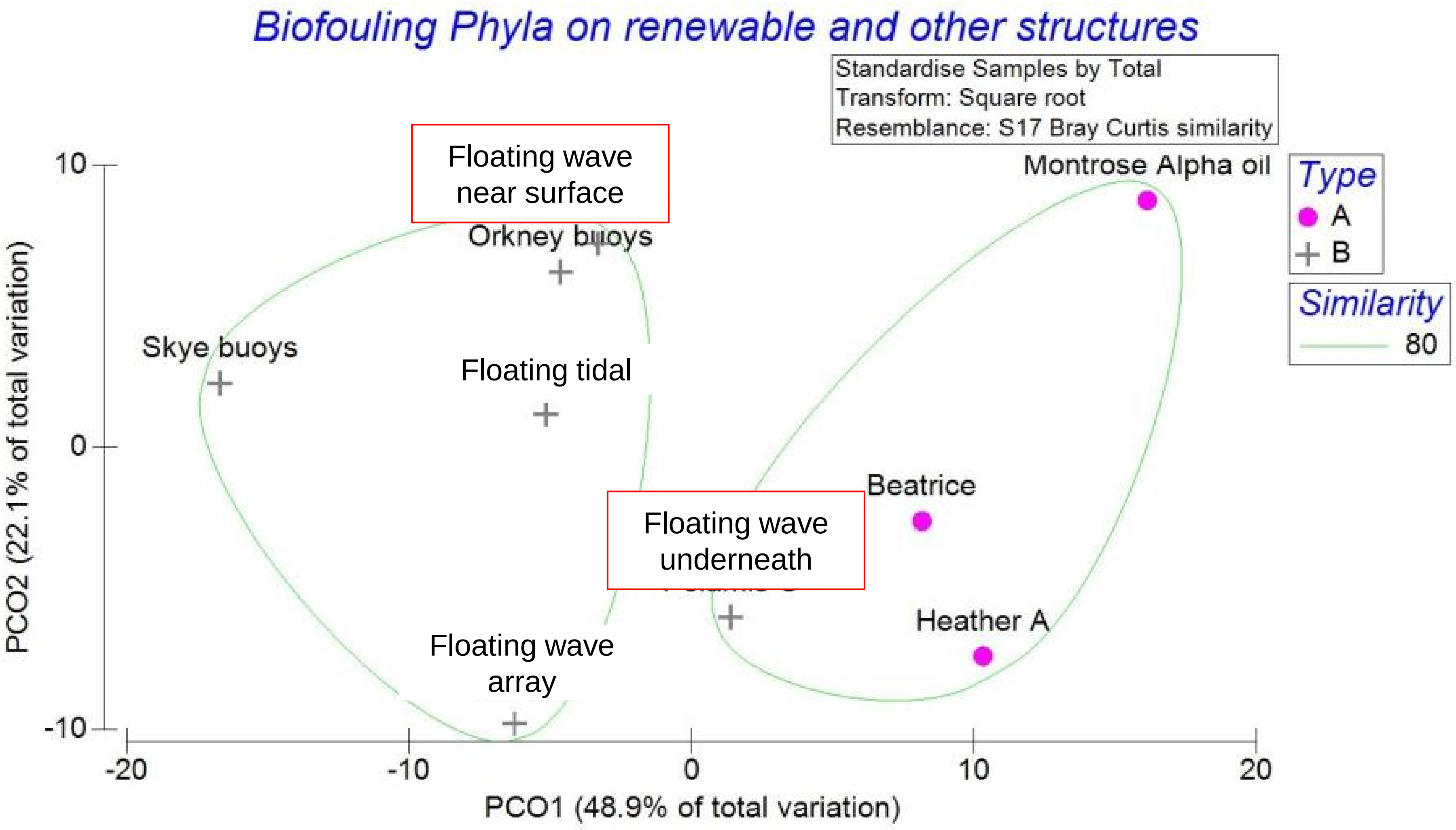
Comparing to other manmade structures – location and type

Type: floating nearshore devices (B) and other (A)



PCO with vector overlay (showing only pearson correlations >0.5)

Comparison within Scotland.



