

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                   |                                                 |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-------------------------------------------------|
| <b>Institution:</b> Aberystwyth University                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                   |                                                 |
| <b>Unit of Assessment:</b> 6: Agriculture, Veterinary and Food Science                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                   |                                                 |
| <b>Title of case study:</b> Ecologically sensitive design of marine infrastructure improves natural capital                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                   |                                                 |
| <b>Period when the underpinning research was undertaken:</b> 2011- 2020                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                   |                                                 |
| <b>Details of staff conducting the underpinning research from the submitting unit:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                   |                                                 |
| <b>Name(s):</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | <b>Role(s) (e.g. job title):</b>                                                  | <b>Period(s) employed by submitting HEI:</b>    |
| Dr Joe Ironside                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Lecturer; Senior Lecturer                                                         | 1 October 2004- present                         |
| Dr Pippa Moore                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Lecturer; Reader                                                                  | 1 January 2011- 30 June 2020                    |
| Dr Ally Evans                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Marine Ecology Research Assistant; Post Doctoral Research Assistant- Ecostructure | 5 May 2015- 4 August 2015; 1 July 2017- present |
| <b>Period when the claimed impact occurred:</b> October 2014 – present                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                   |                                                 |
| <b>Is this case study continued from a case study submitted in 2014?</b> N                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                   |                                                 |
| <b>1. Summary of the impact</b> (indicative maximum 100 words) <p>Artificial structures are proliferating in the marine environment yet are poor substitutes for natural rocky reefs. Aberystwyth University's research on eco-engineering of artificial marine structures shows that relatively small and inexpensive interventions can lead to positive biodiversity outcomes and improved natural capital. Our research has impacted on Welsh marine planning policy with the Welsh National Marine Plan explicitly encouraging enhancements such as those trialled and tested by Aberystwyth University. Our eco-engineered interventions have also been incorporated into UK best practice guidelines and have resulted in behavioural change in the UK and overseas with policy makers, regulators and practitioners seeking to incorporate ecologically sensitive design within planned and existing structures.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                   |                                                 |
| <b>2. Underpinning research</b> (indicative maximum 500 words) <p>Artificial structures associated with coastal defence, ports, marinas and offshore renewable energy devices have proliferated in the marine environment in what has been termed 'ocean sprawl'. These structures can have negative impacts on the environment, and support different and less diverse communities of marine life compared to natural rocky shores, in part because of lower topographic complexity. Ecological engineering of artificial structures provides opportunities to enhance biodiversity and natural capital by increasing habitat complexity. This beneficial effect has been tested at the micro scale (<math>\mu\text{m}</math>-mm) by creating textured surfaces, at the small-to-medium scale (mm-cm) by adding artificial pits, crevices and pools, and at the macro scale (cm-m) by incorporating pre-cast habitat units into structure designs. Alternative construction materials have also been tested to improve the habitat quality of structures and/or reduce their environmental footprint.</p> <p>Since 2011 research at Aberystwyth University, led by Pippa Moore, has focused on improving the evidence base for eco-engineering of marine artificial structures, understanding the barriers to its widespread implementation in marine and coastal engineering projects, and working with policymakers, regulators and practitioners to increase awareness and uptake of ecoengineering solutions. In particular, research by Moore and her group have identified the challenges and opportunities associated with ocean sprawl [3.1], demonstrated the biodiversity and</p> |                                                                                   |                                                 |

environmental benefits of alternative concrete materials [3.2], and demonstrated that simple and relatively cheap interventions can have biodiversity benefits [3.3; 3.4]. With colleagues in the School of Management and Business, the research has identified perceived cross-sector barriers to the uptake of marine ecoengineering solutions including cost, funding priorities, lack of evidence that biodiversity benefits are achievable, lack of policy drive and legislative support, and poor communication between sectors during planning [3.5]. Since many of these perceived barriers to implementation appear to be unfounded, the researchers have attempted to boost confidence in the ecoengineering approach by outlining a strategy towards effective implementation of ecoengineering solutions [3.6]. This initial research has led to the attainment of substantial Ireland-Wales INTERREG funding to fill remaining knowledge gaps, develop and test new eco-engineering approaches, and develop new tools and resources to make the eco-engineering approach more accessible to developers and regulators [3.8].

