Annex IV Environmental Research Webinar Series

Role of Biofouling in Marine Renewable Energy Development
Presenters

- 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
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?
Life history traits of biofouling
Life history traits of biofouling

(28 days)

Adapted from Pechenik et al. 1998
Types of biofouling communities

Macleod et al. (2016) Biofouling 32:3, 261-276
Types of biofouling communities

- **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

Legislation and regulations for biofouling

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

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:

<table>
<thead>
<tr>
<th>Depth below MWL (m)</th>
<th>Marine growth thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Central and Northern North Sea (56° to 59° N)</td>
</tr>
<tr>
<td>-2 to 40</td>
<td>100</td>
</tr>
<tr>
<td>&gt;40</td>
<td>50</td>
</tr>
</tbody>
</table>

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.
Legislation for biofouling – invasive species

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

Guidelines for the control and management of ships’ ballast water
to minimize the transfer of harmful aquatic organisms and pathogens

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
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

Vance et al 2016 / ReDAPT
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?

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

Devices Surveyed
- Offshore Wind (Floating)
- Tidal (Floating)
- Wave (Floating)
- Wave Energy (Coastal OWC)
- Wave Energy (Floating)
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

![Bar chart showing the number of species for different energy types: Floating Tidal, Floating Wave, Floating wave (array), Floating wind, and Coastal OWC. The categories shown are algae, Animalia other, Mollusca, Echinodermata, Cnidaria, Chordata, Bryozoa, Arthropoda, and Annelida.](chart.png)
Comparing to other man made structures

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

<table>
<thead>
<tr>
<th>Site</th>
<th>Location</th>
<th>Type</th>
<th>latitude</th>
<th>longitude</th>
<th>reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heather A</td>
<td>Shetland</td>
<td>Offshore fixed oil platform</td>
<td>61.36304</td>
<td>1.579761</td>
<td>Picken (1986)</td>
</tr>
<tr>
<td>Floating Wave</td>
<td>Orkney</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Floating Tidal</td>
<td>Orkney</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beatrice</td>
<td>N. Scotland</td>
<td>Offshore fixed oil platform</td>
<td>58.11667</td>
<td>-3.08333</td>
<td>Picken (1986)</td>
</tr>
<tr>
<td>Montrose Alpha oil</td>
<td>N.E Scotland</td>
<td>Offshore fixed oil platform</td>
<td>57.45065</td>
<td>1.388264</td>
<td>Forteath et al. (1982)</td>
</tr>
<tr>
<td>Floating wave array</td>
<td>W Scotland</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skye buoys</td>
<td>W Scotland</td>
<td>Nearshore floating buoy</td>
<td>57.27505</td>
<td>-5.71501</td>
<td>A Macleod PhD (2013)</td>
</tr>
<tr>
<td>Princess Amalia wind</td>
<td>Netherlands</td>
<td>offshore fixed wind</td>
<td>52.59</td>
<td>4.22</td>
<td>Vanagt et al. (2013)</td>
</tr>
<tr>
<td>Horns Rev windfarm</td>
<td>Denmark</td>
<td>offshore fixed wind</td>
<td>55.50001</td>
<td>7.820015</td>
<td>Leonhard &amp; Pederson (2006)</td>
</tr>
<tr>
<td>OWEZ</td>
<td>Netherlands</td>
<td>offshore fixed wind</td>
<td>52.606</td>
<td>4.419</td>
<td>Bouma Lengkeek (2012)</td>
</tr>
<tr>
<td>Floating wind</td>
<td>N. Portugal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aguda sea wall</td>
<td>N. Portugal</td>
<td>Inshore fixed seawall</td>
<td>41.04815</td>
<td>-8.65674</td>
<td>Santos J (2008)</td>
</tr>
<tr>
<td>coastal OWC</td>
<td>Azores</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Azores</td>
<td>Azores</td>
<td>natural shoreline</td>
<td>36.97</td>
<td>-25.1</td>
<td>Botehlo + (2009)</td>
</tr>
</tbody>
</table>
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)

**Biofouling Phyla on renewable and other structures**

- Standardise Samples by Total
- Transform: Square root
- Resemblance: S17 Bray Curtis similarity

**PCO with vector overlay (showing only pearson correlations >0.5)**
Comparison within Scotland.

*Biofouling Phyla on renewable and other structures*

- Floating wave near surface
- Floating tidal
- Floating wave underneath
- Floating wave array

PCO1 (48.9% of total variation)

PCO2 (22.1% of total variation)

Montrose Alpha oil

Skye buoys

Orkney buoys

Beatrice

Heather A

Type

A

B

Similarity

80

Standardise Samples by Total Transform: Square root Resemblance: S17 Bray Curtis similarity
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

<table>
<thead>
<tr>
<th>PANELS INSTALLED</th>
<th>PLANNED IN 2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wave site, Portugal</td>
<td>Floating tidal device, Orkney</td>
</tr>
<tr>
<td>Coastal OWC, Azores</td>
<td>floating wind device, Scotland</td>
</tr>
<tr>
<td>Test site, Ireland</td>
<td></td>
</tr>
<tr>
<td>Floating wave array, W Scotland</td>
<td></td>
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</table>
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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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
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…
Identifying issues & drivers
Biofouling Concerns

Identifying issues & drivers

- antifouling coating
- component failure
- design
- ecological...
- invasive species risk
- knowledge exchange
- maintenance
- mitigation
- operational impacts...
- predicting biofouling
- quantifying biofouling
- regulation

[Graph showing biofouling concerns with specific issues and drivers quantified by numerical values on the y-axis.]
• 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
• Operational impacts
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• Knowledge exchange
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  – Wider marine industry
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
THANK YOU!

Recordings of presentations will be posted on Tethys at:

http://Tethys.pnnl.gov/environmental-webinars

- Information on previous and upcoming Annex IV workshops

Watch for announcements on Tethys and your email for the next Annex IV webinar

For those of you who are not on the webinar mailing list, simply send a blank email to join-tethys-webinars@lyris.pnnl.gov

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