Pelamis: an example

Floating wave device (Orkney)

Near surface biofouling statistically different to underside biofouling.

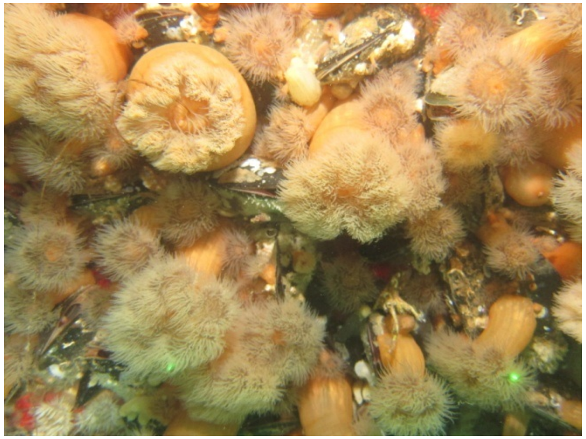
Why?

- Influence of depth
- Influence of light

Which are the defining phyla (from vector overlay analysis)

Beatrice (oil), Heather A (oil), Montrose Alpha (oil) and Pelamis underside (Orkney).

• Bryozoa (moss animals)
• Cnidaria (e.g. soft corals and anenomes)
• Echinoderms (e.g. starfish and urchins)



Orkney and Skye buoys, floating tidal (Orkney), floating wave array (W. Scotland) and Pelamis near surface (Orkney).

• Arthropoda (e.g. barnacles)
• Chordata (e.g. seasquirts)
• Porifera (sponges)

Invasive species

- With the exception of the Pico Plant (coastal OWC), all devices were colonised by non-native invasive species.

Caprella mutica (japanese skeleton shrimp)

Schizoporella japonica (orange ripple bryozoan)

Schizoporella errata (bryozoan)

Corella eumyota (orange tipped seasquirt)

Dasysiphonia japonica (algae)

All these species also documented in nearby marinas and harbours. Devices are unlikely to have introduced the species, just provided a new habitat.

Long distance wet-towing does still constitute a potential risk.

Summary

- Broadly speaking, location matters. (e.g. Scotland vs Portugal)
- Biofouling in the top ~3m of floating structures is different to biofouling on fixed structures and at greater depths.
- Invasive species do occur on renewable energy devices BUT they have not necessarily been introduced on the device and may already have been widespread in the area.

Settlement panels

- Species list (device and/or site specific)
- Enable quantitative measurement of biomass, thickness and rugosity of biofouling
- Seasonality of settlement
- Differential biofouling on different device materials, coatings and locations
- Growth rates during different seasons
- Can be used to intelligently structure antifouling strategies

PANELS INSTALLED	PLANNED IN 2016
Wave site , Portugal	Floating tidal device , Orkney
Coastal OWC , Azores Test site, Ireland Floating wave array, W Scotland	floating wind device, Scotland

Settlement panels – installation and challenges.

- Minimum of three replicate panels (20cm x 15cm) at each site.
- Either installed on the device or at the energy site
- Changed seasonally, at least 3 x per year.
- Installed in the top 1m of water for floating devices; installed at varying depths using SCUBA for bottom mounted or deeper devices.

Settlement panels – challenges

- Installation method often needs to be different between sites and devices, dependent on energy of site.
- Extremely high energy sites can make installation difficult and risk of experiment loss higher.

More sites needed! Please contact jennifer.loxton@uhi.ac.uk if you would like to be involved.

Thanks

Co-authors

Chris Nall
Ines Machado
Teresa Simas
Erica Cruz

All developers and test site owners who helped us sample their sites.

Thank you for listening

Where does this leave us?

What's the right time to think about biofouling?