### 3. References to the research (indicative maximum of six references)

- 3.1** Firth, L.B., Knights, A.M., Thompson, R.C., Mieszkowska, N., Bridger, D., **Evans, A., Moore, P.J.**, O'Connor, N.E., Sheehan, E.V., Hawkins, S.J. (2016). Ocean sprawl: challenges and opportunities for biodiversity management in a changing world. *Oceanography and Marine Biology Annual Review* 54: 189-262. DOI: [10.1201/9781315368597-9](https://doi.org/10.1201/9781315368597-9)
- 3.2** Dennis, H.D., **Evans, A.J.**, Banner, A. and **Moore, P.J.** (2017) *Reefcrete: Reducing the environmental footprint of concrete for eco-engineering marine structures*. *Ecological Engineering* DOI: [10.1016/j.ecoleng.2017.05.031](https://doi.org/10.1016/j.ecoleng.2017.05.031)
- 3.3** Firth, L.B., Airoidi, L., Bohn, K., Bouma, T.J., Bozzeda, F., Ceccherelli, V.U., Colangelo, M.A., **Evans, A.**, Ferrario, F., Hinz, H., Hoggart, S.P.G., Jackson, J., **Moore, P.**, Morgan, E.H., Perkol-Finkel, S., Strain, E.M., Thompson, R.C., van Belzen, J., Hawkins, S.J. (2014) *Between a rock and a hard place: Environmental and designing coastal defence structures* Coastal Engineering – THESEUS special volume 87: 122-135 DOI: [10.1016/j.coastaleng.2013.10.015](https://doi.org/10.1016/j.coastaleng.2013.10.015)
- 3.4** **Evans, A.J.**, Firth, L.B., Hawkins, S.J., Morris, E., Goudge, H. and **Moore, P.J.** (2015) Drill-cored rock pools: an effective method of ecological enhancement on artificial structures. *Marine & Freshwater Research* DOI: [10.1071/MF14244](https://doi.org/10.1071/MF14244)
- 3.5** **Evans, A.J.**, Garrod, B., Firth, L.B., Hawkins, S.J., Morris, E.S., Goudge, H. and **Moore, P.J.** (2017) *Stakeholder priorities for multi-functional defence developments and steps to effective implementation*. *Marine Policy* 75: 143-155 DOI: [10.1016/j.marpol.2016.10.006](https://doi.org/10.1016/j.marpol.2016.10.006)
- 3.6** **Evans, A.J.**, Firth, L.B., Hawkins, S.J., **Ironside, J.**, Thompson, R.C. and **Moore, P.J.** (2019) *From ocean sprawl to blue-green infrastructure – a UK perspective on an issue of global significance*. *Environmental Science and Policy* 91: 60-69 DOI: [10.1016/j.envsci.2018.09.008](https://doi.org/10.1016/j.envsci.2018.09.008)

#### Research grants

- 3.7** **Evans, A.J.**; ESF funded Knowledge Economy Skills Scholarship (KESS) PhD studentship. *Artificial defence structures as surrogate habitats for natural rocky shores: giving nature a helping hand*; European Social Fund (ESF) through the European Union Convergence Programme (Wales and the Valleys); 2011-2015; approximately GBP63,000
- 3.8** **Ironside, J.**; *Ecostructure: climate change adaptation through ecologically sensitive coastal infrastructure* project; European Regional Development Fund (ERDF) INTERREG Ireland-Wales Cooperation Programme; (1 March 2017 - 30 April 2021); EUR6,000,000: [www.ecostructureproject.eu](http://www.ecostructureproject.eu)