Engineer's TO DO list:

1. Design device
2. Build scale model
3. Tank test device
4. Refine device
5. Sea trials – scale
6. Build & test commercial-scale device
7. Plan commercial development
8. Build development
9. Produce electricity
10. Profit!

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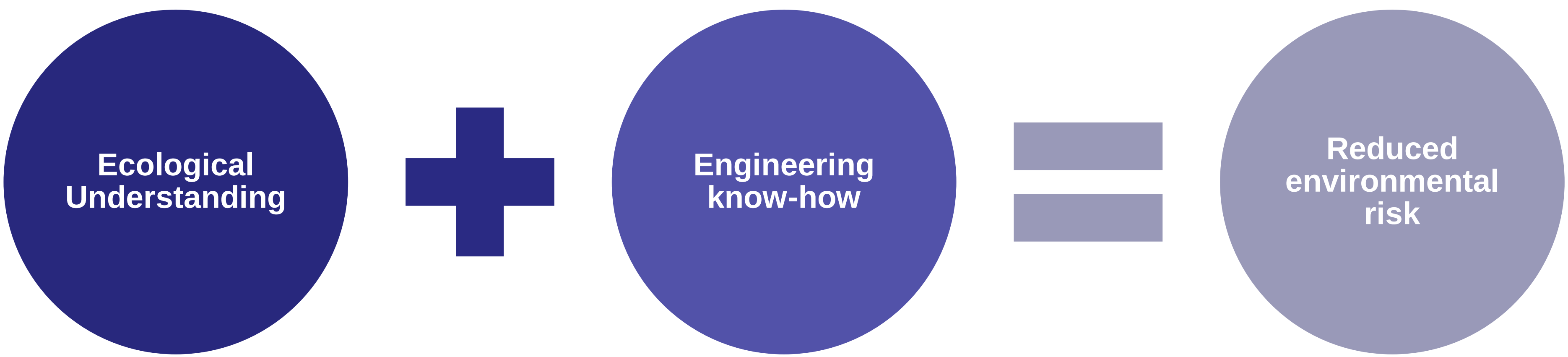
Making science relevant

What if we could bring industry, engineers, and ecologists together at an early stage to ‘design out’ as many of these issues as possible?



Ecologists are knowledgeable about fouling organisms:

- Life history
- Larval dispersal
- Habitat preferences
- Invasion abilities
- Competitive interactions & predator-prey dynamics