**4. Details of the impact** (indicative maximum 750 words)

**Industry Best Practice Guidelines:** Our research has been incorporated into the Coastal and Marine Environmental Site Guide produced by the Construction Industry Research and Information Association (CIRIA) in the form of a case study [5.1.1 - Case Study 1.2]. CIRIA's guides are often adopted as the industry standard for excellence. Our drill cored rockpools were also included in the publication 'State of the possible' within Greening the Grey: a framework for integrated green grey infrastructure [5.2] which is targeted at local authorities, national agencies, public bodies, asset managers and local community groups. This publication identifies the opportunities, economic costs, wider benefits and risks of incorporating different ecological engineering enhancements. Our researchers are acknowledged specifically as contributors to the document [5.2, p24] and four of our research publications [3.1; 3.2; 3.3; 3.5] are cited [5.2 Business Case p9, Case Study CS-C7 & AP-C2]. Our drill-cored rock pool technique is presented as an example of what is possible [5.2 – AP-C3] and its award for 'Most Innovative' design by CIRIA in 2014 [5.1.2; 5.1.3] is mentioned.

**Evidence-Based Conservation:** through our Ecostructure project, we are working in cooperation with Conservation Evidence [5.3] to produce a thorough review of all marine eco-engineering enhancements and their efficacy. Conservation Evidence is an authoritative information resource designed to support decisions about how to maintain and restore global biodiversity. Our review will be published on the Conservation Evidence website [www.conservationevidence.com](http://www.conservationevidence.com) providing practitioners with a one-stop shop for informing planning decisions.

**Policy:** In 2015, Aberystwyth University researchers Ironside and Evans were invited to present their research findings to the Welsh Government's Marine Conservation and Biodiversity Branch. This led, in 2016, to the appointment of Evans to the Welsh Government's Restoring and Enhancing Marine Biodiversity Task and Finish Group. The Draft Welsh National Marine Plan (WNMP) [5.4.1] which was released for consultation in December 2017 specifically recommended that *"small changes to intertidal structures that allow the formation of crevices in walls or pools at low tide [...] can provide additional environment for [...] species that would otherwise be unable to exist there."* [5.4.1 ENV\_01 pt 219 p90], a clear reference to our experiments on drilled cored rockpools, pits and crevices published in 2015 [3.4] which states that *"Although the novel habitats did not support the same communities as natural rock pools, they clearly provided important habitat for several species that were otherwise absent at mid-shore height on the breakwater."* Although this wording does not appear in the final version of the Welsh National Marine Plan [5.4.2] published and adopted November 2019, its inclusion in the draft WNMP led environmental regulator and advisor Natural Resources Wales (NRW) to commission a report *Supporting the implementation of the Welsh National Marine Plan: Enhancing marine ecosystems* [5.4.3] to *"help them better understand and explore options for the implementation of draft plan policy ENV\_01"* focusing specifically on *"the 'enhancement' aspects of draft policy ENV\_01"* [5.4.3 p11]. Two research publications from Aberystwyth University are cited in this report [3.3 (pp.31, 32); 3.4 (p32)] and the Ecostructure project is mentioned specifically [3.8 (pp.27, 29, 30, 33)]. Since the WNMP was adopted, NRW has published the first Marine Area Statement for Wales [5.5.1; 5.5.2]. This includes as one of its three themes: 'Nature-based solutions and adaptation at the coast' wherein the Ecostructure project is referenced. The Ecostructure project was also invited by NRW to provide a Case Study for this section, which is completed, pending publication. [5.5.3].

**Behaviour change:** Following publication of their report into *Enhancing Marine Ecosystems*, NRW has approached our researchers directly for advice and guidance on eco-engineering interventions and installation methods for the Welsh Government Capital Funds project *Milford Haven Intertidal Restoration and Naturalisation*, for casework on the Mumbles Promenade and Porthcawl Breakwater [5.5.4] and to support an internal funding bid to purchase a stock of ecological enhancement units for use on projects in the future. More generally, by producing peer-reviewed research on the suitability and efficacy of various artificial enhancements and holding discussions with NRW staff, our researchers have significantly influenced their approach

to enhancing biodiversity on coastal structures [5.5.4]. NRW has also begun to encourage developers to include ecological enhancements within applications involving coastal defences in order to improve local biodiversity. Since the Ecostructure project began in 2017, our researchers have been approached by at least ten practitioners, regulators and developers, all considering incorporation of ecologically sensitive designs into specific projects and seeking advice. In several cases, developers have been directed to our researchers specifically by NRW [5.5.4].

**Commercialisation:** Celtest, a construction materials testing and diamond drilling company, undertook drill-core work for the Ecostructure project to create experimental rock pools and produced a case study [5.6.1] to showcase this new avenue of business for the company on their website. Celtest have since been approached twice to quote for undertaking similar work in other locations, one of which led to a successful contract. Celtest are currently installing rock pools on four different sites in the port of Milford Haven as well as other wall-mounted artificial habitat units. [5.6.2]

**Global Impact:** Drill-cored rockpools based on designs developed and tested at Aberystwyth University have been used by a Malaysian research team to enhance the biodiversity on coastal defence structures in Penang, Malaysia. A publication arising from this work [5.7 - Chee *et al.* 2020] extensively cites our publication on drill-cored rock-pools [3.4] and acknowledges Evans' "immense contribution to the project". The pools supported more species than the surrounding unenhanced boulders, demonstrating that our drill-cored rock-pool method can be used successfully in the tropics.

**Prizes, media and outreach:** In 2014, our drilled cored rockpools were named the Most Innovative Design and runner up for the Overall Prize in CIRIAs BIG Challenge annual awards beating 119 submitted case studies [5.1.3]. Winning this award increased the profile of our research and led to the incorporation of our research in CIRIAs Environmental Site Guide [5.1.1] (see above).

The Aberystwyth University led Ecostructure project [3.8] was presented with the Better World award by singer Sting at the 2020 .eu Web Awards (16 December 2020), which celebrates websites that encourage green initiatives [5.8]. The project brings together five leading universities in Wales and Ireland to raise awareness of eco-engineering solutions in response to the challenge of coastal adaptation to climate change.

Our research has received national media coverage appearing on BBC Radio 4 Today programme (October 2017) (over 1,000,000 listeners daily), BBC Countryfile Diaries (Feb 2018) (26.3% share of 1,300,000 average audience), BBC Wales Today (August 2019) (31.3% share of 106,000 listeners) and the BBC News website [5.9.1; 5.9.2]. Our research has also featured in the Environmental Science Journal for Teens [5.10.1] which rewrites, in age-appropriate language, the latest and most topical peer-reviewed research papers. When the article was published (December 2016), the site averaged over 700 unique visitors per day from 159 countries [5.10.2].

## 5. Sources to corroborate the impact (indicative maximum of 10 references)

### 5.1 Construction Industry Research and Information Association (CIRIA)

**5.1.1** John, S., Meakins, N., Basford, K., Craven, H. and Charles, P. (Editors) Coastal and marine environmental site guide. 2<sup>nd</sup> Edition pp180 CIRIA ISBN: 978-0-86017-749-4 Case study 1.2.

**5.1.2** Testimonial from the Director of the Construction Industry Research and Information Association (CIRIA)

**5.1.3** BIG Challenge Case Study – Artificial Rock Pools, Big Biodiversity Challenge Awards 2014: Winners [www.bigchallenge.info/big-challenge-award-winners](http://www.bigchallenge.info/big-challenge-award-winners) and Nominations for the CIRIAs BIG Biodiversity Challenge 2014 [www.bigchallenge.info/case-studies](http://www.bigchallenge.info/case-studies)