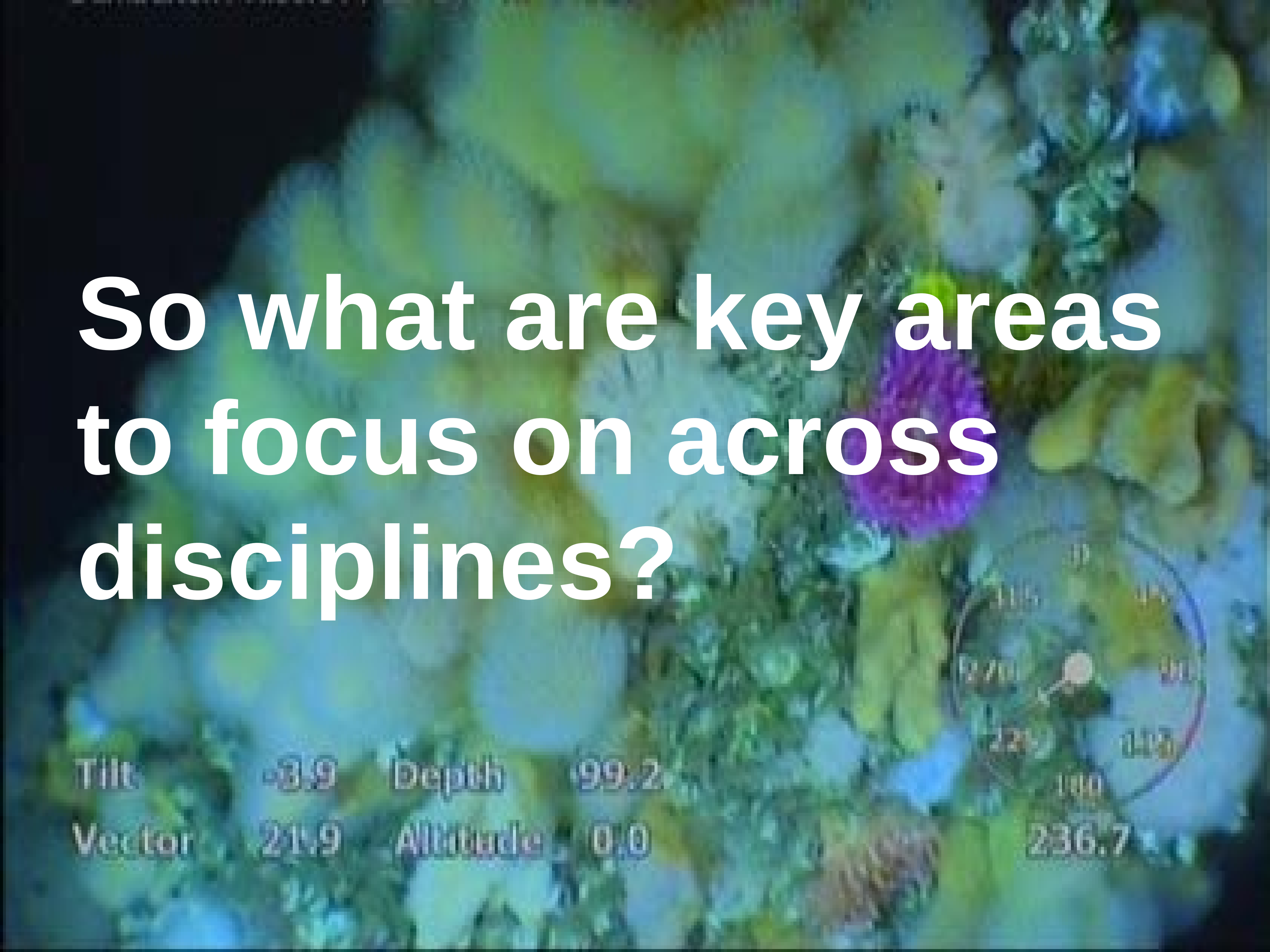
www.pelamiswave.com

Wave & Tidal devices are highly tuned to optimise energy extraction

Engineers need to understand:

- Structural drag?
- Increased weight?
- Buoyancy change?
- Corrosion & component survivability?
- Niche areas?
- Maintenance scheduling?

So what are key areas to focus on across disciplines?



We asked the experts…

SAMS

DNV·GL

PML Plymouth Marine Laboratory

AkzoNobel

CATAPULT Offshore Renewable Energy

marinescotland

University of the Highlands and Islands
Oilthigh na Gàidhealtachd agus nan Eilean