- 5.2** Naylor, L.V., Kippen, H., Coombes, M.A., Horton, B., MacArthur, M. and Jackson, N. (2017) Greening the grey: a framework for integrated green grey infrastructure (IGGI). University of Glasgow report URL: [eprints.gla.ac.uk/150672/](https://eprints.gla.ac.uk/150672/)
- 5.3** Testimonial from Senior Research Associate, University of Cambridge synopsis of Conservation Evidence - *Enhancing Biodiversity on Marine Artificial Structures*.
- 5.4 Welsh Government**
- 5.4.1** The Welsh National Marine Plan – Consultation document. Welsh Government WG31640 (7 December 2017)
- 5.4.2** The Welsh National Marine Plan. Welsh Government WG37346 November 2019
- 5.4.3** Armstrong, S., West, V.A., Hull, S., and Scott, C.R. 2019. Supporting the implementation of the Welsh National Marine Plan: Enhancing marine ecosystems. 106 pp, NRW, Bangor.
- 5.5 Natural Resources Wales (NRW)**
- 5.5.1** NRW Marine Area Statement Wales [naturalresources.wales/about-us/area-statements/marine-area-statement/?lang=en](https://naturalresources.wales/about-us/area-statements/marine-area-statement/?lang=en)
- 5.5.2** NRW Marine Area Statement Nature Based Solutions: [naturalresources.wales/about-us/area-statements/marine-area-statement/nature-based-solutions-and-adaptation-at-the-coast/?lang=en](https://naturalresources.wales/about-us/area-statements/marine-area-statement/nature-based-solutions-and-adaptation-at-the-coast/?lang=en)
- 5.5.3** Testimonial from Marine All Wales Advice Team Leader
- 5.5.4** Testimonial from the Senior Marine Advisor, Natural Resources Wales
- 5.6 Celtest**
- 5.6.1** Celtest case study [www.celtest.com/aberystwyth-university-rock-pool](http://www.celtest.com/aberystwyth-university-rock-pool)
- 5.6.2** Testimonial from Operations Manager, Celtest
- 5.7** Chee, S. Y., Wee, J. L. S., Wong, C., Yee, J. C., Yusup, Y. and Mujahid, A. (2020) Drill-Cored Artificial Rock Pools Can Promote Biodiversity and Enhance Community Structure on Coastal Rock Revetments at Reclaimed Coastlines of Penang, Malaysia. *Tropical Conservation Science* 13: 1-15. [journals.sagepub.com/doi/full/10.1177/1940082920951912](https://journals.sagepub.com/doi/full/10.1177/1940082920951912)
- 5.8** The 2020 .eu Web Awards winners: [webawards.eurid.eu](https://webawards.eurid.eu)
- 5.9 Media and Outreach: BBC**
- 5.9.1** BBC News Science & Environment online article (25 October 2017): *Wildlife colonises man-made rockpools* [www.bbc.co.uk/news/science-environment-41665459](https://www.bbc.co.uk/news/science-environment-41665459)
- 5.9.2** BBC News Wales, TV coverage and online video interview piece (1 August 2019): *Aberystwyth Uni hopes tiles can attract marine life* [www.bbc.co.uk/news/av/uk-wales-politics-49200185/aberystwyth-uni-hopes-tiles-can-attract-marine-life](https://www.bbc.co.uk/news/av/uk-wales-politics-49200185/aberystwyth-uni-hopes-tiles-can-attract-marine-life)
- 5.10 Media and Outreach: Other**
- 5.10.1** Firth, L., Evans, A., Knights, A., Nash, R., Browne, K., Moore, P. Morris-Webb, E., Goudge, H. and Hawkins, S. (2016) *Could this be a concrete solution to biodiversity loss?* *Environmental Science Journal for Teens*. (December 2016) [www.sciencejournalforkids.org/science-articles/could-this-be-a-concrete-solution-to-biodiversity-loss](https://www.sciencejournalforkids.org/science-articles/could-this-be-a-concrete-solution-to-biodiversity-loss)
- 5.10.2** Science Journal for Kids: A Year of Growth 2016 Impact Report [sciencejournalforkids.org/wp-content/uploads/2019/08/2016\\_impact\\_report.pdf](https://sciencejournalforkids.org/wp-content/uploads/2019/08/2016_impact_report.pdf)