WavEC Offshore Renewables

The University of Edinburgh

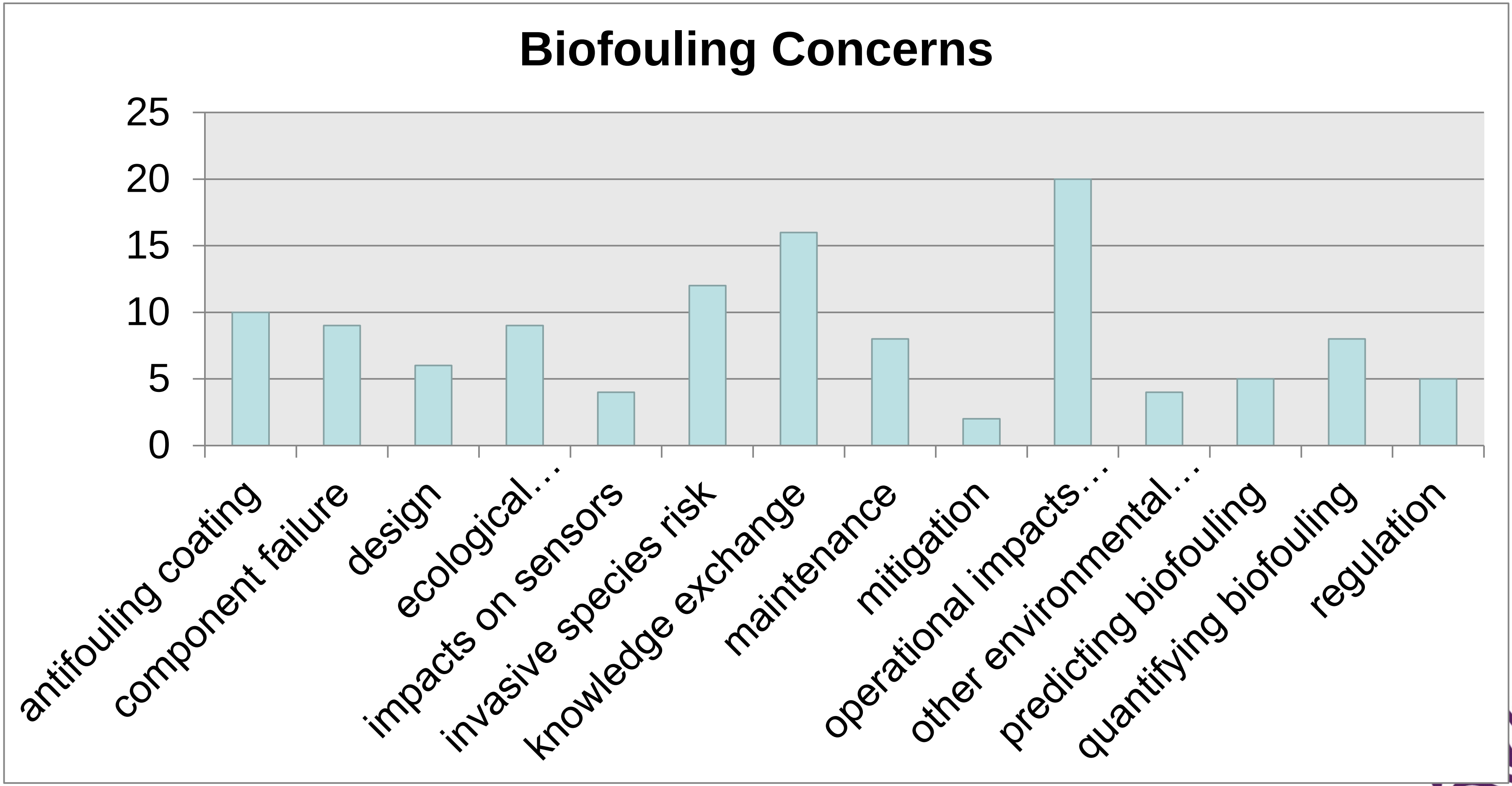
Prifysgol Bangor University

Albatern Wave Energy

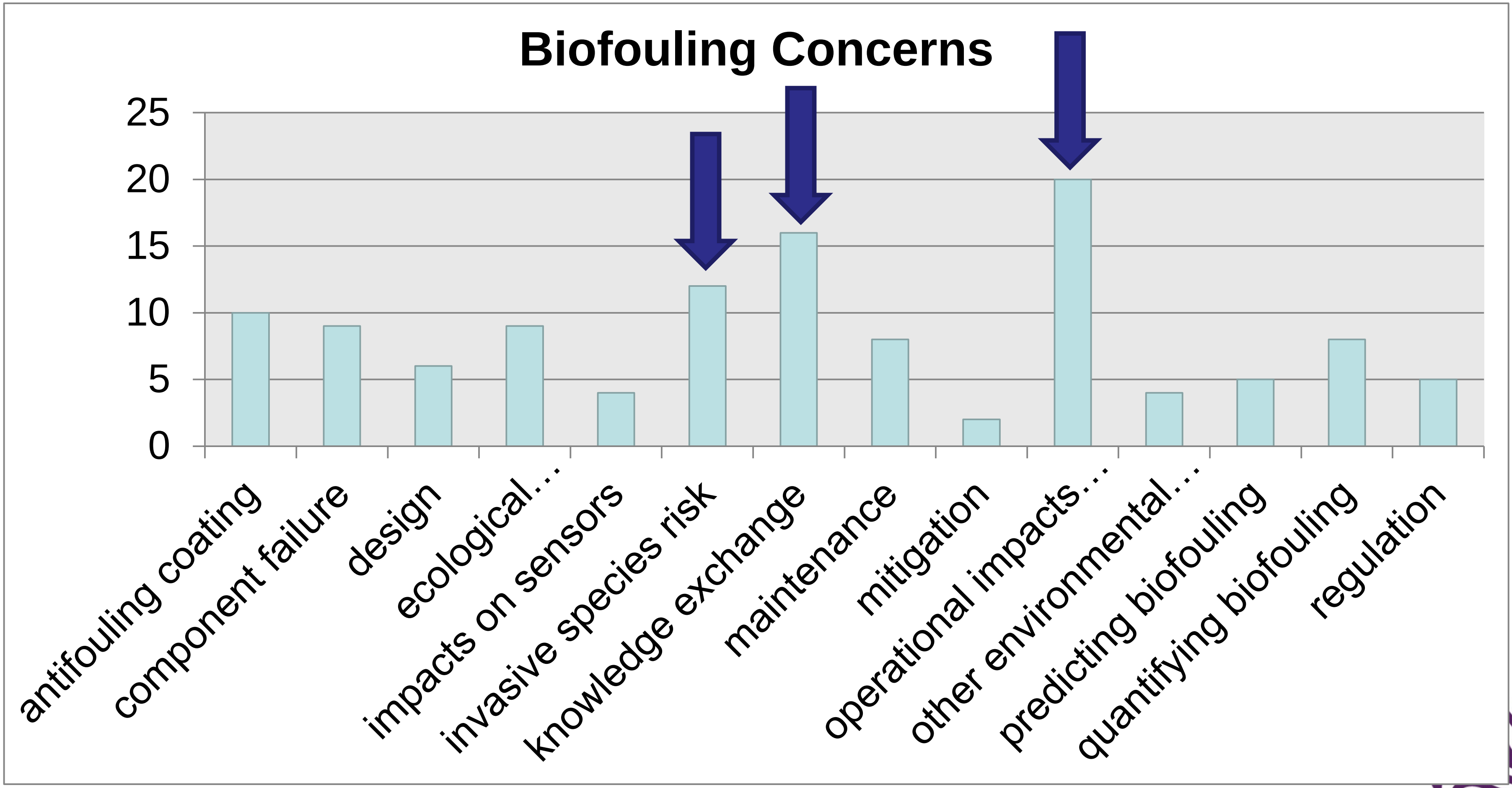
INNOVATION Nova Innovation Ltd

Heriot Watt University

Identifying issues & drivers



Identifying issues & drivers



- Operational impacts
  - Corrosion, loading, efficiency
- Invasive species risk
  - Harbours as sources of contamination
  - Effectiveness of antifouling
- Knowledge exchange
  - Science/engineering/regulator/industry
  - Wider marine industry

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Next steps:

- Have a better steer on engineering needs (device operation is key!)
- Peer reviewed publication (Loxton et al.) – watch this space!
- Biofouling prediction
  - in progress
  - Incorporating key issues and drivers

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ANNEX IV
Environmental Effects of Marine Energy Development around the World